

T.R.
BOLU ABANT İZZET BAYSAL UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
Department of Biology



**DETERMINING AGRO-MORPHOLOGICAL AND MOLECULAR
CHARACTERISTICS OF BOLU PROVINCE WHEAT LANDRACE
AND BRED WHEATS AND MODELLING THEIR SPATIAL
DISTRIBUTION BY GEOGRAPHIC INFORMATION SYSTEMS
AND REMOTE SENSING**

DOCTOR OF PHILOSOPHY

ÇİSEM NİLDEM KESKİN

ACADEMIC SUPERVISOR
Prof. Dr. EKREM GÜREL

BOLU, JUNE 2024

APPROVAL OF THE THESIS

Determining Agro-morphological and Molecular Characteristics of Bolu Province Wheat Landrace and Bred Wheats and Modelling Their Spatial Distribution by Geographic Information Systems and Remote Sensing submitted by **Çisem Nildem KESKİN** and defended before the Examining Committee Members listed below in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** in **Department of Biology, Institute of Graduate Studies of Bolu Abant İzzet Baysal University** in **11.06.2024** by

Examining Committee Members

Signature

Supervisor
Prof. Dr. Ekrem GÜREL
Bolu Abant İzzet Baysal University

.....

Member
Prof. Dr. Göksel ÖZER
Bolu Abant İzzet Baysal University

.....

Member
Prof. Dr. İsmail EKER
Bolu Abant İzzet Baysal University

.....

Member
Prof. Dr. Mustafa YILDIZ
Ankara University

.....

Member
Assoc. Prof. Orhan Mete KILIÇ
Gaziosmanpaşa University

.....

Prof. Dr. İbrahim KÜRTÜL
Director of Institute of Graduate Studies

ETHICAL DECLARATION

In this thesis dissertation that was properly prepared according to the Thesis Writing Rules of Bolu Abant İzzet Baysal University of the Institute of Graduates Studies, I hereby declare that;

- All data, information, and documents presented in the thesis were obtained in accordance with the academic and ethical rules,
- All data, documents, assessments, and results were presented in accordance with the scientific ethical and moral rules,
- All works that were benefitted in the thesis were appropriately cited,
- No alteration was made in the data used,
- Study presented in this thesis is original,

Otherwise, I declare that I accept the loss of all my rights in case any contradiction that may arise against me.

The similarity rate obtained by using the Turnitin program, a plagiarism detection software, is within the limits approved by the University Senate.

Çisem Nildem KESKİN

ABSTRACT

**DETERMINING AGRO-MORPHOLOGICAL AND MOLECULAR
CHARACTERISTICS OF BOLU PROVINCE WHEAT LANDRACE AND
BRED WHEATS AND MODELLING THEIR SPATIAL DISTRIBUTION
BY GEOGRAPHIC INFORMATION SYSTEMS AND REMOTE SENSING
PHD THESIS**

**ÇİSEM NİLDEM KESKİN
BOLU ABANT İZZET BAYSAL UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF BIOLOGY
(SUPERVISOR: PROF. DR. EKREM GÜREL)**

BOLU, JUNE 2024

xviii + 197

Landraces are more important than ever today due to both breeding studies and people's tendency towards healthier and higher quality products. It is necessary to know and understand genetic and agro-morphological structures as well as geographical distribution of landraces for serious management of breeding and production studies. In this study, the genetic, agro-morphological characteristics and geographical distributions of local populations of *Triticum monococcum* L. ssp. *monococcum* (IZA), *Triticum aestivum* L. cv. Çalıbasan and *Triticum aestivum* L. cv. Sarı Serez in Bolu province were researched. Genetic polymorphisms between populations and variants of these two species were investigated with 5 SCoT markers. Thousand kernels weight (TKW), flag leaf area (FLL), flag leaf length (FLL), flag leaf width (FLW), spike length (SL), plant height (PH), upper node length (UNL), number of kernels per spike (KPS), spikes fertile per square meter (SFPS), and yield (YLD) were investigated as agro-morphological variables. Moreover, topographic (elevation, slope, aspect), climate (precipitation, maximum-minimum-mean temperatures and bioclimate), soil (bulk density, coarse fragment, sand, silt, clay, cation exchange capacity (CEC), nitrogen, organic carbon, pH, great soil groups and land use capability) and CORINE (land use/cover) complementary database (raster maps) of Bolu province were created and relationships between agro-morphological and these environmental variables were investigated by correlation analysis. All in all, in IZA wheat TKW-SL, TKW-FLL, TKW-elevation, FLL-elevation, SL-elevation, YLD-precipitation (in April) shows significant ($p<0.01$) and high correlations at values of 0.692, 0.644, 0.793, 0.773, 0.702, 0.554, respectively. According to the results of start codon targeted (SCoT) analysis markers, primers amplified 48 polymorphic fragments with an average of 9.60. The average polymorphism information content (PIC) value of SCoT markers was 0.08. As a result of dendrogram analysis, *T. aestivum* and *T. monococcum* ssp. *monococcum* divided into two main clusters with 62% genetic similarity. Using yield and the environmental variables strongly effective on yield, a yield model of IZA wheat that shows potential growing areas was developed by multiple regression and mapped by GIS at the end of this study.

KEYWORDS: Geographical Information Systems (GIS), Remote Sensing (RS), Molecular Marker, Wheat

ÖZET

BOLU İLİ KÖY VE ISLAH EDİLMİŞ BUĞDAYLARININ AGRO-MORFOLOJİK VE MOLEKÜLER ÖZELLİKLERİNİN İNCELENEREK UZAYSAL DAĞILIMLARININ COĞRAFI BİLGİ SİSTEMLERİ VE UZAKTAN ALGILAMA İLE MODELLENMESİ
DOKTORA TEZİ
ÇİSEM NİLDEM KESKİN
BOLU ABANT İZZET BAYSAL ÜNİVERSİTESİ
LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ
BİYOLOJİ ANABİLİM DALI
(TEZ DANIŞMANI: PROF. DR. EKREM GÜREL)

BOLU, HAZİRAN - 2024

xviii + 197

Gerek ıslah çalışmaları gerekse insanların daha sağlıklı ve kaliteli ürünlere yönelmesi nedeniyle yerel çeşitler günümüzde her zamankinden daha fazla önem kazanmıştır. Islah ve üretim çalışmalarının ciddi bir şekilde yönetilmesi için yerel çeşitlerin coğrafi dağılımlarının yanı sıra genetik ve agromorfolojik yapılarının da bilinmesi ve anlaşılması gerekmektedir. Bu çalışmada *Triticum monococcum* L. ssp. *monococcum* (IZA), *Triticum aestivum* L. cv. Çalıbasan and *Triticum aestivum* L. cv. Sarı Serez yerel popülasyonlarının genetik, agro-morfolojik özellikleri ve coğrafi dağılımları araştırılmıştır. Genetik polimorfizm, bu iki türün popülasyonları ve varyantları arasında 5 SCoT belirteçler markörleri ile araştırıldı. Bin tane ağırlığı (BDA), bayrak yaprak alanı (BYA), bayrak yaprak uzunluğu (BYU), bayrak yaprak genişliği (BYG), başak uzunluğu (BU), bitki boyu (BB), üst boğum uzunluğu (ÜBU), başakta dane sayısı (BDS), metrekafe başına düşen başak sayısı (MKBS) ve verim (VRM) agro-morfolojik değişkenler olarak araştırıldı. Ayrıca Bolu ilinin topografik (yükseklik, eğim, bakı), iklim (yağış, maksimum-minimum-ortalama sıcaklıklar ve biyoiklim), toprak (yığın yoğunluğu, iri parça, kum, silt, kil, katyon değişim kapasitesi (CEC), nitrojen, organik karbon) ve CORINE (arazi kullanımı/örtüsü) tamamlayıcı veri tabanı (raster haritaları) oluşturulmuş ve agro-morfolojik değişkenler ile bu çevresel değişkenler arasındaki ilişkiler korelasyon analizi ile araştırılmıştır. Sonuç olarak, IZA buğdayında BDA-BU, BDA-BYU, BDA-yükseklik, BYU-yükseklik, BU-yükseklik, VRM-yağış (Nisan ayında) arasında anlamlı ($p<0.01$) ve sırasıyla 0.692, 0.644, 0.793, 0.773, 0.702, 0.554 değerlerinde yüksek ilişki görülmüştür. SCoT analizleri sonuçlarına göre, ortalama 9.60 ile markörler 48 polimorfik bant üretmişlerdir. SCoT markörlerinin ortalama polimorfik bilgi içeriği (PIC) değeri 0.08 çıkmıştır. Dendrogram analizi sonucuna göre *T. aestivum* ve *T. monococcum* ssp. *monococcum* türleri %62 genetik benzerlik ile iki ana kümeye ayrılmıştır. Bu çalışmanın sonunda verim ve verime güçlü bir şekilde etki eden çevresel değişkenler kullanılarak, IZA buğdayının potansiyel yetiştirme alanlarını gösteren bir verim modeli çoklu regresyonla geliştirilmiş ve CBS ile haritalandırılmıştır.

ANAHTAR KELİMELELER: Coğrafi Bilgi Sistemleri (CBS), Uzaktan Algılama (UA), Moleküler Markörler, Buğday

TABLE OF CONTENTS

	<u>Page</u>
APPROVAL OF THE THESIS	iii
ETHICAL DECLARATION.....	iv
ABSTRACT	v
ÖZET	vi
TABLE OF CONTENTS.....	vii
LIST OF FIGURES	ix
LIST OF TABLES.....	xii
LIST OF ABBREVIATIONS AND SYMBOLS.....	xvi
ACKNOWLEDGEMENTS.....	xviii
1. INTRODUCTION	1
1.1 Wheat.....	1
1.1.1 Evolution of Wheat.....	2
1.1.2 Einkorn (<i>Triticum monococcum</i> ssp. <i>monococcum</i>) Wheat.....	3
1.1.3 Bread (<i>Triticum aestivum</i>) wheat	7
1.2 The Importance of Geographic Information System and Remote Sensing in the Protection of Genetic Resources	8
1.3 Start Codon Targeted (SCoT) Marker	10
1.4 Agro-morphological Feature of Wheat.....	12
2. AIM AND SCOPE OF THE STUDY.....	14
3. MATERIALS AND METHODS.....	15
3.1 Material.....	15
3.2 Methodology	21
3.2.1 Field Studies	23
3.2.2 Laboratory Studies.....	27
3.2.3 Office Studies	34
4. RESULTS	47
4.1 Complementary Database	47
4.1.1 Topographic Database	47
4.1.2 ISRIC Soil Database	50
4.1.3 CHELSA Climate Database	62
4.1.4 CORINE Land Use/Cover Database	69
4.1.5 Türkiye's National Soil (KHGM) Database	72
4.2 Statistical Analyses.....	76
4.2.1 Genotypic Analyses	76
4.2.2 Genetic Diversity Analyzes.....	76
4.2.3 Exploring Data	81

4.2.4	Correlation Analyses.....	91
4.2.5	Modeling and Mapping the Most Suitable (Potential) Cultivation Areas for IZA in GIS	168
5.	DISCUSSION	180
5.1	Agro-morphological Features	180
5.2	Polymorphism Studies	184
5.3	Geographic Information Systems and Remote Sensing	188
6.	CONCLUSIONS AND RECOMMENDATIONS	190
7.	REFERENCES	191



LIST OF FIGURES

	<u>Page</u>
Figure 1.1. Origin of wheat. Image adapted from (9).	3
Figure 1.2. <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA).	4
Figure 3.1. Districts and general topographic features of the study area (Bolu province).	16
Figure 3.2. Location of the study area in the geographic regions of Türkiye.	17
Figure 3.3. (a) Köppen Climate Types Map of Türkiye (64), and (b) Bolu Province Köppen Climate Types map produced in ArcGIS environment by utilizing Köppen Climate Types map of Türkiye.	18
Figure 3.4. Monthly distribution of important climatic variables of Bolu province: (a) monthly mean rainfall (mm) and temperature (°C), (b) highest-lowest and mean temperatures (°C), and (c) average number of rainy days and monthly mean sunlight time (hour) (produced by using 1991-2020 data from General Directorate of Meteorology (67)).	20
Figure 3.5. Distribution of cultivated agricultural land of Bolu according to product basis in the year 2021 (69).	21
Figure 3.6. Flowchart of the methodology (rectangular is the main title of the work done, rectangle with rounded corners indicates the operation performed, globe refers the used tool in the operation, cylinder means created database, and rhombus shows achieved result).	22
Figure 3.7. Sampling points (populations) in the study area (a), and sampling procedure applied in each sampling points (b).	26
Figure 3.8. Examples of field work; measured geomorphological variables (a), measuring plant height (b), measuring spike length (c), counting spikes fertile per square meter (d), taking 10 whole plant samples from each wheat population (e).	27
Figure 3.9. Five wheat grains of each population were seeded and grown in climate room.	30
Figure 3.10. Some steps of extraction. A: Samples were stored in tubes, B: samples were cut out and placed in dry block heater with lysis buffer, C: homogenization, D: chloroform/isoamyl alcohol added to the samples, E: centrifugation, F: precipitation with isopropanol, G: measuring DNA samples with a nano spectrophotometer.	32
Figure 3.11. Download of precipitation databases from CHELSA official website.	38
Figure 3.12. Download of CORINE-2018 database from official website (Copernicus) (68).	41
Figure 3.13. In Google Earth, digitizing the population areas by utilizing field sampling point data (point shape file).	45
Figure 4.1. Digital elevation map of the study area (Bolu province).	47
Figure 4.2. Slope (degree) raster map of the study area (Bolu province).	48
Figure 4.3. Slope (%) raster map of the study area (Bolu province).	48

Figure 4.4. Aspect (degree) raster map of the study area.....	49
Figure 4.5. Aspect (classified direction) raster map of the study area.....	49
Figure 4.6. Bulk density (cg/cm ³) maps at different soil depths and mean bulk density raster map (resolution: 250 m).	51
Figure 4.7. Coarse fragments (cm ³ /dm ³) maps at different soil depths and mean coarse fragments raster map (resolution: 250 m).	52
Figure 4.8. Sand (g/kg) maps at different soil depths and mean sand raster map (resolution: 250 m).	53
Figure 4.9. Silt (g/kg) maps at different soil depths and mean silt raster map (resolution: 250 m).	54
Figure 4.10. Clay (g/kg) maps at different soil depths and mean clay map (resolution: 250 m).	55
Figure 4.11. CEC (mmol(c)/kg) maps at different soil depths and mean CEC raster map (resolution: 250 m).	58
Figure 4.12. Nitrogen (cg/kg) maps at different soil depths and mean nitrogen raster map (resolution: 250 m).....	59
Figure 4.13. Organic Carbon (dg/kg) maps at different soil depths and mean organic carbon raster map (resolution: 250 m).	60
Figure 4.14. pH Water (pH x 10) maps at different soil depths and mean pH Water raster map (resolution: 250 m).	61
Figure 4.15. Interpolated CHELSA Bioclimatic raster maps (resolution 100 m).....	64
Figure 4.16. Interpolated CHELSA monthly precipitation raster maps (resolution 100 m).	65
Figure 4.17. Interpolated CHELSA monthly maximum temperature raster maps (resolution 100 m).	66
Figure 4.18. Interpolated CHELSA monthly minimum temperature raster maps (resolution 100 m).	67
Figure 4.19. Interpolated CHELSA monthly mean temperature raster maps (resolution 100 m).	68
Figure 4.20. Bolu Province 2018 CORINE Level-1 Land Use/Cover Map (Note: Downloaded from Copernicus, and processed in ArcGIS).....	69
Figure 4.21. Bolu Province 2018 CORINE Level-2 Land Use/Cover Map (Note: Downloaded from Copernicus, and processed in ArcGIS).....	70
Figure 4.22. Bolu Province 2018 CORINE Level-3 Land Use/Cover Map (Note: Downloaded from Copernicus, and processed in ArcGIS).....	71
Figure 4.23. Great Soil Groups map of Bolu province (Note: Obtained from Türkiye's National Soil (KHGM) Database, and processed in ArcGIS).....	74
Figure 4.24. Land suitability classes map of Bolu province (Note: Obtained from Türkiye's National Soil (KHGM) Database, and processed in ArcGIS).....	75
Figure 4.25. DNA image of <i>T. monococcum</i> ssp. <i>monococcum</i> isolate.....	76
Figure 4.26. Electrophoresis images of SCoT 13 primer PCR results of wheat species. L: ladder; P: Population of <i>T. monococcum</i> ssp. <i>monococcum</i> ; SS: Sarı Serez; CB: Çalibasan.	77
Figure 4.27. Dendrogram which is showing the relationship between the population of <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) and <i>T.</i>	

<i>aestivum</i> (cv. Çalibasan and cv. Sarı Serez), grown in Bolu province.....	80
Figure 4.28. Histograms of Agro-morphological variables of <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA).....	84
Figure 4.29. Histograms of Agro-morphological variables of <i>T. aestivum</i> (cv. Çalibasan).....	87
Figure 4.30. Histograms of Agro-morphological variables of <i>T. aestivum</i> (cv. Sarı Serez).	90
Figure 4.31. Scatter plots and linear regression models of detected significant correlations among agro-morphological variables of IZA. (Note: Variables considered dependent are shown on the y-axis).	166
Figure 4.32. Scatter plots and linear regression models of detected significant correlations between agro-morphological variables of IZA and topographic-climatic variables (Note: Dependent variables are shown on the y-axis).	167
Figure 4.33. Scatter plots and linear regression models of detected significant correlations between yield of IZA and topographic-climatic variables (NOTE: Dependent variables are shown on the y-axis).....	168
Figure 4.34. Yield model raster map of IZA wheat.....	174
Figure 4.35. IZA yield model raster map was classified by using 1 standard deviation function in ArcGIS.	176
Figure 4.36. The agricultural areas of Bolu province according to CORINE 2018 Third Level Map.	177
Figure 4.37. IZA wheat suitability map of Bolu Province.	178
Figure 4.38. The areas covered by the classes of IZA wheat suitability map.	179

LIST OF TABLES

	<u>Page</u>
Table 1.1. Nutritional values of bread wheat (30)	7
Table 3.1. The unit and definition of wheat agro-morphological variables determined in the field and the number of samples measured in each population (Note: Pre-harvest and post-harvest samplings are shown in the table).	24
Table 3.2. General information about the populations of <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) and <i>T. aestivum</i> (cv. Çalibasan and cv. Sarı Serez) species (N: Number, RN: The registration number, CN: Chromosome Number).	28
Table 3.3. Amount of chemicals to prepare 50 ml of lysis buffer.	31
Table 3.4. Primer name, sequence and annealing temperature.....	33
Table 3.5. Reaction components and their amount.	34
Table 3.6. PCR program.	34
Table 3.7. Downloaded IRSIC soil layers.	37
Table 3.8. Information about the centers and the database they produced (78).....	38
Table 3.9. Downloaded raster climate maps from CHELSA and information about climatic layers (78).....	39
Table 3.10. Downloaded climatic layers and their transformation equations with scale (multiplier) and offset (additive) values supplied by CHELSA (78).....	40
Table 3.11. Utilized KHGM map layers and their original and renumarated classes.	42
Table 4.1. The amplification results of 69 accession of <i>T. monococcum</i> ssp. <i>monococcum</i> and <i>T. aestivum</i> (cv. Çalibasan and cv. Sarı Serez) by using five SCoT primers.	78
Table 4.2. Descriptive statistics of agro-morphological variables of <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA).	83
Table 4.3. Descriptive statistics of agro-morphological variables of <i>T. aestivum</i> (cv. Çalibasan).	86
Table 4.4. Descriptive statistics of agro-morphological variables of <i>T. aestivum</i> (cv. Sarı Serez).....	89
Table 4.5. Correlation matrix of agro-morphological characteristics for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).	93
Table 4.6. Correlation matrix of agro-morphological characteristics for <i>T. aestivum</i> (cv. Çalibasan) (N=4).....	94
Table 4.7. Correlation matrix of agro-morphological characteristics for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).	95
Table 4.8. Correlation matrix of agro-morphological characteristics and topographic (elevation, slope and aspect) variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).	98
Table 4.9. Correlation matrix of agro-morphological characteristics and topographic (elevation, slope and aspect) variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).....	99

Table 4.10. Correlation matrix of agro-morphological characteristics and topographic (elevation, slope and aspect) variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).	100
Table 4.11. Correlation matrix of agro-morphological characteristics and precipitation variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).	105
Table 4.12. Correlation matrix of agro-morphological characteristics and mean temperature variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).	106
Table 4.13. Correlation matrix of agro-morphological characteristics and maximum temperature variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).	107
Table 4.14. Correlation matrix of agro-morphological characteristics and minimum temperature variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).	108
Table 4.15. Correlation matrix of agro-morphological characteristics and bioclimatic variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).	109
Table 4.16. Correlation matrix of agro-morphological characteristics and precipitation variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).	113
Table 4.17. Correlation matrix of agro-morphological characteristics and mean temperature variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).	114
Table 4.18. Correlation matrix of agro-morphological characteristics and maximum temperature variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).	115
Table 4.19. Correlation matrix of agro-morphological characteristics and minimum temperature variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).	116
Table 4.20. Correlation matrix of agro-morphological characteristics and bioclimatic variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).	117
Table 4.21. Correlation matrix of agro-morphological characteristics and precipitation variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).	120
Table 4.22. Correlation matrix of agro-morphological characteristics and mean temperature variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).	121
Table 4.23. Correlation matrix of agro-morphological characteristics and maximum temperature variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).	122
Table 4.24. Correlation matrix of agro-morphological characteristics and minimum temperature variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).	123
Table 4.25. Correlation matrix of agro-morphological characteristics and bioclimatic variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).	124
Table 4.26. Correlation matrix of agro-morphological characteristics and bulk density variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).	127
Table 4.27. Correlation matrix of agro-morphological characteristics and coarse fragments variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).	128

Table 4.28. Correlation matrix of agro-morphological characteristics and sand variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).....	129
Table 4.29. Correlation matrix of agro-morphological characteristics and silt variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).....	130
Table 4.30. Correlation matrix of agro-morphological characteristics and clay variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).....	131
Table 4.31. Correlation matrix of agro-morphological characteristics and CEC variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).....	134
Table 4.32. Correlation matrix of agro-morphological characteristics and nitrogen variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).....	135
Table 4.33. Correlation matrix of agro-morphological characteristics and soil organic carbon variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).....	136
Table 4.34. Correlation matrix of agro-morphological characteristics and pH-water variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).....	137
Table 4.35. Correlation matrix of agro-morphological characteristics and KHGM soil (Great Soil Group and Land Use Suitability) variables for <i>T. monococcum</i> ssp. <i>monococcum</i> (IZA) (N=69).....	138
Table 4.36. Correlation matrix of agro-morphological characteristics and bulk density variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).....	141
Table 4.37. Correlation matrix of agro-morphological characteristics and coarse fragments variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).....	142
Table 4.38. Correlation matrix of agro-morphological characteristics and sand variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).	143
Table 4.39. Correlation matrix of agro-morphological characteristics and silt variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).....	144
Table 4.40. Correlation matrix of agro-morphological characteristics and clay variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).	145
Table 4.41. Correlation matrix of agro-morphological characteristics and CEC variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).	148
Table 4.42. Correlation matrix of agro-morphological characteristics and nitrogen variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).....	149
Table 4.43. Correlation matrix of agro-morphological characteristics and soil organic carbon variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).....	150
Table 4.44. Correlation matrix of agro-morphological characteristics and pH variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4).....	151
Table 4.45. Correlation matrix of agro-morphological characteristics and KHGM soil (Great Soil Group and Land Use Suitability) variables for <i>T. aestivum</i> (cv. Çalibasan) (N=4)	152
Table 4.46. Correlation matrix of agro-morphological characteristics and bulk density variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).....	154

Table 4.47. Correlation matrix of agro-morphological characteristics and coarse fragments variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).....	155
Table 4.48. Correlation matrix of agro-morphological characteristics and sand variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).....	156
Table 4.49. Correlation matrix of agro-morphological characteristics and silt variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).	157
Table 4.50. Correlation matrix of agro-morphological characteristics and clay variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).....	158
Table 4.51. Correlation matrix of agro-morphological characteristics and CEC variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).....	161
Table 4.52. Correlation matrix of agro-morphological characteristics and nitrogen variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).	162
Table 4.53. Correlation matrix of agro-morphological characteristics and soil organic carbon variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).....	163
Table 4.54. Correlation matrix of agro-morphological characteristics and pH-water variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).	164
Table 4.55. Correlation matrix of agro-morphological characteristics and KHGM soil (Great Soil Group and Land Use Suitability) variables for <i>T. aestivum</i> (cv. Sarı Serez) (N=5).....	165
Table 4.56. Yield (Multiple Regression) model summary of IZA Wheat.....	169
Table 4.57. ANOVA results of yield (Multiple Regression) model of IZA Wheat.....	170
Table 4.58. Coefficients results of yield (Multiple Regression) model of IZA Wheat.....	172

LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	: Analysis of Variance
ASTER	: Advanced Spaceborne Thermal Emission and Reflection Radiometer
B₁	: Thiamine
B₂	: Riboflavin
B₅	: Pantothenic Acid
B₉	: Folate
CEC	: Cation Exchange Capacity
CHELSEA	: Climatologies at High Resolution for the Earth's Land Surface Areas
CORINE	: Coordination of Information on the Environment
CBDP	: CAAT-box Derived Polymorphism
CDDP	: Conserved DNA-Derived Polymorphism
CTAB	: Hexadecyltrimethylammonium Bromide
DEM	: Digital Elevation Model
DNA	: Deoxyribo Nucleic Acid
EEA	: European Environment Agency
FAD	: Flavin-Adenine-Dinucleotide
FLA	: Flag Leaf Area
FLL	: Flag Leaf Length
FLW	: Flag Leaf Width
GEF	: Global Environment Facility
GEKYA	: Gene Conservation and Management Areas
GDEM	: Global Digital Elevation Model
GIS	: Geographic Information Systems
IBS	: Irritable Bowel Syndrome
ISC	: International Science Council
ISRIC	: International Soil Reference and Information Center
ISSR	: Inter Simple Sequence Repeat
KHGM	: General Directorate of Rural Affairs
KPS	: Number of Kernels per Spike
MI	: Marker Index
mM	: Millimole
MSCA	: Most Suitable Cultivation Area

NASA	: The National Aeronautics and Space Administration
NTSYS	: Numerical Taxonomy Multivariate Analysis System
OLS	: Ordinary Least-Squares
PB	: Polymorphic Bands
PCR	: Polymerase Chain Reaction
PH	: Plant Height
pH	: Power of Hydrogen
PIC	: Polymorphism Information Content
PPB (%)	: Percentage of Polymorphic Bands
PSD	: Plant Spatial Distribution
RAPD	: Random Amplified Polymorphic DNA
ROS	: Reactive Oxygen Species
RP	: Resolving Power
RS	: Remote Sensing
RuBisCO	: Ribulose-1, 5-Bisphosphate Carboxylase/Oxygenase
SCoT	: Start Codon Targeted
SFPS	: Spikes Fertile per Square Meter
SL	: Spike Length
SOC	: Soil Organic Carbon
SPSS	: Statistical Package for Social Sciences
TB	: Total Band
TKW	: Thousand Kernels Weight
UNL	: Upper Node Length
UPGMA	: Unweighted Pair Group Method with Arithmetic Mean
UV	: Ultraviolet
VIF	: Variance Inflation Method
WDS	: World Data System
WSI	: World Soil Information
YLD	: Yield
α-TP	: α -tocopherol
α-TT	: α -tocotrienol

ACKNOWLEDGEMENTS

I would like to express my gratitude to my advisor Prof. Dr. Ekrem Gürel, who always supported me in my studies and trusted me. Also, I would like to thank Prof. Dr. Nusret Zencirci, who supported me from the beginning to the end of my thesis. Their knowledge, experience and advice will always be with me.

I am indebted to Prof. Dr. Göksel Özer and his dear student/my dear friend Tuğba Bozoğlu. I am so grateful to them for opening place in their hearts and laboratories for me. I would like to thank them again for their great contribution to my thesis with their patience, suggestions and motivating powers.

I would also like to thank my dear father Hakan Mete Doğan and my dear mother Selma Doğan, who have always supported in my every decision I made. They encouraged me to overcome the obstacles that came on my way and made me believe that there is nothing that a person cannot achieve. Finally, I would like to send my love to my husband, Umut Keskin, corresponding to his endless love and trust.

This thesis study was supported by The Scientific and Technological Research Council of Türkiye (TÜBİTAK) under “2211-A National PhD Scholarship Program”.

1. INTRODUCTION

1.1 Wheat

According to the recent years' archeological studies, agriculture started in the Fertile Crescent region which includes southeast of Türkiye. From then until now it spreads all over the World (1-3). The oldest agricultural products known as einkorn wheat, emmer wheat, barley, lentils, peas and flax. Modern molecular studies showed that einkorn (*Aegilops monococcum* L.) was first cultivated wheat near Karacadag region in Şanlıurfa Siverek province of Türkiye about 10,000 years ago (4). As a result of natural evolution, artificial selection or natural hybridizations, first hulled wheat cultural forms and then unhulled wheat cultural forms have been developed. Before modern wheat varieties became widespread, Siyez/IZA (Einkorn - *Triticum monococcum* ssp. *monococcum*) and Gernic (*T. dicoccon*) had been cultivated in Anatolia (5).

Türkiye is one of the leading countries about growing local varieties. Research on wild relatives (genetic sources) of wheat and development of local varieties began in the first quarter of the 20th century. The first and most important study on this subject belongs to Mirza Gökgöl. Gökgöl defined 18,000 different types and 256 new varieties of wheat which were registered for Türkiye (6).

In the middle of 20th century semi-dwarf varieties were brought from Mexico to Türkiye and this event significantly improved wheat production. This period was called "Green Revolution" and was led by Norman Borlaug. The aim of the Green Revolution was to prevent famine, but with this program the cultivation of local wheats decreased in Türkiye. All in all, while modern wheat varieties cultivation has been increased, the cultivation areas of local wheat varieties decreased rapidly and began to disappear after Green Revolution (7).

Wheat breeding studies aiming to develop varieties with high resistance to biotic-abiotic factors, high yield and rich nutritional contents. After the proclamation of the Turkish Republic, wheat breeding studies started in Eskisehir Seed Improvement Station in 1925. In these studies, selection and adaptation studies among the village varieties was started for improving bread and durum

varieties. Efforts to develop modern wheat varieties in Türkiye gained momentum in 1960s (8).

1.1.1 Evolution of Wheat

Aegilops L. and *Triticum* L. are important models for the study of polyploidy and domestication of wheat genome evolution. Of the three genomes involved in the evolution of modern wheat, the donor of the A genome is *Triticum urartu* Thumanjan ex Gandiljan. While there is some controversy over the donor of the B genome, *Aegilops speltoides* Tausch is considered to be the origin. There is a consensus that D genom comes from *Aegilops tauschii* Coss. (9).

In the evolution of modern wheat, allopolyploidization happened with several diploid species. This formed tetraploid and hexaploid wheat species (9, 10). *Triticum* ssp. *urartu* Thum. Ex Gandil. (which gave A genom, $2n=14$, AA) and *Aegilops speltoides* (which gave B genome, $2n=14$ BB) hybridized to form *Triticum turgidum* L. ($2n=28$, AABB), 0.5 to 3 million years ago (9, 10). 7,000 to 9,500 years ago, additional polyploidization happened and hexaploid wheat species *Triticum aestivum* ($2n=6x=42$, AABBDD) appeared. *Triticum turgidum* ssp. *dicoccum* (Schränk ex Schübl.) Thell. ($2n=4x=28$, AABB) and *Aegilops tauschii* ($2n=2x=14$) then hybridized to form *T. aestivum* ssp. *spelta* ($2n=6x=42$) Figure 1.1 (9).

Plant species domestication is very important for genome evolution. Farmers had selected suitable types of polyploid species for a long time and they pioneered the spread of these (10). Consequently, with domestication, genetic diversity of cultivated plant species has decreased compared to wild progenitors (9, 11).

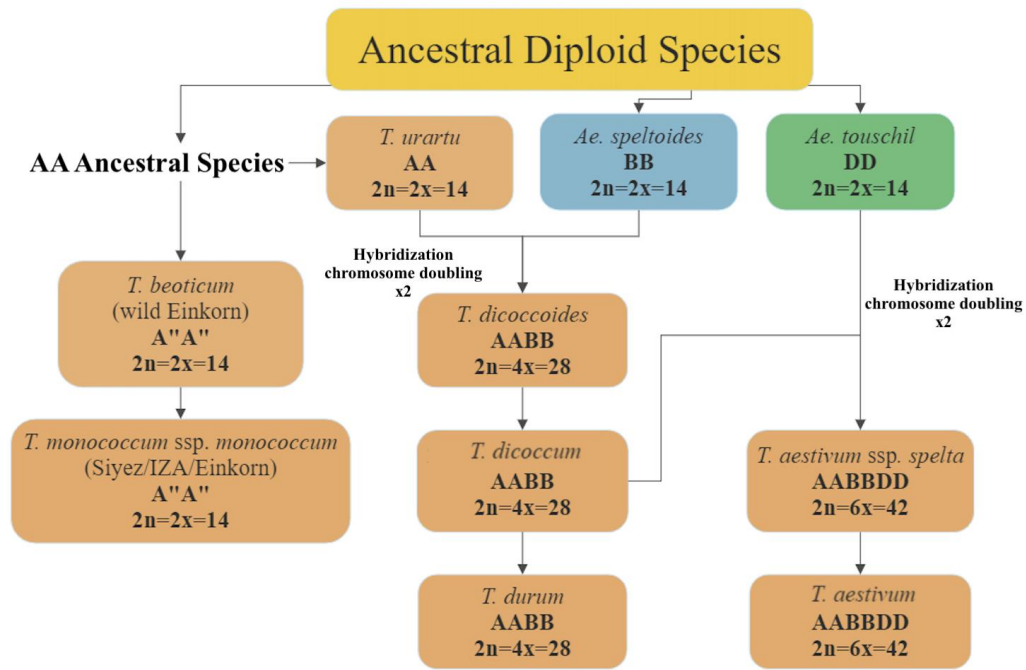


Figure 1.1. Origin of wheat. Image adapted from (9).

1.1.2 Einkorn (*Triticum monococcum* ssp. *monococcum*) Wheat

Einkorn is a wheat species that each spikelet contains one or two grains (Figure 1.2). It has been given different nicknames in different regions. While it is called IZA by the people who live in Bolu, it is called Siyez in Kastamonu. Einkorn wheat is known as an ancestral wheat species which is resistant to many abiotic factors (12, 13). In addition, this species was found to be rich in nutritional value. Despite such beautiful features, it is not preferred to cultivate by farmers, as it gives less product and it is difficult to separate hulls from grains. It is still being cultivated in small areas in Mediterranean region. However, nowadays, with the increasing importance of organic nutrition, the cultivation areas of einkorn are gradually increasing (14).



Figure 1.2. *T. monococcum* ssp. *monococcum* (IZA).

The resistance of einkorn to abiotic stress has been the subject of few studies. Cold stress is very important for the plants especially at the time of germination. That effects the plant enzymes or respiration which decrease the water uptake from soil by plant roots. It also inhibits ion and mineral uptake, limits nutrient transport to other parts of the plant. Thus, it inhibits plant growth. Beside these, low temperature causes micro-cellular damage and causes reactive oxygen species (ROS) (15). Cold stress decrease leaf area, grain number per spike, length of leaf and photosynthesis rate in wheat, as well (16). Aslan et al. (13) investigated the resistance of einkorn wheat against cold stress. It was concluded that einkorn samples obtained from high regions will be an important genetic resource due to their resistance to cold (13). One of the other important abiotic stresses on plants is drought stress. When the plant faced with drought stress, low turgor pressure of the leaf that causes to close the stomata. Thus, photosynthesis decreases as a result of limiting CO₂ entry. Low concentration of CO₂ lead to decrease ribulose-1, 5-bisphosphate carboxylase/oxygenase (RuBisCO) activity (17). In an experiment that the resistance of einkorn wheat to drought stress was measured, einkorn wheat performed well in terms of germination rate, germination power, shoot root length ratio (12).

Einkorn is also at the forefront in terms of nutritional value. It has been found to be valuable in terms of vitamins B and E (18). There are few studies showed that thiamine (B₁), riboflavin (B₂), pantothenic acid (B₅) and folate (B₉) vitamins were detected in einkorn. B vitamins play an important role in carbohydrate, fat and protein metabolism. Vitamin B₁ is involved in energy metabolism, and it has many functions on tissue, organs and cells. It supports development and growth, as well. However, its deficiency causes beriberi, depression and inflammation of nerves (neuritis) (19). Vitamin B₂ participates in the structure of flavin-adenine-dinucleotide (FAD) which has an important place in cellular respiration. B₂ has a great place in hair, nail and skin health (20). B₅ vitamin take place in the structure of coenzyme-A, which is involved in fatty acid synthesis. On the other hand, neurological symptoms appear in B₅ deficiency (21). Vitamin B₉ is an important type of vitamin to protect from cancer, vascular diseases, neural tube defect (22). Vitamin E is known as a powerful antioxidant and protects the cell from oxidative stress. There are two types of provitamin E which are called tocopherol and tocotrienol. Vitamine E is effective for eye and skin health. It reduces the risk of cholesterol and heart disease (23). B and E provitamin contents in wheat were studied before. In Karakas et al. (18) study, not only the B and E vitamins in wheat grains, but also these contents were examined in wheatgrass. Some B vitamin group and provitamin E group were examined on einkorn, emmer (*T. dicoccum* ssp. *dicoccum* Schrank.), durum (*T. durum* Desf.) and bread wheat (*T. aestivum*). Values of B₁, B₂ and B₅ came out higher in einkorn grass than other species. On the other hand, wheat grain contains high value of vitamin B₁ and B₂, as well. According to the provitamin E values, the α -tocopherol (α -TP) and α -tocotrienol (α -TT) values were seen the highest in einkorn grass and grain (18).

Vitamin A is one of the fat-soluble vitamins, and provitamins of vitamin A are carotenoids (α and β -carotene). Vitamin A deficiency prevents night vision and also reduces the risk of cancer. Carotenoids have antioxidant properties, thus preventing the formation of free radicals. Xanthophyll and lutein are the most abundant carotenoids in plants. Lutein, zeaxanthin and β -carotene were investigated among wheat species and were found in significant amounts in einkorn wheat. It has been determined that the lutein content of einkorn is higher than emmer and spring wheat. Zeaxanthin and β -carotene values of einkorn were higher

than other species such as bread wheat and emmer. It has been determined that einkorn contains more β -carotene than bread wheat and emmer (24).

Plants produce phenolic molecules which are known as secondary metabolites under the stress condition such as ultraviolet (UV) radiation, drought and salt. DNA, cells and tissues are protected from ROS by these molecules. Furthermore, they have anti-aging and antimicrobial feature (25). In the study conducted between einkorn, emmer, durum and bread wheat species, einkorn wheat grain and grass showed the highest value in terms of total flavonoids. According to the antioxidant properties, einkorn grass showed important results. All in all, einkorn has higher antioxidant ability, phenolic and flavonoid content compared to modern wheat (25).

Celiac disease is genetic disorders that causes sensitivity to gluten which has seen in cereal products. It is autoimmune disease and creates malabsorption in intestine, therefore most people avoid gluten-containing foods. Patients who have type 1 diabetes, neurological diseases, autism, dermatitis, irritable bowel syndrome (IBS), rheumatoid arthritis, cardiovascular diseases, obesity and insulin resistance prefer gluten-free diet (26). Although einkorn is not completely suitable for celiac patients, it is suitable for people who want healthy lifestyle with less gluten products (14). A study conducted between spelt, durum, bread wheat, emmer and einkorn showed that einkorn and emmer had low value of gluten content. However, spelt and durum wheat had high gluten value (27).

Although einkorn has low fiber, it is rich in proteins, lipids and trace elements. Compared to bread wheat, einkorn seems to be superior in terms of lipid value. Einkorn, which has a low content of saturated fatty acid, contains high values of monounsaturated fatty acid and polyunsaturated fatty acid (28). Einkorn has higher trace element than bread wheat, as well. It has been determined that einkorn has richer content of Zn, Fe, Mn, Mg and P elements than bread wheat (29).

1.1.3 Bread (*Triticum aestivum*) wheat

One of the most consumed wheat species in the world is the *T. aestivum*. For this reason, the knowledge of nutritional values of this species gained importance and many study had been done. The major nutritional content of bread wheat are starch, protein and cell wall polysaccharides. Calcium, potassium and phosphorus were identified as the main inorganic substances in *T. aestivum*, as well (Table 1.1) (30).

Table 1.1. Nutritional values of bread wheat (30)

Nutrients	Value per 100 g		Minerals	Value per 100 g	
Sugar	0.41	g	Magnesium	1.37	mg
Fiber	10.70	g	Calcium	34.00	mg
Carbohydrate	71.97	g	Iron	3.60	mg
Protein	13.21	g	Sodium	2.00	mg
Lipid	2.50	g	Zinc	2.60	mg
			Phosphorus	357	mg
			Potassium	363	mg

Ferulic acid constitutes 85% of phenolic acids which is followed by coumaric, sinapic ve caffeic acid in the grain of bread wheat (30). However, wheatgrass of bread wheat has rutin, chlorogenic acid, tocopherol and gallic acid. These compounds play important role in protecting against harmful effects from *Salmonella typhi*, *Staphylococcus aureus* and *Vibrio cholerae* (31). Phenol and antioxidant properties were found to be high in bread wheat, but removing the outer bran part of wheat causes to decrease these antioxidant abilities (32).

In Bolu province, local people grow Çalibasan and Sarı Serez as local bread wheat. Sarı Serez is consumed as bread and bulgur. On the other hand, Çalibasan is mostly consumed as dessert. Çalibasan mostly grown in Mudurnu and Göynük districts. People who live in these regions cook different dishes from Çalibasan, but the most important of them is Ugut Dessert which is healthy and sugar-free. It is one of the traditional foods that Turks have consumed since the time they had lived in Central Asia. Because the dessert had came from Central Asia, it has been given different names in different countries. For instance, in Kyrgyzstan, it is called Sümelek, in Afghanistan it is called Sümenek, in Iran it is called Samanu and in Türkiye it is called Uhut or Pugut. It is a type of dessert obtained by boiling the

germinated wheat for a long time, without using any sugar. This dessert is recommended for patient who have indigestion, non-healing wounds, memory loss, constipation and rheumatoid arthritis. Ugut contains 0.09-0.33% fat, 5.29-8.20% protein and 31.92-59.52% carbohydrates. Despite having these beautiful features, it is known in few regions in Türkiye and almost forgotten (33).

1.2 The Importance of Geographic Information System and Remote Sensing in the Protection of Genetic Resources

There are two valid methods has been used for protection of genetic resources in the world, and one of these methods is called *ex situ*. The genetic resources are preserved at out of their own location by freezing in the gene banks with this method. The other protection method is called *in situ* which the genetic resources are preserved in their own location. The location of these resources is identified and the areas are protected (34-36). Identifying, mapping and monitoring *in situ* areas are very important, especially for the protection of wheat genetic resources and the use of these resources for breeding purposes in Türkiye.

The most important study had been started in 1993-1998 with the help of World Bank and the United Nations Global Environment Facility (GEF) for *in situ* (34). The project focused on identifying and establishing *in situ* conservation areas for protection of genetic resources, important agricultural areas and forest tree species areas in Türkiye. It was carried out under the name of "Türkiye – *in situ* Conservation of Genetic Diversity Project" in cooperation with the Ministry of Environment, the Ministry of Agriculture and Rural Affairs and the Ministry of Forestry, as they were known at the time (34). Since determining *in situ* areas requires the use of Geographic Information System (GIS) and Remote Sensing (RS) technologies, the serious establishment and use of GIS and RS infrastructure was initiated with this project in Türkiye. The most important areas where wild wheat, barley, chickpea, lentil, pear, walnut, chestnut, olive, apple, peanut and some fir species grown were mapped with this project (areas: Ceylanpınar Agricultural Enterprise-Şanlıurfa, Kaz Mountains National Park-Balıkesir, Bolkar Mountains-Mersin, Aladağlar-Kayseri and Niğde). Gene Protection and Management Centers (GEKYA) had been established in these areas (36-40). Following these studies, many protected areas in Türkiye have been identified and mapped. 48 National

Parks, 261 Nature Parks, 31 Nature Reserve Areas, 113 Natural Monuments, 85 Wildlife Development Areas, 14 Ramsar Sites, 59 Wetlands of National Importance, 59 Wetlands of Local Importance, 55 Conservation Forests, 134 Urban Forest, 339 Gene Protection Forests, 213 Seed Gardens and 311 Seed Stands has been determined by the Ministry of Agriculture and Forestry, General Directorate of Nature Conservation and National Parks (41).

Due to Türkiye's digital databases are not yet available most of studies remain limited with creating basic layers of digital database such as topographic, soil, geological and forest maps between 1996 to 2003. Today, GIS and RS technologies have an indispensable place in mapping plant genetic resources and determining *in situ* areas. It has become easy to reach Global databases which are archive of various national and international satellite images. Computer hardware, GIS and RS software have also developed at a dizzying pace and increased their user-friendly features. Topographic, soil, geological, forest and parcel map layers of Türkiye, which are basic database, had been done in this process. Although some important databases have been completed, some remain incomplete. For example, all of the Gene Conservation and Management Areas (GEKYA) in Türkiye, which have very rich plant biodiversity, have not been determined completely, yet. At this stage, more detailed studies at the local level need to be added to the studies carried out at the national level in order to solve complex planning and management problems. In order to carry out detailed studies, new methods and detailed databases are needed (42).

Çankırı, Çorum, Sinop, Kayseri, Kastamonu and Bolu are known as special places for growing ancestral and local wheats in Türkiye. *T. monococcum* ssp. *monococcum* which is grown in Kastamonu and Bolu, has recently become famous because of its healthy nutrition approach. This wheat species is called by different nick names in different regions; for example, in Kastamonu people call Siyez while in Bolu people call IZA. This ancestral wheat that is important and valuable as a breeding material, has populations distributed in Bolu. Moreover, a small number of local bread wheat varieties have been grown in Bolu province by limited local people. These varieties are known as Çalibasan and Sarı Serez. Local people make sugar-free dessert from Çalibasan, and Sarı Serez is served as bulgur. *In situ*

protection of these species are significant due to their own feature. Since the determination of Gene Protection and Management Areas has not been fully completed, the distribution and the characteristic feature of these species in Bolu have not been studied, yet.

1.3 Start Codon Targeted (SCoT) Marker

Start codon targeted (SCoT) marker is used in many studies such as plant genetics, genomics and molecular breeding. This marker targets the ATG base sequences which is located within the short conserved region of start codon (43, 44). Start codon targeted markers show higher polymorphism and better resolvability than other dominant DNA markers such as random amplified polymorphic DNA (RAPD) and inter simple sequence repeat (ISSR). Therefore it became more popular (45). In addition to being highly polymorphic, this marker is also affordable and new (44). The SCoT markers are effective in analyzing population genetics in a wide range of plants, and they are sensitive to low genetic variation, as well. They are also suitable markers in polymorphism studies of the same species populations (46).

The SCoT markers were used in a study that also included *T. monococcum* and *T. aestivum* species. In the study of Guo et al. (47), seven species were chosen from *Thinopyrum* (2 *Th. bessarabicum*, 1 *Th. elongatum*, 2 *Th. intermedium* and 2 *Th. ponticum*), eleven species were chosen from *Triticum* (2 *Aegilops tauschii*, 5 *T. aestivum*, 2 *T. timopheevii*, 1 *T. monococcum* and 1 *T. turgidum*), and *Hordeum vulgare* cv. Golden.. Seventeen types of SCoT markers and ten types of conserved DNA-derived polymorphism (CDDP) marker were used to see phylogenetic relationships of these species. SCoT showed 8.5 and CDDP showed 6.6 of mean number of alleles. All in all, *Thinopyrum* species were found to be closer to *Triticum* species, while *H. vulgare* was found to be distant from these species (47).

In another study, ten different SCoT marker were used on durum wheat (*Triticum turgidum* var. *durum* (Desf.)). Wheat was obtained from Italy, Mexico and different regions in Iran. From this study, it was determined that wheat in the closer geographical region showed closer genetic similarities to each other than wheat in different locations. According to the SCoT markers, dendrogram showed

two major clusters. One of the clusters included the genotypes of durum wheat which was collected from North-West and North-east Iran. Other cluster includes durum wheat which were collected from South Iran, Italy and Mexico (48).

Twenty-five breeding lines and 18 landraces of *Triticum turgidum* var. *durum* (Desf.) were involved in one of another study which six SCoT marker and fifteen ISSR markers were used. The SCoT marker showed 100% polymorphism. The values of effective number of alleles (n_{ae}), Shannon's Information index (I) and Nei's gene diversity (h) was high in landrace, and five clusters were formed on the dendrogram. Eight landraces formed one cluster, and other clusters included breeding lines (49).

Another SCoT marker study was conducted on *Triticum* species which were grown in Iran. The marker study was carried out with seventy samples which include *T. boeoticum*, *T. urartu*, *T. durum* and *T. aestivum* species. Fifteen types of SCoT markers were used. A total of 166 bands had been detected and out of them 162 bands were polymorphic. According to the Analysis of Molecular Variance (AMOVA) result, 63% of the variation was found among populations. *T. boeoticum* showed higher value of effective number of alleles (n_{ae}), Shannon's Information index (I) and Nei's gene diversity (h). The dendrogram formed three clusters. It has been observed that there was remarkable genetic diversity among Iran *Triticum* species, especially *T. boeoticum* (50).

Nineteen SCoT markers and 15 CAAT-box derived polymorphism (CBDP) markers were tested on 85 *T. urartu* species in the study of Gholamian et al. (51). CBDP created 185 polymorphic bands (PB) with an average of 9.74 per primer, while SCoT created 141 PB with an average of 9.40 fragments per primer. The polymorphism information content (PIC) value of the SCoT marker varied between 0.40 and 0.50. On the other hand, the PIC value of the CBDP marker was found to range from 0.40 to 0.49. It was determined that they were divided into two main cluster groups in the dendrogram (51).

Ahmad (52) studied on 51 wheat species, which were contained *Aegilops* and *Triticum* specieses. Eighteen of SCoT marker were used, and 139 alleles were seen. While the PIC value showed 0.56, the marker index (MI) value showed 3.7.

The dendrogram was divided into three main clusters and all *Triticum* species were grouped into a single group (52).

1.4 Agro-morphological Feature of Wheat

Observing of photosynthetic organs as an agro-morphological feature is very important in wheat. Photosynthesis is the oxidation-reduction that occurs in chlorophyll, which converts light energy into chemical energy and forms organic substances for the plant (53). Stem, leaves, spike and awns are photosynthetic organs, but the most important photosynthetic organ is known as the flag leaf in wheat. Before the heading period of nutrients which are produced by photosynthesis are used from leaves, stems, roots and spike whereas during the heading period these nutrients are transported to the grains. At the grain filling period most of the nutrients are synthesized by the photosynthetic organs in the upper part of the wheat plant (54). Especially flag leaf is the main source of nutrients required for grains in wheat. The flag leaf has two parts: blade and sheath (55). However, most of the time the sheath is neglected and only the flag leaf blade is expressed as the total flag leaf (53). The flag leaf has great importance in plant productivity. For this reason, it is observed at the top among the agro-morphological characteristics of wheat.

Plant height is an important factor in the plant's tendency to lodging. Lodging is a condition that causes significant yield losses in cultivated plants, and it is most common in cereals. Planting time and frequency, excessive use of fertilizers, increased irrigation opportunities, pests, ecological factors and field conditions effect lodging in wheats. Those factors may reduce cereal yield up to 80%. Shorter plants are more resistant to it whereas some tall varieties which give high yield can be resistant, as well (56). This is why, short hybridized wheat is generally preferred. Reitz and Salmon (57) stated that resistance to lodging is related not only the strength of the stem, but also the stem elasticity. The thick stem and strong root structure can protect the plant from lodging (56). Not only the applied amount and frequency of plant fertilization but also root and stem diseases may cause lodging. It was observed that there was 70% crop loss due to root and stem diseases (58). Beside these, it has been determined that early lodging affects the number of kernels per spike (KPS), while late lodging affects kernels size. These

situations indirectly affect the economy (59). Artificial plant growth regulators can be used to prevent low productivity due to lodging. Although ethephon which is a type of plant growth regulator, cope with these problems in Europe, it was not effective in North America (60).

Wheat yield is related to the number of grains per spike, thousand kernels weight and number of spikes. In fact, plant height, spike length and spike compactness features are also related to the thousand kernels weight and the number of KPS. Moreover, the relationship between spike height and fusarium head blight has been determined and found to be inversely proportional. All these agromorfological features directly or indirectly affect the yield (61).



2. AIM AND SCOPE OF THE STUDY

Çankırı, Çorum, Sinop, Kayseri, Kastamonu and Bolu are known as special places for growing ancestral and local wheat accessions in Türkiye. The most grown wheat species in Bolu province is known as *T. monococcum* ssp. *monococcum*. Local people have given different nicknames to einkorn wheat in Kastamonu and Bolu. People who live in Bolu call this species IZA, whereas in Kastamonu they call Siyez. Nowadays, healthy eating has become popular. For this reason, einkorn wheat is a blessing in terms of nutritional content and fiber. Einkor, is important and valuable as a breeding material, has grown in districts and villages of Bolu province. This study also included two local wheat varieties (*T. aestivum* cv. Çalibasan and *T. aestivum* cv. Sarı Serez) preferred to be grown by farmers. It is important to preserve these genetic resources that are rich in nutrient and resistance to biotic and abiotic stress for in situ. Since GEKYA has not yet been completed in Türkiye, the distribution and characteristics of these local populations within the province have not been extensively studied scientifically. It is important to map the geographical distributions of wheat populations using GIS and RS technology. Moreover, investigation of agro-morphological and polymorphic characteristics guides for future studies. This thesis gives information about the natural conditions in Bolu where land raced of wheat were grown. Elevation values were examined by using Advanced Spaceborne Thermal Emission and Reflection Radiometer Digital Elevation Model (ASTER) Digital Elevation Model (DEM) data, climate values by using Climatologies at High Resolution for the Earth's Land Surface Areas (CHELSA) data, topographic structure by using International Soil Reference and Information Center (ISRIC) data, and land cover/use by using the Coordination of Information on the Environment (CORINE) database. Moreover, Great Soil Groups and Land suitability was examined by using General Directorate of Rural Affairs (KHGM) data. This study aimed to create a model that can be used to determine suitable areas where these wheat species can grow. Another aim of our study is to determine the genetic polymorphism and affinity relationships of local wheat varieties grown in Bolu province.

3. MATERIALS AND METHODS

This chapter contains the information about the study area and applied methods. First, the physiographic setting and general topography of the study area were shortly explained. Then, detailed information about the followed methodology in the study was given.

3.1 Material

This study was carried out in Bolu province that covers an area of 8,313 km² in Türkiye and offers a unique opportunity to study the biodiversity and natural processes of agro-forest ecosystems. The study area is located between 40°08'29.86" - 41°00'36.07" north latitudes and 30°30'0.47" - 32°35'56.44" east longitudes, and the altitude varies between 278 and 2,371 m (Figure 3.1). Kapıorman Mountains, Elmacık Mountain, Abant Mountains, Bolu Mountains, Sünnice Hill, Çeledoruğu Hill and Gökçeler Mountain, which are located on the northwest-northeast axis; Köroğlu Mountains, Çal Mountain, Karlık Mountain, located on the southwest-southeast axis, and Kartalkaya Hill, Asarlık Hill and Köroğlu Mountain located in the mid-south of the district are the main landforms in the province. Himmetoğlu, Mudurnu, Bolu, Seben, Yeniçağa and Gerede plains are also among these main landforms.

Bolu has a total of 9 districts and the largest area covered by the Central (1,616 km²) district. This is followed by Göynük (1,407 km²), Mudurnu (1,314 km²), Gerede (1,060 km²), Mengen (874 km²), Seben (683 km²), Dörtdivan (634 km²), Kırısıcık (562 km²) and Yeniçağa (163 km²) (62).

The study area is located at the intersection areas of the Marmara, Aegean, Black Sea and Central Anatolian geographical regions of Türkiye (Figure 3.2). As a result, it is influenced by the climates in these geographic areas. Basically, the Aegean region has a typical temperate Mediterranean climate characterized by hot-dry summers and humid cool winters (63).

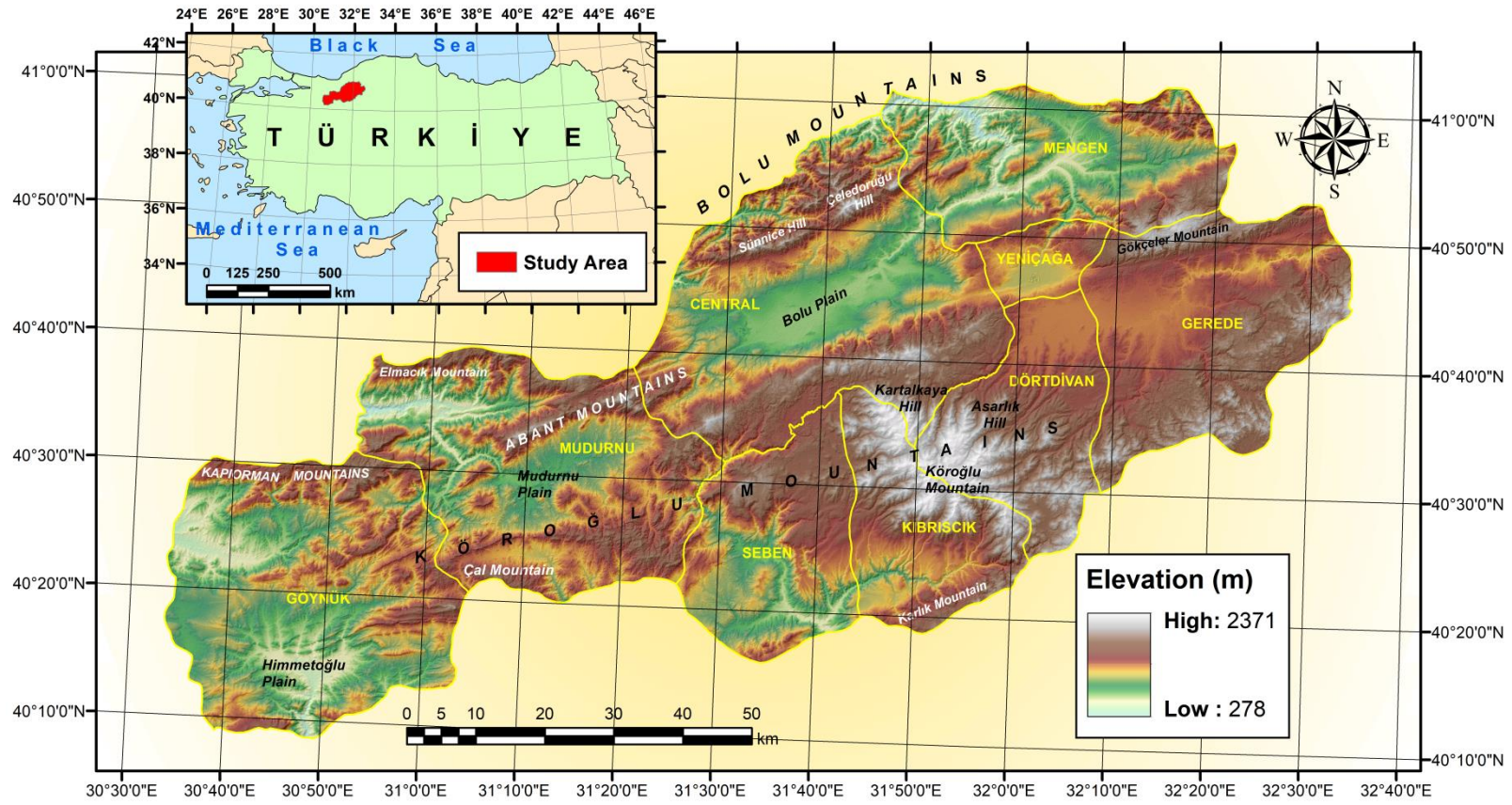


Figure 3.1. Districts and general topographic features of the study area (Bolu province).

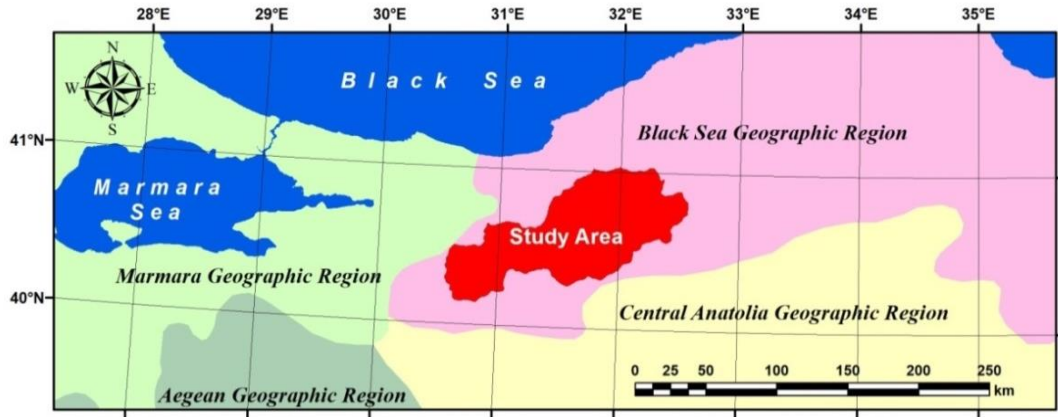


Figure 3.2. Location of the study area in the geographic regions of Türkiye.

The Black Sea region has a temperate oceanic climate with warm-wet-summers and cool to cold wet winters, and has the greatest amount of precipitation (~2,500 mm annually). Marmara region has a transitional climate between a temperate mediterranean climate and a temperate oceanic climate, and has warm to hot, moderately dry summers and cool to cold, wet winters. Generally, snow does not occur on the coastal areas. Finally, Inland Anatolian plateau (Central Anatolia), which is located at the south of the study area experiences extremes of hot summers and cold winters with limited (~400 mm annually) rainfall (63). Therefore, the climate of the study area has transitional characteristics between the maritime climate of Black Sea and the continental (steppe) climate of Central Anatolia. In places close to the Black Sea, summers are cool, and winters are mild, and the difference between summer and winter is small. In the interior, the temperature difference between summer and winter, and between night and day, increases. In these parts, winters are cold and snowy.

The most detailed Köppen Climate Types map of Türkiye was produced by Peterson (64) using the Köppen Climate Classification (65) which is one of the most frequently used climate classification methods all over the world (66).

According to Peterson's Köppen Climate Types map of Türkiye, a total of 13 climate classes have been identified (Figure 3.3a). In this study, Bolu Province Köppen Climate Types map produced in ArcGIS environment by making use of Türkiye Köppen Climate Types map is given in Figure 3.3b. According to this map, there are four climate types (Cfb, Csa, Csb, Dsb) in Bolu province.

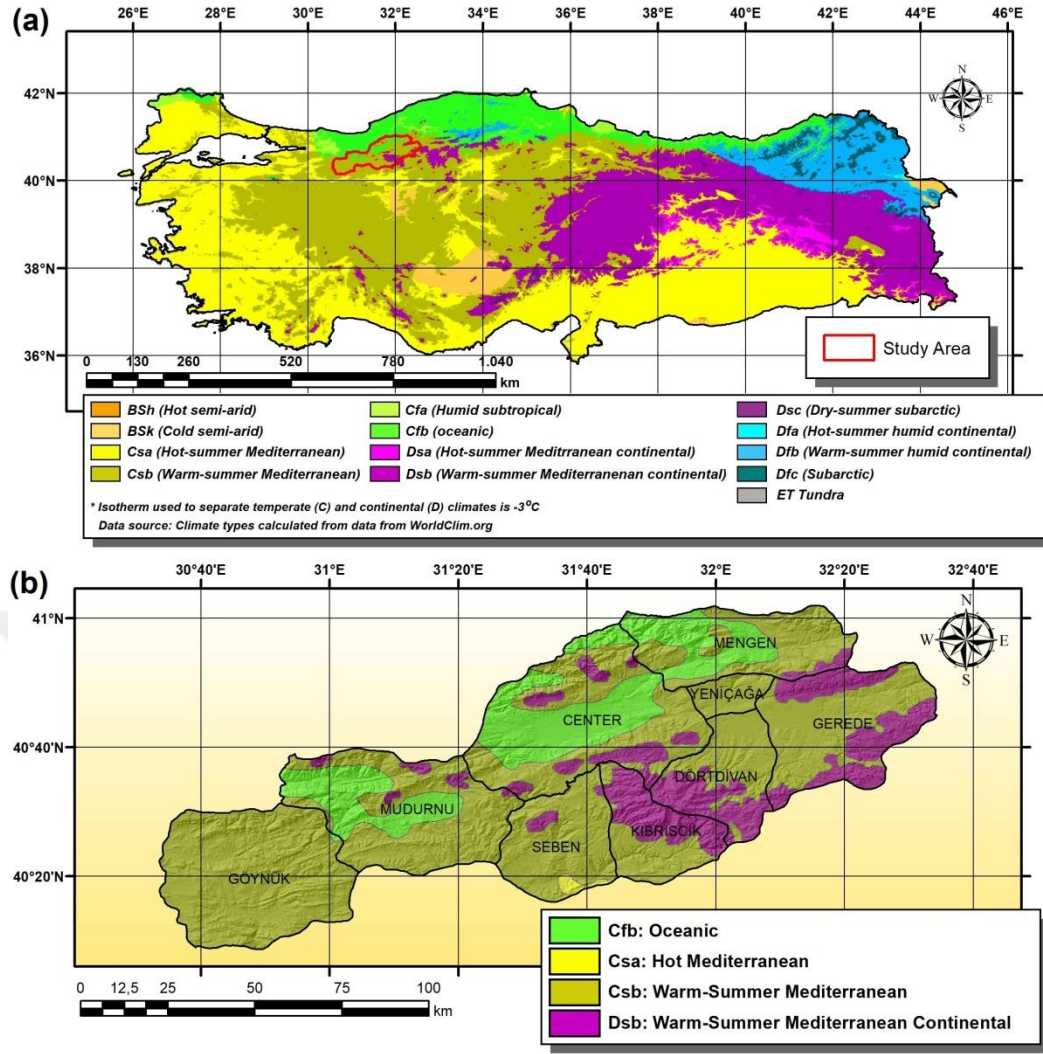


Figure 3.3. (a) Köppen Climate Types Map of Türkiye (64), and (b) Bolu Province Köppen Climate Types map produced in ArcGIS environment by utilizing Köppen Climate Types map of Türkiye.

Cfb refers to the temperate oceanic climate which is no significant difference in precipitation between seasons (66). Average temperatures in all months are below 22 °C and there are at least four months on average above 10 °C (eg England, Iceland, Northern Türkiye).

Csa refers to a Hot-summer Mediterranean climate where the mean coldest month is above 0 °C or -3 °C, at least one month average temperature is above 22 °C and at least four months is above 10 °C (66). In this climate class, the wettest month of winter receives at least three times more precipitation than the driest month of summer, and the driest month of summer receives less than 30 mm of precipitation. (e.g., Western and Southern Türkiye, Greece, Portugal).

Csb defines a Warm-summer Mediterranean climate, where the average coldest month is above 0 °C or -3 °C, average temperatures are below 22 °C in all months, with an average of at least four months above 10 °C (66). In this climate type, at least three times more precipitation is received in the wettest month of winter than in the driest month of summer, and precipitation is less than 30 mm in the driest month of summer.

Dsb, describes hot summer humid continental climate influenced by the Mediterranean where the mean temperature of the coldest month is below 0 °C or -3 °C, the average temperature of the warmest month is below 22 °C, and the average temperatures of at least four months are above 10 °C (66). In this climate type, at least three times more precipitation is received in the wettest month of winter than in the driest month of summer, and less than 30 mm of precipitation is received in the driest month of summer.

In this study, graphs showing the monthly distribution of important climatic parameters of Bolu province were also produced by utilizing the data covering the years 1991-2020 available on the official website of the Ministry of Environment, Urbanization and Climate Change, General Directorate of Meteorology (67). The monthly distribution of climate variables in the province of Bolu, such as precipitation (mm), temperature (°C), number of rainy days and sunshine time (hours) are given in the Figure 3.4.

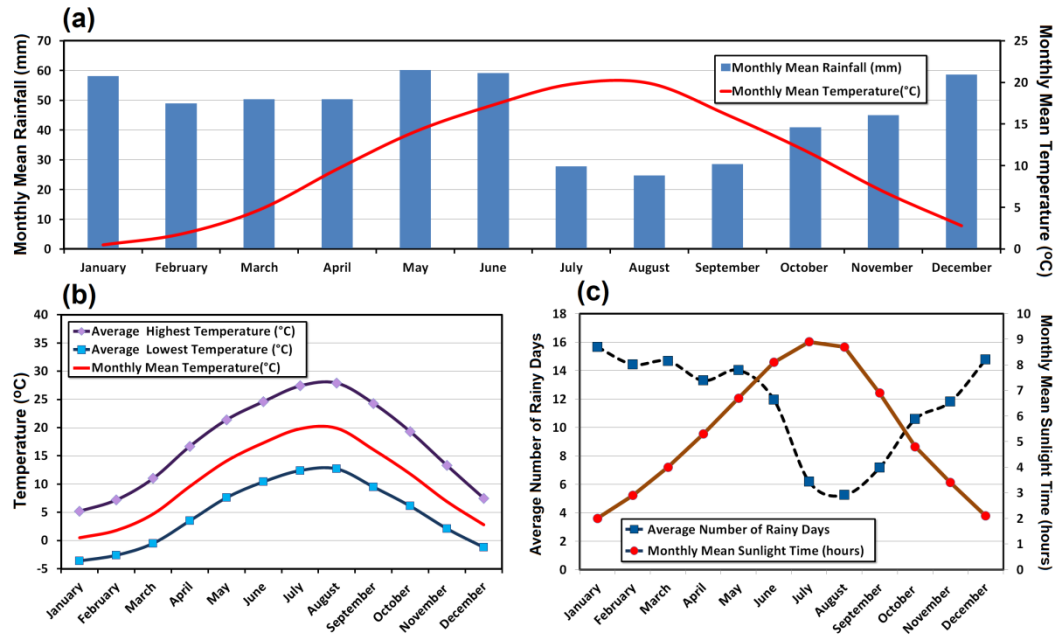


Figure 3.4. Monthly distribution of important climatic variables of Bolu province: (a) monthly mean rainfall (mm) and temperature (°C), (b) highest-lowest and mean temperatures (°C), and (c) average number of rainy days and monthly mean sunlight time (hour) (produced by using 1991-2020 data from General Directorate of Meteorology (67)).

In land cover point of view, the majority of the study area has forest and semi-natural characteristics (74.92%) followed by agricultural land (23.53%) (68). According to Turkish Statistical Institute (69), a total of 946.36 km² of agricultural land was planted in Bolu in 2021 and distribution of these cultivated areas by products is given in the chart below (Figure 3.5). As can be seen from the graph, wheat is the most planted product in Bolu province with a cultivation area of 476.01 km². Barley and alfalfa (greengrass) are the second and third crops with a cultivation area of 179.21 km² and 71.13 km², respectively. The other products seen in the Figure 3.5 below followed these products.

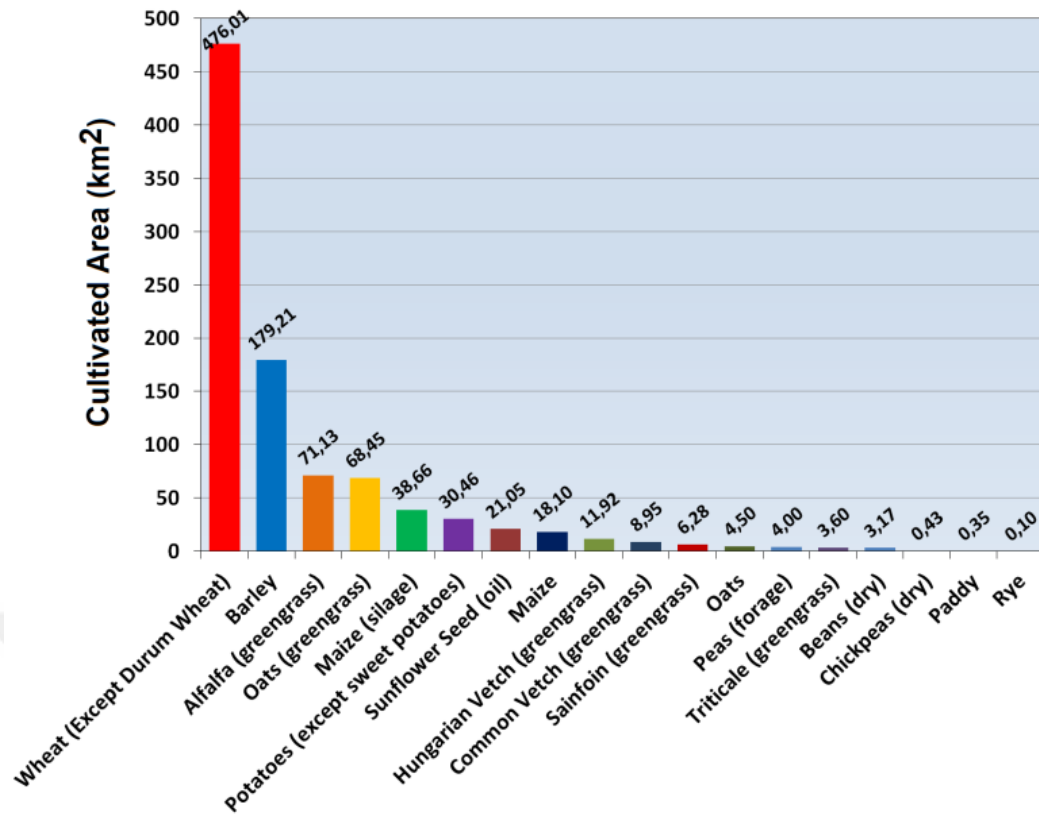


Figure 3.5. Distribution of cultivated agricultural land of Bolu according to product basis in the year 2021 (69).

3.2 Methodology

The methodology followed in this study has been created with a new perspective and has a high potential to be used for future studies. The flowchart of the applied methodology is summarized in Figure 3.6. Briefly, the study was carried out in three stages including [1] field, [2] laboratory, and [3] office studies.

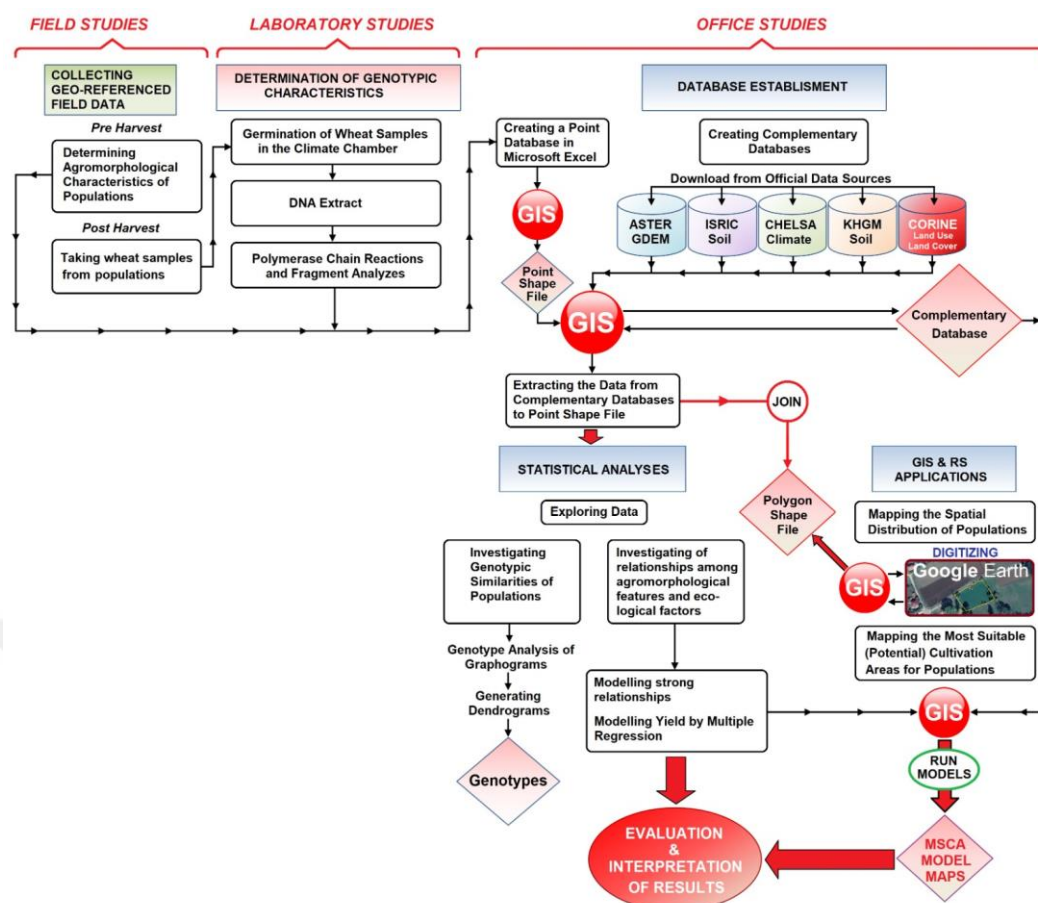


Figure 3.6. Flowchart of the methodology (rectangular is the main title of the work done, rectangle with rounded corners indicates the operation performed, globe refers the used tool in the operation, cylinder means created database, and rhombus shows achieved result).

Field studies included collecting geographically referenced data, determining agro-morphological features in pre-harvest, and taking wheat samples from populations in post-harvest.

Studies on the determination of polymorphic characteristics contained germination of wheat samples in the climate chamber, DNA extraction, polymerase chain reactions (PCR) and fragment analysis.

Office work can be summarized as database establishment, statistical analyses, and GIS applications. Finally, evaluation and interpretation of the results constitute the last stage of the methodology.

3.2.1 Field Studies

Pre-harvest field studies were carried out in June-July 2021. At this stage, the agro-morphological variables (Table 3.1) were determined in the field and recorded. Information and support about the locations of wheat landraces populations to be sampled were obtained from Bolu Parks and Gardens Directorate and sampling locations were determined accordingly. Land samplings were done in all of the determined locations.



Table 3.1. The unit and definition of wheat agro-morphological variables determined in the field and the number of samples measured in each population (Note: Pre-harvest and post-harvest samplings are shown in the table).

Agro-morphological Variables		Unit	Description	Measured Sample Number in Each Population
PRE-HARVEST	Plant height (PH)	cm	The height of plant from ground level to end of spike excluding awns at maturity.	10
	Spike length (SL)	mm	The length of spike excluding awns at maturity.	10
	Number of kernels per Spike (KPS)	number	Number of grains counted on main spike.	10
	Upper Node Length (UNL)	cm	Distance from 4 th node to the end of spike	10
	Spikes fertile per square meter (SFPS)	number	The number of spikes per square meter was calculated by counting affected the spikes contained in 1 m of one of the central rows in each plot.	10
	Flag leaf width (FLW)	cm	The widest part of the flag leaf blade was measured.	10
	Flag leaf length (FLL)	cm	The flag leaf length was measured and determined in cm.	10
POST HARVEST	Thousand kernels weight (TKW)	g	Average weight (g) of 4 lots of 100 seeds, multiplied by 10 (the weight in grams of 1,000 seeds).	10
Total Measurement Number in each Population				80

During field studies, the geographical coordinates of the sampling points, which will represent the populations, were determined by GPS. For this aim, the GPS device Magellan Explorist 710 about ± 3 m accuracy was used to collect geo-referenced data.

We determined three different wheat landraces within the borders of Bolu Province namely; (1) *T. monococcum* ssp. *monococcum* (called IZA in Bolu province), (2) *T. aestivum* (cv. Çalibasan), (3) *T. aestivum* (cv. Sarı Serez). However, samples of Siyez wheat (*T. monococcum* ssp. *monococcum*) which were taken from Kastamonu (in the North west of Bolu province) province was used as a control group just only in polymorphism studies. Since the samples taken from Kastamonu were outside our study area, we used these only as control data in polymorphism studies.

Total 78 points (locations) was sampled (*T. monococcum* ssp. *monococcum* samples were taken from 69 points, *T. aestivum* cv. Çalibasan were taken from 4 points, *T. aestivum* cv. Sarı Serez were taken from 5 points) in Bolu province. Sampled points in this study were shown in Figure 3.7a. A sampling (population) number was given to each sampled point and the data obtained from this point were recorded. In order to represent the sampled population as healthy, agro-morphological measurements at each sampling point were made with 10 replications. While determining the agro-morphological characteristics of the populations, the sampling procedure given in the Figure 3.7b was applied.

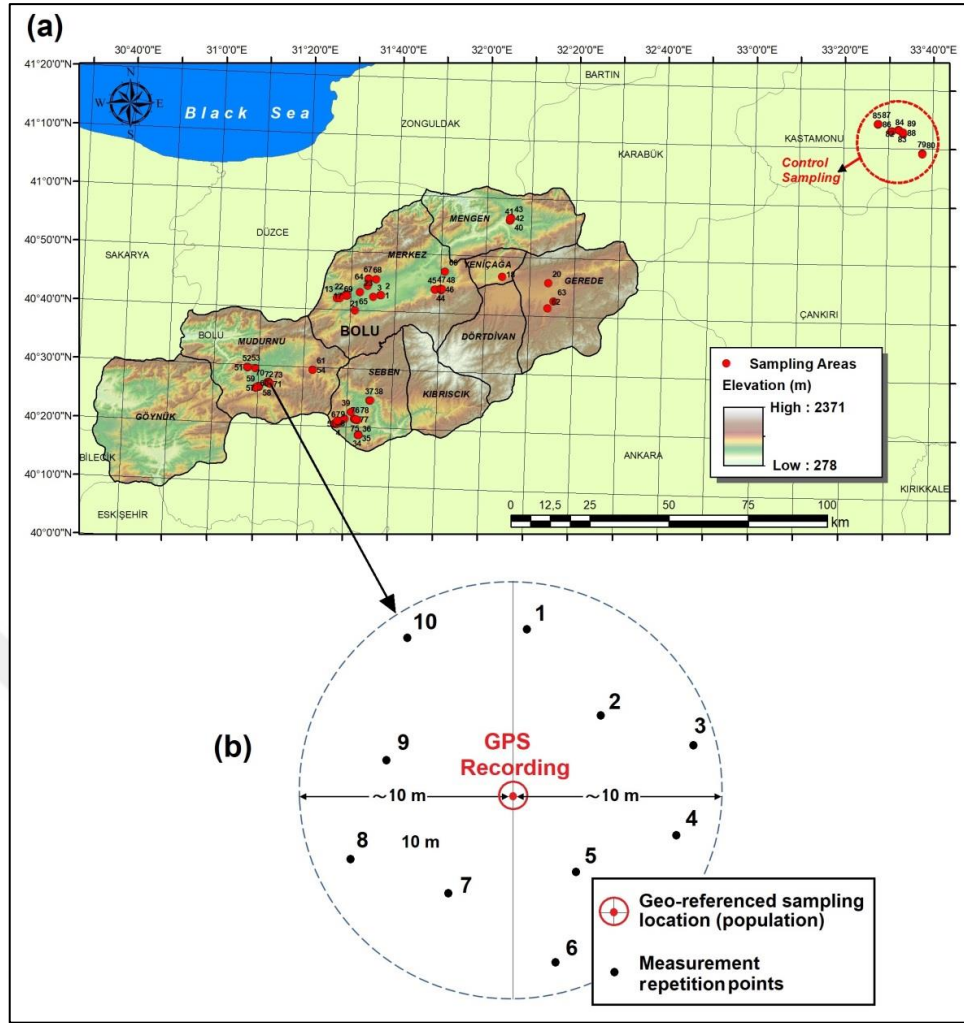


Figure 3.7. Sampling points (populations) in the study area (a), and sampling procedure applied in each sampling points (b).

In post harvest, 1 kg of wheat which was taken from each population to measure the weight of TKW. Each population was carefully packaged and labeled while in the field. Accordingly, all measurements of agro-morphological variables (except TKW) were made in 10 different places randomly selected in a circle with a diameter of approximately 20 m centered on the sampling point, and recorded. Thus, measurements of each variable were made with 10 replications in each population. In this process, 10 whole plant samples were also taken from each wheat population and labeled. Some examples of field studies are given in Figure 3.8. A total of 78-point data, and 780 whole plant samples were collected within this period. In Mapping and Statistical Analyses; the averages of 10 repeated measurements taken from each sampling point were utilized.

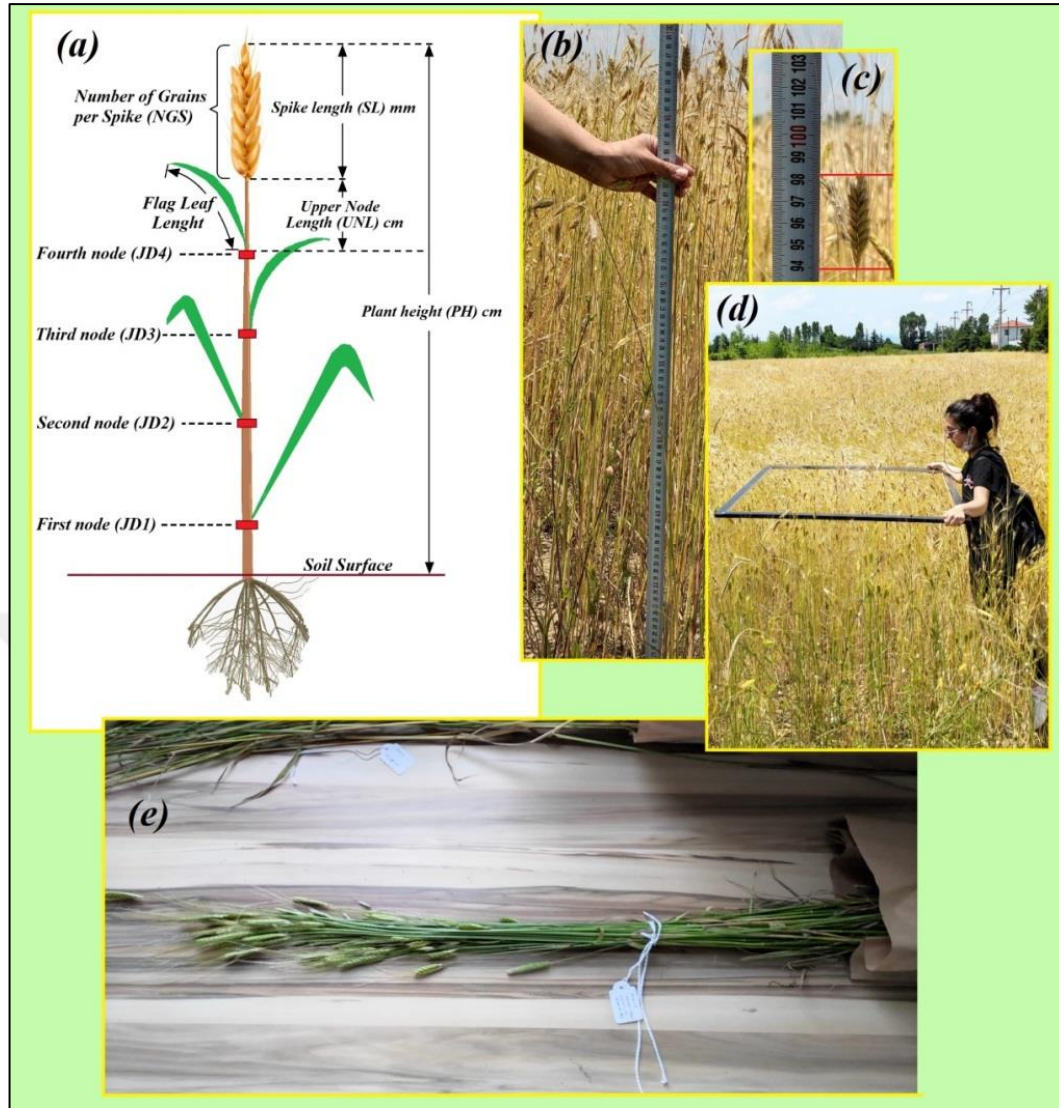


Figure 3.8. Examples of field work; measured geomorphological variables (a), measuring plant height (b), measuring spike length (c), counting spikes fertile per square meter (d), taking 10 whole plant samples from each wheat population (e).

3.2.2 Laboratory Studies

3.2.2.1 Plant Materials

In this study, molecular characterization of polymorphism was studied on different varieties of *T. aestivum* (cv. Çalıbasan, cv. Sarı Serez) and different populations of *T. monococcum* ssp. *monococcum* (IZA), which were grown in Bolu villages of Türkiye. SCoT markers were used for polymorphism study. In total, 69 populations were collected for IZA, 4 population were collected for Çalıbasan and 5 population were collected for Sarı Serez. 10 samples were taken from each

population and were given population number. In our study, polymorphism was not observed among IZA species grown in the Bolu region. For this reason, the species grown in Kastamonu region were also added to the study for control group. IZA samples with the number of 70-77 populations were obtained from Kastamonu which were harvested in 2021 (Table 3.2).

Table 3.2. General information about the populations of *T. monococcum* ssp. *monococcum* (IZA) and *T. aestivum* (cv. Çalıbasan and cv. Sarı Serez) species (N: Number, RN: The registration number, CN: Chromosome Number).

N	RN	Species	CN	Coordinates	
				X	Y
1	86	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.6126	40.7126
2	87	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.6140	40.7123
3	88	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5846	40.7072
4	89	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4616	40.3413
5	90	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4613	40.3416
6	91	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4602	40.3425
7	92	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4595	40.3426
8	93	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4649	40.3439
9	94	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4647	40.3434
10	95	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4656	40.3430
11	96	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4674	40.3416
12	97	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4770	40.3498
13	98	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4493	40.6998
14	99	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4817	40.7092
15	100	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4837	40.7116
16	101	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4859	40.7081
17	102	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4859	40.7078
18	103	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	32.0641	40.7759
19	104	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5939	40.7568
20	105	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	32.2377	40.7619
21	106	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4832	40.7094
22	107	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4857	40.7074
23	108	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5353	40.7188
24	109	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.1571	40.4911
25	110	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4749	40.3449
26	111	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4747	40.3456
27	112	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4718	40.3490
28	113	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4709	40.3487
29	114	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4699	40.3498
30	115	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4697	40.3502

31	116	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4689	40.3510
32	117	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4949	40.3571
33	118	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5490	40.3128
34	119	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5484	40.3125
35	120	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5466	40.3119
36	121	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5482	40.3119
37	122	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5859	40.4117
38	123	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5876	40.4112
39	124	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5184	40.3763
40	125	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	32.0872	40.9377
41	126	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	32.0878	40.9369
42	127	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	32.0905	40.9444
43	128	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	32.0873	40.9437
44	129	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.8152	40.7335
45	130	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.8145	40.7336
46	131	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.8383	40.7330
47	132	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.8370	40.7369
48	133	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.8417	40.7355
49	134	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.2029	40.4525
50	135	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.2034	40.4519
51	136	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.1262	40.4935
52	137	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.1281	40.4926
53	138	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.1261	40.4933
54	139	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.3695	40.4930
55	140	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.1713	40.4392
56	141	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.1705	40.4399
57	142	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.1718	40.4381
58	143	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.1700	40.4407
59	144	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.1594	40.4354
60	145	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.1610	40.4364
61	146	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.3690	40.4926
62	147	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	32.2371	40.6901
63	148	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	32.2582	40.7101
64	149	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5626	40.7380
65	150	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5185	40.6659
66	151	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.8501	40.7856
67	152	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5661	40.7581
68	153	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.5666	40.7570
69	154	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	31.4607	40.6998
70	8	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.6299	41.1545
71	9	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.6292	41.1525
72	10	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.5142	41.2171
73	11	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.5380	41.2205
74	12	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.5416	41.2190

75	13	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.5109	41.2167
76	14	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.4611	41.2358
77	15	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.4619	41.2367
78	16	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.4601	41.2361
79	19	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.5553	41.2091
80	20	<i>T. monococcum</i> ssp. <i>monococcum</i>	2n=2x=14	33.5556	41.2130
Çlb1	71	<i>T. aestivum</i> (cv. Çalibasan)	2n=6x=42	31.2070	40.4544
Çlb2	76	<i>T. aestivum</i> (cv. Çalibasan)	2n=6x=42	31.2094	40.4528
Çlb3	79	<i>T. aestivum</i> (cv. Çalibasan)	2n=6x=42	31.2088	40.4497
Çlb4	83	<i>T. aestivum</i> (cv. Çalibasan)	2n=6x=42	31.2120	40.4474
Ss1	72	<i>T. aestivum</i> (cv. Sarı Serez)	2n=6x=42	31.5300	40.3576
Ss2	73	<i>T. aestivum</i> (cv. Sarı Serez)	2n=6x=42	31.5430	40.3551
Ss3	74	<i>T. aestivum</i> (cv. Sarı Serez)	2n=6x=42	31.5339	40.3563
Ss4	75	<i>T. aestivum</i> (cv. Sarı Serez)	2n=6x=42	31.5359	40.3550
Ss5	77	<i>T. aestivum</i> (cv. Sarı Serez)	2n=6x=42	31.5376	40.3562

3.2.2.2 Germination of Wheat Samples

Soils were sterilized in autoclave at 121 °C for 15 minutes. Then they were transferred to the pots and five wheat grains of each population were seeded into these soils. The pots were placed into the climate room (Figure 3.9). The seeds were grown in climate room with 16 h light / 8 h dark period at 24 ± 2 °C till they germinate. Germinated wheat samples were cut into tubes and prepared for DNA isolation. They kept at -20 °C until the isolation process was carried out.

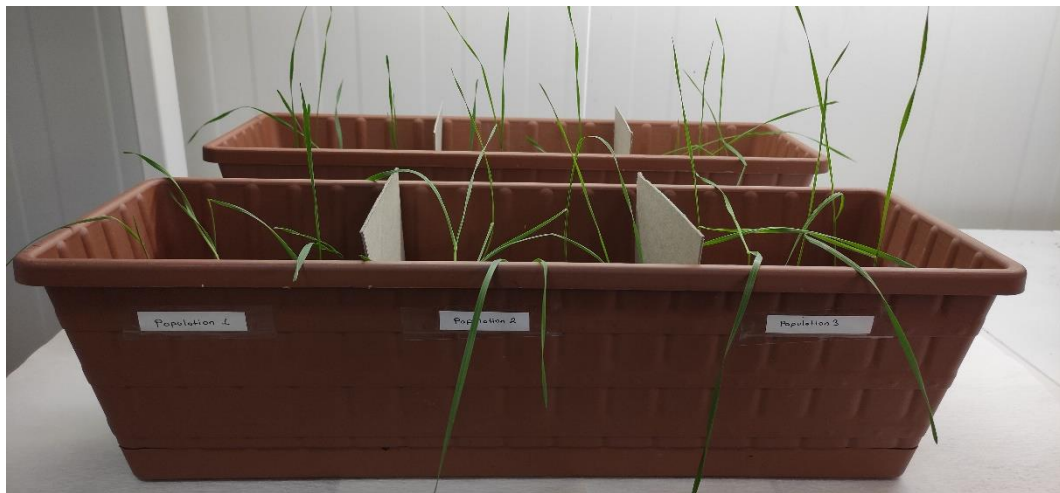


Figure 3.9. Five wheat grains of each population were seeded and grown in climate room.

3.2.2.3 DNA Extraction

DArT DNA isolation (70) method was used for the extraction of DNA. This method is based on hexadecyltrimethylammonium bromide (CTAB) tampon solution. The chemicals which were used for lysis buffer is shown on Table 3.3.

Table 3.3. Amount of chemicals to prepare 50 ml of lysis buffer.

Extraction–Lysis Buffer Content	Amount
Tris HCl pH 8.0 ml	6.25
EDTA pH 8.0 ml	2.29
5M NaCl ml	8.33
Sorbitol g	1.33
CTAB g	0.42
Sarcosyl g	0.42
PVP-40 g	1.00
Sodium disulfite g	0.25
ddH ₂ O ml	29.71

Steps used for DNA isolation (Figure 3.10);

1. The prepared lysis buffer was heated to 65 °C.
2. Then, 750 µl lysis buffer was added to each Eppendorf tube
3. Wheatgrass was cut into small pieces to fit into the tubes and they incubated at 65 °C for 60 min in a DB-2D model dry block heater (Techne, Cambridge, UK).
4. Samples were then crushed with a homogenizer.
5. Samples were kept outside until their temperature dropped to 4 °C.
6. 750 µl of chloroform/isoamyl alcohol (24:1 w/w) was added to the samples and slowly turned upside down for 10 minutes.
7. They were centrifuged for 15 minutes at 13,000 rpm at +4 °C
8. Supernatants were transferred to new 1.5 ml centrifuge tubes and 350 µl of cold isopropanol was added for DNA precipitation.
9. Again, they were turned upside down for 5 minutes.
10. They were centrifuged for 10 minutes at 13,000 rpm at +4 °C

11. The supernatant was poured and centrifuge tubes left to dry at room temperature.
12. Then, the tubes were washed with 70% cold ethanol and dried at room temperature for 30 minutes.
13. DNAs were dissolved in 100 μ l of sterile ultrapure sterile water.
14. Concentration of the DNAs were measured with the aid of a DS-11 FX+ model nano spectrophotometer (Denovix Inc., Wilmington, DE, USA) and adjusted to 20 ng/ μ l for PCR studies.

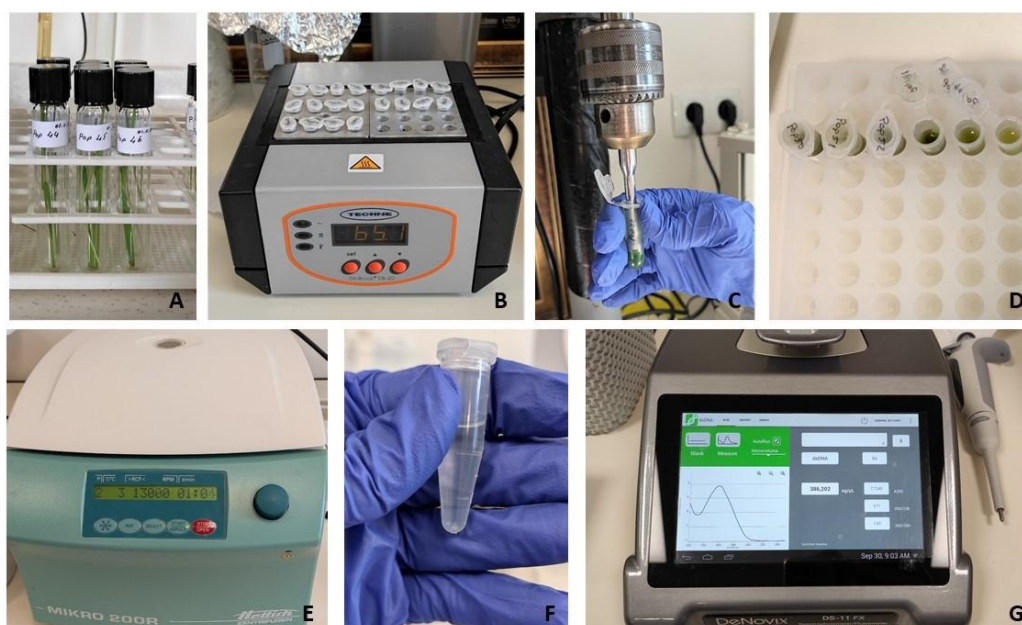


Figure 3.10. Some steps of extraction. A: Samples were stored in tubes, B: samples were cut out and placed in dry block heater with lysis buffer, C: homogenization, D: chloroform/isoamyl alcohol added to the samples, E: centrifugation, F: precipitation with isopropanol, G: measuring DNA samples with a nano spectrophotometer.

3.2.2.4 Polymerase Chain Reactions and Fragment Analyses

To evaluate genetic diversity among genotypes belonging to IZA wheat, Çalibasan and Sarı Serez, genomic DNA underwent PCR amplification using 5 SCoT primers, as detailed in Table 3.4. The PCR amplification for these primers was conducted on a T100 thermal cycler (Bio-Rad, Hercules, CA, USA). Each PCR

reaction was prepared in a 20 μ L volume, containing Dream Taq DNA polymerase buffer with 1 $\times$ MgCl₂, 0.24 mM dNTPs, 0.8 μ M primer, 1 unit of Dream Taq DNA polymerase (Thermo Fisher Scientific, Waltham, MA, USA), and 24 ng of genomic DNA (Table 3.5). In the PCR conditions for SCoT primers, annealing temperature was adjusted to 50 °C (Table 3.6).

The resulting PCR products were analyzed on a 1.6% agarose gel using 1 $\times$ TAE (Tris-acetate-EDTA) buffer. 1.6% agarose gel was prepared. For agarose gel, a mixture of 1 $\times$ TAE buffer solution and Prona agarose (BIOMAX, Ardoz-Madrid, İspanya) was homogenized in the microwave oven. The agarose gel mixture, which reached 50 °C at the outside, was poured into the tray. The wells on gel were created by using a comb. After agarose gel get dried, 10 μ l of the PCR products were added to the wells with running dye. The samples were then run in electrophoresis at 110 volts for 70 min. At the end of the period, agarose gel was stained with ethidium bromide for 10 min and visualized under UV light with a gel imaging system (G F3, Syngene, Cambridge, UK).

Table 3.4. Primer name, sequence and annealing temperature.

Primer Name	Sequence	Annealing Temp (°C)
SCoT 13	ACGACATGGCGACCATCG	50
SCoT-25	ACCATGGCTACCACCGGG	50
SCoT-30	CCATGGCTACCACCGGCC	50
SCoT-31	CCATGGCTACCACCGGCG	50
SCoT-34	ACCATGGCTACCACCGCA	50

Table 3.5. Reaction components and their amount.

Reaction Components	Amount for one Reaction (μl)
Taq DNA polymerase	0.2
MgCl ₂ (2 mM)	2
dNTP (0.2 mM)	2
Primer (0.4 mM)	1.2
DNA (20 ng/μl)	1.2
ddH ₂ O	13.4
Total	20

Table 3.6. PCR program.

Steps	Temperature (°C)	Period (min)	Number of Cycles
Initial Denaturation	94	1	1
Denaturation	94	1	
Annealing	50	1	34
Extension	72	2	
Final	72	5	1

3.2.2.5 Statistical Analysis of Data

According to the gel images reproducible and clear DNA bands were scored. Absent band was scored as 0 and presence of the bands were scored as 1. Total band (TB), PB, percentage of polymorphic band [PPB (%)], PIC and resolving power (RP) were calculated. The obtained data were analyzed by using the Numerical Taxonomy Multivariate Analysis System (NTSYS), NTSYS-pc version 2.1, Exeter Software, Setauket, N.Y., USA) package program. First of all, similarity indexes between individuals were calculated. By the help of similarity index, dendrogram was created by using the unweighted pair group method with arithmetic mean (UPGMA) method.

3.2.3 Office Studies

Office studies were carried out in three steps including (1) database establishment, (2) statistical analyses, and (3) GIS and RS applications. The work done in each step is explained below.

3.2.3.1 Database Establishment

In this study, it was aimed not only to determine and map the polymorphic and agro-morphological characteristics of populations but also to investigate the effects of ecological (topographic, climatic and soil) variables on these polymorphic and agro-morphological variants. In this way, besides the determined locations of populations, it was thought that it would be possible to model and map the most suitable (potential) areas where these species can be grown efficiently. As a result, establishing an adequate database in order to carry out these studies was seen as a necessity.

Database establishments were completed in three stages that contains firstly creating a point database in Microsoft Excel, secondly creating complementary databases, and thirdly extraction the data from complementary databases to point shape file. Details about these stages were given below.

3.2.3.1.1 Creating a Point Database

The purpose of creating a point database is to collect all data in a usable format in GIS and to prepare it for spatial analysis. For this purpose, geo-referenced field data were prepared as a Microsoft Excel file in XYZ format in the first stage. XY coordinate data were transferred from GPS records to Microsoft Excel file and all data of these coordinates (measurements based on field sampling and laboratory analysis results) were entered into Microsoft Excel file from Z1 to Zn. Measurements based on field observations [PH (cm), SL (mm), number of KPS (number), UNL (cm), SFPS (number), FLL (cm), and FLW (cm)], and measurements based on laboratory analyses [TKW (g) and YLD (kg/da)] were entered into Microsoft Excel file as proportional (ratio) data. However, laboratory analysis results containing the (primary) values of the populations obtained according to SCoT markers were entered into Microsoft Excel file as yes [1] / no – [0] data.

The prepared Microsoft Excel file was opened in ArcGIS (Desktop Version 10.5) software (71, 72), converted into a point shape (.shp file format) file and saved. This point .shp file was used in the extraction of climate, soil, and

topographic variables from the complementary raster data layers for statistical analyses and modeling studies.

3.2.3.1.2 Creating Complementary Database

The purpose of creating complementary database is to prepare reliable topographic, soil and climatic variables raster maps by utilizing global and national databases. Global databases have gained increasing importance by providing very useful, continuous and reliable spatial data and increased the potential of effective use of GIS. Today, four reliable sources that are especially important for biology, ecology, agriculture, geography and environmental sciences have made topographic, soil, climate, and land use/cover data accessible, usable and permanent. These four trusted global or international data providers are The National Aeronautics and Space Administration (NASA), ISRIC, CHELSA and European Environment Agency (EEA), respectively.

NASA's EARTHDATA contains earth observation data at global level. These data are freely downloadable that can be used and evaluated with the tools such as GIS without restriction. One of the important EARTHDATA source is the ASTER GDEM Version 3 (ASTGTM). Basically, ASTGTM is a reliable DEM that covers land surfaces between 83°N and 83°S with a spatial resolution of 1 arc second (approximately 30 meter horizontal posting at the equator), and is now available in NASA's EARTHDATA (73). In this study, ASTGTM downloaded from the relevant website, then, clipped by using the borders of study area (Bolu province) in ArcGIS software. Slope and aspect raster maps were also produced from the obtained elevation raster map using the 3D functions of ArcGIS software.

ISRIC is an independent foundation that supplies soil information at global, national and sub-national levels for application into sustainable management of soil and land via World Soil Information (WSI) (74). Due to its longstanding reputation for providing reliable global information products about soils, ISRIC's WSI is an accredited organization as the member of International Science Council (ISC)'s World Data System (WDS) (75). Basically, WSI provides valuable layers of soil that are freely available on the web. The spatial resolution of these soil layers is 250 m. In this study, ISRIC layers in Table 3.7 were downloaded from the relevant

website (76), clipped by using the borders of study area (Bolu province) in ArcGIS software, and prepared for modeling.

Table 3.7. Downloaded IRSIC soil layers.

Physical Soil Properties	Unit	Soil Depth (cm)
Bulk Density	cg/cm ³	0-5
Coarse Fragments	cm ³ /dm ³	5-15
Sand	g/kg	15-30
Silt	g/kg	30-60
Clay	g/kg	60-100
Chemical Soil Properties	Unit	Soil Depth (cm)
Cation Exchange Capacity	mmol(c)/kg	0-5
Nitrogen	cg/kg	5-15
Soil Organic Carbon	dg/kg	15-30
pH water	pH*10	30-60
		60-100
Resolution: 250 m		

CHELSEA is hosted by the Swiss Federal Forest, Snow and Landscape Research Institute WSL, and established to provide free access to high resolution climate data including climate layers for various time periods and variables, ranging from the last glacial maximum, to the present and future (77). CHELSA has a mission to serve the international community as a reliable database provider, and supplies high resolution (30 arc·sec, ~1km) global climate data that is constantly updated and refined for research and application. Basically CHELSA supplies database originated from the 5 research centers around the World including GFDL-ESM4, IPSL-CM6A-LR, MPI-ESM1-2-HR, MRI-ESM2-0 and UKESM1-0-LL (78). Information about these centers were given in Table 3.8. Although the databases produced by these centers are close to each other, the CHELSA layers (version: 2) produced by the GFDL-ESM4 center which is the first in order of priority was preferred and downloaded (Figure 3.11) from the relevant website (79) to obtain a climate database for Bolu.

Table 3.8. Information about the centers and the database they produced (78).

Title & Model	Institution	Native Resolution	Ensemble Member	Priority
GFDL-ESM4 gfdl-esm4	National Oceanic and Atmospheric Administration, Geophysical Fluid Dynamics Laboratory, Princeton, NJ 08540, USA	288x180	r1i1p1f1	1
UKESM1-0-LL ukesm1-0-ll	Met Office Hadley Centre, Fitzroy Road, Exeter, Devon, EX1 3PB, UK	192x144	r1i1p1f2	2
MPI-ESM1-2-HR mpi-esm1-2-hr	Max Planck Institute for Meteorology, Hamburg 20146, Germany	384x192	r1i1p1f1	3
IPSL-CM6A-LR ipsl-cm6a-lr	Institut Pierre Simon Laplace, Paris 75252, France	144x143	r1i1p1f1	4
MRI-ESM2-0 mri-esm2-0	Meteorological Research Institute, Tsukuba, Ibaraki 305-0052, Japan	320x160	r1i1p1f1	5

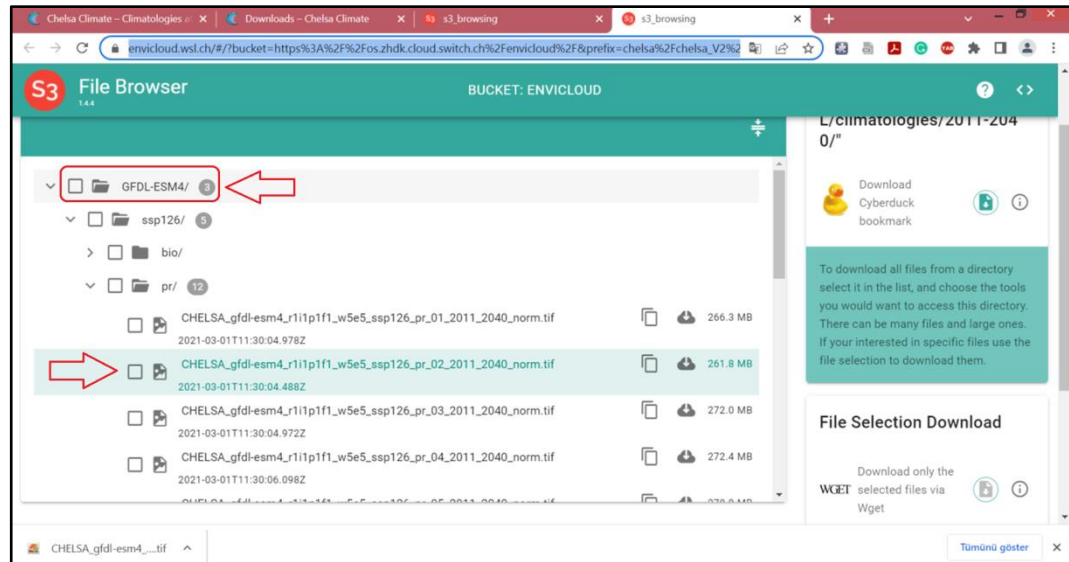


Figure 3.11. Download of precipitation databases from CHELSA official website.

Downloaded raster climate maps were given in Table 3.9. Because the downloaded raster database has raw data characteristics, it needs to be processed by using the transformation equations (Table 3.10) supplied by CHELSA documentation (78). Accordingly downloaded database were transformed to actual climatic variables in ArcGIS software by utilizing supplied equations (multiplier and additive values) in Table 3.10.

Table 3.9. Downloaded raster climate maps from CHELSA and information about climatic layers (78).

Short name	Explanation	Unit	Resolution
bio1	Mean annual daily mean air temperatures averaged over 1 year	°C	~700 m
bio8	The wettest quarter of the year is determined (to the nearest month)	°C	~700 m
bio9	The driest quarter of the year is determined (to the nearest month)	°C	~700 m
bio10	The warmest quarter of the year is determined (to the nearest month)	°C	~700 m
bio11	The coldest quarter of the year is determined (to the nearest month)	°C	~700 m
bio12	Accumulated precipitation amount over 1 year	kg·m ⁻²	~700 m
bio13	The precipitation of the wettest month.	kg·m ⁻²	~700 m
bio14	The precipitation of the driest month.	kg·m ⁻²	~700 m
bio16	The wettest quarter of the year is determined (to the nearest month)	kg·m ⁻²	~700 m
bio17	The driest quarter of the year is determined (to the nearest month)	kg·m ⁻²	~700 m
bio18	The warmest quarter of the year is determined (to the nearest month)	kg·m ⁻²	~700 m
bio19	The coldest quarter of the year is determined (to the nearest month)	kg·m ⁻²	~700 m
pr	"Amount" means mass per unit area. "Precipitation" in the earth's atmosphere means precipitation of water in all phases.	kg·m ⁻²	~700 m
tasmax	Daily maximum air temperatures at 2 metres from hourly ERA5 data	°C	~700 m
tas	Daily mean air temperatures at 2 metres from hourly ERA5 data	°C	~700 m
tasmin	Daily minimum air temperatures at 2 metres from hourly ERA5 data	°C	~700 m

Table 3.10. Downloaded climatic layers and their transformation equations with scale (multiplier) and offset (additive) values supplied by CHELSA (78).

Short Name	Long Name	Scale (Multiplier)	Offset (Additive)	Transformation Equations
bio1	Mean annual air temperature	0.1	-273.15	bio1 * 0.1 + (-273.15)
bio8	Mean daily mean air temperatures	0.1	-273.15	bio8 * 0.1 + (-273.15)
bio9	Mean daily mean air temperatures of the driest quarter	0.1	-273.15	bio9 * 0.1 + (-273.15)
bio10	Mean daily mean air temperatures of the warmest quarter	0.1	-273.15	bio10 * 0.1 + (-273.15)
bio11	Mean daily mean air temperatures of the coldest quarter	0.1	-273.15	bio11 * 0.1 + (-273.15)
bio12	Annual precipitation amount	0.1	0	bio12 * 0.1
bio13	Precipitation amount of the wettest month	0.1	0	bio13 * 0.1
bio14	Precipitation amount of the driest month	0.1	0	bio14 * 0.1
bio16	Mean monthly precipitation amount of the wettest quarter	0.1	0	bio16 * 0.1
bio17	Mean monthly precipitation amount of the driest quarter	0.1	0	bio17 * 0.1
bio18	Mean monthly precipitation amount of the warmest quarter	0.1	0	bio18 * 0.1
bio19	Mean monthly precipitation amount of the coldest quarter	0.1	0	bio19 * 0.1
pr	Precipitation amount	0.1	0	pr * 0.1
tasmax	Mean daily maximum 2 m air temperature	0.1	-273.15	tasmax * 0.1 + (-273.15)
tas	Mean daily air temperature	0.1	-273.15	tas * 0.1 + (-273.15)
tasmin	Mean daily minimum air temperature	0.1	-273.15	tasmin * 0.1 + (-273.15)

Resolution of raster climate maps, downloaded and converted to actual values, were improved from 700 m to 100 m in ArcGIS software. For this purpose, in the first stage, raster climate maps covering Bolu province were first converted into a point database, and then a 100 m spatial resolution raster map was produced for each climate variable by using the nearest neighbor interpolation method from

spatial analysis functions. Interpolated raster climate maps were clipped by using the borders of study area (Bolu province). As a result, the climate database of Bolu province was obtained.

EEA's CORINE land use/cover database includes data sets for the years 1990, 2000, 2006 and 2012 of member countries including Türkiye (80). Later, the database for 2018 was added to this data set (68). The purpose of producing the CORINE database and making it available to users is to ensure that local researchers can benefit from this database in a reliable and efficient manner and thus to provide basic data that will be the basis for planning studies. In this study, the land cover/use classes map of Bolu province was produced using the CORINE 2018 vector database. For this purpose, CORINE 2018 vector database (Figure 3.12) was downloaded from the official web site (68), and clipped using the Bolu province border vector map and ArcGIS software (71). The resulting vector map was evaluated in ArcGIS software and the area covered by each land cover/use class was calculated. The classification is based on the three-level CORINE classification system, progressing from general to detailed. Level-1 contains general, Level-2 intermediate and Level-3 detailed data. The CORINE Database created for Bolu has been prepared as three separate digital maps, including these three levels.



Figure 3.12. Download of CORINE-2018 database from official website (Copernicus) (68).

In addition to ISRIC's global soil database, Türkiye's National Soil Database (KHGM Database) was also utilized in this study to create a complementary data set. This database, based on the most detailed soil mapping study covering the whole of Türkiye, was created by the Former General Directorate of Soil Water (Toprak Su) in traditional paper map format between 1966 and 1972 according to the American 1938 classification system. Since 1:25000 scale topographic maps are used as a base, these maps are the highest quality data set available. Those maps were digitized by KHGM in 1998-2003 and the Turkish National Soil (KHGM) Database was created. Great soil groups (nominal data) and land suitability classes maps in the KHGM Database that have the potential to be used as a basis in today's studies were utilized in this study. Utilized KHGM map layers and their original and renumbered classes were summarized in Table 3.11. Enumerated KHGM vector map was converted to raster format in ArcGIS software, and used. (Note: To apply parametric methods, nominal data should be explained in numeric form. For this reason, the nominal data were enumerated to obtain the integrity of the data analysis in this study.)

Table 3.11. Utilized KHGM map layers and their original and renumbered classes.

Layers	Classes	Renumerated Classes
Great Soil Groups	Alluvial (A)	1
	Colluvial (K)	2
	Lime Free Brown Forest Soils (N)	3
	Brown Forest Soils (M)	4
	Gray Brown Podzolic (G)	5
	Red Yellow Podzolic (P)	6
	Reddish Chestnut (D)	7
	Redzinas (R)	8
	Hydromorphic (H)	9
	Vertisols (V)	10
Land Suitability Classes	I	1
	II	2
	III	3
	IV	4
	V	5
	VI	6
	VII	7
	VIII	8

3.2.3.1.3 Extracting the Data from Complementary Databases to Point Shape File

At this stage, values of topography, soil, and bioclimate variables were extracted by overlaying the point shape file on the complementary data raster maps and using ArcGIS spatial analysis (extract values to points) function. Thus, a comprehensive Microsoft Excel analysis file was created for spatial analysis and modeling studies.

3.2.3.2 Statistical Analyses

The work done within the scope of statistical analyses can be summarized as exploring data, investigation of genotypic similarities of populations, and investigation of relationships among agro-morphological features and ecological factors. All the work done were described below in subheadings.

3.2.3.2.1 Exploring Data

The first step of data analysis should always be detailed examination of the data regardless of the simplicity or complexity of the problem to be solved and statistical method to be used (81). There are several important reasons for examining data before the beginning of any statistical analysis. Identifying mistakes is one of the important reasons for examining data because errors and mistakes can be made during any step of any research including measurement and data gathering stages. Examination of the data also supplies enough information to establish some additional hypotheses or to modify existing hypotheses at the beginning of the statistical analyses. Another reason for examining the data is to decide the appropriate statistical methods to be conducted. The distribution of data is also important for evaluating the appropriateness of the statistical techniques for hypothesis testing or model building (81). For these reasons, descriptive statistics was used to explore data characteristics at the first stage of statistical analysis in this study. Range, minimum, maximum, mean, standard deviation, variance, skewness and curtosis were employed as descriptive statistics.

All statistics were determined by using Statistical Package for the Social Sciences (SPSS) (version: 22) software (82) were utilized to determine descriptive statistics.

3.2.3.2.2 Investigating Genotypic Similarities of Populations

In this study, polymorphic similarities of populations were investigated by utilizing UPGMA which is a simple agglomerative (bottom-up) hierarchical clustering method. The object is to group together objects or records that are “close” to one another in this method. UPGMA dendograms were created in NTSYS software according to the determined genotypic characteristics using the yes/no data (83). The obtained dendrogram data were transferred to the Microsoft Excel spreadsheet in XYZ format as a "genetic proximity" variable in order to define genotypes of the populations.

3.2.3.2.3 Investigating of Relationships among Agro-morphological Features and Ecological Factors

Correlation or bivariate analysis is a frequently used statistical analysis to investigate whether or not a relationship exists between variables and to determine the magnitude and action of that relationship (84).

Within the scope of this study, correlation analysis was used to investigate and understand relationships between agro-morphological and ecological variables. Within this process, PH, SL, number of KPS, UNL, SFPS, FLW, FLL, and TKW were employed as agro-morphological variables. Topographic (elevation, slope, and aspect), climatic (maximum-minimum-mean temperatures, precipitation and 12 bioclimate variables) and soil (sand-silt-clay contents, bulk density, coarse fragments, cation exchange capacity (CEC), nitrogen, soil organic carbon, and pH variables were used as ecological variables. In SPSS software (82), correlation analysis was conducted and interpreted for all available database employing Pearson Correlation coefficient and two tailed test of significance.

3.2.3.2.4 Modelling Strong Relationships

Multiple regression is a statistical technique that aims to model the linear relationship between the explanatory (independent) variables and response (dependent) variables. Because it contains more than one explanatory variable, it can be defined as the extension of ordinary least-squares (OLS) regression (84). In this study, multiple regression was employed to develop models for the yield of wheat landraces by utilizing the reduced dimension variables and SPSS software.

Throughout the multiple regression process yield was defined as dependent variable (Y), while the reduced dimension variables in factor analysis stage were described as independents (X_n). Consequently, three models were produced for the three wheat landraces namely; [1] *T. monococcum* ssp. *monococcum* (called IZA in Bolu province), [2] *T. aestivum* (variant: Çalıbasan), [3] *T. aestivum* (variant: Sarı Serez).

3.2.3.3 GIS and RS Applications

3.2.3.3.1 Mapping the Spatial Distribution of Populations

Created point shape file (Figure 3.7) was converted to KMZ format in ArcGIS, and opened in Google Earth. Then, areas of the wheat populations were digitized in the form of polygons by utilizing these point data and satellite images. In another word, parcel area of each sampled point was digitized in Google Earth and saved in KMZ format. The produced KMZ file was opened in ArcGIS software (71, 72) and converted into a shape (polygon) file. Consequently, a polygon shape file of wheat populations was obtained (Figure 3.13).



Figure 3.13. In Google Earth, digitizing the population areas by utilizing field sampling point data (point shape file).

3.2.3.3.2 Mapping the Most Suitable Cultivation Areas for Populations

Mapping process is simply the run of the three developed models (regression equations) by using math functions of spatial analysis tools of ArcGIS and complementary database (raster maps of ecological variables). In ArcGIS software, the map calculator dialog aids in the creation of an expression that produces a new output raster theme. The expression can be based on a single raster theme or multiple raster themes. The Map Calculator can create simple expressions with a single function or complex with many operations and functions. Mathematical operators apply a mathematical operation to the values in two or more input raster themes; mathematical functions apply a mathematical function to the values in a single input raster theme.

The Arithmetic operators (*, /, -, +) allow for the addition, subtraction, multiplication, and division of two raster themes, or numbers, or combination of the two. There are also four subgroups of mathematical functions: Logarithms, Arithmetic, Trigonometric, and Powers.

Consequently, mathematical operations can easily be conducted on raster maps of ecological variables with the power of GIS. In this study, complementary database and ArcGIS map calculator functions were used throughout the running process of the three models.

As a result, three separate yield model maps were obtained by running the models developed for three wheat varieties. All three raster yield maps were classified into 5 classes: very good, good, medium, bad and very bad, and the areas in the good and very good classes were evaluated as potential cultivation areas.

4. RESULTS

4.1 Complementary Database

4.1.1 Topographic Database

Digital elevation map of the study area (Bolu province) produced from ASTGTM was given in Figure 4.1. Slope raster maps were produced in both degree and percent (%) (Figure 4.2 and Figure 4.3) basis, while aspect raster maps were produced in both degree and classified direction basis (Figure 4.4 and Figure 4.5).

The topography of Bolu province has a mountainous character and 56% of the total area is covered by mountains (Figure 4.1). The altitude varies between 278 and 2,371 m. Elmacık Mountain (1,543 m), Abant Mountains (1,748 m) and Bolu Mountains are located in the northwest-northeast direction of the province. In the Bolu mountains belt, there are Sünnice Mountains (1,849 m) and Çele Doruğu Hill (1,980 m, the highest point in the north). Arkut Mountains (1,877 m) extend to the north of Gerede district. Volcanic mountains, lie in the south and higher than the other mentioned mountains above is called Köroğlu Mountains (the highest point is 2,499 m).

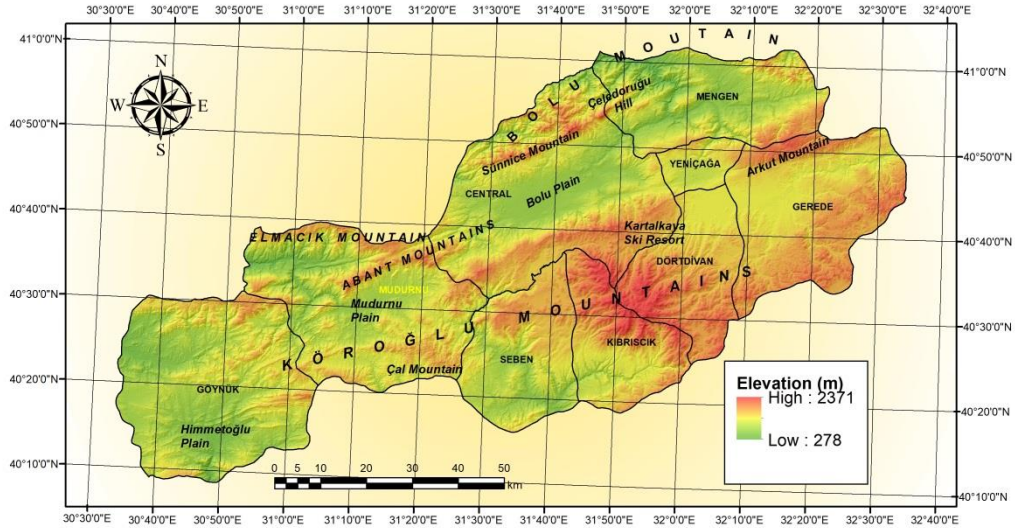


Figure 4.1. Digital elevation map of the study area (Bolu province).

The slope characteristics of Bolu province, expressed in degrees and percentages (%), also reflect the mountainous character of the study area. Slope maps of the study area show that the slope varies between 0 - 69.83 degrees (Figure 4.2) or 0-100% (Figure 4.3). On both maps, the areas shown in green area actually low-slope areas represent the Bolu, Mudurnu, Himmetoğlu, Mengen and Seben plains. On the other hand, orange and red colors refer to mountainous areas with steep slopes.

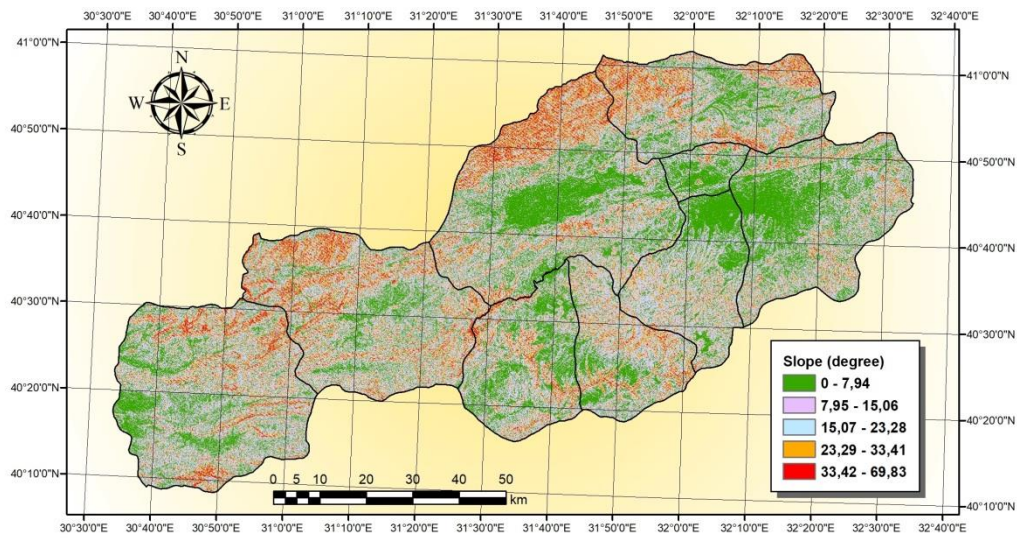


Figure 4.2. Slope (degree) raster map of the study area (Bolu province).

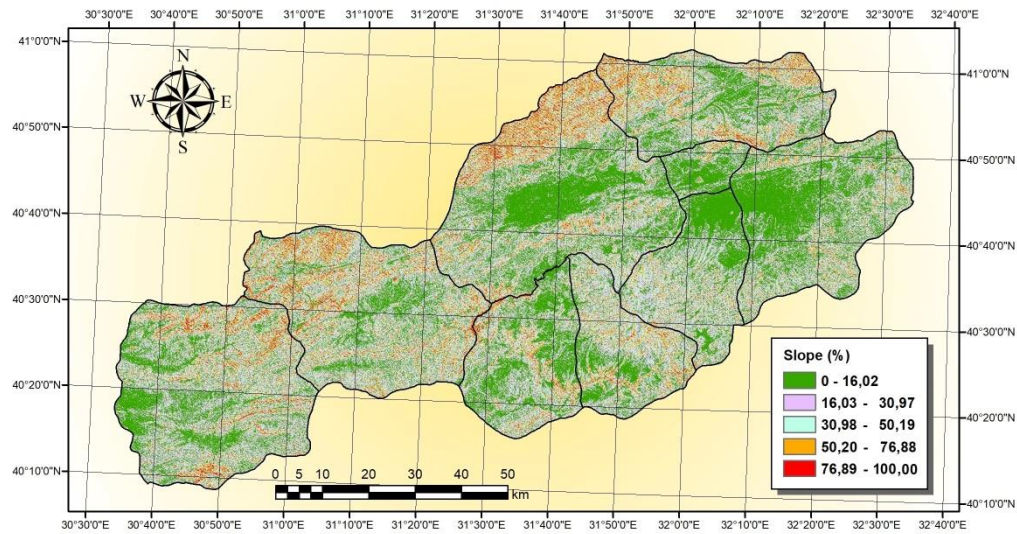


Figure 4.3. Slope (%) raster map of the study area (Bolu province).

The aspect characteristics of Bolu province, expressed in degree and classified direction basis were shown in Figure 4.4 and Figure 4.5, respectively. In degree point of view, -1 degree refers to flat areas, the other degree values changes between 0 and 360 degree (Figure 4.4). Aspect classes in degrees can also be classified as East (45-135), South (135-225), West (225-315), North (315-360 and 0-45), and Plain (-1). In this study, these class values were reclassified using numbers from 1 to 5 (dummy variables) according to the preferences of the plants, and classified direction raster map shown in Figure 4.5 was produced.

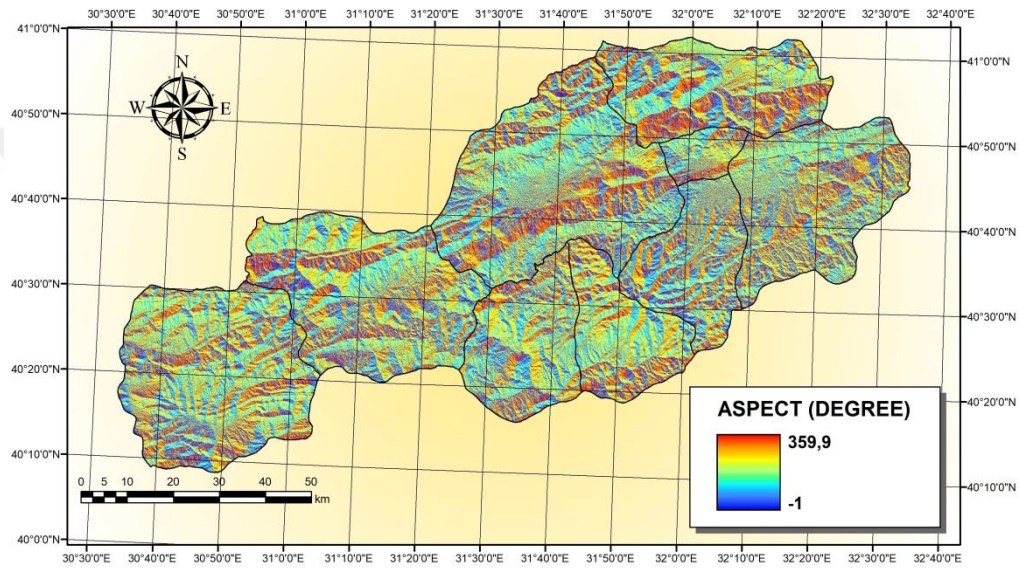


Figure 4.4. Aspect (degree) raster map of the study area.

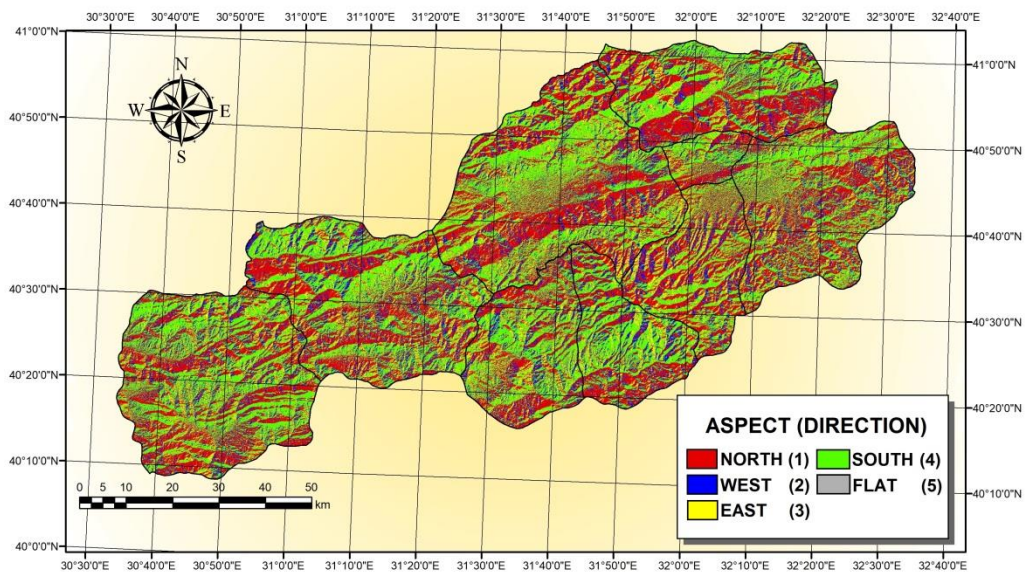


Figure 4.5. Aspect (classified direction) raster map of the study area.

4.1.2 ISRIC Soil Database

Raster maps of physical and chemical soil variables were produced using the downloaded ISRIC data. Physical soil variables (bulk density, coarse fragments, sand, silt, clay) raster maps were shown in Figure 4.6, Figure 4.7, Figure 4.8, Figure 4.9 and Figure 4.10.

Bulk density is defined as the dry mass of soil (cg) in a given volume (cm^3), and its unit is cg/cm^3 . In agriculture, less dense soil is favorable because it helps planting. To accomplish this, the soil is plowed, increasing volume and therefore lowering bulk density. Spatial distribution of Bulk Density (cg/cm^3) values of the study area at different soil depths (0-5, 5-15, 15-30, 30-60 and 60-100 cm) was shown in Figure 4.6.

Coarse fragments are soil particles' volume (cm^3) with a nominal diameter greater than 2 millimeters in a given volume (dm^3), and its unit is cm^3/dm^3 . In agricultural point of view, soils that have high coarse fragments values are undesirable for most applications. Because a high proportion of coarse fragments below a depth of 100 centimeters lessen the effectiveness of the fine earth part of the soil. Spatial distribution of Coarse fragments (cm^3/dm^3) values of the study area at different soil depths (0-5, 5-15, 15-30, 30-60 and 60-100 cm) was shown in Figure 4.7.

The relative amounts of sand, clay and silt particles that make up the solid phase of the soil in the soil mass and their ratios to each other express the texture of the soil. Units of the sand, silt and clay are expressed as percentage (%) or per thousand (‰). In agriculture, sand and clay silt ratios are desired to be close to each other. It is not desired that the sand or clay ratios are too high. Because an excess of sand content causes rapid removal of water required for plants from the soil, while a high clay content causes excess water retention in the soil and drainage problems. Spatial distribution of sand (‰), silt (‰), and clay (‰) values of the study area at different soil depths (0-5, 5-15, 15-30, 30-60 and 60-100 cm) was shown in Figure 4.8, Figure 4.9, and Figure 4.10, respectively.

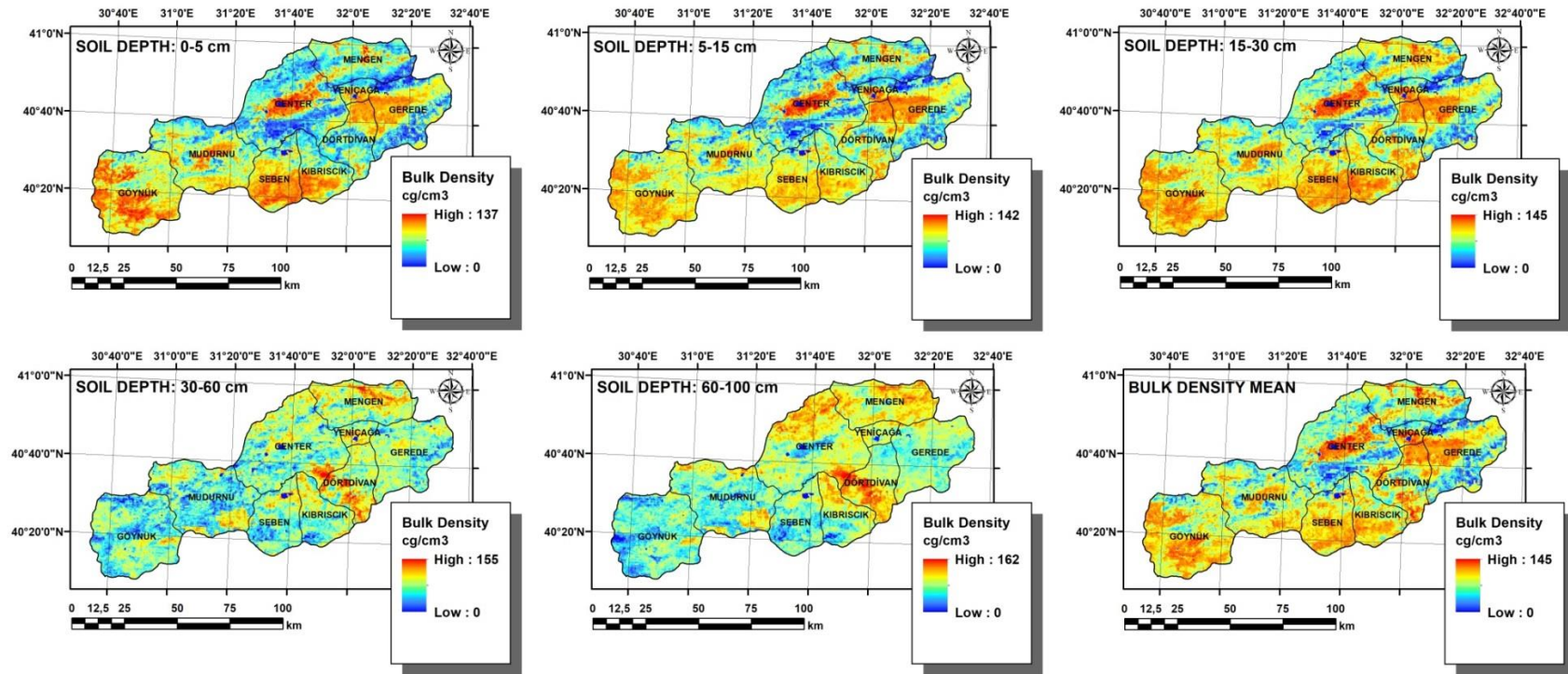


Figure 4.6. Bulk density (cg/cm³) maps at different soil depths and mean bulk density raster map (resolution: 250 m).

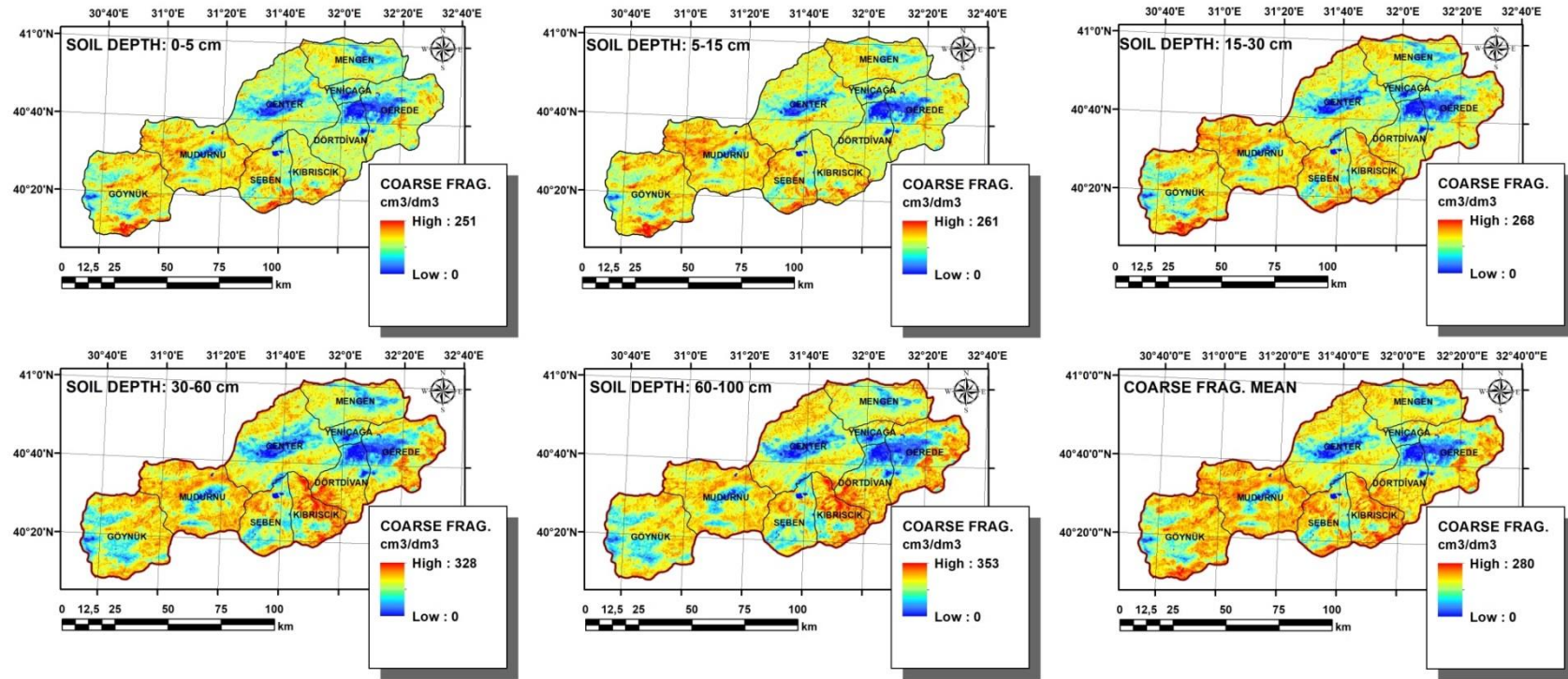


Figure 4.7. Coarse fragments (cm³/dm³) maps at different soil depths and mean coarse fragments raster map (resolution: 250 m).

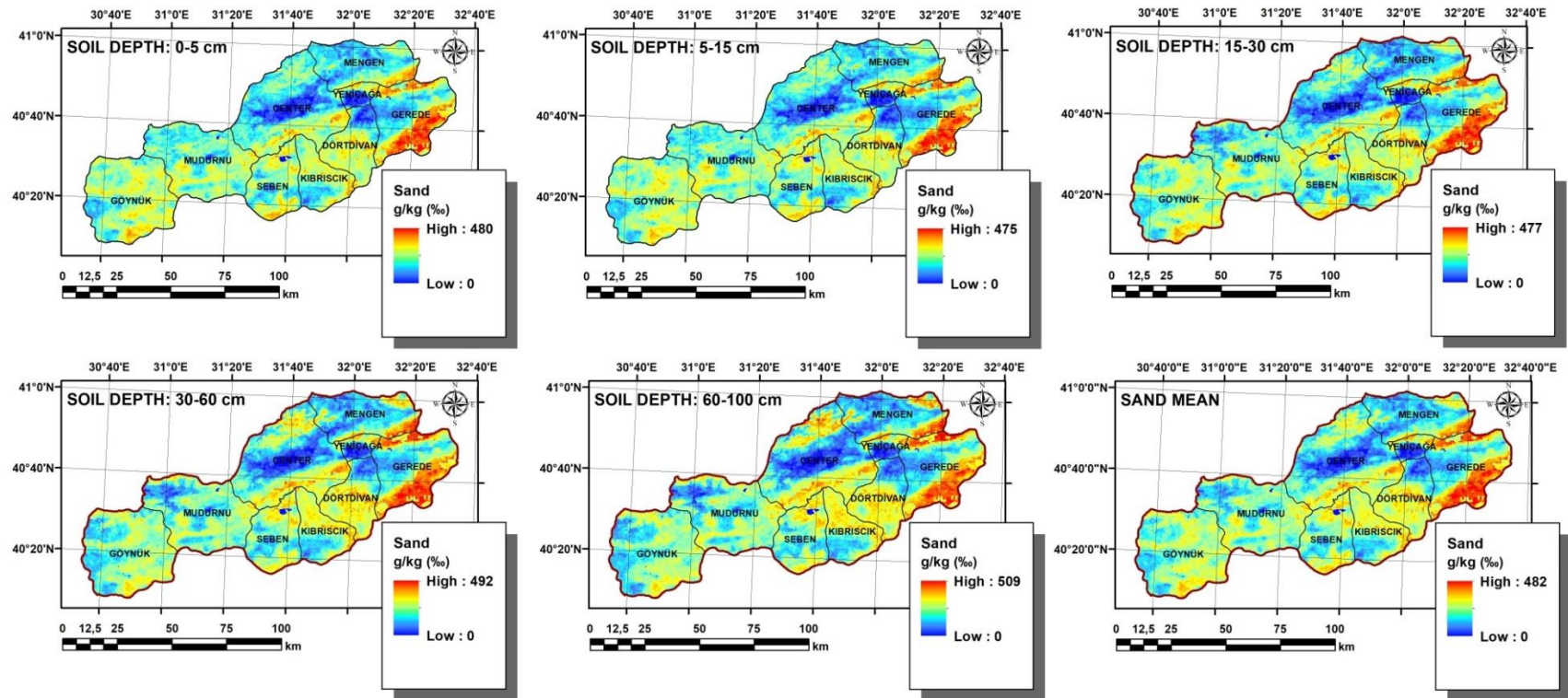


Figure 4.8. Sand (g/kg) maps at different soil depths and mean sand raster map (resolution: 250 m).

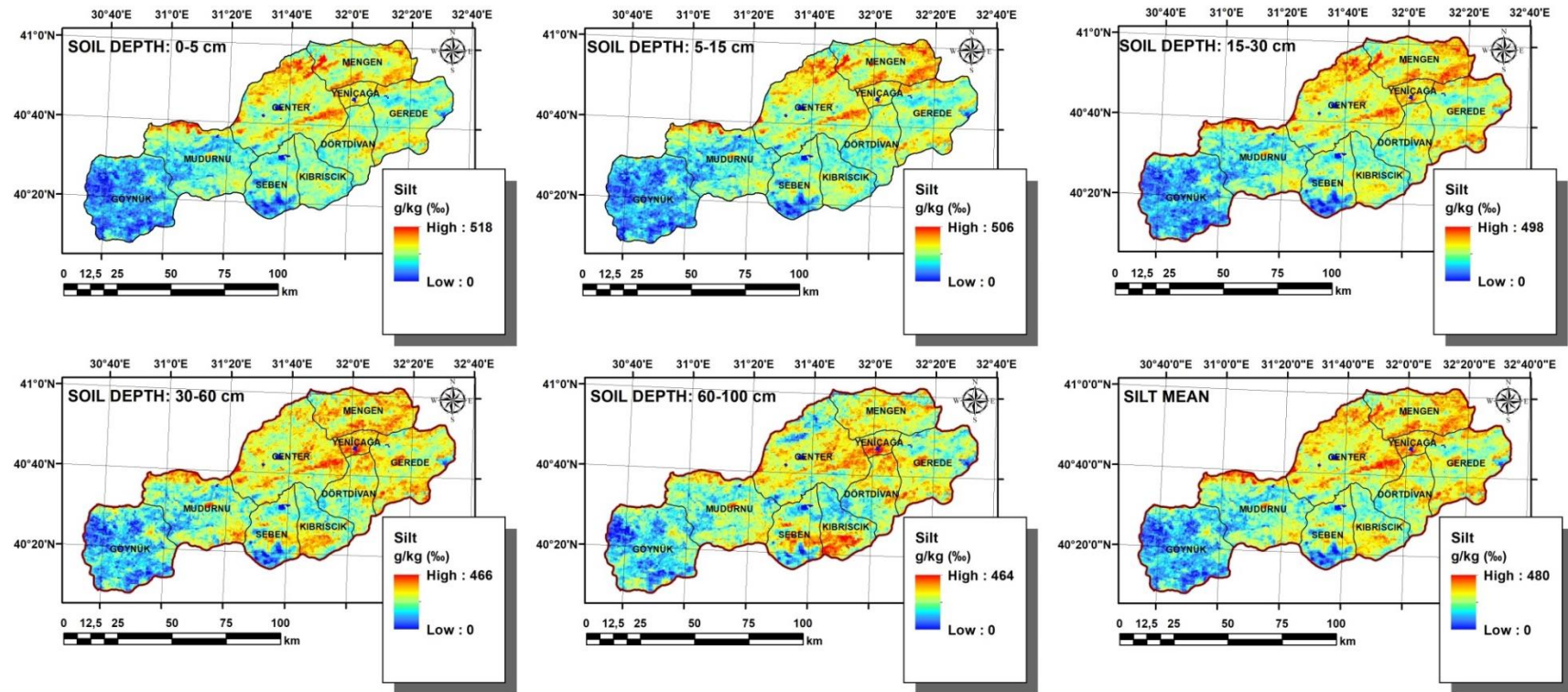


Figure 4.9. Silt (g/kg) maps at different soil depths and mean silt raster map (resolution: 250 m).

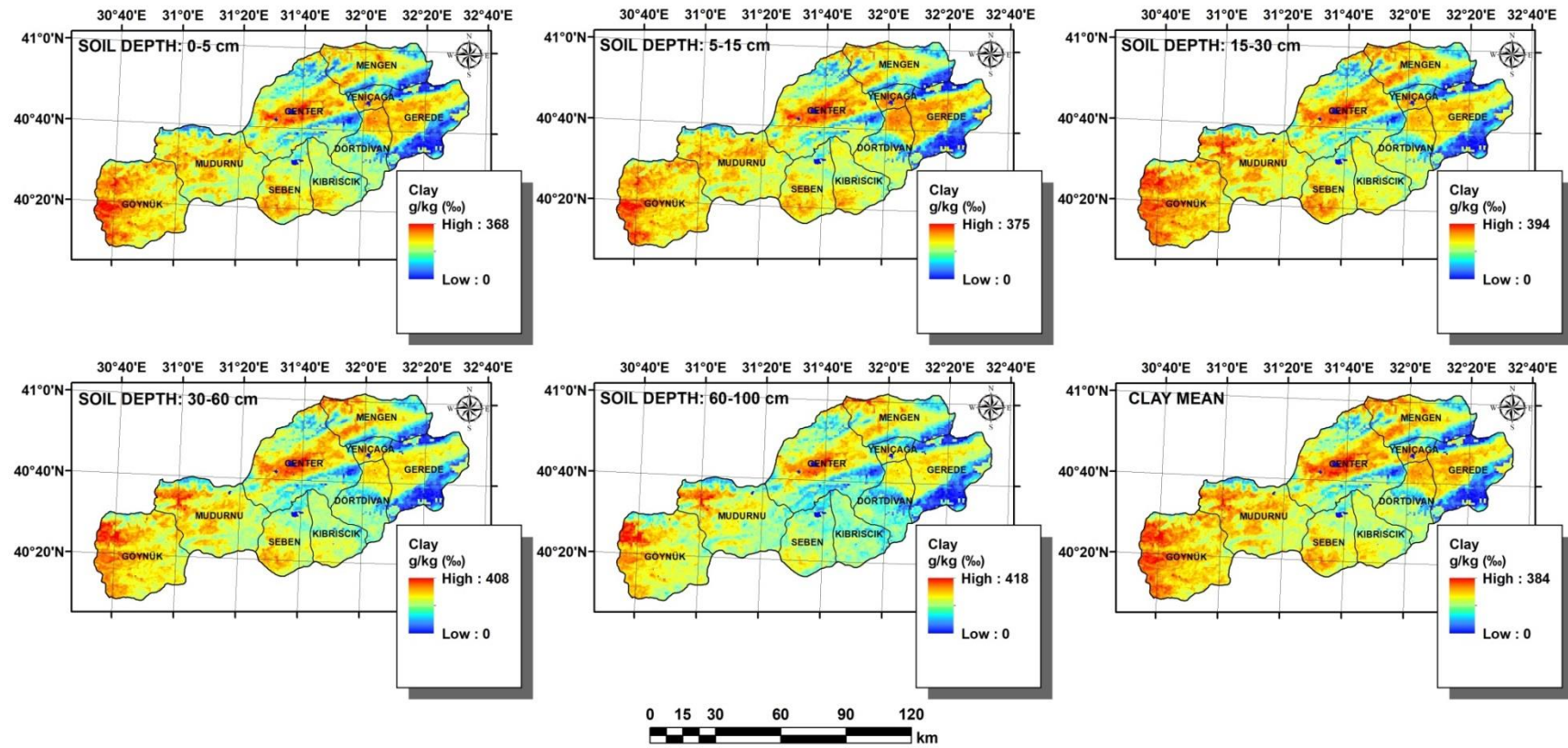


Figure 4.10. Clay (g/kg) maps at different soil depths and mean clay map (resolution: 250 m).

Chemical soil variables (CEC, Nitrogen, Organic Carbon, pH-Water) raster maps were shown in Figure 4.11, Figure 4.12, Figure 4.13 and Figure 4.14.

CEC is a soil variable that means measure of the total negative charges within the soil that adsorb plant nutrient cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+). It is expressed as millimole per kilogram (mmol(c)/kg). In fact, CEC is a soil variable that describes its capacity to supply nutrient cations to the soil solution for plant uptake and shows the soil's ability to supply three important plant nutrients: calcium, magnesium and potassium. Therefore, one of the most important factors is CEC to determine soil fertility, and higher CEC values refer higher soil fertility. Spatial distribution of CEC (mmol(c)/kg) values of the study area at different soil depths (0-5, 5-15, 15-30, 30-60 and 60-100 cm) was shown in Figure 4.11.

Soil mineralizable nitrogen that reflects the release of mineral nitrogen from organic matter by soil microorganisms is measured in centigram of nitrogen per kilogram of soil (cg/kg). This is also known as potentially mineralisable nitrogen. Soil mineralizable nitrogen is determined by weather (soil moisture and temperature variations), soil texture and organic matter. Since nitrogen is also an important plant nutrient element, it is an important actor in soil fertility. Spatial distribution of mineralizable nitrogen (cg/kg) values of the study area at different soil depths (0-5, 5-15, 15-30, 30-60 and 60-100 cm) was shown in Figure 4.12.

Soil organic carbon (SOC) is the carbon that remains in the soil after partial decomposition of any material produced by living organisms. Basically, gravimetric content of organic carbon in the fine earth fraction of the soil is measured in decigrams of organic carbon per kilogram of soil (dg/kg). The organic carbon content and composition of the soil is a determining factor for soil fertility in well-drained soils. Spatial distribution of soil organic carbon (dg/kg) values of the study area at different soil depths (0-5, 5-15, 15-30, 30-60 and 60-100 cm) was shown in Figure 4.13.

Potential of hydrogen or power of hydrogen (pH) is the measure we use to understand the acidity or alkalinity of a substance. Basically, measurement is made according to the density of acidic hydrogen ions in the substance and pH gets values between 0 and 14. Zero means extremely acid, 14 means extremely alkaline. A pH level of 7 indicates that the substance is

neither acidic nor alkaline, that is, the substance is neutral. pH-Water in the ISRIC soil database has been obtained by multiplying the pH values by ten. Spatial distribution of pH-Water values of the study area at different soil depths (0-5, 5-15, 15-30, 30-60 and 60-100 cm) was shown in Figure 4.14.



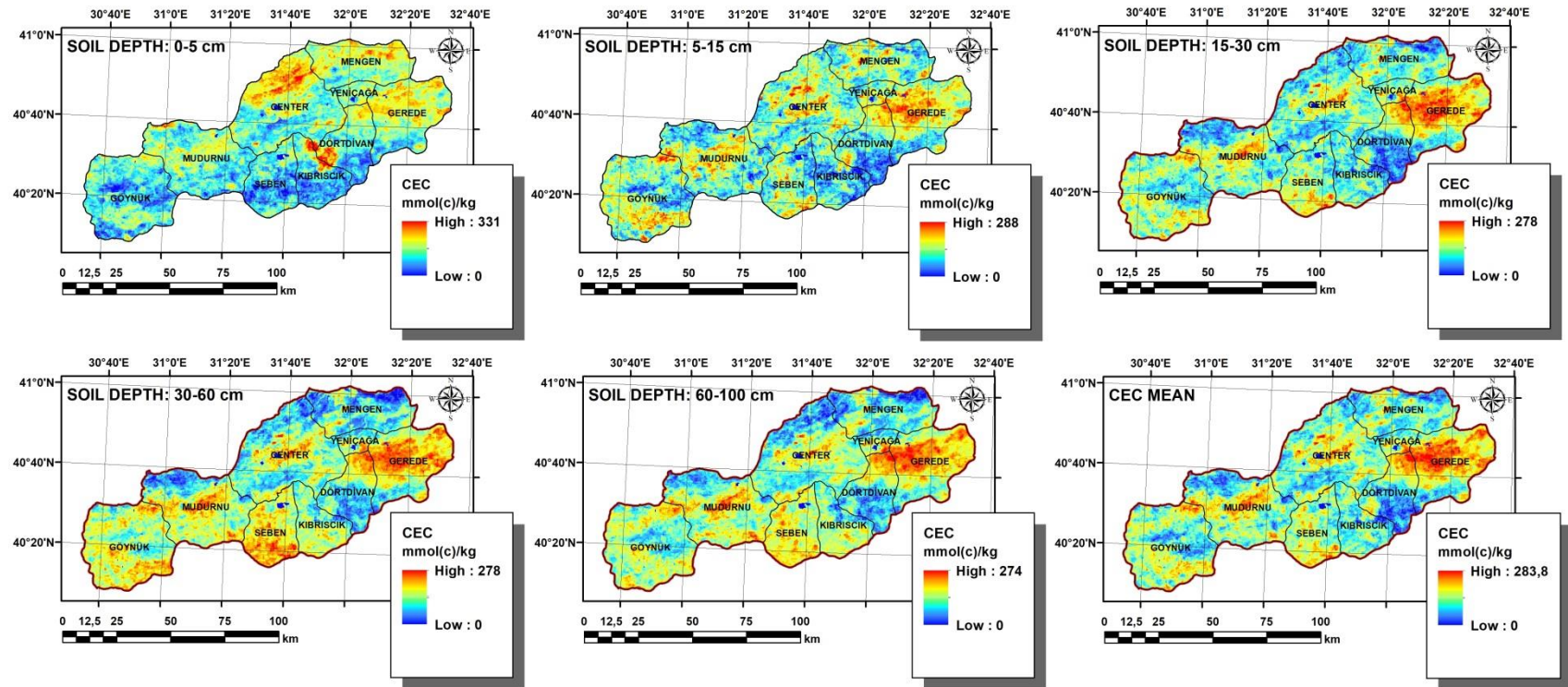


Figure 4.11. CEC (mmol(c)/kg) maps at different soil depths and mean CEC raster map (resolution: 250 m).

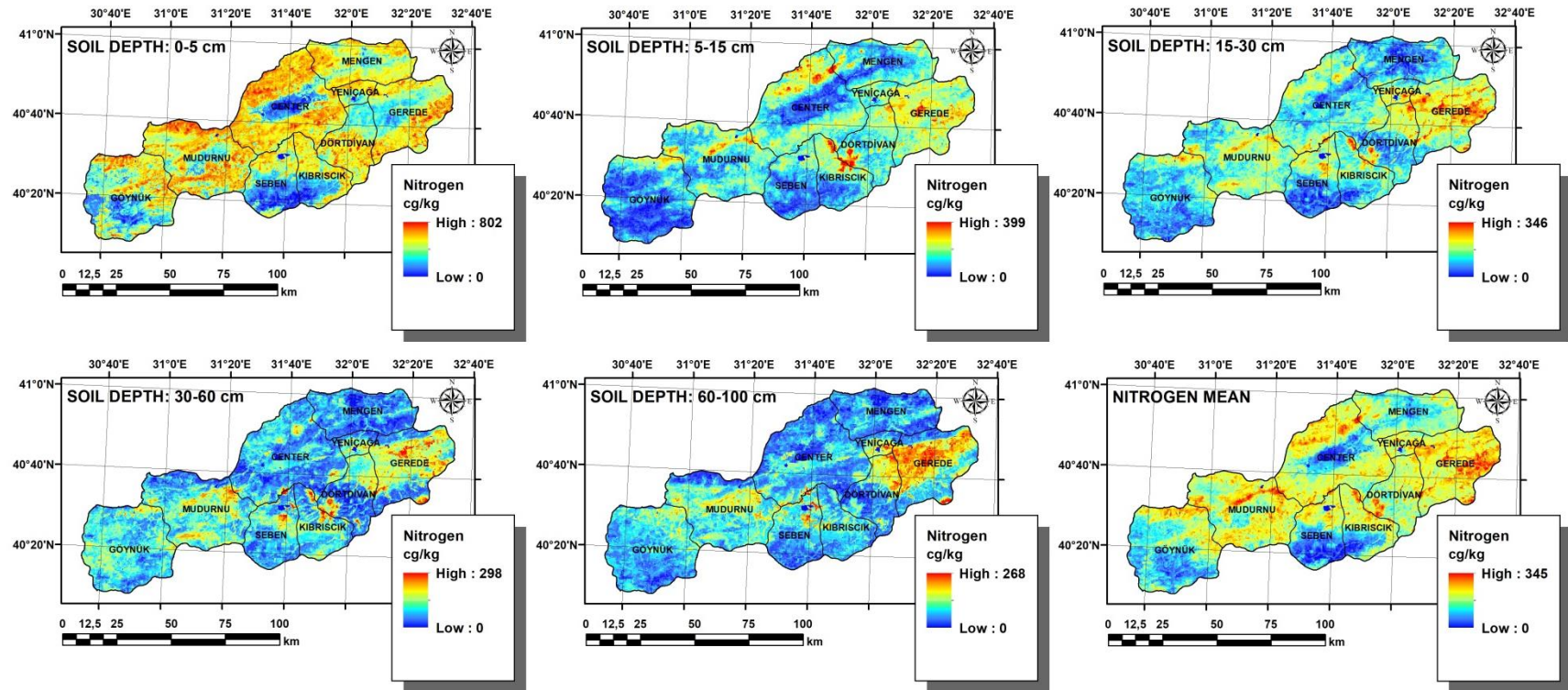


Figure 4.12. Nitrogen (cg/kg) maps at different soil depths and mean nitrogen raster map (resolution: 250 m).

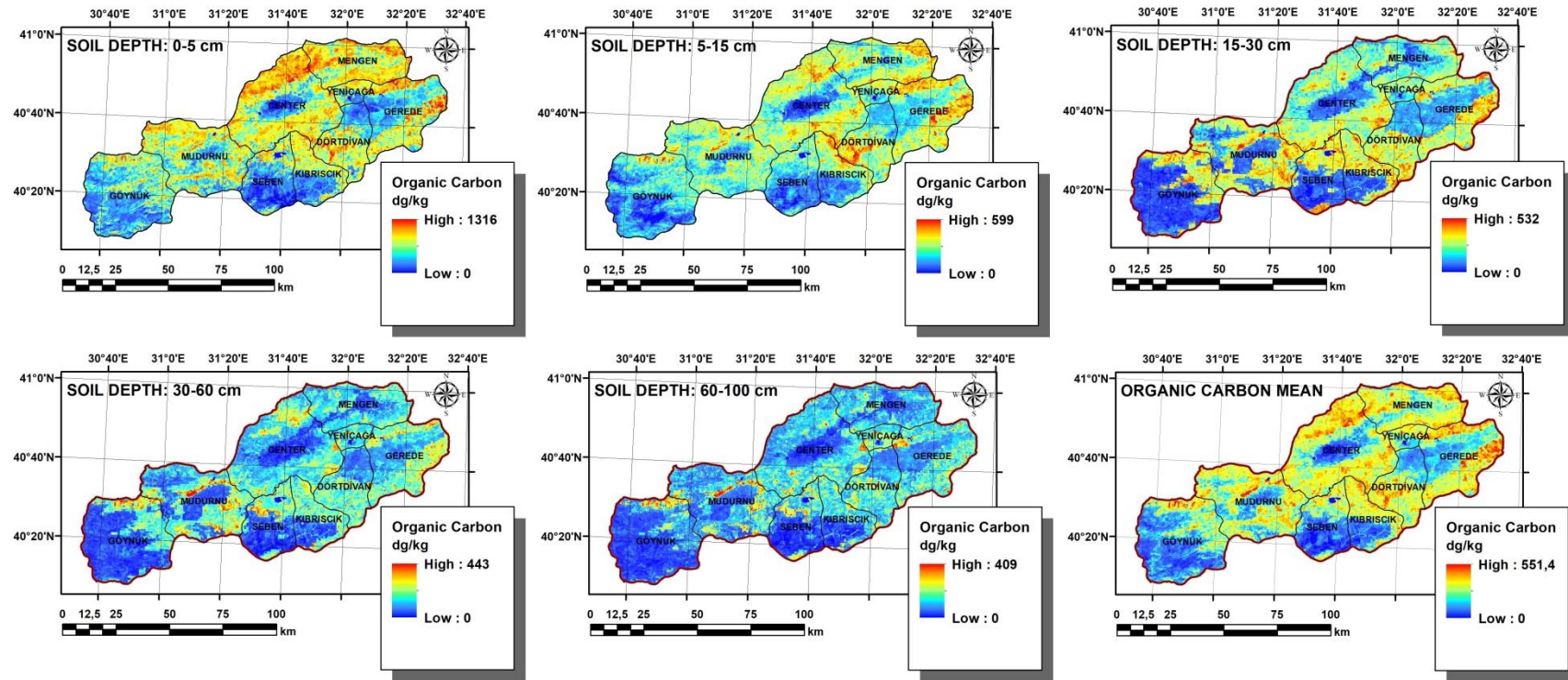


Figure 4.13. Organic Carbon (dg/kg) maps at different soil depths and mean organic carbon raster map (resolution: 250 m).

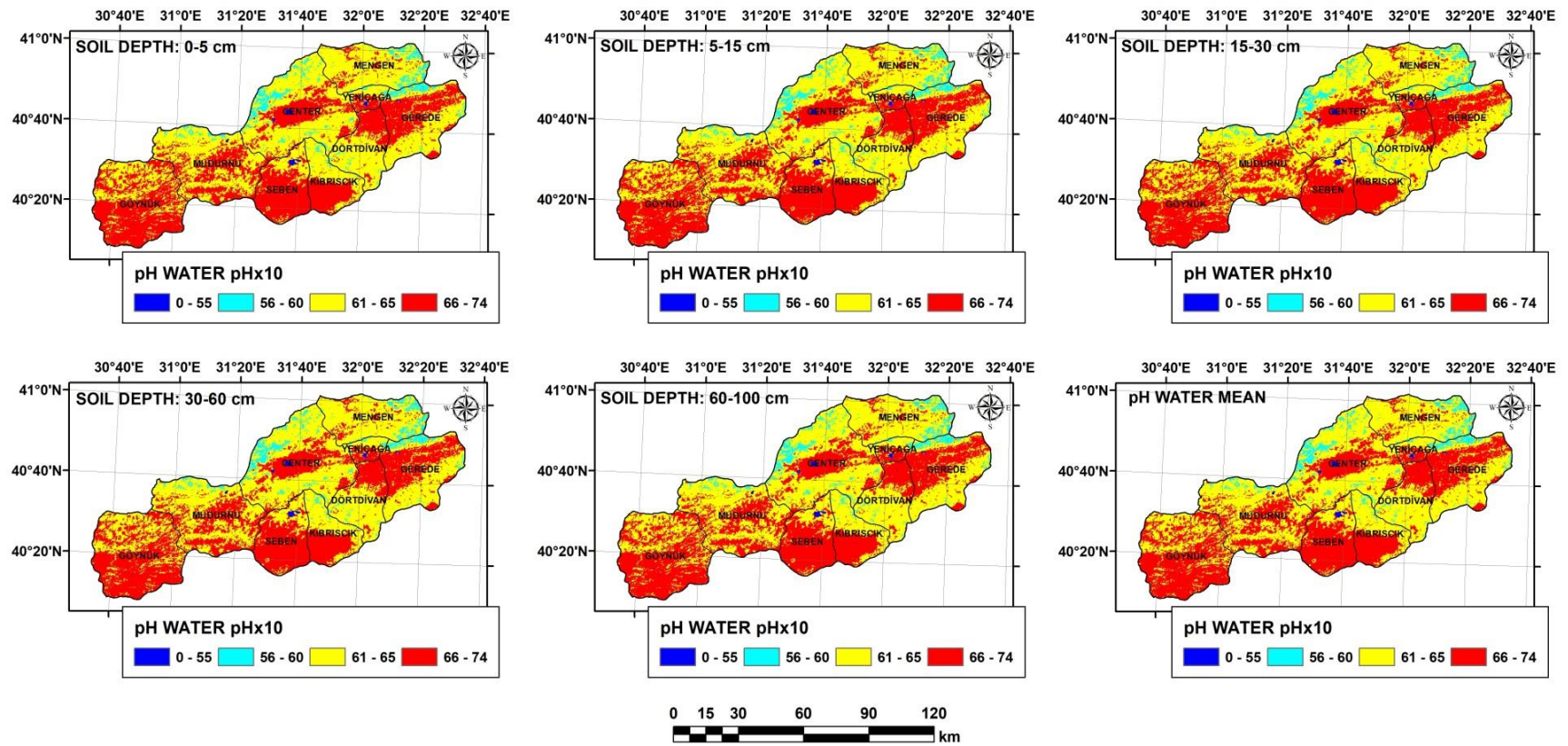


Figure 4.14. pH Water (pH x 10) maps at different soil depths and mean pH Water raster map (resolution: 250 m).

4.1.3 CHELSA Climate Database

Interpolated raster maps of climatic variables were produced using the downloaded CHELSA database. Detailed information about these downloaded CHELSA layers had been given in Table 3.9 in Methodology Section before. Interpolated CHELSA raster maps of bioclimatic variables (Bio-1, Bio-8, Bio-9, Bio-10, Bio-11, Bio-12, Bio-13, Bio-14, Bio-16, Bio-17, Bio-18, Bio-19) were shown in Figure 4.15. Among them, Bio-1 (mean annual air temperature) raster map has shown mean annual daily mean air temperatures that averaged over 1 year.

Bio-8 (mean daily mean air temperatures of the wettest quarter) raster map has displayed the wettest quarter of the year. Bio-9 (mean daily mean air temperatures of the driest quarter) raster map has shown the driest quarter of the year. Bio-10 (mean daily mean air temperatures of the warmest quarter) raster map has exhibited the warmest quarter of the year. On the other hand, Bio-11 (mean daily mean air temperatures of the coldest quarter) raster map has revealed the coldest quarter of the year. Measurement unit from Bio-1 to Bio-11 raster maps is Celsius or temperature scale (°C).

Bio-12 (annual precipitation amount) raster map has been shown the accumulated precipitation amount over 1 year. Bio-13 raster map has presented the spatial distribution of the precipitation of the wettest month, while Bio-14 has exhibited the precipitation of the driest month. Bio-16 raster map has portrayed the mean monthly precipitation amount of the wettest quarter, and Bio-17 raster map displayed the mean monthly precipitation amount of the driest quarter. Bio-18 raster map as shown the spatial distribution of mean monthly precipitation amount of the warmest quarter, while Bio-19 raster map has described the spatial distribution of the mean monthly precipitation amount of the coldest quarter. Measurement unit from Bio-12 to Bio-19 raster maps is kilogram per square meter (kg m^{-2}) or mm per square meter (mm).

Interpolated CHELSA raster maps of monthly precipitation amount were shown in Figure 4.16. Measurement unit of precipitation raster maps is kilogram per square meter ($\text{kg}\cdot\text{m}^{-2}$) or mm per square meter (mm).

Interpolated CHELSA raster maps of monthly maximum, minimum and mean temperatures were shown in Figure 4.17, Figure 4.18, Figure 4.19, respectively. Measurement unit of all temperature raster maps is Celsius as temperature scale.



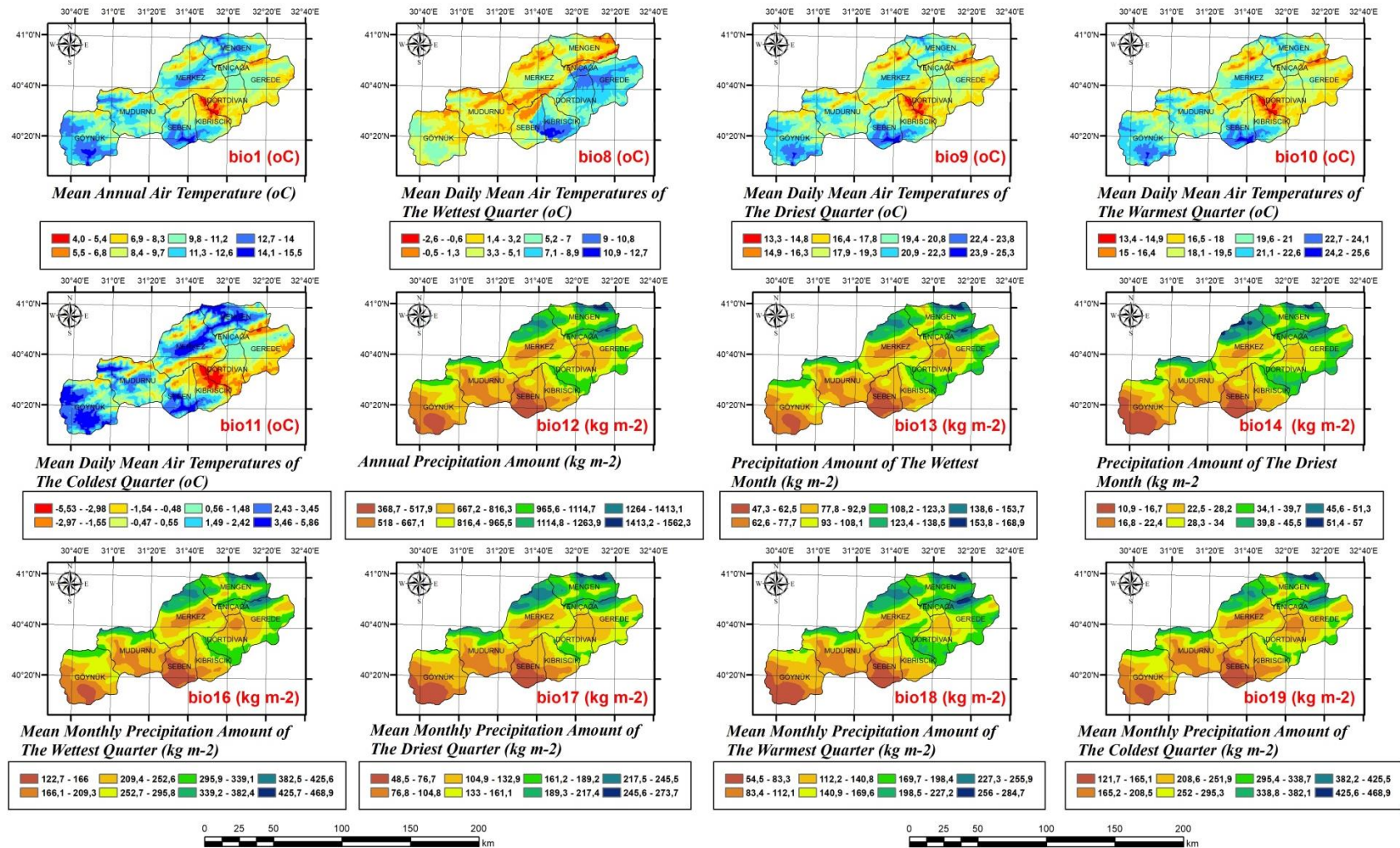


Figure 4.15. Interpolated CHELSA Bioclimatic raster maps (resolution 100 m).

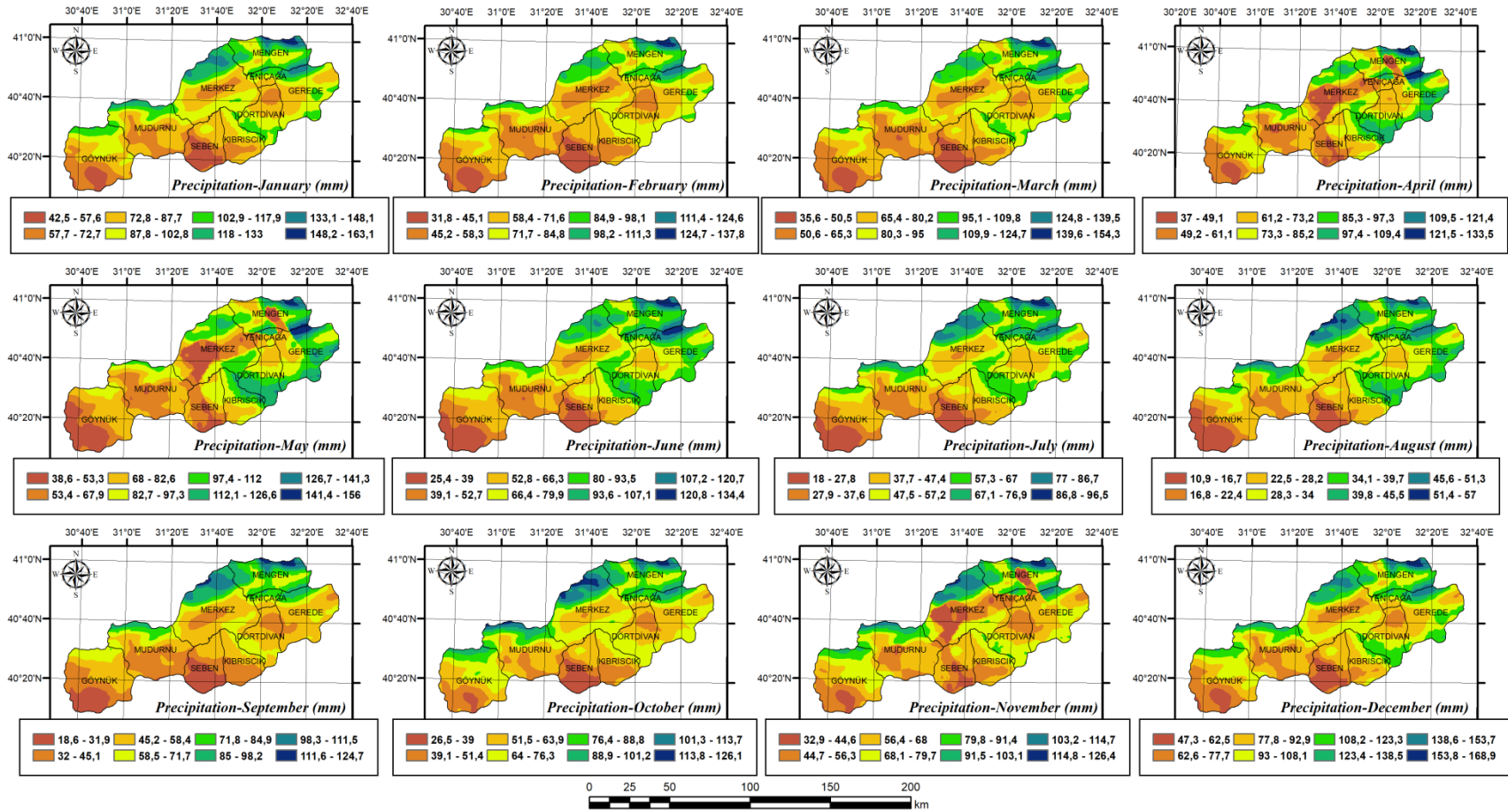


Figure 4.16. Interpolated CHELSA monthly precipitation raster maps (resolution 100 m).

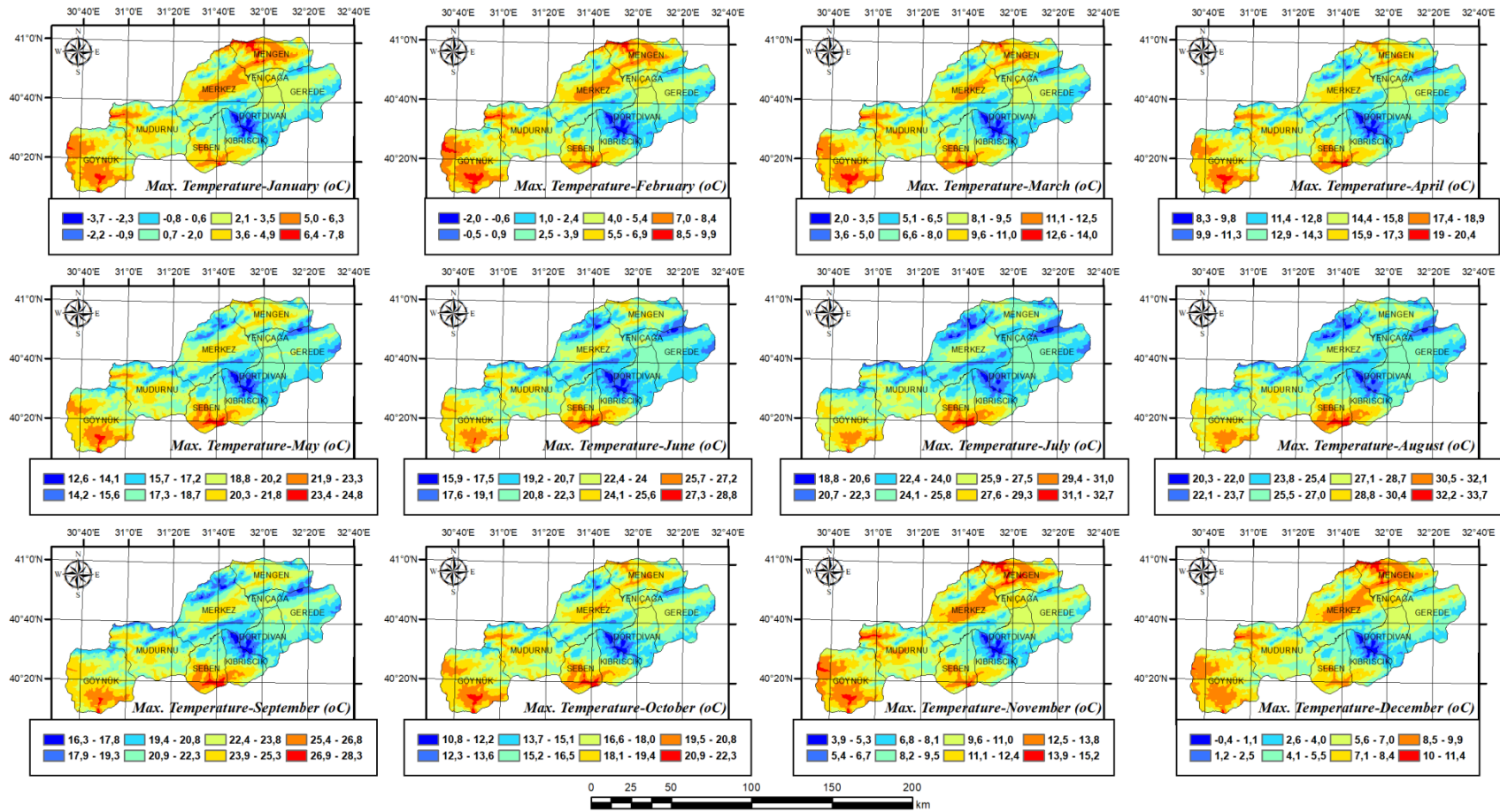


Figure 4.17. Interpolated CHELSA monthly maximum temperature raster maps (resolution 100 m).

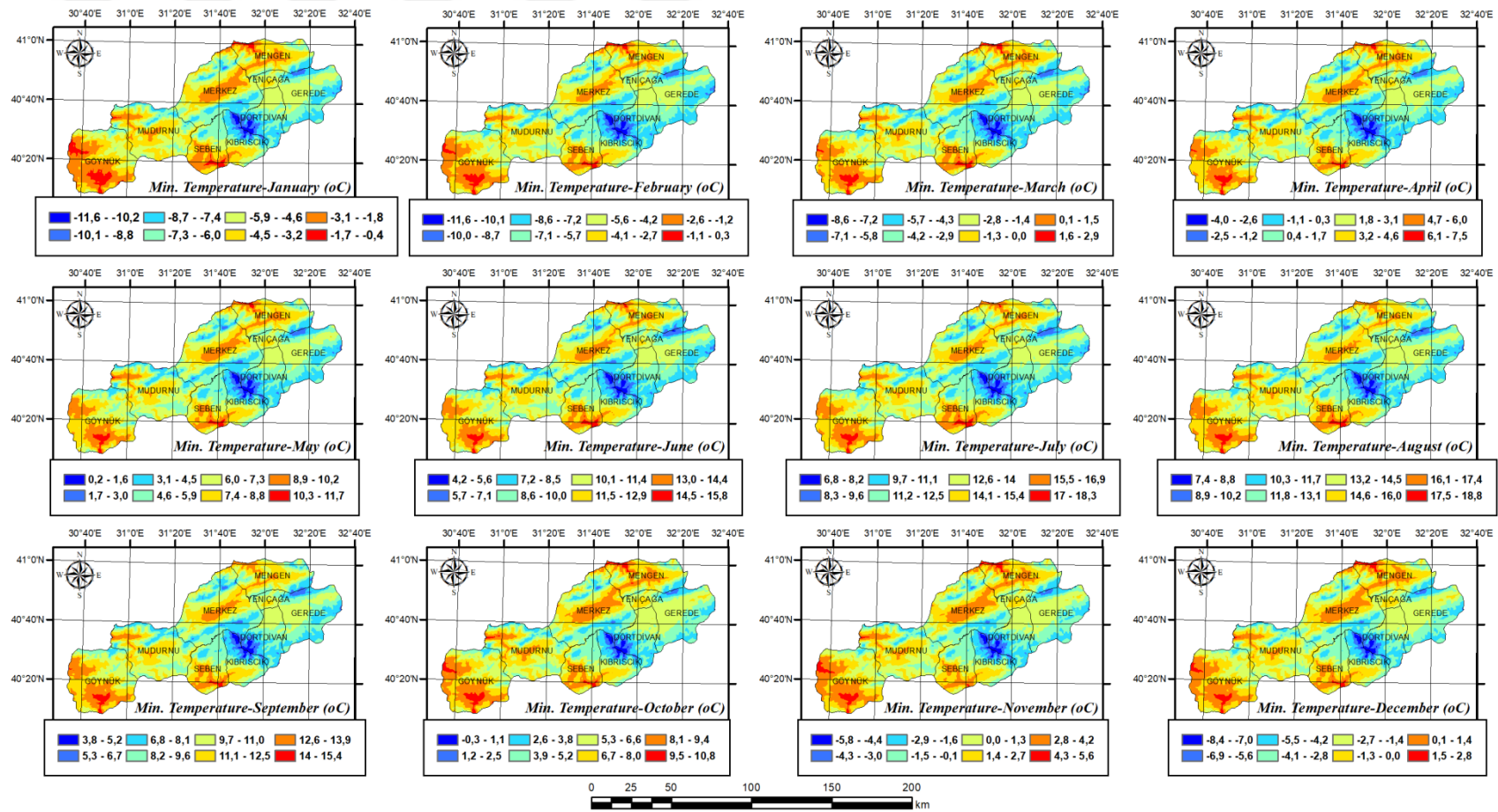


Figure 4.18. Interpolated CHELSA monthly minimum temperature raster maps (resolution 100 m).

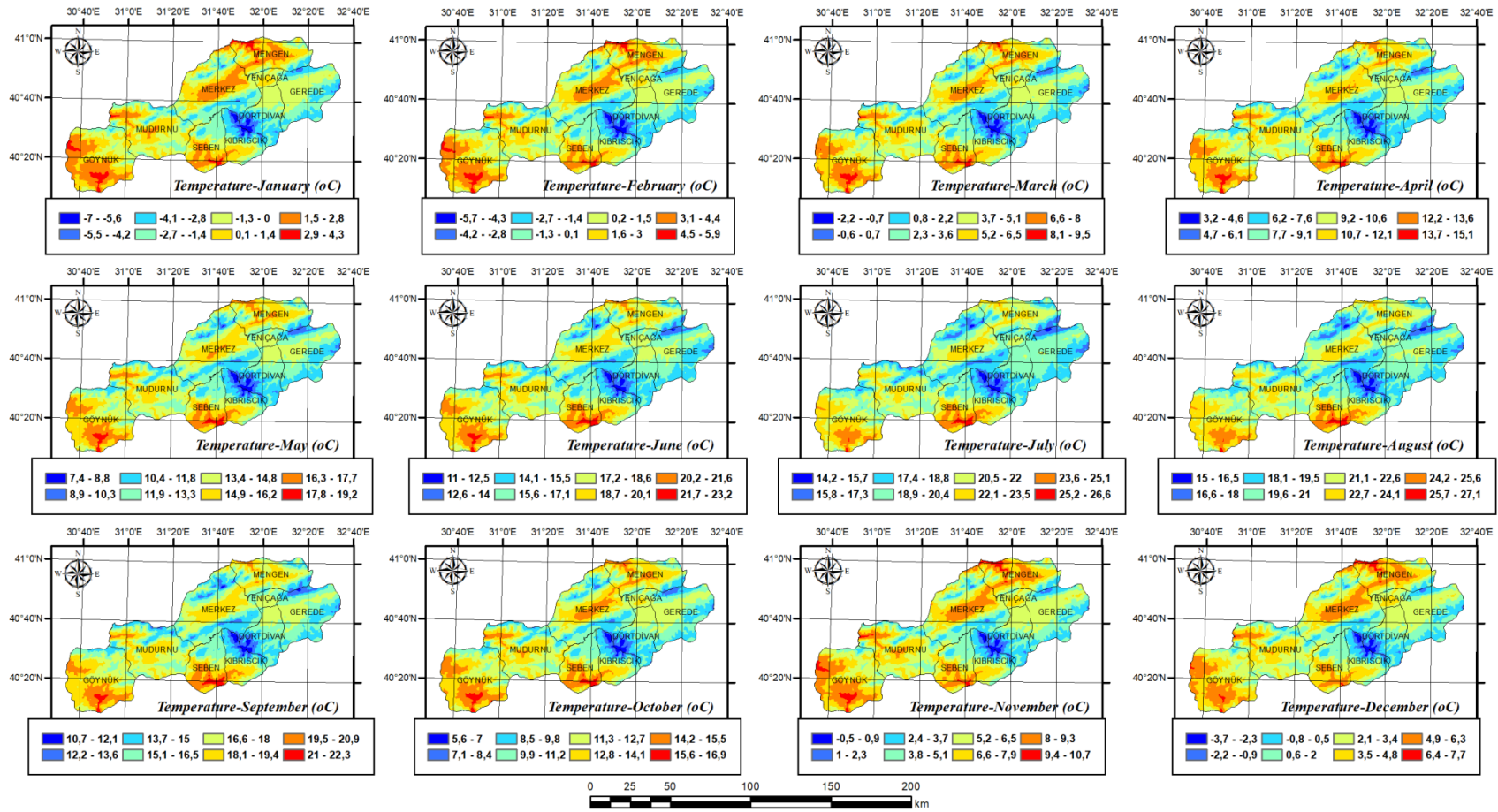


Figure 4.19. Interpolated CHELSA monthly mean temperature raster maps (resolution 100 m).

4.1.4 CORINE Land Use/Cover Database

CORINE land use/cover (Level-1, 2, 3) digital maps of Bolu province are given in Figure 4.20, Figure 4.21 and Figure 4.22, respectively. According to the CORINE Level-1 map, Bolu province's land use/cover classes, from largest to smallest area, were ranged as forest and semi-natural areas (74.79%), agricultural areas (23.67%), artificial surfaces (1.26%), water bodies (0.24%), and wetlands (0.04%). As can be seen, according to the first determinations, forests and semi-natural areas cover the most area in Bolu province (Figure 4.20).

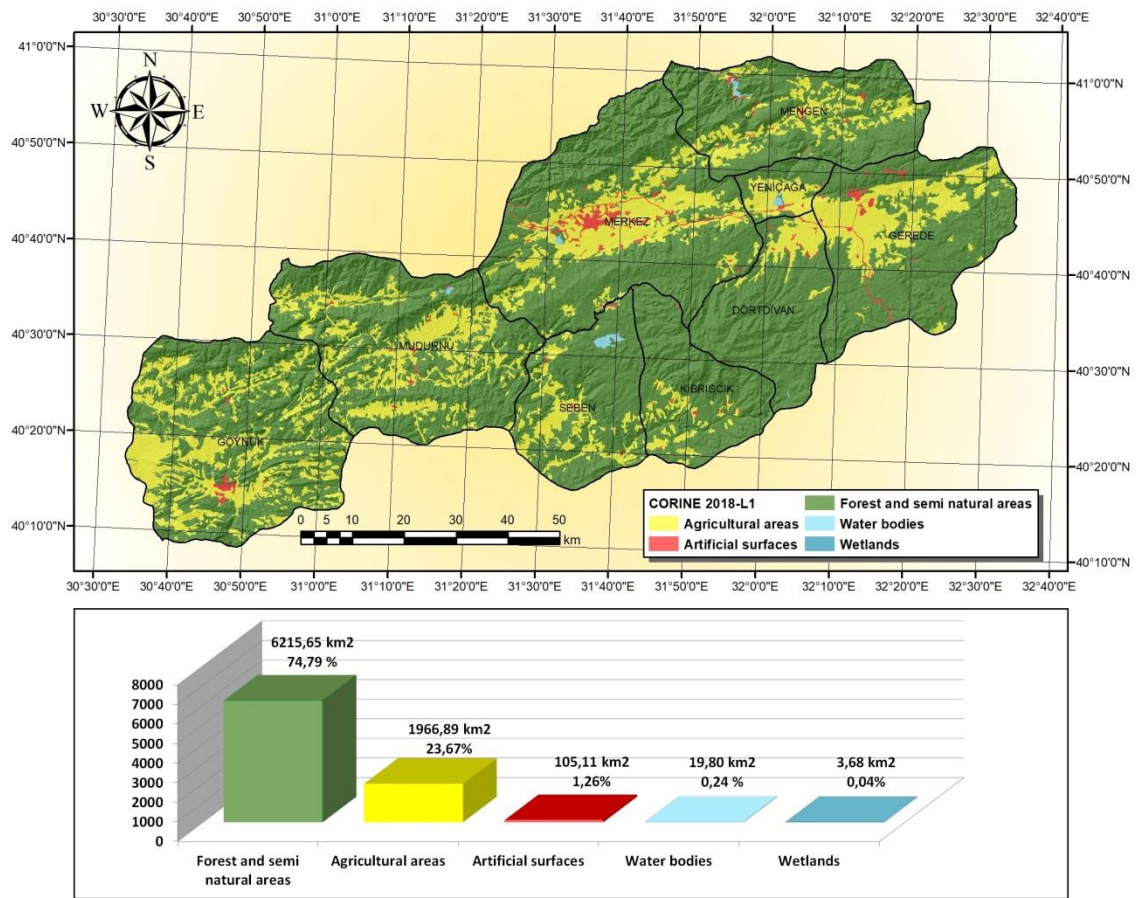


Figure 4.20. Bolu Province 2018 CORINE Level-1 Land Use/Cover Map (Note: Downloaded from Copernicus, and processed in ArcGIS).

In the CORINE Level-2 digital map, it can be seen that land use/cover classes are more detailed (Figure 4.21). According to the CORINE Level-2 map, Bolu province's land use/cover classes, from largest to smallest area, were ranged as forests (50.32%), scrub and herbaceous vegetation associations (22.81%), heterogeneous agricultural areas (13.04%), arable land (10.06%), open spaces with

little or no vegetation (1.66%), urban fabric (0.58%), industrial-commercial-transport units (0.45%), pastures (0.43%), inland waters (0.24%), mine-dump-construction sites (0.20%), permanent crops (0.14%), inland wetlands (0.04%), and artificial-nonagricultural vegetated areas (0.03%).

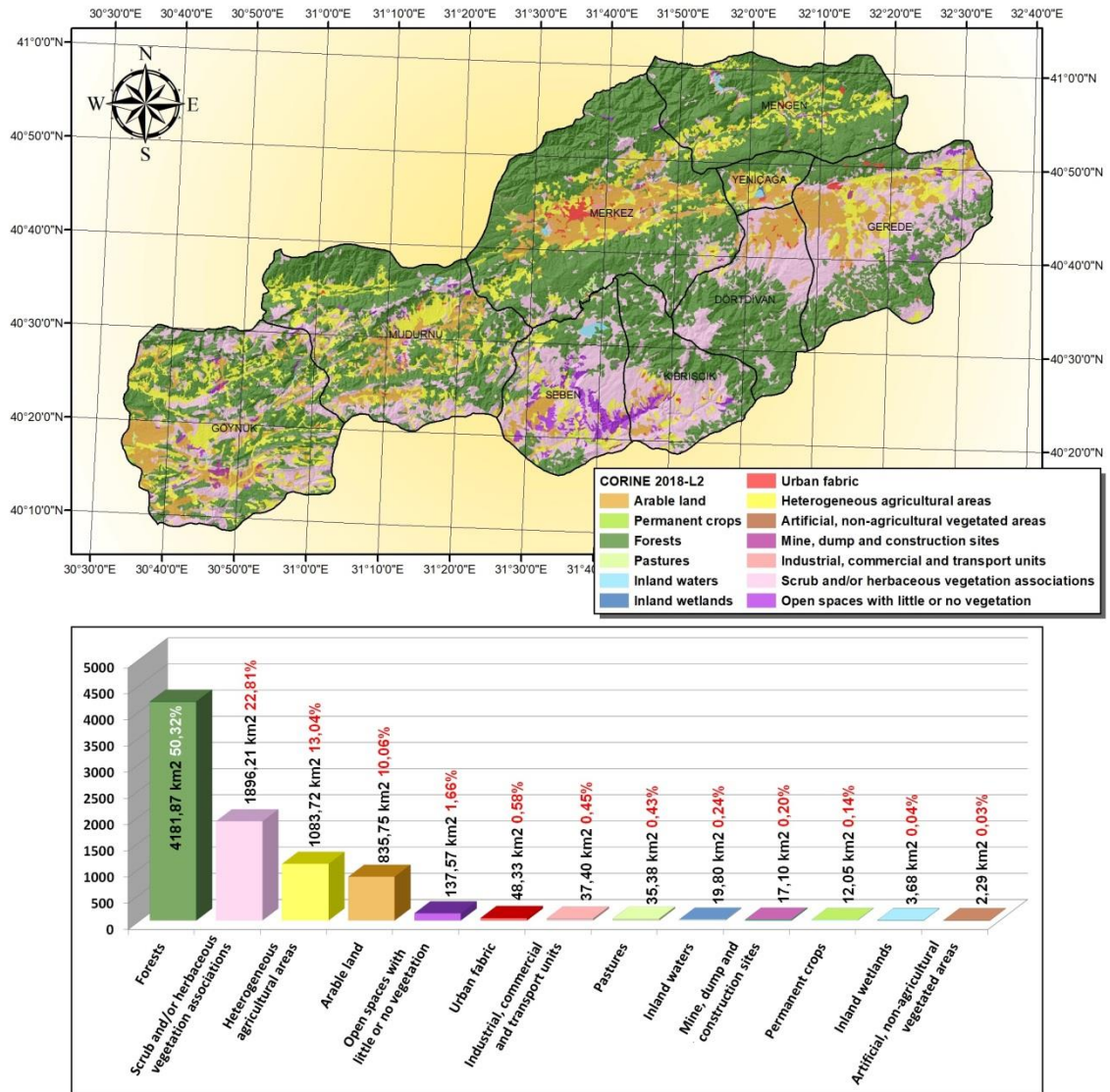


Figure 4.21. Bolu Province 2018 CORINE Level-2 Land Use/Cover Map (Note: Downloaded from Copernicus, and processed in ArcGIS).

Land use/cover classes have become most detailed in the CORINE Level-3 digital map (Figure 4.22). According to the CORINE Level-3 map, Bolu province's land use/cover classes, from largest to smallest area, were ranged as coniferous forest (33.13%), transitional woodland-shrub (11.75%), mixed forest (11.36%), natural grasslands (11.06%), agriculture and natural vegetation (7.95%), non-

irrigated arable land (6,87%), broad-leaved forest (5.83%), complex cultivation patterns (5,09%), permanently irrigated land (3.18%), sparsely vegetated areas (1.63%), discontinuous urban fabric (0.50%), pastures (0.43%), road and rail networks and associated land (0.26%), water bodies (0.24%), mineral extraction sites (0.17%), industrial or commercial units (0.16%), fruit trees and berry plantations (0.15%), continuous urban fabric (0.08%), inland marshes (0.04%), construction sites (0.04%), sport and leisure facilities (0.03%), beaches-dunes-sands (0.03%), and bare rocks (0.02%).

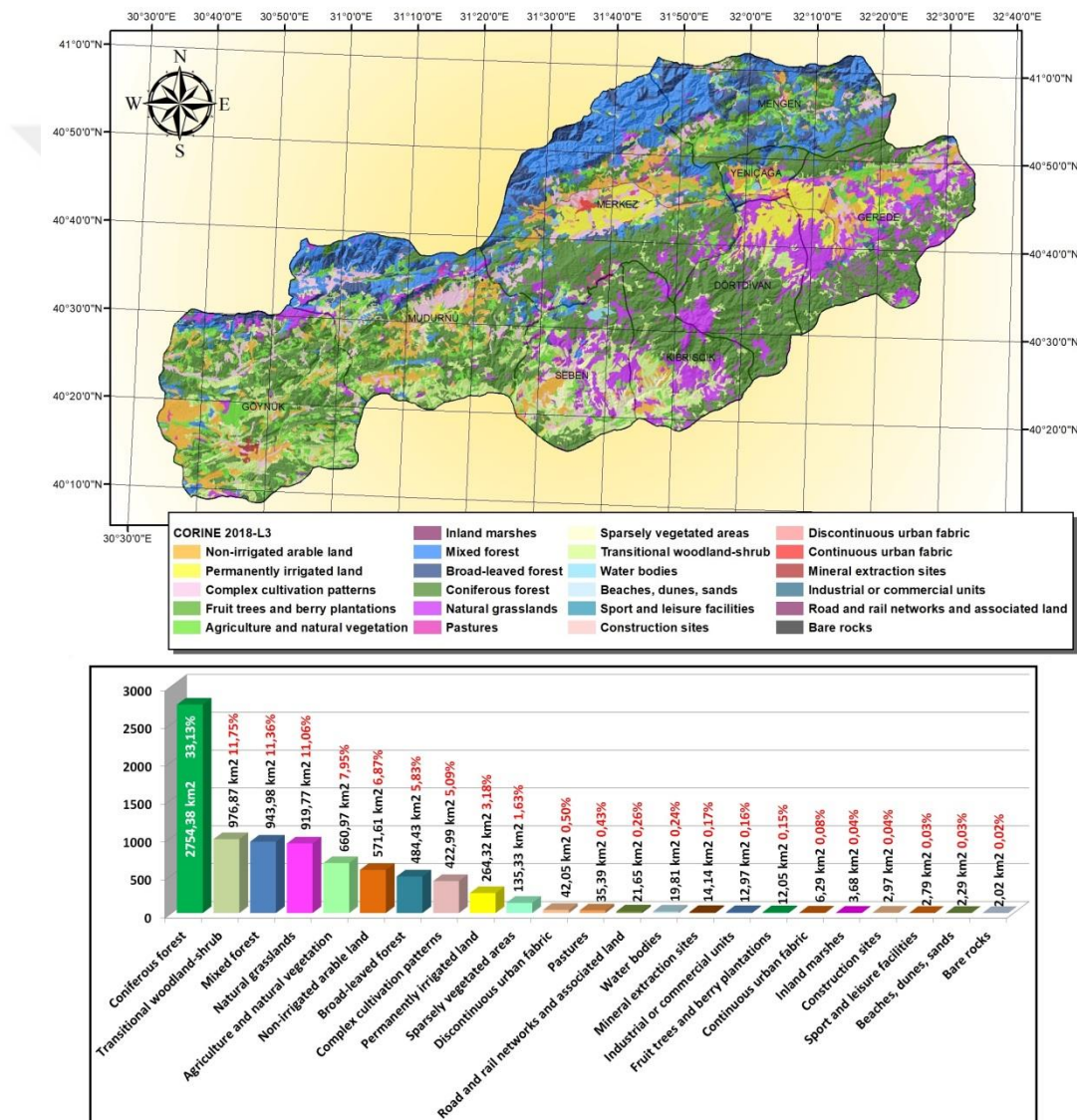


Figure 4.22. Bolu Province 2018 CORINE Level-3 Land Use/Cover Map (Note: Downloaded from Copernicus, and processed in ArcGIS).

4.1.5 Türkiye's National Soil (KHGM) Database

Produced Great Soil Groups and Land suitability classes' maps by utilizing KHGM database were given in Figure 4.23 and Figure 4.24, respectively.

According to the Great Soil Groups map (Figure 4.23), there are ten major Great Soil Groups in the study area. From largest to smallest cover area, those Great Soil Groups were ranged as Brown Forest (56.37%), Lime Free Brown Forest (32.97%), Alluvial (4.11%), Colluvial (2.03%), Gray Brown Podzolic (1.69%), Red Yellow Podzolic (1.22%), Reddish Chestnut (0.24%), Redzinas (0.10%), Hydromorphic (0.05%), and Vertisols (0.01%). Places corresponding to residential areas are classified as out of evaluation. Since large soil groups are also reclassified using dummy variables, their numerical values are given in parentheses in the map legend.

As seen in Figure 4.23, Brown Forest soils, which cover the largest area (56.37%), are common almost everywhere of the study area. Limeless Brown Forest soils (32.97%) are mostly found in the middle and southeast of the province, and locally in the north and northwest. Alluvial (4.11%) and Colluvial (2.03%) soils are located on river axes and locations where the slope decreases, respectively. The remaining large soil groups are located in very small local areas and cover between 1.69% and 0.01%. Since a large part of the research area (95.48%) consists of Brown Forest (56.37%), Limeless Brown Forest (32.97%), Alluvial (4.11%) and Colluvial (2.03%) soils, literature information about these soils is summarized below.

Brown Forest and Lime Free Brown Forest Soils are the soils of temperate zone, under deciduous forest cover. Organic matter is mixed with the mineral matter in the topsoil. Carbonates are washed away from the soil in places where rainfall is high. They are also called lime-free soils with acid reaction (pH value less than 7). On the other hand, in areas with low rainfall, carbonates accumulate in the B horizon. These soils with a slightly alkaline reaction (pH value greater than 7) are considered calcareous forest soils. In these soils, the decomposition of plant residues on the soil surface ensures that plant nutrients washed from the soil return to the soil (85, 86).

Alluvial soils are formed by the accumulation of fine materials carried by streams in the areas where streams spread. The physical and chemical properties of these soils are determined by the physical and chemical properties of the material coming from the fields where the Alluvial material originates. Heavy-textured Alluvial soils predominate in the afterswamp reservoirs, where floating clays accumulate in water. On the other hand, sandy soils are dominant on the sandy materials (natural embankments) accumulated by water overflowing from the river bed. In general, Alluvial soils with good drainage are rich in nutrients and form soils suitable for agriculture (85, 86).

The sandy, angular gravel deposit formed as a result of the accumulation of materials of various sizes decomposed along the sloping slopes at the foot of the mountains is called Colluvial deposit, and the soil formed on them is called Colluvial soil. These soils, which are generally located at the foothills of steep slopes and at the mouths of valleys, are common at the foot of mountains and garden establishment is only possible in places with sufficient rainfall (85, 86).

According to the land suitability classes map (Figure 4.24), there are eight major land suitability classes in the study area. From largest to smallest cover area, those land suitability classes were ranged as VII (68.92%), VI (12.04%), IV (6.10%), I (4.35%), III (4.33%), II (2.97%), VIII (0.35%), and V (0.08). Places corresponding to residential areas are classified as out of evaluation. Since land suitability classes are also reclassified using dummy variables, their numerical values are given in parentheses in the map legend.

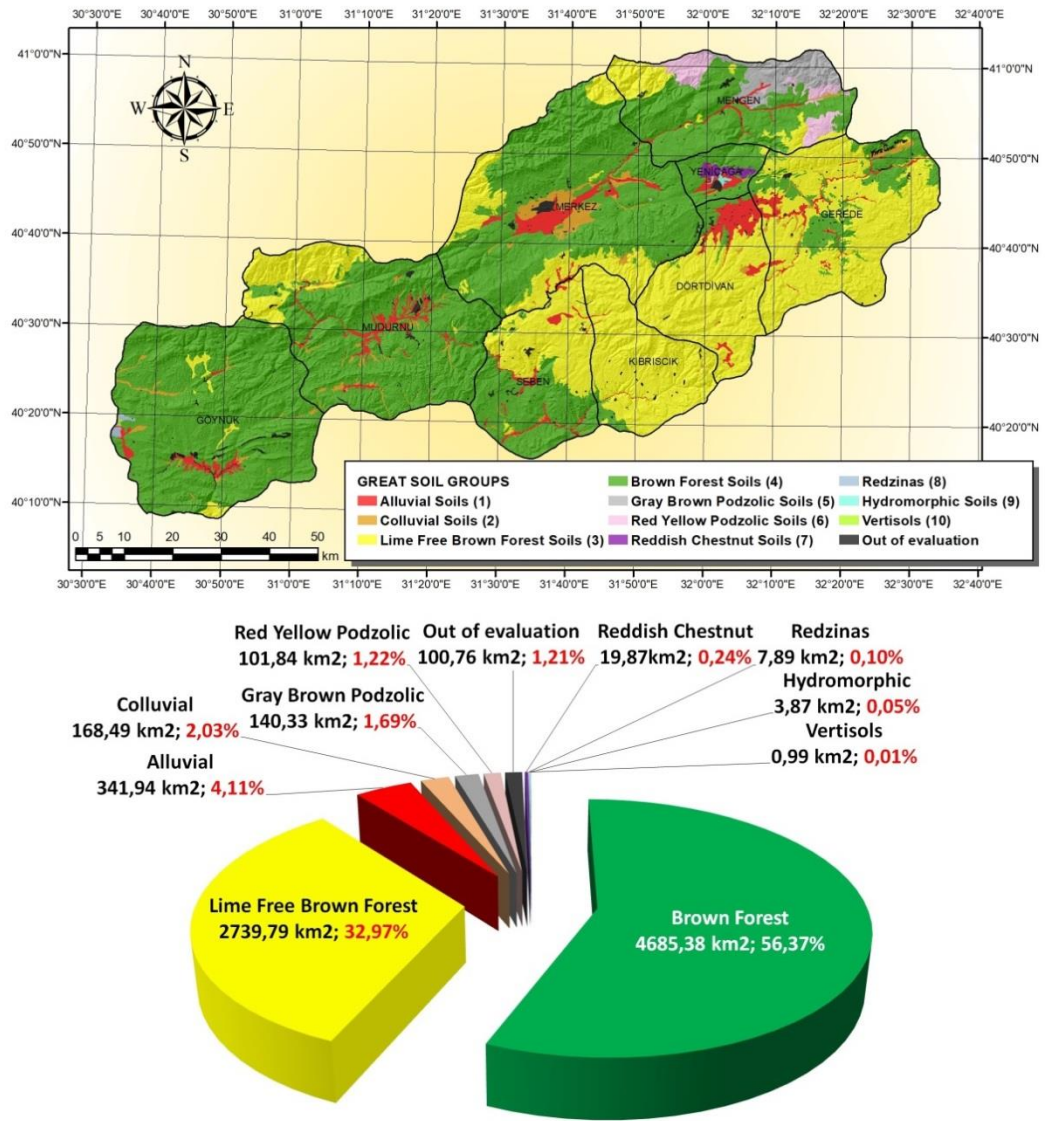


Figure 4.23. Great Soil Groups map of Bolu province (Note: Obtained from Türkiye's National Soil (KHGM) Database, and processed in ArcGIS).

4.2 Statistical Analyses

4.2.1 Genotypic Analyses

Wheat samples grown in climate chamber was cut after a week. Then DNA isolation had done with DArT-CTAB (70) method. DNA isolation studies were carried out very efficiently, and high quality of DNA obtained (Figure 4.25).

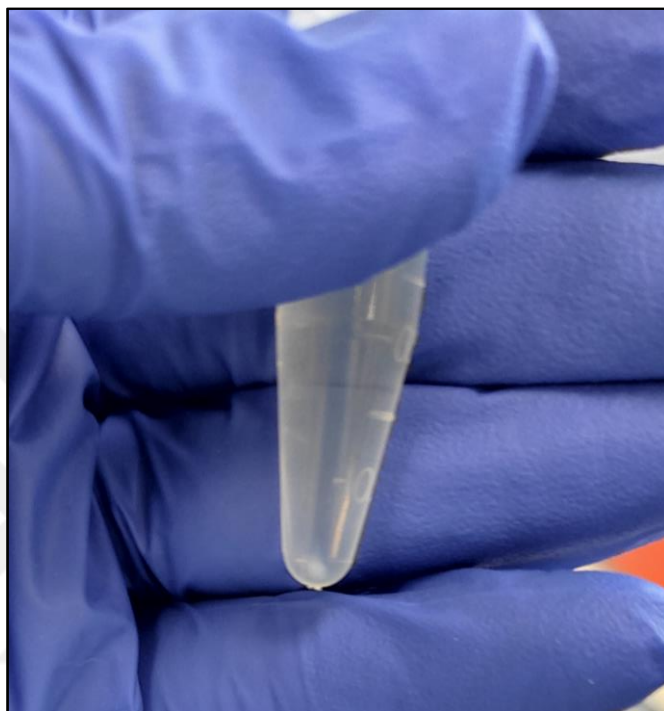


Figure 4.25. DNA image of *T. monococcum* ssp. *monococcum* isolate.

4.2.2 Genetic Diversity Analyzes

In this study, 5 SCoT primers were used to investigate the genetic diversity of 80 *T. monococcum* ssp. *monococcum* populations, 4 *T. aestivum* cv. Çalibasan and 5 *T. aestivum* cv. Sarı Serez variants. Since no visible results could be obtained from genetic diversity in the *T. monococcum* ssp. *monococcum* populations which were collected from Bolu, a control group was created by taking samples from Kastamonu. Control group samples were given numbers from 70 to 80. The electrophoresis image which created by the SCoT 13 primer is given below (Figure 4.26).

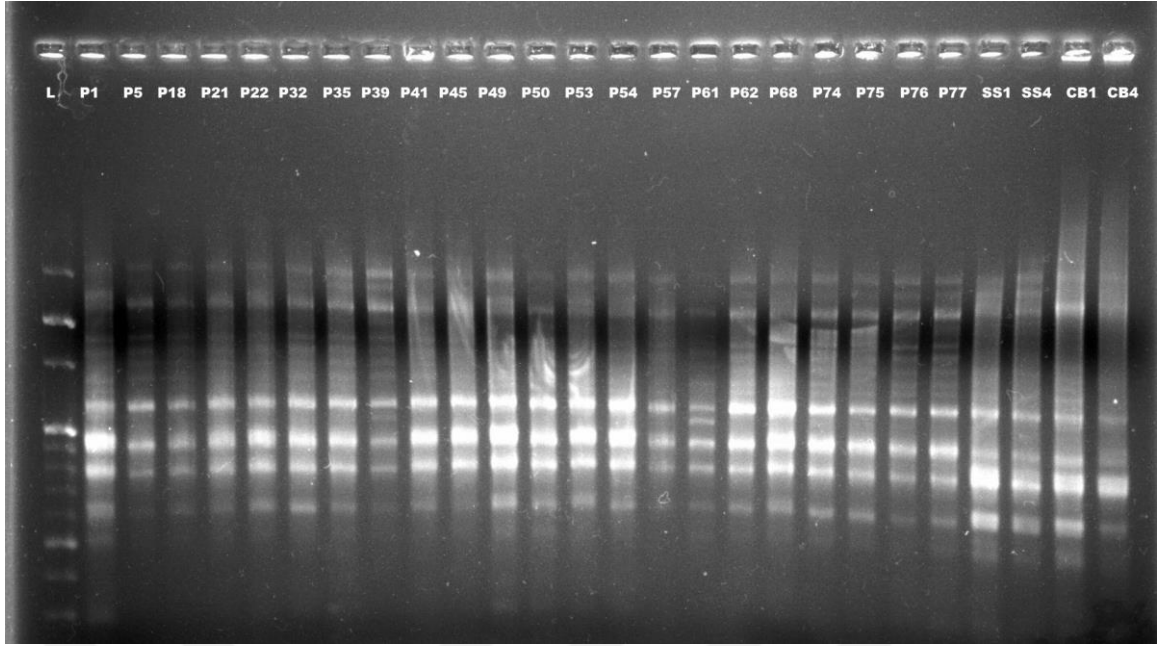


Figure 4.26. Electrophoresis images of SCoT 13 primer PCR results of wheat species. L: ladder; P: Population of *T. monococcum* ssp. *monococcum*; SS: Sarı Serez; CB: Çalibasan.

The amplification results of 80 accession of *T. monococcum* ssp. *monococcum* and *T. aestivum* (cv. Çalibasan and cv. Sarı Serez) by using five SCoT primers are given in Table 4.1. The TB varied between 14 (Scot 13) and 21 (SCoT 30) with an average of 17.80. The number of PB ranged from 3 (SCoT 34) to 13 (SCoT 31) with the mean of 9.60. Percentage of PPB varied between 20.00 (SCoT 34) and 78.57 (SCoT 13) with the average of 53.72. The PIC ranged from 0.02 (SCoT 34) to 0.11 (SCoT 13 and SCoT 31) with the mean of 0.08. The RP varied between 0.43 (SCoT 34) and 2.36 (SCoT 31) with the average of 1.63.

TB and PB were examined within the species. While the TB in *T. monococcum* ssp. *monococcum* varies between 12 (SCoT 13) and 20 (SCoT 30), the PB varies between 2 (SCoT 13) and 6 (SCoT 31). TB ranged from 10 (SCoT 13) to 18 (SCoT 31), while the PB ranged from between 0 (SCoT 30) to 4 (SCoT 31) in *T. aestivum*.

Table 4.1. The amplification results of 69 accession of *T. monococcum* ssp. *monococcum* and *T. aestivum* (cv. Çalibasan and cv. Sarı Serez) by using five SCoT primers.

			Interspecies		Intraspecies						
					<i>T. monococcum</i> ssp. <i>monococcum</i>		<i>T. aestivum</i>				
SCoT ID	Primer sequences (5'–3')	GC (%)	TB	PB	TB	PB	TB	PB	PPB (%)	PIC	RP
13	ACGAC <u>ATG</u> GCGACCATCG	61	14	11	12	2	10	3	78.57	0.11	1.73
25	ACC <u>ATG</u> GCTACCACCGGG	67	19	10	18	5	16	3	52.63	0.07	1.48
30	CC <u>ATG</u> GCTACCACCGGCG	72	21	11	20	3	14	0	52.38	0.09	2.16
31	CC <u>ATG</u> GCTACCACCGCCT	67	20	13	17	6	18	4	65.00	0.11	2.36
34	ACC <u>ATG</u> GCTACCACCGCA	61	15	3	15	3	14	1	20.00	0.02	0.43
<i>Total</i>			<i>89</i>	<i>48</i>							
<i>Avg./primer</i>			<i>17.80</i>	<i>9.60</i>					<i>53.72</i>	<i>0.08</i>	<i>1.63</i>

*Abbreviations: TB: total bands; PB: number of polymorphic bands; PPB: percentage of polymorphic bands; PIC: polymorphism information content; RP: resolving power

Clustering analysis of the populations was performed, and it was observed that the resulting dendrogram populations were clustered according to their genetic distance (Figure 4.27). The genotypes analyzed were divided into two main clusters, showing 62% genetic similarity. The results indicated that *T. aestivum* cv. Sarı Serez and *T. aestivum* cv. Çalibasan were more closely related than *T. monococcum* ssp. *monococcum* (IZA). The first cluster consisted of 80 *T. monococcum* ssp. *monococcum* (IZA) genotypes, while the second cluster consisted of 9 *T. aestivum*. Both groups showed intraspecific polymorphism among themselves. Although the *T. monococcum* ssp. *monococcum* (IZA) genotypes were separated from each other with a similarity of 92%, it was seen that the 69 genotypes did not show any genetic variation at intraspecies level. Moreover, there were 9 genotypes in the *T. aestivum* group, which varied with 90% similarity.

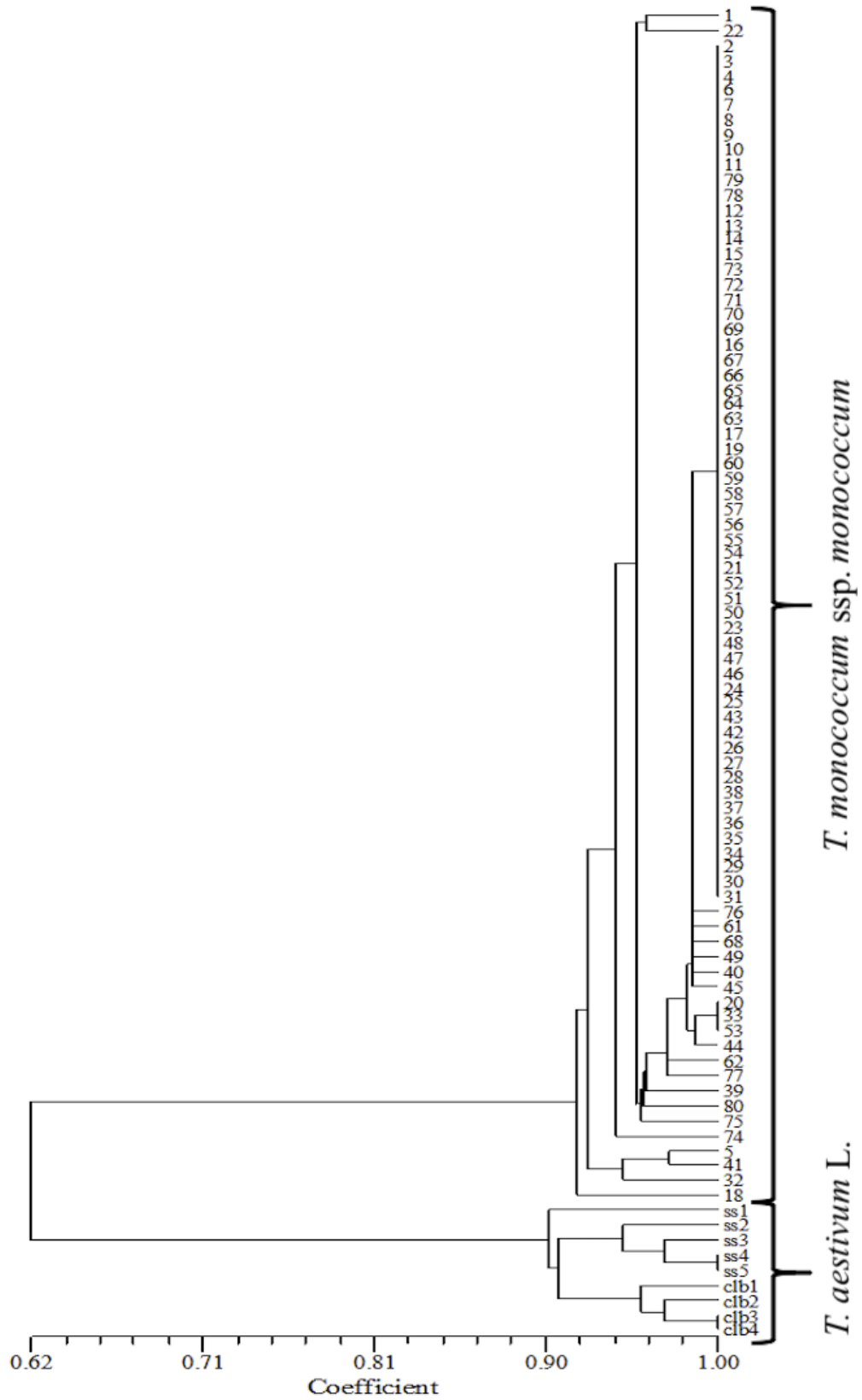


Figure 4.27. Dendrogram which is showing the relationship between the population of *T. monococcum ssp. monococcum* (IZA) and *T. aestivum* (cv. Çalıbasan and cv. Sarı Serez), grown in Bolu province.

4.2.3 Exploring Data

Both descriptive statistics and graphical representations (histograms) have been used to explore agro-morphological data characteristics of wheat landraces in this study. Measure of central tendency (mean), measures of dispersion (maximum, minimum, range, standard deviation, and variance), the asymmetry of a data distribution (skewness) and the heaviness of the distribution tails (kurtosis) have been used as descriptive statistics. Histograms have been utilized to gain more insight about the overall data visually.

Descriptive statistics of agro-morphological variables that belongs to three wheat landraces were summarized in Table 4.2, Table 4.3, and Table 4.4. In these tables, minimum refers to the smallest measured value of the agro-morphological variable in question, and maximum refers to the highest measured value. The difference between the maximum and minimum values shows the range value. Mean however refers to the arithmetic mean of each agro-morphological variable. Standard deviation is a measure of how dispersed the data is in relation to the mean. Variance is the square of the standard deviation, and shows that how far each number in the set was from the mean (average) and therefore from all other numbers in the set. The skewness shows the symmetry of the distribution. Positive skewness values indicates that the distribution is skewed to the right, and negative skewness values indicates that the distribution is skewed to the left. Kurtosis values indicates the degree to which there are too many or too few samples in the middle of the distribution. In other words, it refers to the flatness or steepness of the distribution curve. Positive kurtosis values indicated steep distribution, and negative kurtosis expressed a flat distribution.

The histograms of the agro-morphological characteristics of each local wheat landrace were presented after its own descriptive statistics table (as Table 4.2 - Figure 4.28, Table 4.3 - Figure 4.29, and Table 4.4 - Figure 4.30 pairs).

According to the agro-morphological descriptive statistics results of *T. monococcum* ssp. *monococcum* (IZA) (Table 4.2), TKW changed between 35.44 g (maximum) and 21.73 g (minimum) with a range 13.71 g, and its arithmetic mean was determined as 28.44 g. Flag leaf area (FLA) changed between 17.76 cm²

(maximum) and 1.85 cm² (minimum) with a range 15.91 cm², and its arithmetic mean was determined as 8.86 cm². FLL varied between 20.00 cm (maximum) and 3.00 cm (minimum) with a range 17.00 cm, and its arithmetic mean was detected as 10.66 cm. Maximum, minimum, range and mean values of FLW were found as 3.40 cm, 0.18 cm, 3.22 cm, and 1.19 cm, respectively. Moreover, SL changed between 5.10 cm, 3.97 cm with a range 1.14 cm, and its arithmetic mean was detected as 4.42 cm. According to these measurements, the highest plant height (PH) was 116.89 cm and the lowest was 56.00 cm. The average plant length was calculated as 92.79 cm. Additionally, the highest UNL was measured as 27.20 cm, the lowest value was detected as 16.70 cm and the average value was 20.86 cm. The maximum and minimum values of the number of KPS were found as 41.97 and 15.00 kernels/spike, respectively. Moreover, the average number of grains per spike (KPS) was 28.86 kernels/spike.

We experienced during our field studies that the spikes fertile per square meter can vary depending on the farmers' preferences. For example, we noticed that some farmers plant very densely, while others plant infrequently. In these circumstances, SFPS varied between 248.00 (maximum) and 203.00 (minimum) with a range 45.00, and its arithmetic mean was detected as 218.25. Finally, yield (YLD) changed between 207.99 kg/da (maximum) and 171.99 kg/da (minimum) with a range 36.01 kg/da, and its arithmetic mean was determined as 183.91 kg/da.

The histogram, based on the frequency distribution and represented graphically the agro-morphological data of IZA wheat exhibited us our data characteristics in a visual way in Figure 4.28. While TKW, FLA, FLL, KPS exhibited close to normal distributions with skewness values close to zero, the remaining agro-morphological variables, especially FLW, YLD and SFPS, exhibited an appearance far from normal distribution due to their high skewness values.

Table 4.2. Descriptive statistics of agro-morphological variables of *T. monococcum* ssp. *monococcum* (IZA).

	Range	Min.	Max.	Mean	Std. Dev.	VAR	Skew.	Kurt.
TKW	13.71	21.73	35.44	28.44	3.39	11.48	0.08	-0.73
FLA	15.91	1.85	17.76	8.86	4.28	18.28	0.20	-0.94
FLL	17.00	3.00	20.00	10.66	4.95	24.46	0.22	-1.18
FLW	3.22	0.18	3.40	1.19	0.65	0.42	1.20	1.57
SL	1.14	3.97	5.10	4.42	0.28	0.08	0.47	-0.54
PH	60.89	56.00	116.89	92.79	12.70	161.36	-0.77	1.04
UNL	10.50	16.70	27.20	20.86	2.74	7.52	0.35	-0.75
KPS	26.97	15.00	41.97	28.86	6.27	39.33	-0.22	-0.73
SFPS	45.00	203.00	248.00	218.25	9.82	96.45	0.65	0.48
YLD	36.01	171.99	207.99	183.91	7.87	61.94	0.69	0.15

Abbreviations

TKW:	Thousand kernels weight (g)	PH :	Plant height (cm)
FLA :	Flag Leaf area (cm ²)	UNL :	Upper Node Length (cm)
FLL :	Flag leaf length (cm)	KPS :	Number of Kernels per Spike
FLW:	Flag leaf width (cm)	SFPS :	Spikes fertile per square meter
SL :	Spike length (cm)	YLD :	Yield (kg/da)

N = 69

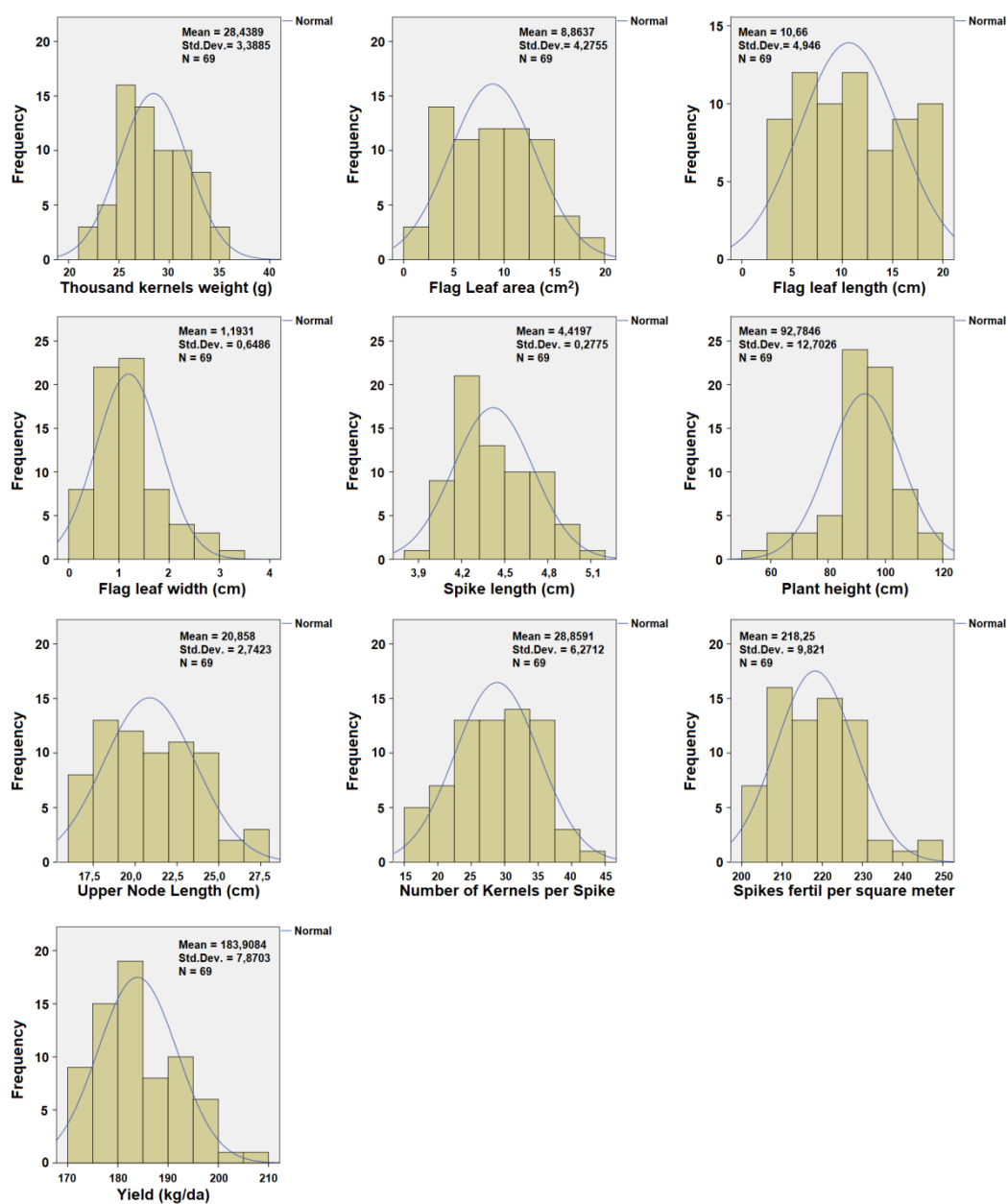


Figure 4.28. Histograms of Agro-morphological variables of *T. monococcum* ssp. *monococcum* (IZA).

The agro-morphological descriptive statistics results of *T. aestivum* (cv. Çalibasan) were summarized in Table 4.3. According to this table, TKW varied between 32.00 g (maximum) and 27.92 g (minimum) with a range 4.08 g, and its arithmetic mean was determined as 30.83 g. FLA altered between 12.33 cm² (maximum) and 6.12 cm² (minimum) with a range 6.21 cm², and its arithmetic mean was determined as 8.28 cm². FLL changed between 14.10 cm (maximum) and 10.17 cm (minimum) with a range 3.94 cm, and its arithmetic mean was detected as 11.98 cm. Maximum, minimum, range and mean values of FLW were found as 1.34 cm, 0.67 cm, 0.67 cm, and 0.88 cm, respectively. Moreover, SL changed between 4.85 cm, 4.51 cm with a range 0.34 cm, and its arithmetic mean was detected as 4.64 cm. According to these measurements, the highest PH was 81.60 cm and the lowest was 66.38 cm (range: 15.22). The average plant length was calculated as 70.75 cm. Additionally, the highest UNL was measured as 17.00 cm, the lowest value was detected as 11.00 cm (range: 6.00) and the average value was 13.91 cm. The maximum and minimum values of KPS were found as 35.26 and 22.81 kernels/spike, respectively (range: 12.45). Moreover, the average number of grains per spike (KPS) was 28.20 kernels/spike.

Depending on the farmers' preferences (as explained before), SFPS varied between 232.00 (maximum) and 206.00 (minimum) with a range 26.00, and its arithmetic mean was detected as 219.75. Finally, YLD changed between 199.03 kg/da (maximum) and 177.80 kg/da (minimum) with a range 21.23 kg/da, and its arithmetic mean was determined as 185.55 kg/da.

The histogram in Figure 4.29, based on the frequency distribution and represented graphically the agro-morphological data of Çalibasan wheat showed in a visual way data features. While UNL, SFPS, and FLL exhibited close to normal distributions with low skewness values, the remaining agro-morphological variables, especially TKW, PH, FLW, YLD, SL, and FLA exhibited an appearance far from normal distribution due to their high skewness values.

Table 4.3. Descriptive statistics of agro-morphological variables of *T. aestivum* (cv. Çalibasan).

	Range	Min.	Max.	Mean	Std. Dev.	VAR	Skew.	Kurt.
TKW	4.08	27.92	32.00	30.83	1.95	3.82	-1.933	3.758
FLA	6.21	6.12	12.33	8.28	2.88	8.30	1.369	1.309
FLL	3.94	10.17	14.10	11.98	1.62	2.63	0.550	1.451
FLW	0.67	0.67	1.34	0.88	0.31	0.10	1.886	3.667
SL	0.34	4.51	4.85	4.64	0.15	0.02	1.566	2.931
PH	15.22	66.38	81.60	70.75	7.31	53.37	1.890	3.586
UNL	6.000	11.00	17.00	13.91	2.46	6.03	0.212	1.424
KPS	12.45	22.81	35.26	28.20	5.18	26.83	0.924	1.904
SFPS	26.00	206.00	232.00	219.75	11.03	121.58	-0.351	-0.276
YLD	21.23	177.80	199.03	185.55	9.29	86.26	1.611	3.001

Abbreviations

TKW:	Thousand kernels weight (g)	PH :	Plant height (cm)
FLA :	Flag Leaf area (cm ²)	UNL:	Upper Node Length (cm)
FLL :	Flag leaf length (cm)	KPS :	Number of Kernels per Spike
FLW:	Flag leaf width (cm)	SFPS:	Spikes fertile per square meter
SL :	Spike length (cm)	YLD :	Yield (kg/da)

N = 4

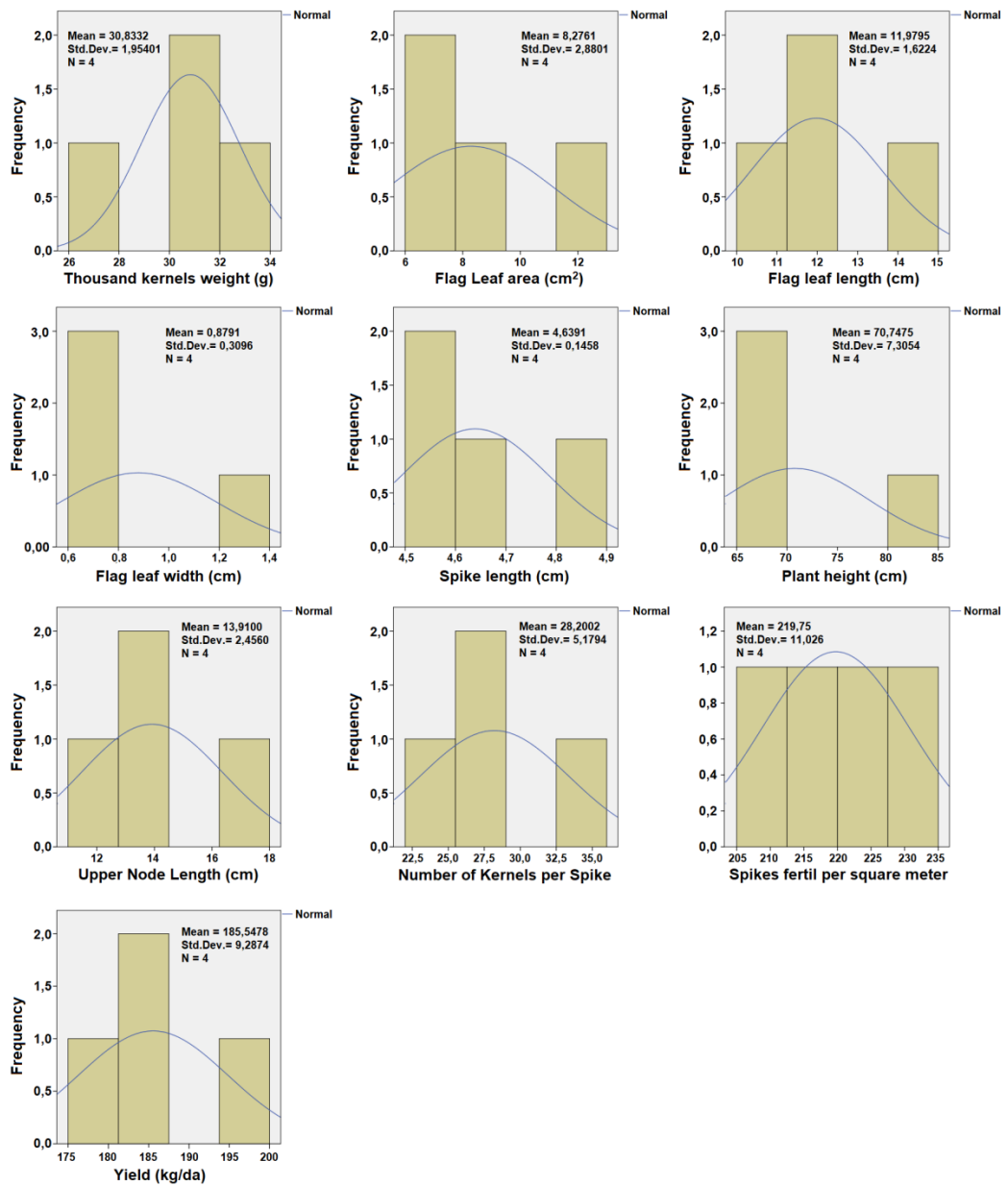


Figure 4.29. Histograms of Agro-morphological variables of *T. aestivum* (cv. Çalibasan).

The agro-morphological descriptive statistics results of *T. aestivum* (cv. Sarı Serez) (Table 4.4) showed that TKW varied between 33.00 g (maximum) and 28.41 g (minimum) with a range 4.59 g, and its arithmetic mean was determined as 30.87 g. FLA altered between 16.00 cm² (maximum) and 11.00 cm² (minimum) with a range 5.00 cm², and its arithmetic mean was determined as 12.54 cm². FLL changed between 13.70 cm (maximum) and 12.00 cm (minimum) with a range 1.70 cm, and its arithmetic mean was detected as 12.98 cm. Maximum, minimum, range and mean values of FLW were found as 1.66 cm, 1.01 cm, 0.64 cm, and 1.24 cm, respectively. Moreover, SL changed between 4.90 cm, 4.20 cm with a range 0.70 cm, and its arithmetic mean was detected as 4.63 cm. According to these measurements, the highest PH was 80.00 cm and the lowest was 56.10 cm (range: 23.90). The average plant length was calculated as 62.40 cm. Additionally, the highest UNL was measured as 15.00 cm, the lowest value was detected as 12.00 cm (range: 3.00) and the average value was 13.40 cm.

The maximum and minimum values of KPS were found as 41.28 and 24.32 kernels/spike, respectively (range: 16.96). Moreover, the average number of grains per ear was 33.40 kernels/spike. SFPS varied between 229.00 (maximum) and 202.00 (minimum) with a range 27.00, and its arithmetic mean was detected as 217.80. Finally, YLD changed between 190.09 kg/da (maximum) and 174.80 kg/da (minimum) with a range 15.28 kg/da, and its arithmetic mean was determined as 183.65 kg/da.

The histogram in Figure 4.30, based on the frequency distribution and represented graphically the agro-morphological data of Sarı Serez wheat showed in a visual way data features. While UNL, KPS, and TKW exhibited close to normal distributions with low skewness values, the remaining agro-morphological variables, especially FLW, FLA, and PH exhibited an appearance far from normal distribution due to their high skewness values.

Table 4.4. Descriptive statistics of agro-morphological variables of *T. aestivum* (cv. Sarı Serez).

	Range	Min.	Max.	Mean	Std. Dev.	VAR	Skew.	Kurt.
TKW	4.59	28.41	33.00	30.87	1.77	3.12	-0.315	-0.399
FLA	5.00	11.00	16.00	12.54	2.05	4.20	1.543	2.384
FLL	1.70	12.00	13.70	12.98	0.81	0.65	-0.601	-3.069
FLW	0.64	1.01	1.66	1.24	0.27	0.07	1.167	0.363
SL	0.70	4.20	4.90	4.63	0.29	0.08	-0.886	-0.262
PH	23.90	56.10	80.00	62.40	10.13	102.52	1.954	3.818
UNL	3.00	12.00	15.00	13.40	1.27	1.61	0.084	-1.811
KPS	16.96	24.32	41.28	33.40	8.34	69.53	-0.299	-3.054
SFPS	27.00	202.00	229.00	217.80	11.17	124.70	-0.679	-1.182
YLD	15.28	174.80	190.09	183.65	5.76	33.23	-0.830	1.057

Abbreviations

TKW :	Thousand kernels weight (g)	PH:	Plant height (cm)
FLA:	Flag Leaf area (cm ²)	UNL:	Upper Node Length (cm)
FLL:	Flag leaf length (cm)	KPS:	Number of Kernels per Spike
FLW:	Flag leaf width (cm)	SFPS:	Spikes fertile per square meter
SL:	Spike length (cm)	YLD:	Yield (kg/da)

N = 5

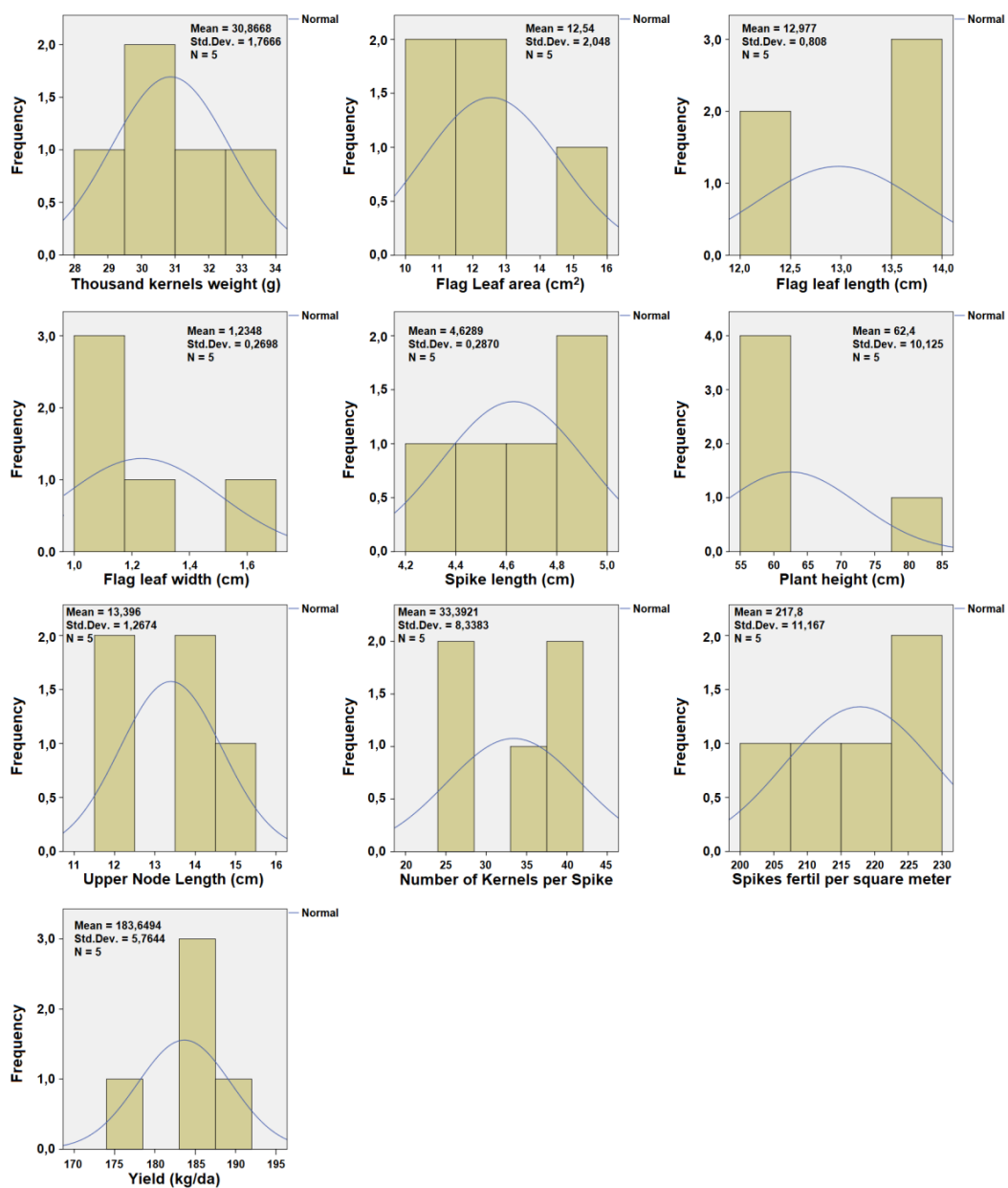


Figure 4.30. Histograms of Agro-morphological variables of *T. aestivum* (cv. Sari Serez).

4.2.4 Correlation Analyses

Correlation (bivariate) analysis presents relationship between two variables and the magnitude and action of this relationship. In this study, correlation analyses were conducted at four stages. In the first stage, correlations between the agro-morphological characteristics of each wheat landrace were searched. In the second stage, the correlations between the agro-morphological characteristics of wheat landraces and topographic variables were investigated. In the third stage, the correlations between the agro-morphological characteristics of wheat landraces and climatic variables were explored. Finally, the correlations between the agro-morphological characteristics of wheat landraces and soil variables were investigated in fourth stage.

4.2.4.1 Relationships among Agro-morphological Variables

The correlations between the agro-morphological characteristics of each wheat landrace were summarized in Table 4.5, Table 4.6 and Table 4.7, respectively.

Correlation (Pearson) matrix of agro-morphological characteristics for *T. monococcum* ssp. *monococcum* (IZA) was shown in Table 4.5. According to the correlation analysis results, a total of 17 different relationships were found to be statistically significant at the 0.01 level and 6 different relationships were found to be statistically significant at the 0.05 level.

Two negative relationships were found between FLW and SL (-0.265) and between TKW and FLW (-0.254) at the 5% level. As can be seen from the table, these two negative relationships are not strong enough. On the other hand, only one negative relationship (-0.472) between FLL and FLW was found significant at the 1% level that can be accepted strong enough. In another words, FLL and FLW are inversely proportional.

The highest and most significant positive correlation was found between TKW and SL (0.692) variables at the 0.01 level. This one was followed by TKW-FLL (0.644), FLL-FLA (0.559), and SL- FLL (0.554) pairs.

Positive relationships between SL and SFPS (0.456), TKW and SFPS (0.444), FLL and YLD (0.444), TKW and FLA (0.434), PH and UNL (0.420) were found to be significant at the 0.01 level. All these positive correlations can be accepted as strong.

Other important positive correlations between SL - YLD (0.425), FLA - YLD (0.407), and TKW - YLD (0.400) emphasizes the agro-morphological features that mostly affect the yield of IZA wheat. All these positive correlations can also be accepted as strong.

The remaining relationships that were significant at the 0.01 and 0.05 levels but Correlation coefficient found lower than 0.400 were not found strong enough.

Correlation matrix of agro-morphological characteristics for *T. aestivum* (cv. Çalibasan) was given in the Table 4.6. According to these results, none of the relationships were found significant except the relationship between UNL and SL (0.953) at the 0.05 level. This may be due to the few numbers of samples (N=4) (There are only four populations in the study area).

Correlation matrix of agro-morphological characteristics for *T. aestivum* (cv. Sarı Serez) was shown in Table 4.7. According to this table; the highest positive correlations were found between FLA and FLW (0.984), and between SL and SFPS (0.984) at the 0.05 level. Although some correlations seemed high because the number of samples was few, they were not found significant neither at the 5% nor 1% level. This is also be due to the few numbers of samples (N=5) (There are only five populations in the study area).

Table 4.5. Correlation matrix of agro-morphological characteristics for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	TKW	FLA	FLL	FLW	SL	PH	UNL	KPS	SFPSM	YLD
TKW	1									
FLA	0.434**	1								
FLL	0.644**	0.559**	1							
FLW	-0.254*	0.365**	-0.472**	1						
SL	0.692**	0.334**	0.554**	-0.265*	1					
PH	0.074	-0.043	0.050	-0.083	0.059	1				
UNL	0.269*	0.156	0.173	-0.043	0.289*	0.420**	1			
KPS	0.382**	0.124	0.156	-0.067	0.323**	0.140	0.051	1		
SFPS	0.444**	0.189	0.284*	-0.090	0.456**	-0.042	0.159	0.274*	1	
YLD	0.400**	0.407**	0.444**	-0.040	0.425**	0.062	0.025	0.087	0.106	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.6. Correlation matrix of agro-morphological characteristics for *T. aestivum* (cv. Çalibasan) (N=4).

	TKW	FLA	FLL	FLW	SL	PH	UNL	KPS	SFPSM	YLD
TKW	1									
FLA	0.530	1								
FLL	0.670	0.190	1							
FLW	0.309	0.943	-0.146	1						
SL	0.627	0.950	0.079	0.931	1					
PH	0.291	-0.056	0.905	-0.363	-0.254	1				
UNL	0.834	0.876	0.311	0.779	0.953*	-0.074	1			
KPS	-0.923	-0.211	-0.538	-0.032	-0.394	-0.165	-0.643	1		
SFPS	-0.677	-0.489	-0.939	-0.175	-0.337	-0.824	-0.495	0.429	1	
YLD	0.075	0.095	0.750	-0.159	-0.181	0.925	-0.109	0.153	-0.777	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.7. Correlation matrix of agro-morphological characteristics for *T. aestivum* (cv. Sarı Serez) (N=5).

	TKW	FLA	FLL	FLW	SL	PH	UNL	KPS	SFPSM	YLD
TKW	1									
FLA	0.071	1								
FLL	-0.221	-0.769	1							
FLW	0.121	0.984**	-0.870	1						
SL	0.526	-0.669	0.208	-0.576	1					
PH	0.508	-0.568	0.607	-0.596	0.407	1				
UNL	0.000	-0.760	0.947*	-0.843	0.257	0.823	1			
KPS	-0.076	-0.209	0.426	-0.266	-0.324	0.651	0.615	1		
SFPS	0.607	-0.663	0.287	-0.592	0.984**	0.521	0.355	-0.253	1	
YLD	-0.052	-0.693	0.094	-0.564	0.739	0.043	0.072	-0.241	0.620	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

4.2.4.2 Relationships between Agro-morphological and Topographic Variables

Correlation matrix of agro-morphological characteristics and topographic (elevation, slope and aspect) variables for *T. monococcum* ssp. *monococcum* (IZA) was shown in Table 4.8. According to the correlation analysis results, a total of 11 different relationships were found to be statistically significant at the 0.01 level, and 7 different relationships were found to be statistically significant at the 0.05 level. All statistically significant relationships showed up positive correlations, while no statistically significant negative correlations were found. The highest and most significant positive correlation was found between TKW and elevation (0.793) variables at the 0.01 level. This one was followed by FLL-elevation (0.773), SL-elevation (0.702), FLA-elevation (0.684), YLD-elevation (0.501) and SFPS-elevations (0.452). All these positive correlations can be accepted as strong. The remaining relationships that were significant at the 0.01 and 0.05 levels but Correlation coefficient found lower than 0.400 were not found strong enough.

Correlation matrix of agro-morphological characteristics and topographic (elevation, slope and aspect) variables for *T. aestivum* (cv. Çalibasan) was shown in Table 4.9. According to this table, two negative correlations between SFPS and elevation (-0.988), and between FLA and aspect classified (-0.987) were detected statistically significant at the 5% level. On the other hand, five positive relationships between YLD and slope % (0.980), between YLD and slope-degree (0.979), between PH and aspect-degree (0.967), between FLL and elevation (0.954), and between YLD and aspect-degree (0.952) were found statistically significant at the 5% level. All these positive or negative correlations were accepted as strong. Apart from these relationships, no statistically significant relationship was found at neither 0.01 nor 0.05 level.

Correlation matrix of agro-morphological characteristics and topographic (elevation, slope and aspect) variables for *T. aestivum* (cv. Sarı Serez) was given in the Table 4.10. Two positive and three negative correlations were found statistically significant at 0.05 level. The highest and most significant positive correlation was found between TKW and elevation (0.956) variables at the 0.05 level. This one was followed by the positive correlation between PH and aspect classified (0.915). On

the other hand, three negative relationships were found between FLL and slope degree (-0.931), between FLL and slope % (-0.931), and between KPS and aspect degree (-0.879) at the 5% level. All these positive or negative correlations were accepted as strong. Apart from these relationships, no statistically significant relationship was found at the 0.01 or 0.05 level. This may be due to the few numbers of samples (N=4) (There are only four populations in the study area).



Table 4.8. Correlation matrix of agro-morphological characteristics and topographic (elevation, slope and aspect) variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	TOPOGRAPHIC VARIABLES				
	Elevation	Slope Degree	Slope %	Aspect Degree	Aspect Classified
TKW	0.793**	0.389**	0.391**	0.017	0.133
FLA	0.684**	0.257*	0.257*	-0.011	0.119
FLL	0.773**	0.327**	0.328**	0.015	0.034
FLW	-0.178	-0.136	-0.136	0.097	0.057
SL	0.702**	0.283*	0.286*	-0.055	0.114
PH	0.074	0.057	0.057	-0.009	-0.159
UNL	0.330**	0.070	0.071	-0.001	-0.126
KPS	0.283*	0.157	0.160	-0.163	0.106
SFPS	0.452**	0.195	0.197	-0.191	0.037
YLD	0.501**	0.259*	0.259*	0.116	-0.015

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.9. Correlation matrix of agro-morphological characteristics and topographic (elevation, slope and aspect) variables for *T. aestivum* (cv. Çalibasan) (N=4).

	TOPOGRAPHIC VARIABLES				
	Elevation	Slope Degree	Slope %	Aspect Degree	Aspect Classified
TKW	0.773	0.114	0.116	0.040	-0.537
FLA	0.477	0.285	0.282	-0.183	-0.987*
FLL	0.954*	0.711	0.714	0.768	-0.315
FLW	0.158	0.045	0.041	-0.445	-0.887
SL	0.367	-0.001	-0.004	-0.419	-0.894
PH	0.787	0.852	0.855	0.967*	-0.101
UNL	0.555	0.034	0.033	-0.290	-0.838
KPS	-0.561	0.174	0.171	0.079	0.191
SFPS	-0.988*	-0.808	-0.809	-0.688	0.608
YLD	0.689	0.979*	0.980*	0.952*	-0.256

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.10. Correlation matrix of agro-morphological characteristics and topographic (elevation, slope and aspect) variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	TOPOGRAPHIC VARIABLES				
	Elevation	Slope Degree	Slope %	Aspect Degree	Aspect Classified
TKW	0.956*	0.200	0.206	-0.394	0.652
FLA	-0.088	0.514	0.507	0.162	-0.290
FLL	-0.239	-0.931*	-0.930*	-0.226	0.253
FLW	0.004	0.655	0.650	0.172	-0.280
SL	0.671	-0.025	-0.013	0.030	0.295
PH	0.511	-0.475	-0.474	-0.810	0.915*
UNL	-0.006	-0.836	-0.836	-0.514	0.548
KPS	-0.074	-0.305	-0.313	-0.879*	0.680
SFPS	0.712	-0.136	-0.124	-0.056	0.392
YLD	0.219	0.214	0.222	0.172	-0.031

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

4.2.4.3 Relationships between Agro-morphological and Climatic Variables

Correlation matrix of agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and precipitation variables was shown in Table 4.11. According to this table, a total 29 positive correlations between agro-morphological characteristics of IZA and precipitation variables were detected as significant (strong or moderately strong) at the 0.01 level, while no negative correlation were found. TKW, FLA, FLL, and SL agro-morphological variables showed strong positive relationships with monthly precipitation amounts of April (4th Month), May (5th Month), and November (11th Month) which correlation coefficients changing between 0.711 and 0.633. It is important for wheat to receive rainfall during the beginning of heading and milk development. These phases occur in April and May and require rainfall. Therefore, we believe that this correlation analysis gives accurate values. Moreover, correlations that can be considered as strong (correlation coefficients between 0.600 and 0.533) between PH and all precipitation variables except April (4th Month), May (5th Month), and November (11th Month) were also determined. SFPS and YLD agro-morphological variables exposed moderately strong positive relationships with monthly precipitation amounts of April (4th Month), May (5th Month), and November (11th Month) that correlation coefficients changing between 0.554 and 0.444. On the contrary to all these relationships, it was observed that UNL and KPS agro-morphological variables did not show statistically significant relationships with any rainfall variable.

Correlation matrix of agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and mean temperature variables was shown in Table 4.12. According to this table; a total 58 negative correlations between agro-morphological characteristics of IZA and mean temperature variables were detected as significant (strong or moderately strong) at the 0.01 level, while no significant positive correlation were found. TKW, FLL, and SL agro-morphological variables showed strong negative relationships with mean temperature of November (11th Month) and December (12th Month) which correlation coefficients changing between -0.759 and -0.652. Moreover, TKW, FLL, and SL agro-morphological variables showed moderately strong negative relationships with annual monthly mean temperature, annual total mean temperature, mean temperatures of April (4th

Month), May (5th Month), and October (10th Month). In these moderately strong negative relationships, the correlation coefficient varied between -0.569 and -0.474. Among the agro-morphological variables, YLD showed a moderately strong negative relationship with the average temperatures of the November (11th month) and December (12th month). The correlation coefficients in these relationships varied between -0.461 and -0.447. Finally, FLW and KPS agro-morphological variables showed no significant correlations with any mean temperature variables.

Correlation matrix of agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and maximum temperature variables was shown in Table 4.13. According to this table; a total 42 negative correlations between agro-morphological characteristics of IZA and maximum temperature variables were detected as significant (strong or moderately strong) at the 0.01 level, while no significant positive correlation were found. TKW, FLL, and SL agro-morphological variables showed strong negative relationships with maximum temperatures of January (1st Month), February (2nd Month), November (11th Month) and December (12th Month) which correlation coefficients changing between -0.771 and -0.641. Moreover, TKW, FLL, and SL agro-morphological variables showed moderately strong negative relationships with maximum temperatures of March (3rd Month) and April (4th Month) which correlation coefficients changing between -0.553 and -0.451. FLA showed strong negative relationships with maximum temperatures of January, February, November, and December which correlation coefficients changing between -0.662 and -0.557. PH strongly correlated with annual monthly mean maximum temperature, annual total maximum temperature, and maximum temperatures of April, May (5th Month), June (6th Month), July (7th Month), August (8th Month), September (9th Month), October (10th Month) which correlation coefficients changing between -0.692 and -0.560. However, PH showed moderately strong relationship (-0.513) with maximum temperature of March. UNL showed moderately correlations changing between -0.516 and -0.460 with all maximum temperature variables except maximum temperatures of January, July, August, September, November, and December. YLD also displayed moderately strong negative relationships (-0.463 and -0.462) with the maximum temperatures of November and December. FLW, KPS, and SFPS agro-morphological variables showed neither strong nor

moderately strong significant correlations with any maximum temperature variables.

Correlation matrix of agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and minimum temperature variables was shown in Table 4.14. According to this table; a total 75 negative correlations between agro-morphological characteristics of IZA and minimum temperature variables were detected as significant (strong or moderately strong) at the 0.01 level, while no significant positive correlation were found. TKW, FLL, and SL correlated with all minimum temperature variables. TKW showed moderately strong relationships with minimum temperatures of February (2nd Month), July (7th Month), and August (8th Month) which correlation coefficients changing between -0.528 and -0.500. On the other hand, TKW displayed strong relationships with all remaining minimum temperature variables which correlation coefficients changing between -0.736 and -0.549. Similarly, FLL showed moderately strong relationships with minimum temperatures of February, July, and August which correlation coefficients changing between -0.514 and -0.509. However, FLL displayed strong relationships with all remaining minimum temperature variables which correlation coefficients changing between -0.715 and -0.550. Correspondingly SL showed moderately strong relationships with minimum temperatures of January, February, March, June, July, August, and September which correlation coefficients changing between -0.539 and -0.499. On the other hand, SL displayed strong relationships with all remaining minimum temperature variables which correlation coefficients changing between -0.662 and -0.569. UNL showed moderately strong relationships which correlation coefficients changing between -0.542 and -0.462 with all minimum temperature variables except November. PH showed neither strong nor moderately strong relationships with minimum temperatures of April, October, November and December. However, PH showed strong relationship with minimum temperatures of February, July, and August which correlation coefficients changing between -0.561 and -0.547. PH showed moderately strong relationships with the remaining months which correlation coefficients between -0.522 and -0.449. YLD displayed moderately strong relationships with minimum temperatures of November and December which correlation coefficients changing between -0.479 and -0.451.

Finally, FLW, KPS, and SFPS showed no significant relationships with any minimum temperature variables.

Correlation matrix of agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and bioclimatic variables was shown in

Table 4.15. According to this table; a total 21 negative correlations between agro-morphological characteristics of IZA and bioclimatic variables were detected as significant (strong or moderately strong) at the 0.01 level. TKW showed strong negative correlation (-0.707) with BIO-11, and moderately strong negative correlation (-0.492) with BIO-1. PH showed three strong negative correlations with BIO-1 (-0.572), BIO-9 (-0.686), and BIO-10 (-0.684) at 0.01 level. However, PH displayed strong positive correlations with BIO-12 (0.574), BIO-13 (0.600), BIO-14 (0.565), BIO-16 (0.599), BIO-17 (0.549), BIO-18 (0.550) and BIO-19 (0.590) at 0.01 level. UNL displayed moderately strong negative relationships with mean annual air temperature (BIO-1), mean daily mean air temperatures of the driest quarter (BIO-9), mean daily mean air temperatures of the warmest quarter (BIO-10), and BIO-11 which correlation coefficients changing between -0.523 and -0.456. However, FLA showed a strong negative relationship (-0.558) with only BIO-11. FLL showed a strong negative correlation (-0.677) with BIO-11, and a moderately strong negative correlation (-0.494) with BIO-1. FLW, KPS, SFPS and YLD showed neither strong nor moderately strong correlations with any bioclimatic variables.

Table 4.11. Correlation matrix of agro-morphological characteristics and precipitation variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	PRECIPITATION													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.016	-0.016	-0.204	-0.183	-0.158	0.702**	0.695**	-0.119	-0.197	-0.140	-0.304*	-0.269*	0.680**	-0.176
FLA	0.010	0.010	-0.178	-0.145	-0.123	0.693**	0.680**	-0.102	-0.187	-0.134	-0.252*	-0.244*	0.686**	-0.153
FLL	0.010	0.010	-0.179	-0.156	-0.128	0.711**	0.689**	-0.097	-0.175	-0.132	-0.269*	-0.240*	0.678**	-0.153
FLW	0.086	0.086	0.099	0.118	0.103	-0.054	-0.040	0.084	0.068	0.078	0.116	0.081	-0.020	0.104
SL	0.071	0.071	-0.107	-0.089	-0.058	0.670**	0.649**	-0.014	-0.093	-0.056	-0.195	-0.175	0.633**	-0.089
PH	0.583**	0.583**	0.589**	0.562**	0.554**	0.067	0.072	0.534**	0.554**	0.565**	0.533**	0.591**	0.048	0.600**
UNL	0.384**	0.384**	0.304*	0.303*	0.322**	0.318**	0.321**	0.343**	0.327**	0.344**	0.242*	0.283*	0.217	0.317**
KPS	0.116	0.116	0.024	0.047	0.061	0.282*	0.301*	0.094	0.045	0.079	0.006	-0.001	0.261*	0.031
SFPS	0.086	0.086	-0.064	-0.018	-0.001	0.514**	0.511**	0.042	-0.053	-0.013	-0.116	-0.127	0.444**	-0.031
YLD	0.076	0.076	-0.069	-0.039	-0.020	0.554**	0.545**	-0.003	-0.084	-0.057	-0.139	-0.143	0.524**	-0.045

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.12. Correlation matrix of agro-morphological characteristics and mean temperature variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	MEAN TEMPERATURE													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.489**	-0.489**	-0.696**	-0.640**	-0.569**	-0.522**	-0.443**	-0.361**	-0.182	-0.168	-0.282*	-0.520**	-0.731**	-0.759**
FLA	-0.354**	-0.354**	-0.545**	-0.474**	-0.424**	-0.393**	-0.319**	-0.245*	-0.075	-0.064	-0.177	-0.388**	-0.601**	-0.629**
FLL	-0.492**	-0.492**	-0.663**	-0.615**	-0.561**	-0.531**	-0.464**	-0.381**	-0.202	-0.196	-0.302*	-0.527**	-0.709**	-0.721**
FLW	0.174	0.174	0.180	0.199	0.186	0.182	0.182	0.160	0.126	0.129	0.133	0.179	0.177	0.161
SL	-0.474**	-0.474**	-0.620**	-0.587**	-0.539**	-0.510**	-0.447**	-0.374**	-0.221	-0.212	-0.304*	-0.503**	-0.652**	-0.653**
PH	-0.575**	-0.575**	-0.382**	-0.451**	-0.519**	-0.545**	-0.593**	-0.637**	-0.692**	-0.694**	-0.663**	-0.539**	-0.286*	-0.208
UNL	-0.518**	-0.518**	-0.471**	-0.499**	-0.519**	-0.521**	-0.503**	-0.511**	-0.481**	-0.477**	-0.506**	-0.515**	-0.429**	-0.376**
KPS	-0.219	-0.219	-0.264*	-0.248*	-0.220	-0.230	-0.216	-0.191	-0.142	-0.133	-0.163	-0.224	-0.254*	-0.259*
SFPS	-0.271*	-0.271*	-0.385**	-0.347**	-0.315**	-0.290*	-0.248*	-0.214	-0.103	-0.094	-0.157	-0.283*	-0.398**	-0.410**
YLD	-0.289*	-0.289*	-0.415**	-0.368**	-0.359**	-0.315**	-0.261*	-0.209	-0.089	-0.085	-0.165	-0.314**	-0.447**	-0.461**

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.13. Correlation matrix of agro-morphological characteristics and maximum temperature variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	MAXIMUM TEMPERATURE													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.385**	-0.385**	-0.759**	-0.712**	-0.548**	-0.451**	-0.287*	-0.141	0.020	0.034	-0.075	-0.392**	-0.771**	-0.768**
FLA	-0.256*	-0.256*	-0.625**	-0.557**	-0.394**	-0.317**	-0.164	-0.036	0.103	0.112	0.005	-0.275*	-0.655**	-0.662**
FLL	-0.401**	-0.401**	-0.726**	-0.690**	-0.553**	-0.467**	-0.307*	-0.168	-0.010	-0.004	-0.122	-0.417**	-0.748**	-0.728**
FLW	0.181	0.181	0.195	0.211	0.215	0.200	0.163	0.136	0.091	0.098	0.124	0.185	0.190	0.159
SL	-0.393**	-0.393**	-0.654**	-0.645**	-0.532**	-0.458**	-0.317**	-0.195	-0.051	-0.041	-0.139	-0.397**	-0.665**	-0.641**
PH	-0.614**	-0.614**	-0.178	-0.336**	-0.513**	-0.560**	-0.645**	-0.682**	-0.692**	-0.682**	-0.672**	-0.593**	-0.103	-0.001
UNL	-0.511**	-0.511**	-0.359**	-0.460**	-0.510**	-0.516**	-0.500**	-0.476**	-0.416**	-0.404**	-0.436**	-0.500**	-0.326**	-0.250*
KPS	-0.191	-0.191	-0.253*	-0.262*	-0.231	-0.212	-0.174	-0.129	-0.075	-0.063	-0.098	-0.191	-0.242*	-0.233
SFPS	-0.194	-0.194	-0.387**	-0.378**	-0.288*	-0.230	-0.159	-0.074	0.014	0.034	-0.025	-0.188	-0.393**	-0.388**
YLD	-0.208	-0.208	-0.439**	-0.418**	-0.307*	-0.257*	-0.151	-0.064	0.041	0.051	-0.019	-0.217	-0.462**	-0.463**

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.14. Correlation matrix of agro-morphological characteristics and minimum temperature variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	MINIMUM TEMPERATURE													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.608**	-0.608**	-0.562**	-0.528**	-0.573**	-0.663**	-0.623**	-0.568**	-0.521**	-0.500**	-0.549**	-0.699**	-0.736**	-0.709**
FLA	-0.478**	-0.478**	-0.418**	-0.367**	-0.426**	-0.537**	-0.499**	-0.453**	-0.391**	-0.390**	-0.436**	-0.578**	-0.619**	-0.584**
FLL	-0.599**	-0.599**	-0.550**	-0.509**	-0.560**	-0.653**	-0.620**	-0.564**	-0.514**	-0.514**	-0.552**	-0.682**	-0.715**	-0.682**
FLW	0.165	0.165	0.163	0.183	0.184	0.177	0.176	0.146	0.152	0.153	0.147	0.159	0.152	0.150
SL	-0.569**	-0.569**	-0.536**	-0.508**	-0.539**	-0.604**	-0.574**	-0.535**	-0.504**	-0.499**	-0.529**	-0.634**	-0.662**	-0.633**
PH	-0.473**	-0.473**	-0.522**	-0.561**	-0.507**	-0.400**	-0.449**	-0.506**	-0.552**	-0.547**	-0.514**	-0.344**	-0.278*	-0.336**
UNL	-0.511**	-0.511**	-0.522**	-0.542**	-0.514**	-0.490**	-0.496**	-0.497**	-0.528**	-0.522**	-0.519**	-0.469**	-0.440**	-0.462**
KPS	-0.252*	-0.252*	-0.249*	-0.232	-0.245*	-0.251*	-0.245*	-0.249*	-0.240*	-0.231	-0.237*	-0.260*	-0.272*	-0.264*
SFPS	-0.352**	-0.352**	-0.336**	-0.293*	-0.320**	-0.375**	-0.349**	-0.344**	-0.315**	-0.302*	-0.318**	-0.396**	-0.429**	-0.407**
YLD	-0.379**	-0.379**	-0.345**	-0.300*	-0.331**	-0.408**	-0.385**	-0.357**	-0.330**	-0.327**	-0.358**	-0.444**	-0.479**	-0.451**

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.15. Correlation matrix of agro-morphological characteristics and bioclimatic variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	BIOCLIMATIC VARIABLES											
	BIO-1	BIO-8	BIO-9	BIO-10	BIO-11	BIO-12	BIO-13	BIO-14	BIO-16	BIO-17	BIO-18	BIO-19
TKW	-0.492**	0.271*	-0.202	-0.239*	-0.707**	-0.169	-0.150	-0.140	-0.174	-0.236	-0.151	-0.189
FLA	-0.354**	0.041	-0.101	-0.126	-0.558**	-0.144	-0.137	-0.134	-0.159	-0.208	-0.139	-0.164
FLL	-0.494**	0.175	-0.230	-0.258*	-0.677**	-0.145	-0.133	-0.132	-0.154	-0.211	-0.132	-0.164
FLW	0.177	-0.128	0.131	0.137	0.183	0.099	0.098	0.078	0.093	0.092	0.078	0.102
SL	-0.473**	0.291*	-0.241*	-0.271*	-0.629**	-0.073	-0.066	-0.056	-0.086	-0.133	-0.050	-0.098
PH	-0.572**	0.084	-0.686**	-0.684**	-0.356**	0.574**	0.600**	0.565**	0.599**	0.549**	0.550**	0.590**
UNL	-0.523**	0.173	-0.486**	-0.495**	-0.456**	0.326**	0.327**	0.344**	0.321**	0.293*	0.340**	0.314**
KPS	-0.215	0.325**	-0.143	-0.159	-0.259*	0.054	0.049	0.079	0.040	0.034	0.075	0.031
SFPS	-0.267*	0.356**	-0.112	-0.134	-0.382**	-0.017	-0.005	-0.013	-0.027	-0.075	-0.001	-0.039
YLD	-0.285*	0.024	-0.108	-0.128	-0.422**	-0.041	-0.034	-0.057	-0.056	-0.104	-0.041	-0.054

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Note: For explanation about the abbreviations of bioclimatic variables please see Table 3.9.

Correlation matrix of agro-morphological characteristics of *T. aestivum* (cv. Çalibasan) and precipitation variables was shown in Table 4.16. According to this table, a total of 9 strong correlations were found to be statistically significant. Five of these were found to be positive at the 0.05 level, three were positive at the 0.01 level, and one was negative at the 0.05 level. Other correlations with high values in the table were found to be significant at neither the 0.01 nor 0.05 levels. The reason for this is that the number of samples, in other words the number of populations, is low ($N = 4$). UNL showed strong positive correlations (0.966 and 0.965) with precipitation amounts of January and October at the 0.05 level. UNL also displayed strong positive correlations (0.992, 0.995, and 0.996) with precipitation amounts of February, March and December at the 0.01 level. SL revealed strong positive correlations (0.966 and 0.967) with precipitation amounts of January and December at the 0.05 level. However, FLA showed strong positive correlation (0.966) with precipitation amounts of January, while it showed strong negative correlation (-0.972) with precipitation amounts of April at the 0.05 level.

Correlation matrix of agro-morphological characteristics of *T. aestivum* (cv. Çalibasan) and mean temperature variables was shown in Table 4.17. According to this table; a total of 25 strong negative correlations were detected as significant, while no significant positive correlation was found. Eighteen of these correlations were found significant at the 0.05 level, and seven of them were found significant at the 0.01 level. When these relationships are examined carefully, it was seen that SL agro-morphological variable correlated with all mean temperature variables except the monthly mean temperatures of July and August. More clearly, SL showed strong negative correlations between 1.00 and 0.997 with annual monthly mean temperature, annual total mean temperature, and mean temperatures of February, April, June, November, and December at the 0.01 level. On the other hand, SL showed strong negative correlations between -0.976 and -0.967 with the average temperature variables of the January, March, May, September and October at the 0.05 level. FLA exposed strong negative correlations between -0.985 and -0.955 with mean temperatures of January, February, April, May, June, November, December at 0.05 level. UNL showed strong negative correlations between -0.956 and -0.951 with mean temperatures of February, May, November and December at

0.05 level. FLW strongly correlated between -0.965 and -0.964 with mean temperatures of June and July at 0.05 level. No statistically significant correlations were detected between the remaining agro-morphological variables (TKW, FLL, PH, KPS, SFPS, and YLD) and mean temperature variables.

Correlation matrix of agro-morphological characteristics of *T. aestivum* (cv. Çalibasan) and maximum temperature variables was shown in Table 4.18. According to this table; a total of 25 strong negative correlations were detected as significant, while no significant positive correlation was found. Nineteen of these correlations were found significant at the 0.05 level, and six of them were found significant at the 0.01 level. When examined these relationships, it was seen that SL agro-morphological variable correlated with all maximum temperature variables except the monthly mean temperatures of July, August and September. Basically, SL showed strong negative correlations changing between -1.000 and -0.994 with annual monthly mean maximum temperature, annual total monthly maximum temperature, and maximum temperatures of February, October, November, and December at the 0.01 level. On the other hand, SL showed strong negative correlations between -0.986 and -0.967 with the maximum temperature variables of the January, March, April, May, and June at the 0.05 level. FLA exposed strong negative correlations between -0.971 and -0.951 with maximum temperature variables of the February, March, April, October, November, and December at the 0.05 level. FLW showed strong negative correlations between -0.980 and -0.954 with annual monthly maximum temperature, annual total monthly maximum temperature, and mean temperatures of April and September at the 0.05 level. UNL showed strong negative correlations between -0.972 and -0.951 with maximum temperatures of March, October, November, and December at the 0.05 level.

Correlation matrix of agro-morphological characteristics of *T. aestivum* (cv. Çalibasan) and minimum temperature variables was shown in Table 4.19. According to this table; a total of 28 strong negative correlations were detected as significant, while no significant positive correlation was found. Twenty-three of these correlations were found significant at the 0.05 level, and five of them were found significant at the 0.01 level. When examined these relationships, it was seen that SL agro-morphological variable correlated with all maximum temperature

variables except the monthly minimum temperatures of February and December. Basically, SL showed strong negative correlations between -1.000 and -0.991 with annual monthly mean minimum temperature, annual total monthly minimum temperature, and minimum temperatures of January, April, and May at the level 0.01 level. On the other hand, SL showed strong negative correlations between -0.984 and -0.972 with the maximum temperature variables of the March, June, July, August, September, October, and November at the 0.05 level. FLW showed strong negative correlations between -0.980 and -0.965 with annual monthly mean minimum temperature, annual total monthly minimum temperature, and minimum temperatures of February, March, June, September, November, and December at the 0.05 level. FLA showed strong negative correlations between -0.971 and -0.951 with minimum temperatures of January, March, April, May, June, and November at the 0.05 level. UNL negatively and strongly correlated (-0.956) with only the minimum temperature of January (1st Month).

Correlation matrix of agro-morphological characteristics of *T. aestivum* (cv. Çalibasan) and bioclimatic variables was shown in Table 4.20. According to this table; a total 12 correlations were detected. Seven of these correlations were found statistically significant at the 0.05 level, while five of them were found statistically significant at the 0.01 level. SL showed strong negative correlations between -0.973 and -0.964 with mean annual air temperature (BIO-1), mean daily mean air temperatures of the wettest quarter (BIO-8), mean daily mean air temperatures of the driest quarter (BIO-9), and mean daily mean air temperatures of the coldest quarter (BIO-11) at the 0.05 level. However, SL showed a strong positive correlation (0.964) with mean monthly precipitation amount of the coldest quarter (BIO-19) at the 0.05 level. UNL also showed strong positive correlations between 0.996 and 0.991 with annual precipitation amount (BIO-12), precipitation amount of the wettest month (BIO-13), mean monthly precipitation amount of the wettest quarter (BIO-16), and mean monthly precipitation amount of the coldest quarter (BIO-19) at the 0.01 level. On the other hand, FLA showed strong negative correlations between -0.991 and -0.985 with BIO-1 at the 0.01 level, BIO-8 and BIO-11 at the 0.05 level.

Table 4.16. Correlation matrix of agro-morphological characteristics and precipitation variables for *T. aestivum* (cv. Çalibasan) (N=4).

	PRECIPITATION													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	0.509	0.509	0.728	0.865	0.852	-0.669	-0.741	0.720	0.647	0.718	0.668	0.743	0.806	0.795
FLA	0.402	0.402	0.966*	0.878	0.887	-0.972*	-0.929	0.766	0.678	0.758	0.663	0.811	0.690	0.874
FLL	-0.295	-0.295	0.326	0.420	0.394	-0.415	-0.535	0.017	-0.110	0.011	-0.088	0.077	0.118	0.222
FLW	0.506	0.506	0.864	0.744	0.761	-0.839	-0.756	0.767	0.722	0.761	0.699	0.792	0.657	0.807
SL	0.667	0.667	0.966*	0.926	0.937	-0.907	-0.862	0.927	0.874	0.922	0.864	0.950	0.870	0.967*
PH	-0.672	-0.672	0.006	0.048	0.022	-0.154	-0.267	-0.389	-0.512	-0.396	-0.495	-0.325	-0.308	-0.167
UNL	0.678	0.678	0.966*	0.992**	0.995**	-0.899	-0.895	0.940	0.876	0.937	0.877	0.965*	0.934	0.996**
KPS	-0.589	-0.589	-0.455	-0.653	-0.639	0.348	0.430	-0.621	-0.599	-0.624	-0.627	-0.616	-0.743	-0.616
SFPS	0.241	0.241	-0.570	-0.598	-0.578	0.674	0.761	-0.178	-0.029	-0.169	-0.041	-0.252	-0.229	-0.413
YLD	-0.794	-0.794	0.060	0.009	-0.009	-0.249	-0.322	-0.440	-0.574	-0.450	-0.572	-0.364	-0.422	-0.192

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.17. Correlation matrix of agro-morphological characteristics and mean temperature variables for *T. aestivum* (cv. Çalibasan) (N=4).

	Annual Monthly Mean	Annual Total	MEAN TEMPERATURE											
			MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.591	-0.591	-0.665	-0.623	-0.577	-0.623	-0.681	-0.623	-0.292	-0.290	-0.473	-0.493	-0.633	-0.638
FLA	-0.947	-0.947	-0.985*	-0.957*	-0.854	-0.971*	-0.979*	-0.971*	-0.851	-0.850	-0.876	-0.879	-0.956*	-0.955*
FLL	-0.034	-0.034	-0.272	-0.089	0.096	-0.126	-0.266	-0.126	0.315	0.318	0.172	0.152	-0.100	-0.105
FLW	-0.944	-0.944	-0.901	-0.934	-0.894	-0.936	-0.897	-0.936	-0.965*	-0.964*	-0.942	-0.938	-0.930	-0.928
SL	-0.999**	-0.999**	-0.971*	-1.000**	-0.971*	-0.997**	-0.976*	-0.997**	-0.917	-0.916	-0.967*	-0.971*	-1.000**	-1.000**
PH	0.293	0.293	0.028	0.240	0.453	0.192	0.044	0.192	0.571	0.574	0.490	0.476	0.231	0.228
UNL	-0.938	-0.938	-0.945	-0.951*	-0.915	-0.948	-0.955*	-0.948	-0.765	-0.764	-0.871	-0.882	-0.955*	-0.956*
KPS	0.361	0.361	0.376	0.383	0.421	0.367	0.402	0.367	0.098	0.097	0.290	0.311	0.395	0.400
SFPS	0.297	0.297	0.536	0.349	0.131	0.393	0.525	0.393	-0.029	-0.032	0.087	0.104	0.358	0.362
YLD	0.208	0.208	-0.060	0.161	0.411	0.104	-0.032	0.104	0.411	0.414	0.395	0.388	0.157	0.155

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.18. Correlation matrix of agro-morphological characteristics and maximum temperature variables for *T. aestivum* (cv. Çalibasan) (N=4).

	MAXIMUM TEMPERATURE													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.547	-0.547	-0.499	-0.623	-0.705	-0.475	-0.473	-0.473	-0.013	-0.144	-0.264	-0.623	-0.633	-0.633
FLA	-0.936	-0.936	-0.880	-0.971*	-0.965*	-0.951*	-0.876	-0.876	-0.588	-0.492	-0.840	-0.957*	-0.970*	-0.956*
FLL	0.031	0.031	0.146	-0.126	-0.241	0.063	0.172	0.172	0.646	0.615	0.341	-0.089	-0.136	-0.100
FLW	-0.954*	-0.954*	-0.937	-0.936	-0.891	-0.980*	-0.941	-0.941	-0.812	-0.705	-0.962*	-0.934	-0.932	-0.930
SL	-0.994**	-0.994**	-0.973*	-0.997**	-0.986*	-0.983*	-0.967*	-0.967*	-0.709	-0.686	-0.905	-1.000**	-0.997**	-1.000**
PH	0.351	0.351	0.472	0.192	0.091	0.351	0.491	0.491	0.839	0.874	0.588	0.240	0.185	0.231
UNL	-0.918	-0.918	-0.885	-0.948	-0.972*	-0.882	-0.871	-0.871	-0.512	-0.548	-0.746	-0.951*	-0.952*	-0.955*
KPS	0.324	0.324	0.317	0.367	0.448	0.229	0.292	0.292	-0.067	0.145	0.072	0.383	0.377	0.395
SFPS	0.237	0.237	0.109	0.393	0.488	0.226	0.086	0.086	-0.410	-0.446	-0.053	0.349	0.401	0.358
YLD	0.255	0.255	0.386	0.104	0.034	0.217	0.397	0.397	0.678	0.812	0.421	0.161	0.100	0.157

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFP	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.19. Correlation matrix of agro-morphological characteristics and minimum temperature variables for *T. aestivum* (cv. Çalibasan) (N=4).

	MINIMUM TEMPERATURE													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.517	-0.517	-0.635	-0.292	-0.475	-0.623	-0.623	-0.475	-0.493	-0.493	-0.475	-0.493	-0.480	-0.303
FLA	-0.942	-0.942	-0.956*	-0.851	-0.951*	-0.971*	-0.971*	-0.951*	-0.880	-0.880	-0.951*	-0.880	-0.951*	-0.855
FLL	0.048	0.048	-0.103	0.315	0.063	-0.126	-0.126	0.063	0.152	0.152	0.063	0.152	0.058	0.305
FLW	-0.965*	-0.965*	-0.929	-0.965*	-0.980*	-0.936	-0.936	-0.980*	-0.939	-0.939	-0.980*	-0.939	-0.979*	-0.965*
SL	-0.991**	-0.991**	-1.000**	-0.917	-0.984*	-0.997**	-0.997**	-0.983*	-0.972*	-0.972*	-0.984*	-0.972*	-0.985*	-0.922
PH	0.355	0.355	0.230	0.571	0.351	0.192	0.192	0.351	0.476	0.476	0.351	0.476	0.347	0.565
UNL	-0.903	-0.903	-0.956*	-0.765	-0.882	-0.948	-0.948	-0.882	-0.882	-0.882	-0.882	-0.882	-0.884	-0.773
KPS	0.286	0.286	0.397	0.098	0.230	0.367	0.367	0.229	0.310	0.310	0.230	0.310	0.235	0.109
SFPS	0.229	0.229	0.360	-0.029	0.227	0.393	0.393	0.226	0.104	0.104	0.227	0.104	0.231	-0.020
YLD	0.244	0.244	0.156	0.411	0.217	0.104	0.104	0.217	0.387	0.387	0.217	0.387	0.215	0.408

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.20. Correlation matrix of agro-morphological characteristics and bioclimatic variables for *T. aestivum* (cv. Çalibasan) (N=4).

	BIOCLIMATIC VARIABLES											
	BIO-1	BIO-8	BIO-9	BIO-10	BIO-11	BIO-12	BIO-13	BIO-14	BIO-16	BIO-17	BIO-18	BIO-19
TKW	-0.628	-0.663	-0.473	-0.061	-0.663	0.863	0.795	0.718	0.788	0.675	0.699	0.788
FLA	-0.991**	-0.985*	-0.876	-0.780	-0.985*	0.873	0.874	0.758	0.863	0.696	0.740	0.859
FLL	-0.234	-0.269	0.172	0.466	-0.269	0.394	0.222	0.011	0.196	-0.069	-0.022	0.190
FLW	-0.920	-0.902	-0.941	-0.943	-0.902	0.748	0.807	0.761	0.804	0.726	0.754	0.802
SL	-0.973*	-0.971*	-0.967*	-0.810	-0.971*	0.932	0.967*	0.922	0.965*	0.885	0.912	0.964*
PH	0.055	0.031	0.491	0.634	0.031	0.016	-0.167	-0.396	-0.198	-0.475	-0.428	-0.205
UNL	-0.932	-0.944	-0.871	-0.598	-0.944	0.996**	0.996**	0.937	0.992**	0.895	0.923	0.991**
KPS	0.334	0.375	0.292	-0.140	0.375	-0.660	-0.616	-0.624	-0.620	-0.617	-0.617	-0.622
SFPS	0.509	0.534	0.086	-0.160	0.534	-0.570	-0.413	-0.169	-0.382	-0.071	-0.132	-0.375
YLD	-0.049	-0.057	0.397	0.403	-0.057	-0.026	-0.192	-0.450	-0.227	-0.541	-0.484	-0.235

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Note: For explanation about the abbreviations of bioclimatic variables please see Table 3.9.

Correlation matrix of agro-morphological characteristics of *T. aestivum* (cv. Sarı Serez) and precipitation variables was shown in Table 4.21. According to this table, a total 10 negative strong correlations between Agro-morphological characteristics of *T. aestivum* (cv. Sarı Serez) and precipitation variables were detected. Eight of them were significant at the 0.01 level, two of them however was significant at the 0.05 level. On the other hand, there is only one positive strong correlation at 0.05 level. TKW highly and positively correlated with all monthly precipitation amounts except the months of April, May, and November. Except monthly precipitation amount of July, all relationships between TKW and monthly precipitation were found statistically significant at 0.01 level. FLW showed a strong negative correlation (-0.881) with precipitation amount of November at the 0.05 level. On the other hand, only one positive correlation (0.919) was found between UNL and precipitation of November at 0.05 level.

Correlation matrix of agro-morphological characteristics of *T. aestivum* (cv. Sarı Serez) and mean temperature variables was shown in Table 4.22. According to this table; a total 14 negative correlations between TKW and monthly mean temperature variables were detected. Twelve of them were found significant at the 0.01 level, and remaining two (months of March and December) were found significant at the 0.05 level. TKW showed high correlations with not only monthly mean temperatures but also annual total mean temperature and annual monthly mean temperature. All these statistically significant relationships have correlation coefficients ranging between -0.990 and -0.883. As a result, they were evaluated as strong negative relationships.

Correlation matrix of agro-morphological characteristics of *T. aestivum* (cv. Sarı Serez) and maximum temperature variables was shown in Table 4.23. According to this table; a total 14 negative correlations between TKW and monthly maximum temperature variables were detected. Ten of them were found significant at the 0.01 level, and remaining four (months of January, June, September and November) were found significant at the 0.05 level. TKW showed high correlations with not only monthly maximum temperatures but also annual total maximum temperature and annual monthly mean maximum temperature. All these statistically

significant relationships have correlation coefficients ranging between -0.980 and -0.933. Consequently, they were evaluated as strong negative relationships.

Correlation matrix of agro-morphological characteristics of *T. aestivum* (cv. Sarı Serez) and minimum temperature variables was shown in Table 4.24. According to this table; a total 14 negative correlations between TKW and monthly maximum temperature variables were detected. Eleven of them were found significant at the 0.01 level, and remaining three (months of July, August, and December) were found significant at the 0.05 level. TKW showed high correlations with not only monthly minimum temperatures but also annual total minimum temperature and annual monthly mean minimum temperature. All these statistically significant relationships have correlation coefficients ranging between -0.974 and -0.937. Herewith, they were evaluated as strong negative relationships.

Correlation matrix of agro-morphological characteristics of *T. aestivum* (cv. Sarı Serez) and bioclimatic variables was shown in Table 4.25. According to this table; a total 12 negative correlations between TKW and bioclimatic variables were detected at the 0.01 level. TKW showed strong correlations with all bioclimatic variables which correlation coefficients changing between -0.994 and -0.961. On the contrary, no statistically significant correlations was detected between the other agro-morphological variables and bioclimatic variables.

Table 4.21. Correlation matrix of agro-morphological characteristics and precipitation variables for *T. aestivum* (cv. Sari Serez) (N=5).

	PRECIPITATION													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.598	-0.598	-0.986**	-0.967**	-0.980**	-0.690	-0.505	-0.962**	-0.948*	-0.972**	-0.967**	-0.971**	-0.042	-0.980**
FLA	-0.763	-0.763	-0.104	-0.267	-0.192	-0.713	-0.808	-0.233	-0.295	-0.172	-0.224	-0.166	-0.856	-0.144
FLL	0.747	0.747	0.170	0.289	0.218	0.711	0.795	0.206	0.253	0.163	0.210	0.155	0.822	0.164
FLW	-0.793	-0.793	-0.132	-0.290	-0.213	-0.746	-0.840	-0.242	-0.302	-0.183	-0.236	-0.176	-0.881*	-0.162
SL	0.053	0.053	-0.488	-0.359	-0.395	-0.010	0.115	-0.328	-0.289	-0.373	-0.344	-0.371	0.349	-0.417
PH	0.327	0.327	-0.484	-0.376	-0.463	0.211	0.434	-0.464	-0.400	-0.512	-0.464	-0.523	0.806	-0.508
UNL	0.696	0.696	-0.021	0.102	0.016	0.626	0.768	0.005	0.064	-0.044	0.008	-0.055	0.919*	-0.039
KPS	0.530	0.530	0.127	0.155	0.084	0.465	0.570	0.050	0.096	0.025	0.057	0.011	0.679	0.056
SFPS	0.026	0.026	-0.585	-0.455	-0.497	-0.048	0.104	-0.439	-0.398	-0.484	-0.453	-0.484	0.393	-0.524
YLD	0.418	0.418	0.150	0.265	0.236	0.404	0.412	0.314	0.349	0.271	0.295	0.271	0.356	0.225

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.22. Correlation matrix of agro-morphological characteristics and mean temperature variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	MEAN TEMPERATURE													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.982**	-0.982**	-0.990**	-0.972**	-0.883*	-0.974**	-0.965**	-0.974**	-0.980**	-0.974**	-0.980**	-0.974**	-0.973**	-0.955*
FLA	-0.172	-0.172	-0.174	-0.266	-0.256	-0.245	-0.013	-0.245	-0.193	-0.245	-0.193	-0.049	-0.251	0.027
FLL	0.203	0.203	0.257	0.285	0.187	0.269	0.063	0.269	0.247	0.269	0.247	0.093	0.272	0.003
FLW	-0.195	-0.195	-0.210	-0.290	-0.249	-0.270	-0.036	-0.270	-0.225	-0.270	-0.225	-0.071	-0.275	0.011
SL	-0.375	-0.375	-0.446	-0.320	-0.354	-0.323	-0.426	-0.323	-0.355	-0.323	-0.355	-0.421	-0.318	-0.437
PH	-0.524	-0.524	-0.438	-0.438	-0.286	-0.471	-0.681	-0.471	-0.517	-0.471	-0.517	-0.644	-0.466	-0.713
UNL	-0.025	-0.025	0.055	0.068	0.078	0.041	-0.193	0.041	0.005	0.041	0.005	-0.155	0.045	-0.247
KPS	-0.015	-0.015	0.128	0.042	0.308	0.000	-0.175	-0.001	-0.044	-0.001	-0.044	-0.128	0.002	-0.192
SFPS	-0.479	-0.479	-0.536	-0.419	-0.460	-0.423	-0.535	-0.423	-0.452	-0.423	-0.452	-0.529	-0.418	-0.552
YLD	0.234	0.234	0.164	0.281	0.324	0.271	0.157	0.271	0.222	0.271	0.222	0.176	0.276	0.161

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.23. Correlation matrix of agro-morphological characteristics and maximum temperature variables for *T. aestivum* (cv. Sari Serez) (N=5).

	MAXIMUM TEMPERATURE													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.973**	-0.973**	-0.937*	-0.964**	-0.964**	-0.964**	-0.980**	-0.933*	-0.980**	-0.980**	-0.955*	-0.980**	-0.937*	-0.974**
FLA	-0.068	-0.068	0.074	-0.026	-0.026	-0.026	-0.224	0.131	-0.193	-0.193	0.006	-0.224	0.074	-0.245
FLL	0.110	0.110	-0.039	0.067	0.067	0.067	0.269	-0.062	0.248	0.247	0.012	0.269	-0.039	0.269
FLW	-0.091	-0.091	0.058	-0.047	-0.047	-0.047	-0.254	0.109	-0.225	-0.225	-0.007	-0.253	0.058	-0.270
SL	-0.404	-0.404	-0.442	-0.413	-0.413	-0.413	-0.350	-0.491	-0.355	-0.355	-0.421	-0.350	-0.442	-0.323
PH	-0.636	-0.636	-0.757	-0.677	-0.677	-0.677	-0.477	-0.777	-0.517	-0.517	-0.703	-0.476	-0.757	-0.471
UNL	-0.141	-0.141	-0.298	-0.189	-0.189	-0.189	0.039	-0.322	0.005	0.005	-0.237	0.039	-0.298	0.041
KPS	-0.136	-0.136	-0.251	-0.179	-0.179	-0.179	0.007	-0.252	-0.045	-0.044	-0.187	0.008	-0.251	0.000
SFPS	-0.511	-0.511	-0.556	-0.522	-0.522	-0.522	-0.447	-0.600	-0.452	-0.452	-0.537	-0.447	-0.556	-0.423
YLD	0.187	0.187	0.137	0.172	0.172	0.172	0.239	0.073	0.222	0.222	0.182	0.239	0.137	0.271

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.24. Correlation matrix of agro-morphological characteristics and minimum temperature variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	MINIMUM TEMPERATURE													
	Annual Monthly Mean	Annual Total	MONTHS											
			1	2	3	4	5	6	7	8	9	10	11	12
TKW	-0.971**	-0.971**	-0.973**	-0.964**	-0.974**	-0.970**	-0.973**	-0.974**	-0.937*	-0.937*	-0.970**	-0.973**	-0.970**	-0.937*
FLA	-0.076	-0.076	-0.250	-0.026	-0.245	-0.084	-0.061	-0.245	0.074	0.074	-0.084	-0.061	-0.084	0.074
FLL	0.105	0.105	0.272	0.067	0.269	0.104	0.097	0.269	-0.039	-0.039	0.104	0.096	0.104	-0.039
FLW	-0.096	-0.096	-0.275	-0.047	-0.270	-0.101	-0.081	-0.270	0.058	0.058	-0.101	-0.081	-0.101	0.058
SL	-0.393	-0.393	-0.318	-0.413	-0.323	-0.386	-0.408	-0.323	-0.442	-0.442	-0.386	-0.409	-0.386	-0.442
PH	-0.634	-0.634	-0.466	-0.677	-0.471	-0.631	-0.640	-0.471	-0.757	-0.757	-0.631	-0.640	-0.631	-0.757
UNL	-0.143	-0.143	0.045	-0.189	0.041	-0.142	-0.151	0.041	-0.298	-0.298	-0.142	-0.151	-0.142	-0.298
KPS	-0.134	-0.134	0.002	-0.179	0.000	-0.132	-0.131	0.000	-0.251	-0.251	-0.132	-0.131	-0.132	-0.251
SFPS	-0.503	-0.503	-0.418	-0.522	-0.423	-0.497	-0.518	-0.423	-0.556	-0.556	-0.497	-0.518	-0.497	-0.556
YLD	0.204	0.204	0.276	0.172	0.271	0.217	0.190	0.271	0.137	0.137	0.217	0.190	0.217	0.137

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.25. Correlation matrix of agro-morphological characteristics and bioclimatic variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	BIOCLIMATIC VARIABLES											
	BIO-1	BIO-8	BIO-9	BIO-10	BIO-11	BIO-12	BIO-13	BIO-14	BIO-16	BIO-17	BIO-18	BIO-19
TKW	-0.989**	-0.981**	-0.980**	-0.994**	-0.981**	-0.977**	-0.980**	-0.972**	-0.978**	-0.963**	-0.961**	-0.974**
FLA	-0.154	0.026	-0.193	-0.119	0.026	-0.220	-0.144	-0.172	-0.162	-0.236	-0.239	-0.198
FLL	0.242	0.047	0.247	0.218	0.047	0.246	0.164	0.163	0.175	0.214	0.211	0.204
FLW	-0.189	0.000	-0.225	-0.157	0.000	-0.242	-0.162	-0.183	-0.179	-0.247	-0.248	-0.214
SL	-0.473	-0.512	-0.355	-0.493	-0.512	-0.379	-0.417	-0.373	-0.400	-0.332	-0.326	-0.381
PH	-0.432	-0.648	-0.517	-0.466	-0.648	-0.438	-0.508	-0.512	-0.500	-0.454	-0.455	-0.465
UNL	0.050	-0.182	0.005	0.019	-0.182	0.046	-0.039	-0.044	-0.030	0.015	0.013	0.006
KPS	0.160	-0.060	-0.044	0.131	-0.060	0.099	0.056	0.025	0.053	0.063	0.059	0.080
SFPS	-0.562	-0.617	-0.452	-0.582	-0.617	-0.479	-0.524	-0.484	-0.507	-0.442	-0.436	-0.486
YLD	0.145	0.104	0.222	0.122	0.104	0.248	0.225	0.271	0.240	0.309	0.316	0.259

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Note: For explanation about the abbreviations of bioclimatic variables please see Table 3.9.

4.2.4.4 Relationships Between Agro-morphological and Soil Variables

Correlations between agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and physical soil variables known as bulk density, coarse fragments, sand, silt, and clay were shown in Table 4.26, Table 4.27, Table 4.28, Table 4.29 and Table 4.30, respectively.

Correlation matrix of agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and bulk density was shown in Table 4.26. According to this table, two positive correlations between agro-morphological characteristics of IZA and bulk density variables were detected as significant at the 0.01 level. However, one negative and one positive correlation were found significant at the 0.05 level. Among these relationships, only the positive relationship between PH and bulk density at 60-100 cm depth was found to be moderately strong (0.477). Although other relationships were found statistically significant, they were not found to be strong enough.

Correlation matrix of agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and coarse fragments was shown in Table 4.27. According to this table, 10 positive correlations between agro-morphological characteristics of IZA and coarse fragment variables were detected as significant at the 0.05 level. On the other hand, 6 positive correlations were found as significant at the 0.01 level. Although all these relationships were found statistically significant, they were not found to be strong enough.

Correlation matrix of agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and sand was shown in Table 4.28. According to this table, six negative and two positive correlations between agro-morphological characteristics of IZA and sand variables were detected as significant at the 0.01 level. However, seven positive correlations were found significant at the 0.05 level. Among these relationships, only the relationship between PH and sand at 60-100 cm depth was found to be moderately strong, and the others were not found to be strong enough.

Correlation matrix of agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and silt was shown in Table 4.29. According to this table, twelve positive correlations, eight of them at the 0.01 level and four of them at the 0.05 level, were detected as statistically significant. Among these relationships, only the relationship between PH and silt at 0-5 cm depth was found to be moderately strong, and the others were not found to be strong enough.

Correlation matrix of agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and clay was shown in Table 4.30. According to this table, nine negative correlations, between agro-morphological characteristics of IZA and clay variables were detected as significant at the 0.05 level. However, none of these correlations were found strong enough.

Table 4.26. Correlation matrix of agro-morphological characteristics and bulk density variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	BULK DENSITY					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	-0.192	-0.217	-0.145	-0.145	-0.145	-0.093
FLA	-0.189	-0.024	-0.081	-0.081	-0.081	-0.242*
FLL	-0.193	-0.166	-0.045	-0.045	-0.045	-0.174
FLW	0.089	0.236	-0.042	-0.042	-0.042	0.018
SL	-0.076	-0.143	-0.074	-0.074	-0.074	-0.013
PH	0.360**	-0.102	0.092	0.092	0.092	0.477**
UNL	0.058	-0.246*	-0.104	-0.104	-0.104	0.267*
KPS	0.187	0.049	0.128	0.128	0.128	0.039
SFPS	0.088	0.080	0.157	0.157	0.157	-0.074
YLD	-0.227	-0.169	-0.212	-0.212	-0.212	-0.065

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.27. Correlation matrix of agro-morphological characteristics and coarse fragments variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	COARSE FRAGMENTS					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.249*	0.278*	0.178	0.255*	0.272*	0.235
FLA	0.350**	0.348**	0.257*	0.335**	0.386**	0.346**
FLL	0.290*	0.259*	0.191	0.288*	0.346**	0.295*
FLW	0.014	0.060	0.045	-0.004	-0.031	0.009
SL	0.215	0.192	0.132	0.230	0.250*	0.224
PH	-0.154	-0.162	-0.150	-0.167	-0.134	-0.113
UNL	0.045	-0.004	0.004	0.019	0.083	0.093
KPS	-0.104	-0.092	-0.111	-0.087	-0.106	-0.105
SFPS	0.086	0.044	-0.007	0.071	0.127	0.151
YLD	0.201	0.193	0.122	0.199	0.224	0.224

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.28. Correlation matrix of agro-morphological characteristics and sand variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	SAND					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.278*	0.332**	0.245*	0.288*	0.279*	0.218
FLA	0.228	0.313**	0.203	0.230	0.225	0.151
FLL	0.164	0.250*	0.158	0.169	0.149	0.081
FLW	0.156	0.127	0.147	0.152	0.173	0.165
SL	0.159	0.201	0.132	0.174	0.171	0.102
PH	-0.377**	-0.333**	-0.347**	-0.354**	-0.390**	-0.420**
UNL	-0.129	-0.100	-0.154	-0.126	-0.085	-0.165
KPS	-0.019	0.024	-0.003	0.009	-0.046	-0.078
SFPS	0.170	0.170	0.132	0.198	0.185	0.149
YLD	0.233	0.269*	0.226	0.218	0.238*	0.190

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.29. Correlation matrix of agro-morphological characteristics and silt variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	SILT					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	-0.140	-0.177	-0.177	-0.227	-0.072	0.044
FLA	-0.071	-0.087	-0.099	-0.153	-0.043	0.093
FLL	-0.077	-0.073	-0.112	-0.150	-0.031	0.036
FLW	0.003	-0.002	0.005	-0.001	-0.012	0.030
SL	0.012	-0.014	-0.020	-0.066	0.070	0.132
PH	0.411**	0.465**	0.387**	0.404**	0.412**	0.258*
UNL	0.316**	0.276*	0.272*	0.344**	0.336**	0.261*
KPS	0.004	0.077	0.022	-0.068	-0.014	0.016
SFPS	-0.036	-0.083	-0.104	-0.076	0.036	0.093
YLD	-0.048	-0.059	-0.079	-0.132	-0.003	0.089

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.30. Correlation matrix of agro-morphological characteristics and clay variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	CLAY					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	-0.216	-0.222	-0.159	-0.104	-0.246*	-0.249*
FLA	-0.215	-0.287*	-0.168	-0.114	-0.211	-0.208
FLL	-0.133	-0.226	-0.105	-0.042	-0.136	-0.104
FLW	-0.191	-0.146	-0.179	-0.192	-0.183	-0.182
SL	-0.204	-0.224	-0.147	-0.146	-0.236	-0.185
PH	0.101	-0.050	0.117	-0.022	0.113	0.267*
UNL	-0.119	-0.147	-0.032	-0.242*	-0.168	0.008
KPS	0.022	-0.099	-0.012	0.067	0.067	0.072
SFPS	-0.176	-0.123	-0.080	-0.164	-0.229	-0.210
YLD	-0.241*	-0.261*	-0.213	-0.125	-0.255*	-0.248*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Correlations between agro-morphological characteristics of *T. monococcum* ssp. *monococcum* (IZA) and chemical soil variables known as CEC, nitrogen, organic carbon, pH-water, KHGM Soil variables were shown in Table 4.31, Table 4.32, Table 4.33, Table 4.34 and Table 4.35, respectively.

Correlation matrix of IZA's agro-morphological variables and CEC was shown in Table 4.31. According to this table, a total 19 correlations were found statistically significant. Eight of them were positive correlations at the 0.01 level and eight of them were positive correlations at the 0.05 level. On the other hand, three negative correlations were detected at the 0.05 level. Among these relationships, only one relationship between PH and CEC at 0-5 cm depth was found to be moderately strong (0.455), and the others were not found to be strong enough.

Correlation matrix of IZA's agro-morphological variables and nitrogen variables was shown in Table 4.32. According to this table, a total 25 correlations were found statistically significant. Nineteen of them were positive correlations at the 0.01 level and six of them were positive correlations at the 0.05 level. Among these, 11 correlations were found to be strong enough. TKW, FLL, and SL agro-morphological variables showed moderately strong correlations with Nitrogen at 5-15 cm between 0.539 and 0.448 correlation coefficients. However, PH showed strong correlations changing between 0.690 and 0.545 with nitrogen amounts of 0-5 cm, 15-30 cm, 30-60 cm, and 60-100 cm depths and mean nitrogen. UPL showed strong and positive correlation changing between 0.646 and 0.577 with nitrogen amounts of mean, 0-5 cm and 60-100 cm depths.

Correlation matrix of IZA's agro-morphological variables and organic carbon variables was shown in Table 4.33. According to this table, a total 16 correlations were found statistically significant. Eleven of them were positive correlations at the 0.01 level and three of them were positive correlations at the 0.05 level. On the other hand, two negative correlations were detected at the 0.05 level. PH and UNL showed strong correlations with organic carbon at 5-15 cm between 0.576 and 0.574 correlation coefficients. PH also showed strong correlation (0.565) with mean soil organic carbon. However, PH moderately correlated, between 0.516

and 0.484 correlation coefficients, with soil organic carbon at 15-30 cm and 60-100 cm depths. Similarly, UNL moderately correlated, between 0.574 and 0.491 correlation coefficients, with soil organic carbon of 15-30 cm, 30-60 cm and 60-100 cm depths and mean soil organic carbon. Remaining significant correlations were not found to be strong enough.

Correlation matrix of IZA's agro-morphological variables and pH-Water variables was shown in Table 4.34. According to this table, a total 12 negative correlations were found statistically significant ($p < 0.01$). PH showed strong correlations between -0.675 and -0.640 with all pH-Water variables, while UNL showed moderately strong correlations between -0.470 and -0.453 with all pH-Water variables. No any other significant relationship was detected between IZA's agro-morphological and pH-Water variables.

Finally, Correlation matrix of IZA's agro-morphological variables and KHGM Soil variables was shown in Table 4.35. According to this table, a total 12 positive correlations (seven at the 0.05 level and five at the 0.01 level) were found statistically significant. Although the highest positive correlation (0.412) was determined between FLA and land use suitability variables, no relationship between agro-morphological variables of IZA and KHGM Soil variables was found strong enough. Discrete data characteristics of KHGM Soil variables may be the reason of these results.

Table 4.31. Correlation matrix of agro-morphological characteristics and CEC variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	CATION EXCHANGE CAPACITY					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.172	-0.228	0.110	0.335**	0.348**	0.198
FLA	0.062	-0.295*	-0.009	0.285*	0.325**	0.020
FLL	0.078	-0.242*	0.030	0.263*	0.300*	0.032
FLW	-0.001	0.088	-0.001	-0.015	-0.042	-0.050
SL	0.160	-0.107	0.104	0.306*	0.259*	0.130
PH	0.117	0.455**	0.168	-0.015	-0.222	0.018
UNL	0.122	0.219	0.068	0.099	-0.027	0.101
KPS	0.233	0.077	0.128	0.239*	0.308**	0.185
SFPS	0.335**	-0.025	0.251*	0.433**	0.428**	0.306*
YLD	-0.063	-0.243*	-0.078	0.111	0.091	-0.079

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.32. Correlation matrix of agro-morphological characteristics and nitrogen variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	NITROGEN					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.322**	0.295*	0.539**	0.064	0.073	0.273*
FLA	0.092	0.103	0.435**	-0.092	-0.072	0.033
FLL	0.191	0.184	0.448**	-0.042	-0.015	0.178
FLW	-0.094	-0.115	-0.025	-0.022	-0.007	-0.131
SL	0.301*	0.327**	0.462**	0.010	0.026	0.279*
PH	0.690**	0.545**	0.279*	0.597**	0.575**	0.581**
UNL	0.646**	0.577**	0.414**	0.382**	0.410**	0.588**
KPS	0.116	0.009	0.312**	0.088	0.001	0.136
SFPS	0.100	-0.077	0.346**	0.052	0.079	0.155
YLD	0.160	0.270*	0.287*	-0.107	0.007	0.074

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.33. Correlation matrix of agro-morphological characteristics and soil organic carbon variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	SOIL ORGANIC CARBON					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.125	-0.077	0.283*	0.141	0.279*	0.212
FLA	-0.147	-0.296*	-0.056	-0.056	0.126	-0.056
FLL	-0.049	-0.258*	0.044	0.066	0.163	0.158
FLW	-0.040	0.034	-0.069	-0.118	0.031	-0.158
SL	0.018	-0.224	0.146	0.125	0.209	0.236
PH	0.565**	0.444**	0.576**	0.516**	0.388**	0.484**
UNL	0.496**	0.248*	0.574**	0.491**	0.542**	0.508**
KPS	-0.081	-0.123	0.071	-0.109	-0.045	-0.030
SFPS	-0.129	-0.130	0.019	-0.214	-0.079	-0.057
YLD	0.008	-0.063	0.111	0.000	0.081	0.024

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.34. Correlation matrix of agro-morphological characteristics and pH-water variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	pH-WATER					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	-0.070	-0.070	-0.029	-0.070	-0.070	-0.070
FLA	0.139	0.139	0.169	0.139	0.139	0.139
FLL	0.049	0.049	0.002	0.049	0.049	0.049
FLW	0.085	0.085	0.075	0.085	0.085	0.085
SL	-0.067	-0.067	0.010	-0.067	-0.067	-0.067
PH	-0.675**	-0.675**	-0.640**	-0.675**	-0.675**	-0.675**
UNL	-0.453**	-0.453**	-0.470**	-0.453**	-0.453**	-0.453**
KPS	-0.156	-0.156	-0.215	-0.156	-0.156	-0.156
SFPS	-0.038	-0.038	0.018	-0.038	-0.038	-0.038
YLD	-0.021	-0.021	0.035	-0.021	-0.021	-0.021

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.35. Correlation matrix of agro-morphological characteristics and KHGM soil (Great Soil Group and Land Use Suitability) variables for *T. monococcum* ssp. *monococcum* (IZA) (N=69).

	KHGM SOIL VARIABLES	
	GREAT SOIL GROUPS	LAND USE SUITABILITY
TKW	0.300*	0.243*
FLA	0.356**	0.412**
FLL	0.273*	0.319**
FLW	0.078	0.002
SL	0.270*	0.261*
PH	0.023	0.120
UNL	0.084	0.331**
KPS	0.185	0.112
SFPS	0.317**	0.221
YLD	0.291*	0.262*

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Correlations between agro-morphological characteristics of *T. aestivum* (cv. Çalibasan) and physical soil variables known as bulk density, coarse fragments, sand, silt, and clay were shown in Table 4.36, Table 4.37, Table 4.38, Table 4.39 and Table 4.40, respectively. Correlation matrix of agro-morphological characteristics of Çalibasan and bulk density was shown in Table 4.36. According to this table, no correlations were found to be significant either at the 0.01 or at the 0.05 levels. Correlation matrix of agro-morphological characteristics of Çalibasan and coarse fragments was shown in Table 4.37. According to this table, no relationships were found to be statistically significant at the 0.01 or 0.05 level.

Correlation matrix of agro-morphological characteristics of Çalibasan and sand was shown in Table 4.38. According to this table, one negative correlation at the 0.05 level, two positive correlations at 0.01 level, and one positive correlation at 0.05 level were found statistically significant. TKW showed strong negative correlation (-0.964) at 0.05 level with sand of 0-5 cm soil depth. YLD showed strong positive correlation (0.994) at 0.01 level with sand of 60-100 cm soil depth, and strong positive correlation (0.963) at 0.05 level with sand of 30-60 cm soil depth at the 0.05 level. KPS showed strong positive correlation (0.992) with sand of 5-15 cm soil depth at the 0.01 level.

Correlation matrix of agro-morphological characteristics of Çalibasan and silt was shown in Table 4.39. According to this table, one negative correlation at the 0.01 level, one positive and one negative correlation at 0.05 level were found statistically significant. FLL showed strong negative correlation (-0.996) with silt of 5-15 cm soil depth, and SFPS showed strong positive correlation (0.964) with silt of 5-15 cm soil depth at the 0.01 level. UNL showed strong negative correlation (-0.961) with silt of 15-30 cm soil depth at the 0.05 level.

Correlation matrix of agro-morphological characteristics of Çalibasan and clay was shown in Table 4.40. According to this table, two negative correlations at the 0.05 level, one negative correlation at 0.01 level, and one positive correlation at 0.05 level were found statistically significant. TKW showed strong positive correlation (0.987) at 0.05 level with clay of 5-15 cm soil depth. KPS showed strong negative correlation (-0.963) at 0.05 level with clay of 5-15 cm soil depth. YLD

showed strong negative correlations (-0.990 and -0.998) with clay of 30-60 and 60-100 cm soil depths at 0.05 and 0.01 levels, respectively.



Table 4.36. Correlation matrix of agro-morphological characteristics and bulk density variables for *T. aestivum* (cv. Çalibasan) (N=4).

	BULK DENSITY					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	-0.950	-0.883	-0.920	-0.920	-0.920	0.433
FLA	-0.700	-0.845	-0.562	-0.562	-0.562	-0.222
FLL	-0.743	-0.613	-0.873	-0.873	-0.873	0.914
FLW	-0.455	-0.645	-0.272	-0.272	-0.272	-0.533
SL	-0.705	-0.835	-0.535	-0.535	-0.535	-0.319
PH	-0.415	-0.286	-0.599	-0.599	-0.599	0.930
UNL	-0.867	-0.933	-0.734	-0.734	-0.734	-0.062
KPS	0.758	0.639	0.743	0.743	0.743	-0.428
SFPS	0.830	0.774	0.911	0.911	0.911	-0.734
YLD	-0.296	-0.245	-0.454	-0.454	-0.454	0.721

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.37. Correlation matrix of agro-morphological characteristics and coarse fragments variables for *T. aestivum* (cv. Çalıbasan) (N=4).

	COARSE FRAGMENTS					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.030	-0.092	-0.276	0.342	0.825	-0.651
FLA	-0.798	-0.744	-0.907	-0.596	0.717	-0.580
FLL	0.008	-0.306	-0.256	0.260	0.818	0.124
FLW	-0.805	-0.645	-0.827	-0.688	0.446	-0.628
SL	-0.603	-0.499	-0.732	-0.397	0.629	-0.806
PH	-0.010	-0.344	-0.175	0.138	0.583	0.532
UNL	-0.409	-0.381	-0.619	-0.142	0.762	-0.830
KPS	-0.399	-0.299	-0.109	-0.658	-0.560	0.652
SFPS	0.328	0.595	0.573	0.058	-0.940	-0.026
YLD	-0.338	-0.622	-0.422	-0.240	0.541	0.636

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.38. Correlation matrix of agro-morphological characteristics and sand variables for *T. aestivum* (cv. Çalibasan) (N=4).

	SAND					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	-0.519	-0.964*	-0.924	-0.410	-0.179	-0.029
FLA	-0.151	-0.523	-0.280	-0.084	0.038	0.068
FLL	0.227	-0.455	-0.457	0.338	0.545	0.674
FLW	-0.231	-0.375	-0.129	-0.201	-0.148	-0.161
SL	-0.452	-0.687	-0.480	-0.391	-0.267	-0.222
PH	0.590	-0.034	-0.060	0.671	0.806	0.886
UNL	-0.531	-0.866	-0.704	-0.446	-0.269	-0.179
KPS	0.696	0.938	0.992**	0.611	0.412	0.260
SFPS	-0.278	0.465	0.376	-0.394	-0.602	-0.712
YLD	0.809	0.190	0.239	0.874	0.963*	0.994**

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.39. Correlation matrix of agro-morphological characteristics and silt variables for *T. aestivum* (cv. Çalıbasan) (N=4).

	SILT					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	-0.621	-0.523	-0.651	-0.948	0.475	0.103
FLA	-0.905	-0.726	-0.252	-0.769	-0.288	-0.719
FLL	-0.565	-0.726	-0.996**	-0.539	0.877	0.529
FLW	-0.721	-0.485	0.083	-0.593	-0.587	-0.904
SL	-0.775	-0.528	-0.119	-0.836	-0.335	-0.710
PH	-0.374	-0.638	-0.911	-0.153	0.857	0.621
UNL	-0.785	-0.570	-0.332	-0.961*	-0.055	-0.463
KPS	0.271	0.175	0.486	0.782	-0.526	-0.316
SFPS	0.807	0.917	0.964*	0.655	-0.660	-0.213
YLD	-0.481	-0.739	-0.788	-0.043	0.597	0.340

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.40. Correlation matrix of agro-morphological characteristics and clay variables for *T. aestivum* (cv. Çalibasan) (N=4).

	CLAY					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.668	0.948	0.987*	0.602	0.052	-0.011
FLA	0.354	0.729	0.387	0.247	0.031	-0.037
FLL	-0.085	0.706	0.695	-0.149	-0.681	-0.716
FLW	0.387	0.497	0.156	0.301	0.263	0.206
SL	0.624	0.741	0.500	0.535	0.312	0.243
PH	-0.492	0.368	0.331	-0.537	-0.908	-0.917
UNL	0.710	0.892	0.740	0.622	0.251	0.178
KPS	-0.766	-0.753	-0.963*	-0.743	-0.247	-0.202
SFPS	0.084	-0.806	-0.646	0.178	0.683	0.733
YLD	-0.690	0.258	0.067	-0.751	-0.990*	-0.998**

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Correlations between agro-morphological characteristics of *T. aestivum* (cv. Çalibasan) and chemical soil variables known as CEC, Nitrogen, Organic Carbon, pH-Water were shown in Table 4.41, Table 4.42, Table 4.43, and Table 4.44, respectively.

Correlation matrix of Çalibasan's agro-morphological variables and CEC was shown in Table 4.41. According to this table, four negative and two positive correlations were found statistically significant at 0.05 level. TKW showed both strong positive (0.967) correlation with CEC of 0-5 cm soil depth and strong negative (-0.985) correlation with CEC of 30-60 cm soil depth. FLL displayed strong positive (0.984) correlation with mean CEC. FLW showed strong negative (-0.965) correlation with CEC of 60-100 cm soil depth. KPS showed strong positive (0.967) correlation with CEC of 30-60 cm soil depth. SFPS revealed strong negative correlations (-0.955) with CEC of 5-15 cm and 15-30 cm soil depths.

Correlation matrix of Çalibasan's agro-morphological variables and nitrogen variables was shown in Table 4.42. According to this table, only one strong negative correlation (-0.955), between SFPS and nitrogen of 15-30 cm soil depth, was detected. Other correlations were found to be insignificant even if they have high correlation coefficients.

Correlation matrix of Çalibasan's agro-morphological variables and organic carbon variables was shown in Table 4.43. According to this table, two negative and one positive correlation were found statistically significant. TKW showed strong positive correlation (0.966) at 0.05 level with organic carbon of 5-15 cm soil depth. UNL revealed strong negative correlation (-0.993) at 0.01 level with organic carbon of 15-30 cm soil depth. UNL showed strong negative correlation (-0.976) at 0.05 level with organic carbon of 0-5 cm soil depth.

Correlation matrix of Çalibasan's agro-morphological variables and pH-Water variables was shown in Table 4.44. According to this table, no relationship between agro-morphological variables of Çalibasan and pH-water variables was found. In another words, correlations could not be computed except pH-water of 5-15 cm soil depth because at least one of the variables is constant. High correlation

coefficients detected were found to be insignificant even if they have high correlation coefficients.

Finally, Correlation matrix of Çalibasan's agro-morphological variables and KHGM Soil variables was shown in Table 4.45. According to this table, no relationship between agro-morphological variables of Çalibasan and KHGM Soil variables was found. In another words, correlations could not be computed because at least one of the variables is constant. It is thought that both low populations or samples ($N = 4$) and discrete data characteristics of KHGM Soil variables may cause this situation.



Table 4.41. Correlation matrix of agro-morphological characteristics and CEC variables for *T. aestivum* (cv. Çalibasan) (N=4).

	CATION EXCHANGE CAPACITY					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.790	0.967*	0.450	0.450	-0.985*	-0.054
FLA	0.256	0.428	0.504	0.504	-0.377	-0.858
FLL	0.984*	0.836	0.840	0.840	-0.690	0.299
FLW	-0.074	0.149	0.223	0.223	-0.147	-0.965*
SL	0.193	0.467	0.278	0.278	-0.493	-0.802
PH	0.816	0.524	0.826	0.826	-0.325	0.414
UNL	0.440	0.706	0.363	0.363	-0.734	-0.587
KPS	-0.675	-0.878	-0.145	-0.145	0.967*	-0.231
SFPS	-0.924	-0.808	-0.955*	-0.955*	0.636	0.042
YLD	0.626	0.299	0.886	0.886	-0.057	0.132

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.42. Correlation matrix of agro-morphological characteristics and nitrogen variables for *T. aestivum* (cv. Çalibasan) (N=4).

	NITROGEN					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.322	0.156	0.912	0.581	0.090	-0.729
FLA	0.824	-0.268	0.565	0.677	0.726	0.128
FLL	0.460	-0.458	0.878	0.797	0.328	-0.382
FLW	0.674	-0.114	0.273	0.412	0.620	0.257
SL	0.611	0.045	0.530	0.491	0.475	-0.101
PH	0.411	-0.680	0.611	0.697	0.374	-0.073
UNL	0.550	0.103	0.727	0.566	0.363	-0.362
KPS	0.067	-0.460	-0.729	-0.255	0.300	0.936
SFPS	-0.733	0.604	-0.919	-0.955*	-0.610	0.173
YLD	0.622	-0.908	0.472	0.756	0.649	0.298

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.43. Correlation matrix of agro-morphological characteristics and soil organic carbon variables for *T. aestivum* (cv. Çalibasan) (N=4).

	SOIL ORGANIC CARBON					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.548	-0.101	0.966*	-0.884	-0.421	0.369
FLA	0.079	-0.291	0.512	-0.853	0.360	0.697
FLL	-0.156	-0.697	0.832	-0.423	0.007	0.646
FLW	0.134	-0.056	0.236	-0.718	0.359	0.483
SL	0.383	-0.003	0.534	-0.916	0.074	0.464
PH	-0.516	-0.842	0.519	-0.040	0.252	0.623
UNL	0.494	-0.031	0.753	-0.993**	-0.121	0.463
KPS	-0.748	-0.191	-0.840	0.689	0.734	-0.002
SFPS	0.243	0.799	-0.839	0.586	-0.246	-0.857
YLD	-0.770	-0.976*	0.328	0.017	0.602	0.780

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.44. Correlation matrix of agro-morphological characteristics and pH variables for *T. aestivum* (cv. Çalıbasan) (N=4).

	pH					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	a	a	-0.498	a	a	a
FLA	a	a	-0.639	a	a	a
FLL	a	a	-0.782	a	a	a
FLW	a	a	-0.378	a	a	a
SL	a	a	-0.427	a	a	a
PH	a	a	-0.725	a	a	a
UNL	a	a	-0.488	a	a	a
KPS	a	a	0.164	a	a	a
SFPS	a	a	0.942	a	a	a
YLD	a	a	-0.809	a	a	a

**.. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.45. Correlation matrix of agro-morphological characteristics and KHGM soil (Great Soil Group and Land Use Suitability) variables for *T. aestivum* (cv. Çalibasan) (N=4)

	KHGM SOIL VARIABLES	
	GREAT SOIL GROUPS	LAND USE SUITABILITY
TKW	a	a
FLA	a	a
FLL	a	a
FLW	a	a
SL	a	a
PH	a	a
UNL	a	a
KPS	a	a
SFPS	a	a
YLD	a	a

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Correlations between agro-morphological characteristics of *T. aestivum* (cv. Sarı Serez) and physical soil variables known as bulk density, coarse fragments, sand, silt, and clay were shown in Table 4.46, Table 4.47, Table 4.48, Table 4.49 and Table 4.50, respectively.

Correlation matrix of agro-morphological characteristics of Sarı Serez and bulk density was shown in Table 4.46. According to this table, one positive correlation at the 0.01 level and three positive correlations at 0.05 level were found statistically significant. TKW showed strong positive correlation (0.991) at 0.01 level with mean bulk density. YLD displayed strong positive correlations (0.913) at 0.05 level with bulk density in 5-15, 15-30 and 30-60 cm soil depths. Apart from these, although some high correlation values were detected, these were found to be statistically insignificant.

Correlation matrix of agro-morphological characteristics of Sarı Serez and coarse fragments was shown in Table 4.47. According to this table, although some high correlation coefficients were detected, no statistically significant correlations between agro-morphological variables of Sarı Serez and coarse fragments variables was found.

Correlation matrix of agro-morphological characteristics of Sarı Serez and sand was shown in Table 4.48. Here, similar situations of Table 4.46 were observed that is no statistically significant correlations between agro-morphological variables of Sarı Serez and sand variables was found.

Correlation matrix of agro-morphological characteristics of Sarı Serez and silt was shown in Table 4.49. According to this table, no statistically significant correlations between agro-morphological variables of Sarı Serez and silt variables was found as in Table 4.46 and Table 4.47.

Correlation matrix of agro-morphological characteristics of Sarı Serez and clay was shown in Table 4.50. According to this table, only one positive strong correlation (0.902) between YLD and clay of 5-15 cm soil depth were found statistically significant at 0.05 level.

Table 4.46. Correlation matrix of agro-morphological characteristics and bulk density variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	BULK DENSITY					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.991**	0.234	-0.355	-0.355	-0.355	0.811
FLA	0.125	-0.805	-0.794	-0.794	-0.794	0.609
FLL	-0.228	0.744	0.340	0.340	0.340	-0.534
FLW	0.167	-0.831	-0.708	-0.708	-0.708	0.625
SL	0.429	0.751	0.505	0.505	0.505	-0.053
PH	0.541	0.546	0.107	0.107	0.107	0.192
UNL	0.017	0.694	0.296	0.296	0.296	-0.321
KPS	0.033	-0.116	0.053	0.053	0.053	0.012
SFPS	0.519	0.808	0.395	0.395	0.395	0.031
YLD	-0.139	0.400	0.913*	0.913*	0.913*	-0.514

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.47. Correlation matrix of agro-morphological characteristics and coarse fragments variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	COARSE FRAGMENTS					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.811	0.752	0.837	0.824	0.858	0.793
FLA	0.372	0.470	0.286	0.334	0.368	0.382
FLL	-0.265	-0.374	-0.197	-0.279	-0.275	-0.242
FLW	0.359	0.464	0.274	0.333	0.360	0.361
SL	0.256	0.195	0.329	0.325	0.261	0.222
PH	0.139	-0.007	0.211	0.126	0.202	0.143
UNL	-0.191	-0.325	-0.117	-0.210	-0.171	-0.172
KPS	-0.399	-0.491	-0.378	-0.449	-0.327	-0.378
SFPS	0.356	0.277	0.432	0.414	0.364	0.327
YLD	-0.394	-0.405	-0.342	-0.318	-0.393	-0.434

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.48. Correlation matrix of agro-morphological characteristics and sand variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	SAND					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.226	0.486	0.373	0.257	-0.300	0.145
FLA	0.694	0.541	0.591	0.757	0.717	0.714
FLL	-0.367	-0.269	-0.225	-0.467	-0.316	-0.613
FLW	0.629	0.486	0.512	0.707	0.632	0.710
SL	-0.269	-0.028	-0.177	-0.286	-0.608	-0.173
PH	-0.435	-0.177	-0.208	-0.467	-0.712	-0.691
UNL	-0.473	-0.315	-0.288	-0.555	-0.517	-0.748
KPS	-0.573	-0.533	-0.457	-0.576	-0.477	-0.797
SFPS	-0.209	0.060	-0.081	-0.234	-0.594	-0.182
YLD	-0.645	-0.571	-0.682	-0.639	-0.646	-0.369

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.49. Correlation matrix of agro-morphological characteristics and silt variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	SILT					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	-0.724	-0.671	-0.680	-0.693	-0.787	-0.333
FLA	0.177	-0.177	-0.047	-0.164	0.307	0.646
FLL	0.365	0.557	0.503	0.547	0.206	-0.093
FLW	0.036	-0.285	-0.171	-0.273	0.177	0.518
SL	-0.823	-0.604	-0.703	-0.618	-0.849	-0.720
PH	-0.148	0.186	0.099	0.155	-0.398	-0.502
UNL	0.247	0.528	0.453	0.508	0.028	-0.266
KPS	0.456	0.753	0.692	0.733	0.213	-0.207
SFPS	-0.782	-0.573	-0.661	-0.589	-0.834	-0.665
YLD	-0.580	-0.289	-0.421	-0.290	-0.568	-0.803

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.50. Correlation matrix of agro-morphological characteristics and clay variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	CLAY					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.413	0.206	0.298	0.464	0.656	0.228
FLA	-0.564	-0.349	-0.484	-0.496	-0.520	-0.722
FLL	-0.042	-0.325	-0.180	-0.140	0.019	0.258
FLW	-0.419	-0.179	-0.322	-0.343	-0.400	-0.620
SL	0.785	0.637	0.766	0.858	0.812	0.625
PH	0.396	-0.008	0.147	0.259	0.605	0.605
UNL	0.117	-0.238	-0.082	-0.021	0.234	0.434
KPS	0.025	-0.214	-0.188	-0.212	0.111	0.394
SFPS	0.719	0.513	0.664	0.784	0.800	0.585
YLD	0.829	0.873	0.902*	0.848	0.638	0.740

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Correlations between agro-morphological characteristics of *T. aestivum* (cv. Sarı Serez) and chemical soil variables known as CEC, Nitrogen, Organic Carbon, pH-Water were shown in Table 4.51, Table 4.52, Table 4.53 and Table 4.54, respectively.

Correlation matrix of Sarı Serez's agro-morphological variables and CEC was shown in Table 4.51. According to this table, three negative correlations were found statistically significant at 0.05 level. TKW showed a strong negative correlation (-0.879) with CEC of 30-60 cm soil depth. SL displayed a strong positive correlation (-0.917) with CEC of 60-100 cm soil depth. SFPS revealed a strong negative correlation (-0.878) with CEC of 30-60 cm soil depth.

Correlation matrix of Sarı Serez's agro-morphological variables and nitrogen variables was shown in Table 4.52. According to this table, two strong positive correlation at 0.05 level and one strong negative correlation at 0.01 level were detected. TKW showed a strong positive correlation (0.901) at 0.05 level with nitrogen of 60-100 cm soil depth. KPS displayed a strong positive correlation (0.887) at 0.05 level with mean nitrogen. YLD displayed a strong negative correlation (-0.961) at 0.01 level with nitrogen of 15-30 cm soil depth. Other correlations were found to be insignificant even if they have high correlation coefficients.

Correlation matrix of Sarı Serez's agro-morphological variables and organic carbon variables was shown in Table 4.53. According to this table, three positive correlations and one negative correlation were found statistically significant at 0.05 levels. PH showed strong positive correlations at the 0.05 level with mean organic carbon (0.914), organic carbon of 0-5 cm soil depth (0.906), and organic carbon of 5-15 cm soil depth (0.926). SFPS revealed strong negative correlation (-0.929) at 0.05 level with organic carbon of 60-100 cm soil depth.

Correlation matrix of Sarı Serez's agro-morphological variables and pH-Water variables was shown in Table 4.54. According to this table, no relationship between agro-morphological variables of Sarı Serez and pH-water variables was

found. Even if detected relationships have high correlation coefficients, they were found to be statistically insignificant.

Finally, Correlation matrix of Sarı Serez's agro-morphological variables and KHGM Soil variables was shown in Table 4.55. According to this table, no relationship between agro-morphological variables of Sarı Serez and KHGM Soil variables was found. In another words, correlations could not be computed because at least one of the variables is constant. It is thought that both low populations or samples ($N = 4$) and discrete data characteristics of KHGM Soil variables may cause this situation.



Table 4.51. Correlation matrix of agro-morphological characteristics and CEC variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	CATION EXCHANGE CAPACITY					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	-0.821	-0.774	-0.823	-0.857	-0.879*	-0.168
FLA	0.224	-0.195	0.239	0.180	0.235	0.774
FLL	0.048	0.216	0.006	0.111	0.068	-0.363
FLW	0.162	-0.206	0.185	0.110	0.163	0.704
SL	-0.832	-0.472	-0.826	-0.816	-0.837	-0.917*
PH	-0.321	-0.082	-0.354	-0.323	-0.410	-0.206
UNL	-0.024	0.192	-0.067	0.018	-0.051	-0.290
KPS	0.481	0.584	0.456	0.459	0.369	0.426
SFPS	-0.871	-0.542	-0.873	-0.853	-0.878*	-0.874
YLD	-0.294	0.146	-0.267	-0.285	-0.308	-0.812

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.52. Correlation matrix of agro-morphological characteristics and nitrogen variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	NITROGEN					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.380	0.169	-0.369	0.085	-0.830	0.901*
FLA	-0.229	-0.555	-0.231	0.676	0.319	0.344
FLL	0.294	0.495	-0.095	-0.133	0.146	-0.370
FLW	-0.243	-0.552	-0.145	0.565	0.203	0.368
SL	0.008	0.178	-0.101	-0.768	-0.865	0.357
PH	0.845	0.849	0.029	0.070	-0.449	0.174
UNL	0.575	0.721	0.005	-0.040	-0.030	-0.250
KPS	0.887*	0.869	0.491	0.445	0.214	-0.383
SFPS	0.097	0.228	-0.206	-0.655	-0.868	0.436
YLD	-0.141	0.184	0.472	-0.961**	-0.513	-0.256

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.53. Correlation matrix of agro-morphological characteristics and soil organic carbon variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	SOIL ORGANIC CARBON					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	0.790	0.799	0.688	0.707	-0.498	-0.718
FLA	-0.452	-0.423	-0.522	-0.485	0.647	0.642
FLL	0.322	0.384	0.335	0.092	-0.357	-0.346
FLW	-0.429	-0.425	-0.485	-0.390	0.588	0.587
SL	0.621	0.598	0.595	0.712	-0.603	-0.877
PH	0.914*	0.906*	0.926*	0.746	-0.865	-0.777
UNL	0.566	0.599	0.594	0.348	-0.598	-0.513
KPS	0.374	0.316	0.487	0.292	-0.534	-0.086
SFPS	0.717	0.715	0.671	0.735	-0.637	-0.929*
YLD	0.152	0.046	0.252	0.475	-0.451	-0.465

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.54. Correlation matrix of agro-morphological characteristics and pH-water variables for *T. aestivum* (cv. Sarı Serez) (N=5).

	pH-WATER					
	MEAN	0-5 cm	5-15 cm	15-30 cm	30-60 cm	60-100 cm
TKW	-0.778	-0.778	-0.778	-0.778	-0.778	-0.778
FLA	-0.420	-0.420	-0.420	-0.420	-0.420	-0.420
FLL	0.362	0.362	0.362	0.362	0.362	0.362
FLW	-0.422	-0.422	-0.422	-0.422	-0.422	-0.422
SL	-0.262	-0.262	-0.262	-0.262	-0.262	-0.262
PH	-0.017	-0.017	-0.017	-0.017	-0.017	-0.017
UNL	0.311	0.311	0.311	0.311	0.311	0.311
KPS	0.509	0.509	0.509	0.509	0.509	0.509
SFPS	-0.340	-0.340	-0.340	-0.340	-0.340	-0.340
YLD	0.344	0.344	0.344	0.344	0.344	0.344

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

Table 4.55. Correlation matrix of agro-morphological characteristics and KHGM soil (Great Soil Group and Land Use Suitability) variables for *T. aestivum* (cv. Sarı Serez) (N=5).

KHGM SOIL VARIABLES		
GREAT SOIL GROUPS		LAND USE SUITABILITY
TKW	a	0.084
FLA	a	0.693
FLL	A	-0.696
FLW	A	0.717
SL	A	-0.138
PH	A	-0.780
UNL	A	-0.838
KPS	A	-0.848
SFPS	A	-0.180
YLD	A	-0.230

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

Abbreviations

TKW	: Thousand kernels weight (g)	SL	: Spike length (cm)	KPS	: Number of kernels per spike
FLA	: Flag Leaf area (cm ²)	PH	: Plant height (cm)	SFPS	: Spikes fertile per square meter
FLL	: Flag leaf length (cm)	UNL	: Upper node length (cm)	YLD	: Yield (kg/da)
FLW	: Flag leaf width (cm)				

4.2.4.5 Modeling Significant Correlations by Scatter Plots and Linear Regression

Correlation analysis results of Sarı Serez and Çalibasan wheats showed that some of the relationships were found to be high (strong) but insignificant, while others were found to be both strong and significant. Since the low population numbers of Sarı Serez and Çalibasan caused the sampling numbers to be low, the high correlation results of these two wheat varieties produced contradictory results as can be seen. For this reason, the correlation results of Sarı Serez and Çalibasan wheats were not taken into account for modelling studies. On the other hand, the correlation results for the IZA wheat were found to be reliable and were taken into account for modelling (linear regression) studies.

Scatter plots and linear regression models of detected significant correlations among agro-morphological variables of IZA wheat were given in Figure 4.31. According to these results; the first strong model ($R=0.692$) was developed for thousand kernels weight (dependent variable) and spike length (independent variable) agro-morphological variables of IZA wheat. According to R values, this model was followed by TKW-FLL, FLA-FLL, SL-FLL models, respectively.

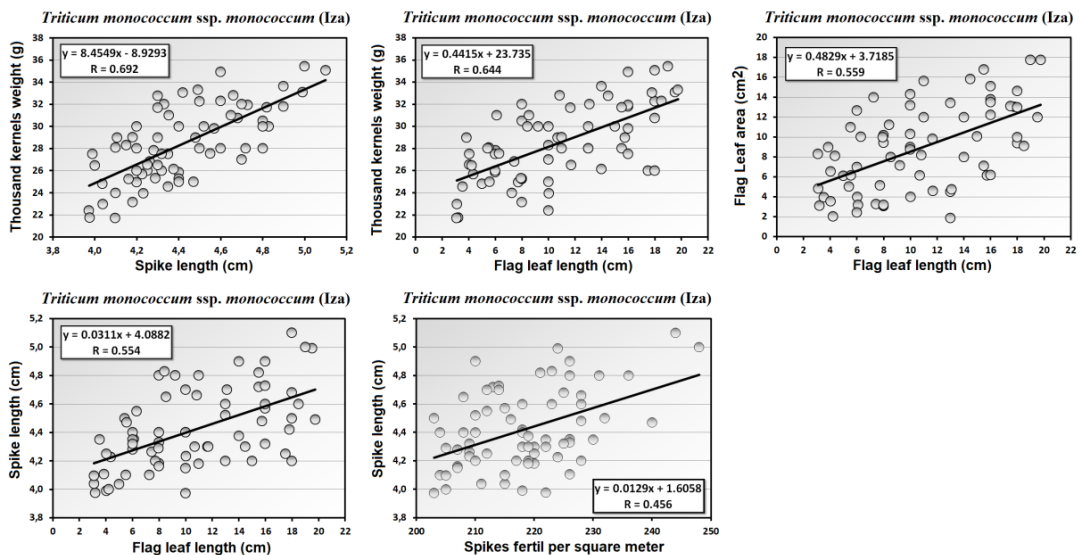


Figure 4.31. Scatter plots and linear regression models of detected significant correlations among agro-morphological variables of IZA. (Note: Variables considered dependent are shown on the y-axis).

Scatter plots and linear regression models of detected significant correlations between agro-morphological variables of IZA and topographic-climatic variables also were given in Figure 4.32. According to these results; the first strong model ($R=0.793$) was developed for thousand kernels weight (dependent variable) of IZA wheat and elevation (independent variable). According to R values, this model was followed by FLL- elevation, SL-elevation, PH- mean temperature of August, FLA-precipitation of April, UNL-nitrogen, and SFPS-precipitation of April models, respectively.

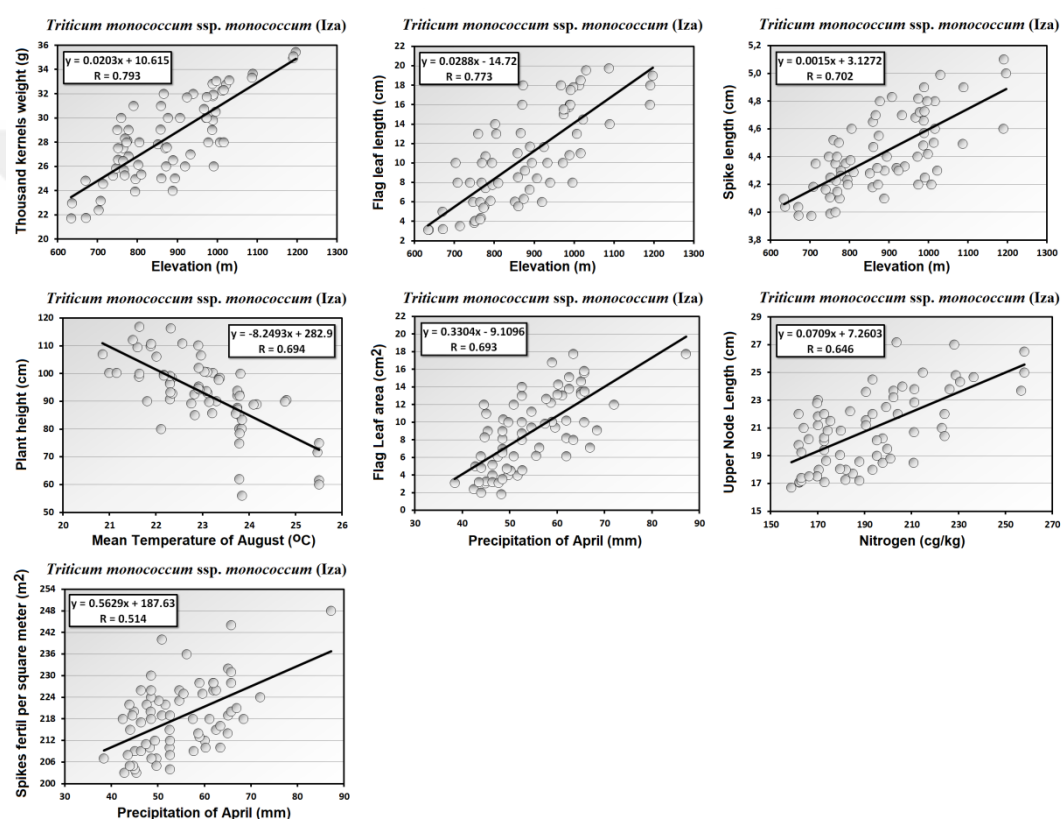


Figure 4.32. Scatter plots and linear regression models of detected significant correlations between agro-morphological variables of IZA and topographic-climatic variables (Note: Dependent variables are shown on the y-axis).

Finally, scatter plots and linear regression models of detected significant correlations between yield of IZA and topographic-climatic variables were given in Figure 4.33. According to these results; the first model ($R=0.554$) was developed for yield (dependent variable) of IZA wheat and precipitation of April (independent variable). According to R values, this model was followed by yield & precipitation of May, YLD-precipitation of November, YLD-elevation, YLD-minimum temperature of November, YLD-maximum temperature of December, YLD-mean

temperature December, and YLD-BIO-11 (mean daily mean air temperatures of the coldest quarter) models, respectively.

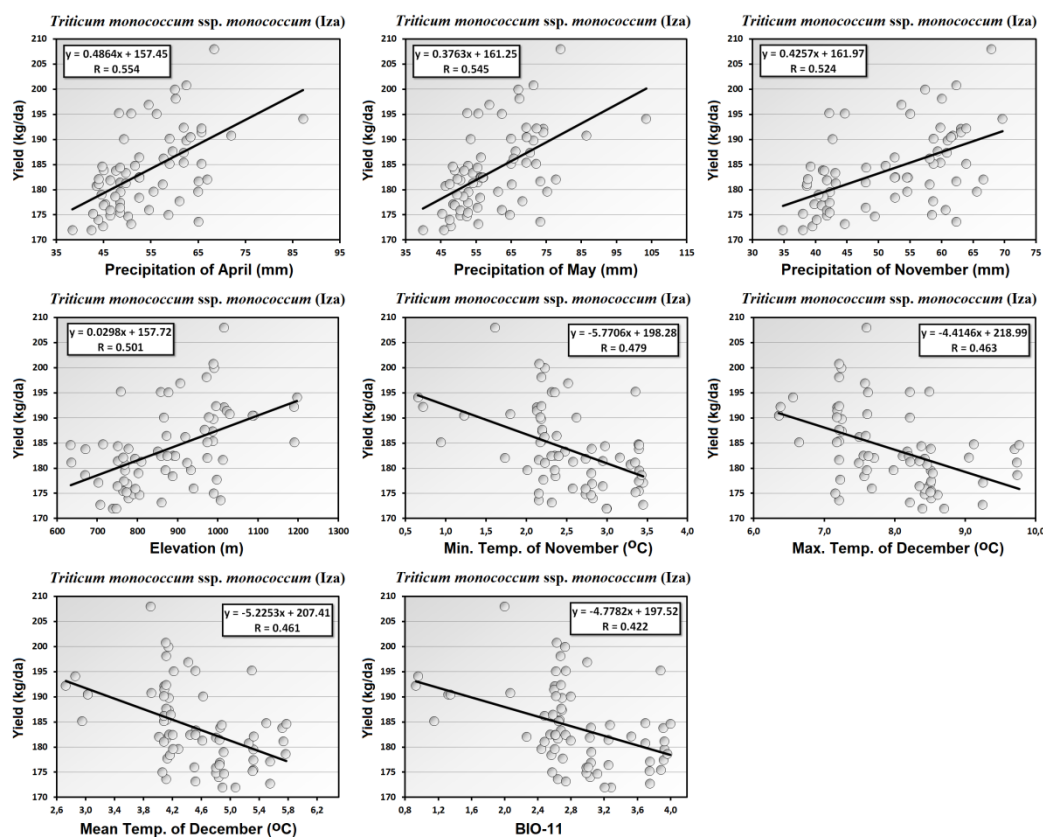


Figure 4.33. Scatter plots and linear regression models of detected significant correlations between yield of IZA and topographic-climatic variables (NOTE: Dependent variables are shown on the y-axis).

4.2.5 Modeling and Mapping the Most Suitable (Potential) Cultivation Areas for IZA in GIS

Scatter plots and linear regression models showed that some of topographic and climatic variables were found effective on yield of IZA wheat. These variables are precipitation of April, precipitation of May, precipitation of November, elevation, minimum temperature of November, maximum temperature of December, minimum temperature of November, mean temperature of December, and BIO-11, respectively (Figure 4.33). Multiple (linear) regression analysis using these variables provided the best modeling of wheat yield of IZA. Basically, multiple regression analysis produced three important tables including model

summary (Table 4.56), analysis of variance (ANOVA) (Table 4.57), and coefficients (Table 4.58). R, R^2 , adjusted R^2 and standard error of the estimate values were shown in the model summary section of the regression tables (Table 4.56). The R value specified here expresses the correlation between the observed and predicted values of the dependent variable. When this value approaches one, it indicates that the relationships are strong (82). In this study, the R value seen in the obtained model summary showed that strength of relationships is above moderately strong (0.578). Accordingly, the model can be expected to run. The R^2 value is defined as the rate of variation in the dependent variable explained by the independent variable. High R^2 values approaching 1 indicate that the model fits the data well (82). R^2 value (0.334) in the model summary table (Table 4.56), presented that obtained model almost fit the data.

Table 4.56. Yield (Multiple Regression) model summary of IZA Wheat.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.578 ^a	0.334	0.246	6.836159077635721
a. Predictors: (Constant), Elevation, Precipitation of April (PR4), Precipitation of May (PR5), Precipitation of November (PR11), Mean Temperature of December (TAS12), Maximum Temperature of December (TASMAX12), Minimum Temperature of November (TASMIN11), Mean Daily Mean Air Temperatures of The Coldest Quarter (BIO11)				

ANOVA results provides the information about explained regression and unexplained residual values by independent variable. In healthy models, the regression sum of squares is expected to be greater than the residual sum of squares. According to the ANOVA results obtained in this study, the larger residual sum of squares (2803.984) compared to the regression sum of squares (1,408.030) indicated that developed model can explain 50.22% of the variation in the dependent variable (Table 4.57).

The F statistical significance (sig.) value in the ANOVA results also gave information about the developed model. In a good model, significance (sig.) values are expected to be less than 0.05 (82). In the developed model, less than five percent

($p < 0.05$) F statistic sig. value showed that the independent variable explains the variation in the dependent variable (Table 4.57).

Table 4.57. ANOVA results of yield (Multiple Regression) model of IZA Wheat.

ANOVA^a					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	1408.030	8	176.004	3.766	.001 ^b
Residual	2803.984	60	46.733		
Total	4212.015	68			
a. Dependent Variable: Yield kg/da					
a. Predictors: (Constant), Elevation, Precipitation of April (PR4), Precipitation of May (PR5), Precipitation of November (PR11), Mean Temperature of December (TAS12), Maximum Temperature of December (TASMAX12), Minimum Temperature of November (TASMIN11), Mean Daily Mean Air Temperatures of The Coldest Quarter (BIO11)					

Finally, Coefficients results of yield (multiple regression) model of IZA Wheat were summarized in Table 4.58. This is basically a table showing a constant value in the equation (in the model), the coefficients of the model variables (by which coefficient the variable will be multiplied), and collinearity statistics (tolerance and Variance Inflation Factor (VIF) values). Developed model (equation) for yield of IZA wheat was given bottom of Table 4.58. Collinearity analysis shows if a correlation between multiple independent variables exists in a multiple regression model. High correlations between multiple independent variables are not desirable situation in multiple regression. For this reason, tolerance values should be higher than 0.10 and VIF values should be lower than 10. In our study, tolerance values lower than 0.10 and VIF values higher than 10 indicated that there is multicollinearity problem. In fact, this was an expected situation, because high correlations among climatic independent variables (PR4, PR5, PR11, TAS12, TASMAX12, TASMIN11, and BIO11) and elevation independent variable were detected in correlation analyses before. When we attempted to model only the relationship between elevation and yield by removing the climate variables that are related to each other, lower regression and higher residual values were observed. Moreover, the failure to detect strong components between soil properties and yield limited the number of useable independent variables in multiple regression stage.

As a result, collinearity analysis results were ignored and the multiple regression results were accepted because there is no other reasonable choice.



Table 4.58. Coefficients results of yield (Multiple Regression) model of IZA Wheat.

Coefficients^a									
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	233.041	68.859		3.384	0.001	95.303	370.779		
Elevation	-0.040	0.042	-.674	-0.955	0.343	-0.124	0.044	.022	44.938
PR4	0.888	0.974	1.012	0.912	0.365	-1.059	2.835	.009	110.952
PR5	-0.324	0.650	-0.469	-0.498	0.620	-1.625	0.977	.013	79.903
PR11	-0.097	0.286	-0.119	-0.338	0.737	-0.669	0.476	.089	11.204
TAS12	10.423	30.421	0.920	0.343	0.733	-50.429	71.275	.002	650.257
TASMAX12	-7.231	12.563	-0.758	-0.576	0.567	-32.361	17.899	.006	156.451
TASMIN11	-20.684	15.555	-1.716	-1.330	0.189	-51.798	10.430	.007	150.020
BIO11	8.553	15.693	0.755	0.545	0.588	-22.838	39.944	.006	172.881

a. Dependent Variable: Yield kg/da

MODEL

YIELD (kg/da) = 233.041 - 0.040*Elevation + 0.888*PR4 - 0,324*PR5 - 0,097*PR11 + 10,423*TAS12 - 7,231*TASMAX12 - 20,684*TASMIN11 + 8,553*BIO11

The yield model raster map of IZA wheat was developed by utilizing model, raster maps of the variables, and ArcGIS raster calculations functions. Before raster calculations, elevation raster map was made compatible with climate maps using ArGIS's projection, resampling and snap raster functions. The resulting yield model raster map of IZA wheat is shown in the Figure 4.34.



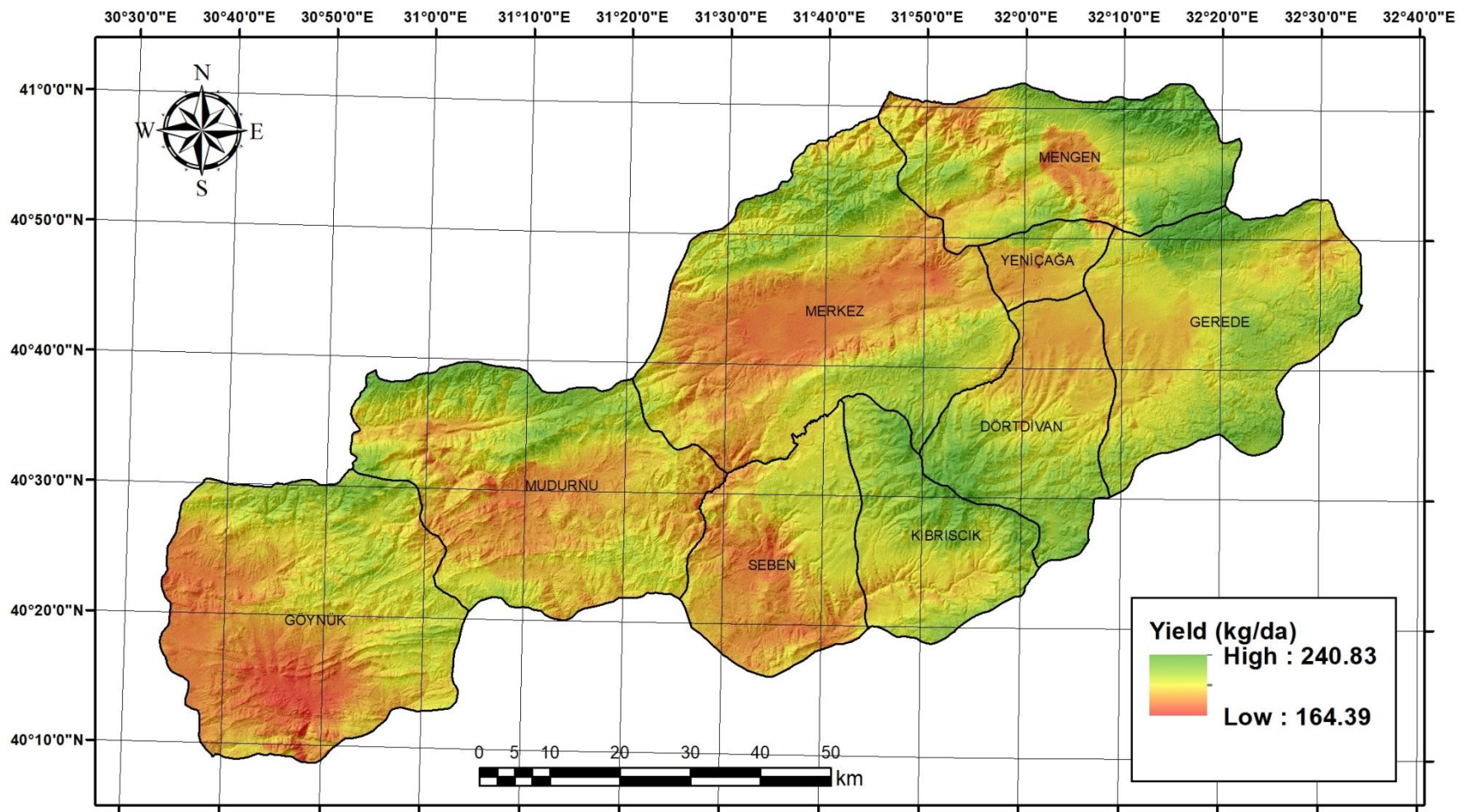


Figure 4.34. Yield model raster map of IZA wheat.

IZA yield model raster map was classified by using 1 standard deviation function in ArcGIS. Thus, the areas where the developed IZA yield model map worked strongly, moderately and weakly were identified (Figure 4.35). However, this map was developed for the entire Bolu province, taking into account the ecological factors affecting IZA yield. In other words, the resulting map includes all land use/cover classes of Bolu province. In order to fully determine the suitable growing areas for IZA wheat, only agricultural areas should be taken into account in this map. The agricultural areas of Bolu province were shown in the CORINE 2018 Third Level Map (Figure 4.36). Using this map, the IZA yield model raster map was clipped in ArcGIS and thus the IZA wheat suitability map was obtained (Figure 4.37).

The areas covered by the classes in the resulting IZA wheat suitability map was determined using the ArcGIS calculating geometry function (Figure 4.38). Accordingly, the highly suitable class covers 58% (1,133.10 km²) of the entire area determined by the model that is also corresponded to the areas where the model works strongly. The yield range in this class was determined between 178.32 and 201.13 kg/da. Moderately Suitable class covered 754.80 km² area that is 38% of the entire area determined by the model. The yield ranges in this class are 166.92-178.31 kg/da and 201.14-212.54 kg/da that showed areas where the model works moderately. Weakly suitable areas (78.02 km²) that covered 4% of the entire area and determined by the model and showed the areas where the model works weakly. The yield ranges in this class were determined as 164.39-166.91 kg/da and 212.55-240.83 kg/da. Although this class included the lowest and highest ranges in yield, it indicated areas where the model works weakly, so it should not be preferred for efficient cultivation of IZA wheat.

When highly and moderately suitable areas are summed (58% + 38%), the accuracy of the model reaches up to 96%. The results showed that IZA wheat can be grown efficiently and safely in Bolu province in highly and moderately suitable areas.

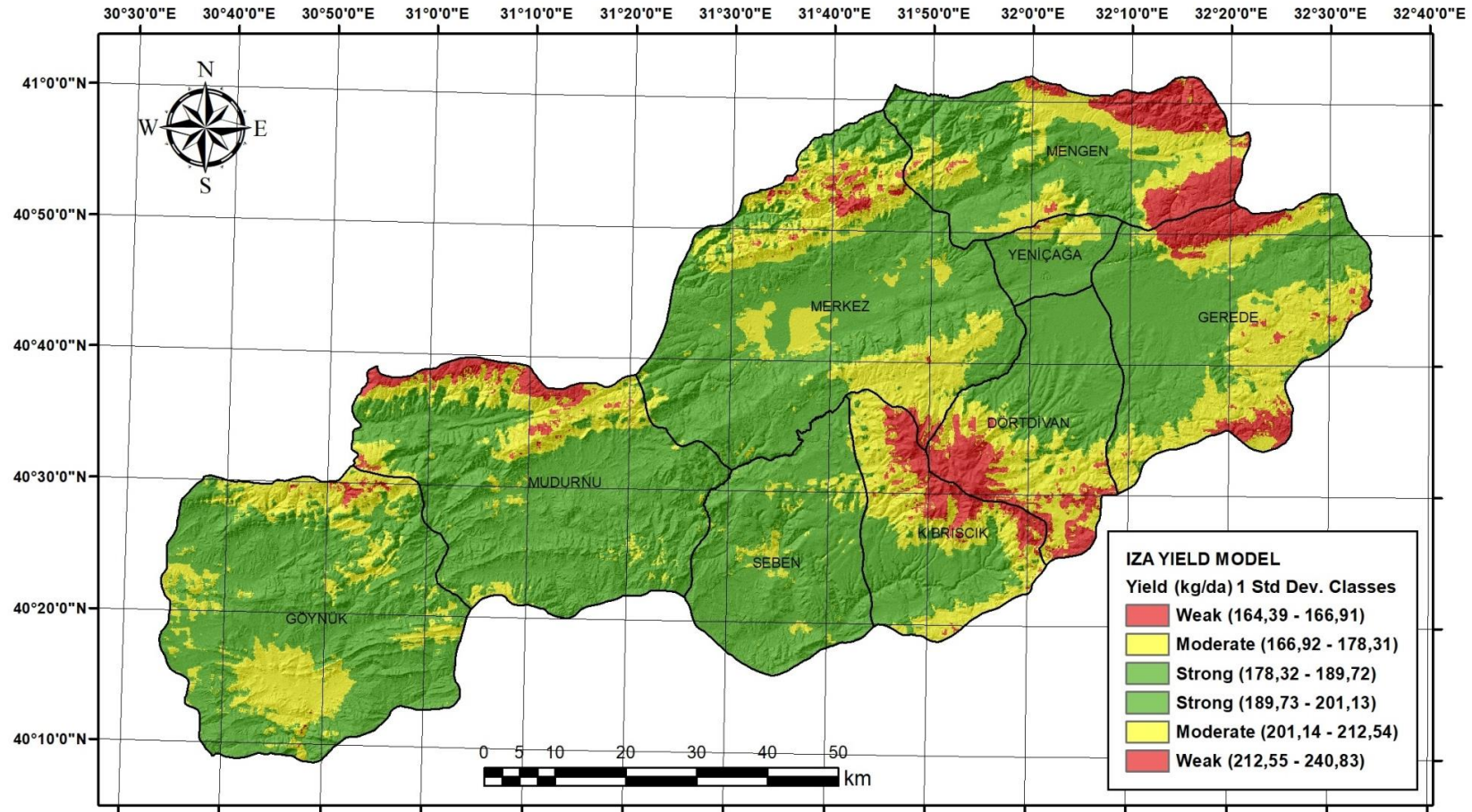


Figure 4.35. IZA yield model raster map was classified by using 1 standard deviation function in ArcGIS.

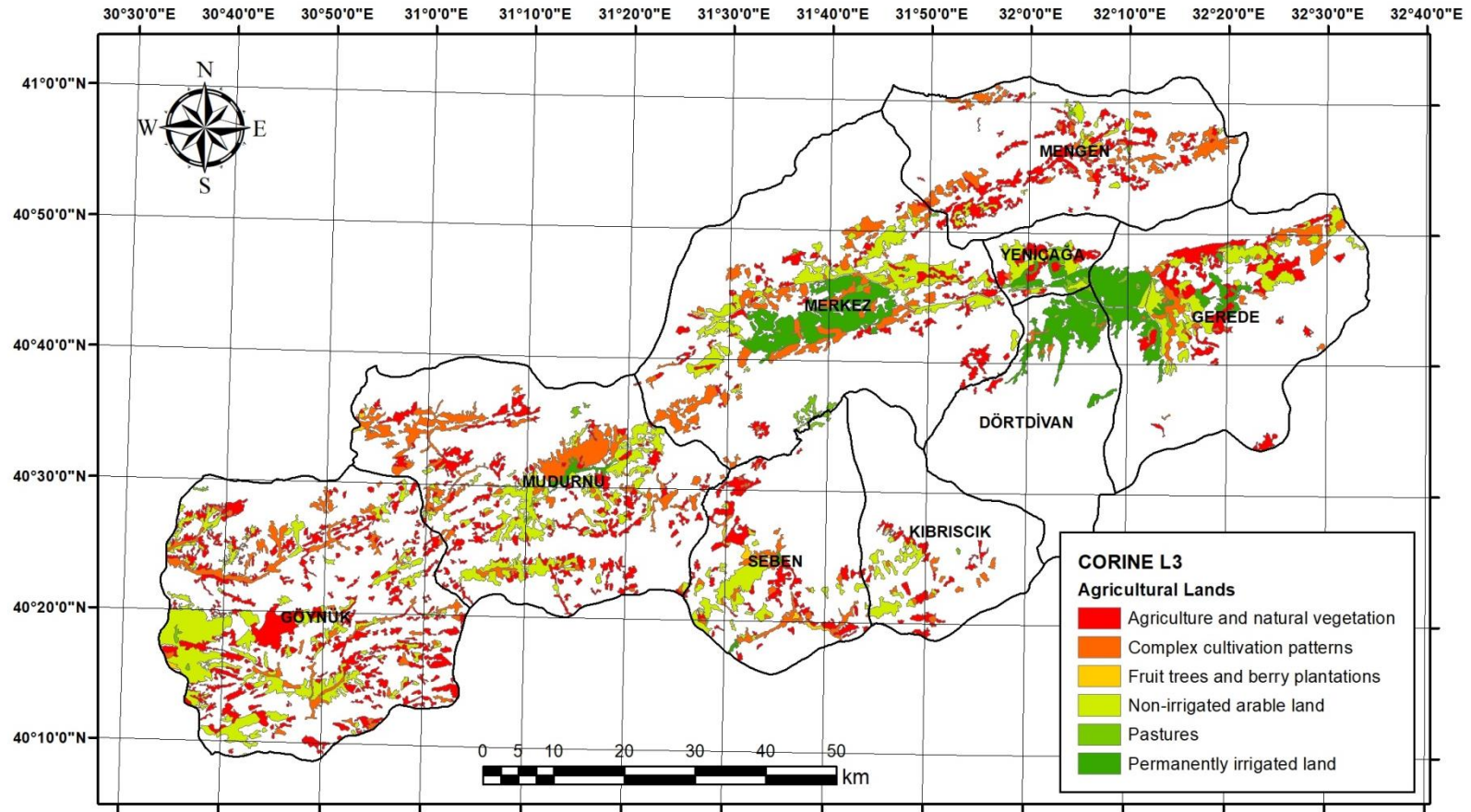


Figure 4.36. The agricultural areas of Bolu province according to CORINE 2018 Third Level Map.

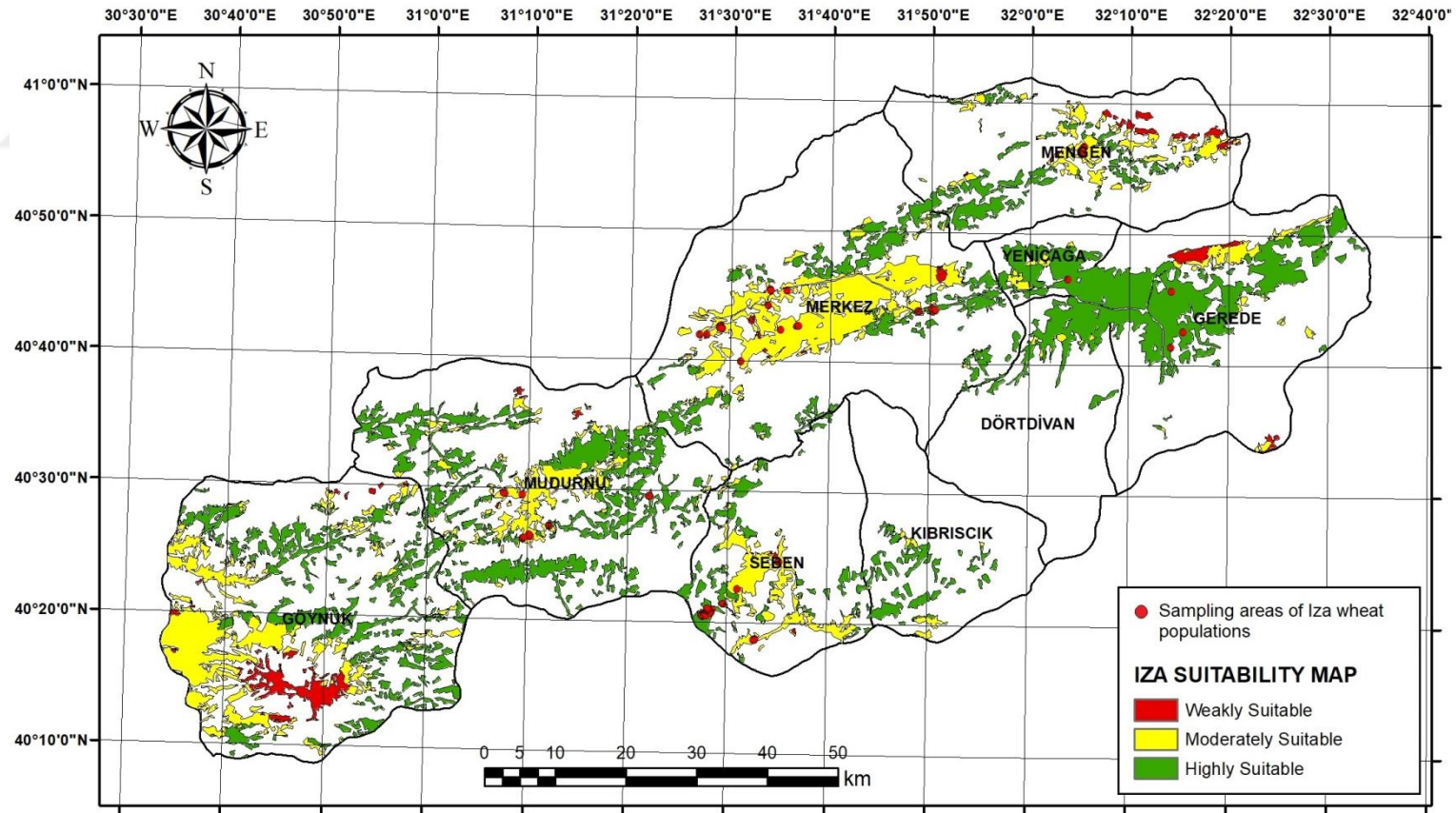


Figure 4.37. IZA wheat suitability map of Bolu Province.

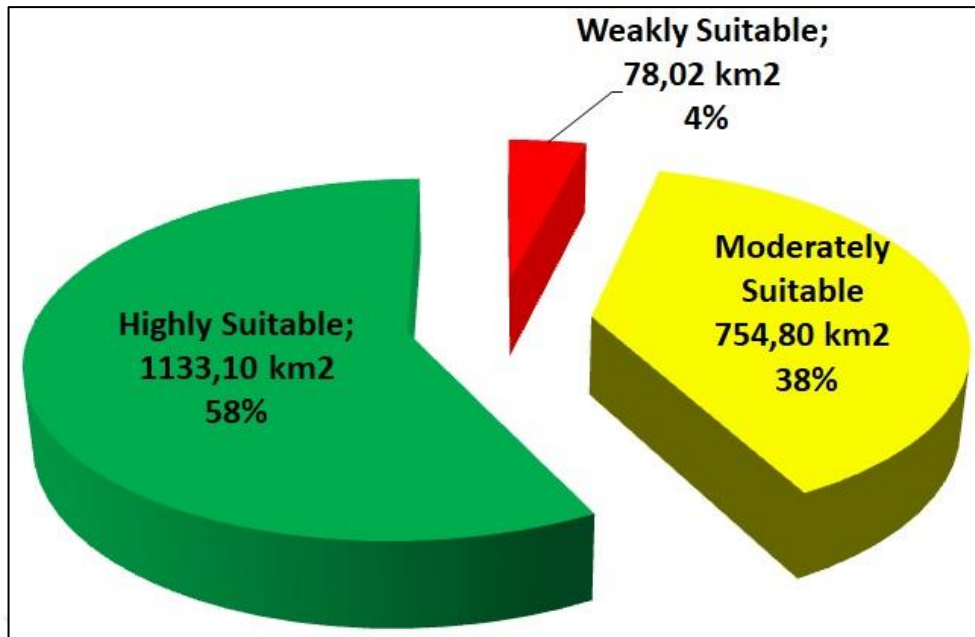


Figure 4.38. The areas covered by the classes of IZA wheat suitability map.

The points showing the sampling areas of IZA wheat populations were overlayed on the IZA wheat suitability map (Figure 4.37). Thus, it has been seen that the majority of the areas where IZA wheat is currently grown have been selected appropriately. Moreover, the IZA wheat suitability map has also revealed the existence of other potential areas where cultivation areas can be expanded efficiently and safely. Therefore, developed map has created an important data source for more accurate cultivation plans of IZA wheat in Bolu. The results also showed that Bolu province has a significant amount of potential area (1,887.9 km²) for IZA wheat cultivation. This area is 22.71% of the province's total area (8,313 km²).

5. DISCUSSION

5.1 Agro-morphological Features

Agro-morphological characteristics of wheat provide information about productivity. For example, having a large flag leaf area increases the photosynthesis ability of wheat. As a result of photosynthesis nutrients and yield increase in wheat plant.

Agro-morphological characteristics of einkorn wheat which grown in different regions of Türkiye, has been studied before. As PH provides information about the lodging of the wheat, it is the most important morphological feature for wheat. The tendency of lodging cause to decrease the yield. In general, wheat types that are not long and have a sturdy stem are preferred by farmers to plant. PH of einkorn which wheat grown in Antalya, Konya, Kastamonu and Isparta conditions, were measured as agro-morphological characteristic. The length of einkorn grown in Antalya conditions varies between 95 and 120 cm, and the average length was 107.9 cm (87). On the other hand, the PH of einkorn wheat grown in Konya were measured, and their average height was seen 74.9 cm. However, the average length of einkorn wheat grown under Kastamonu conditions was 71.3 cm (88). In the study of Karahan et al. (89), einkorn wheat which were come from different countries was grown in Cukurova conditions. The average PH was calculated as 124.88 cm. In the same study, the tallest and the shortest plants that originated from Türkiye were about 151.8 cm and 100 cm, respectively. Einkorn wheat PH was measured not only in Türkiye but also in different regions of the world. It was determined that the length of einkorn wheat grown in Bulgaria varies between 90 and 123 cm with the average of 108.04 cm (90). However, the mean length of einkorn wheat grown under Prague conditions was determined as 101 cm (91). In our study, the minimum PH was measured as 56 cm and the maximum PH was measured as 116.89 cm in Bolu conditions. The average PH of 69 einkorn wheats was 92.79 cm, as well. Even if the plant is long, the flexible structure of the stems of some plant species shows that they are resistant to lodging. Although plant height of IZA was quite long, there were no lodging seen according to our observation.

SL is one of the other researched agro-morphological characteristics in wheat. In a study of Akçura et al. (92), the SL showed significant correlation with the number of SPPS, the number of KPS, the grain weight per spike and TKW in *T. aestivum* varieties. In short, SL may provide information about the yield. There are many studies available on SL measurement of einkorn wheat, and the study of Coşkun et al. (87) was one of them. Einkorn samples were grown in Antalya conditions. The SL of those wheat ranged from 4 cm to 6.5 cm with the mean value of 4.9 cm (87). Approximately similar values were found in our study such as average of SL was 4.42 cm, minimum and maximum length was 3.97 cm, 5.10 cm, respectively. In another research study, the highest SL was measured as 12.45 cm in einkorn, which had been originated from Albania but grown under Çukurova conditions (89). SL of einkorn wheat grown under Bulgarian conditions were also measured. The average SL that including awns were measured as 15.92 cm (90). In the study of Konvalina et al. (91) shows that the average SL of einkorn was 5.3 cm in Prague (91). The reason for the different values in the studies may be due to the difference in growing conditions, genetic predispositions or the different number of samples.

TKW data is important in terms of grain size, fullness, skinniness and flour yield. The weight of TKW shows positive correlation with starch, while negative correlation with protein. Biochemical structure of the soil and ecological factors such as climate may affect the TKW of wheat. Since adverse environmental conditions reduce photosynthesis in wheat, TKW affect negatively, as well (93). In the study of Coşkun et al. (87) that was made in Antalya, the average value of einkorn TKW was measured as 21.6 g. The maximum and minimum measurement of TKW were 18.4 g, 25.5 g, respectively (87). TKW measurements were made in Isparta were found to be close to the measurements in Antalya. The average TKW of einkorn was found to be 25.70 g which were grown in Isparta province condition (94). In a study conducted in Kastamonu, TKW values ranged from 23.08 g to 38.08 g, while the average TKW was found to be 30.93 g (95). Similar results were obtained in our study, as well. In our study, the TKW values varied between 21.73 g and 35.44 g with the average value 28.44 g. In the study of Ekmeksizoğlu (96) which was conducted in Kastamonu, the average TKW of einkorn wheat was found to be 33.72 g. The highest value was measured as 39.49 g and the lowest value was

28.22 g. In another study which made by Ekmeksizoglu (96), a bivariate correlation was calculated between the altitude and TKW of einkorn wheat. According to einkorn samples taken from nine different location in Kastamonu, the Pearson value was found to be 0.782 between TKW and elevation ($p<0.05$) (96). Similar result was seen in our study with the value of 0.793 ($p<0.01$). In the study of Han and Hendek Ertop (95), a positive relationship was found between altitudes and TKW, as well. According to einkorn wheat obtained from four locations in Kastamonu the Pearson value was shown 0.960 ($p<0.05$) (95).

The number of KPS gives information about wheat yield. For this reason, it is one of the leading agro-morphological features that should be measured. In a previous study, 64 einkorn wheat genotypes were grown under Çukurova condition and the number of kernels per spike was counted (89). The highest KPS was found in the genotype coming from Albania with 68.50 kernel/spike, while einkorn wheat originating from Greece gave the lowest value with 17.77 kernel/spike. The average KPS was found to be 37.73 grain/spike, as well (89). In another study, the average of einkorn wheat grown under Konya conditions was calculated as 28.5 kernel/spike (88). The einkorn wheat which grown under Antalya conditions, the value of KPS varied between 13.7 and 40.7 kernel/spike with the mean value 20.9 kernel/spike (87). Similar results were found in this study. The KPS value values ranged from 15 kernel/spike to 41.97 kernel/spike with the average 28.86 kernel/spike.

There are few studies in the literature regarding the agro-morphological correlation studies of einkorn. The values of agro-morphological features of einkorn samples were shared detailed in the article of Coşkun et al. (87). In this article, the highest positive correlations were found between SL and TKW (0.386) at the 0.01 level. Similarly, a positive strong (0.692) significant relationship between SL and TKW had found in our study ($p<0.05$). In another study, Karahan et al. (89) grew 64 einkorn wheat in Adana/Çukurova and compared their morphological characteristics of them. They found a significant ($p<0.05$) positive correlation between UNL and PH (0.557). In this study, we also obtained similar results by achieving the significant ($p<0.05$) medium value (0.420) between UNL and PH. While positive correlations were found between UNL and SL (0.282) at the 0.05

level in the study of Karahan et al. (89), this correlation was found 0.269 at the 0.01 level in this thesis. One of the other result shows that the correlation between SL and KPS had also found significant ($p<0.05$) and strong relationship (0.665) in the study of Karahan et al. (89). According to our result, SL and KPS shows significant ($p<0.05$) and weak (0.323) relationship. Kefi et al. (97) made correlation analysis with some agro morphological values such as PH, SL and SPPS in einkorn. Positive and strong relationship was seen between PH and SL (0.834). In our study, positive but weak correlation was observed between PH and SL (0.059).

Agro-morphological characteristics were also examined in bread wheat varieties. In the study of Aktaş and İkincikarakaya (98), 17 varieties of bread wheat (*T. aestivum*) were grown in Ankara-Haymana condition. PH, FLL and FLW of these plants were measured. While the average FLL was found to be 20.1 cm, the average FLW was 1.57 cm. In addition, the average PH was measured as 72.6 cm. In another study which made by Yıldırım (99), the average PH of bread wheat was found to be 80.75 cm. The average FLW was found to be 1.41 cm, and the average FLL was 17.17 cm. In the same study, average of SL was measured as 6.78 cm, while average of TKW was found to be 31.68 g. Moreover, the mean value of KPS was found to be 24.52 grain/spike (99). In another study, 22 varieties of bread wheat were planted in Edirne conditions and agro-morphological features were examined. The highest flag leaf area (FLA) was measured as 56.32 cm² in the Tina variety, while the lowest FLA was measured as 18.54 cm² in the Kate A-1 variety. The average FLA was calculated as 25.05 cm² in 22 bread wheat varieties. The highest PH was seen in Kate A-1 variety with 119.1 cm, whereas the shortest PH was seen in Golia variety with 72.9 cm. In the study, PH showed negative and relatively weak correlation with FLA. (100). In this thesis, the average TKW of Çalibasan variant was found to be 30.833 g. The average FLL was measured as 11.980 cm, while the FLW was measured as 0.879 cm. According to calculations, the average FLA was seen 8,276 cm². Beside these, the average PH was measured as 70.748 cm. Moreover, the average SL is 4.639 cm and the average KPS is 28.200 kernel/spike in Çalibasan. However, the average TKW of the Sarı Serez variant was 30.867 g. The average FLL was 12.977 cm, while FLW was 1.235 cm. The average FLA of Sarı Serez was calculated as 12.54 cm². Moreover, average of PH was 62.40 cm and average SL was 4.629 cm. The average number of KPS was 33.229

kernel/spike, as well. The reason for these differences between the studies may be due to different variants and environmental conditions where the plants were grown.

Correlational studies on bread wheat are limited in Türkiye. Akçura et al. (92) used 13 types of bread wheat in their study. The highest and most significant relationship found between PH and SL (0.65) at the 0.05 level. On the other hand, positive and significant ($p < 0.05$) relationship between FLL - FLW (0.54), FLL - PH (0.52), FLL - SL (0.43). A significant ($p < 0.05$) but weak relationship was found between TGW - SL (0.28), TGW - PH (0.29). In the study made in Adet and Debra provinces where is in the north of Ethiopia, the agro-morphological characteristics of bread wheat were compared. In the study which made in Adet, a negative and weak relationship was found between TKW and SL, SPPS, KPS in Adet condition. In Debra, there was a negative correlation between TKW and SPPS (101). Another study that made in Tonga/Ethiopia, found that TKW had negative and weak correlation with SL. However, a positive relationship was found with TKW and PH, SPPS, KPS (102). The reason why the values were so different in this thesis was due to the use of fewer samples because only five samples were used from the Sarı Serez variant and four samples were used from the Çalıbasan variant.

5.2 Polymorphism Studies

Einkorn has become famous recently as an organic food. In addition to being rich in nutrients, the plant has genes which provide resistance to insects, drought, lodging, disease and salt stress (103-105). Einkorn is also a species rich in vitamin B₁ and vitamin B₂. Moreover, it has been determined as a result of research that it is rich in α -tocopherol, α -tocotrienol and β -tocotrienol, which are provitamin E (18). Beside these nutrient values, carotenoid types of lutein, zeaxanthin and beta carotenoid found to be high in einkorn (24). Einkorn contains genes which are responsible for carotenoids, tocols and phenolics. It has genes responsible for the uptake of some macro and micro elements, as well (106). Einkorn wheat is suitable to be evaluated in genetic improvement due to these many features. Breeders work all over the world to obtain high resistance wheat to biotic and abiotic stress. Moreover, they work hard to produce high yielding and high-quality plants, as well.

Thus, it is very important to know the heredity and genetic diversity of the plant for wheat breeders (106).

Modern wheats such as *T. aestivum* have narrow genetic diversity than their wild relatives due to the breeding programs. Breeding programs, which have been carried out in the last century, have been caused to loss of cereal genetic diversity. It has been observed that around 75% of the genetic diversity of cultivated plants has been lost in the last century. Local wheat landraces and wild wheat varieties are important genetic resources for the development of modern wheat. That's why, preserving and using local wheat varieties are very important for genetic resources. It constitutes a precaution against an unpredictable future (107).

Polymorphism studies on wheat species, variants and populations are available in the literature. In the study conducted by Yildiz et al. (106), polymorphism study of 41 genotypes (33 genotypes of *T. monococcum* L., 4 genotypes of *T. dicoccon* and 4 genotypes of *T. durum*) were carried out by using 10 SSR markers. UPGMA divides the species into two main clusters. While diploid species of einkorn placed in one group, other group contains tetraploid species of *T. dicoccon* and *T. durum*. *T. monococcum* and *T. dicoccon* had narrow genetic diversity within themselves. Beside that, the genomes of *T. dicoccon* and *T. monococcum* had been found to be markedly different relationship. Einkorn wheats are divided into five groups among themselves. The species with the most genetic similarity to each other were found in populations that were taken from the Samsun and Sinop regions (106). If einkorn had been obtained from different regions of Türkiye, perhaps there would have been differences in our polymorphism study, as well.

In another polymorphism study was made on six einkorn (*T. monococcum* ssp. *monococcum*) landraces and two bread wheat (*T. aestivum*) populations which were grown in Bolu and Kastamonu province. Twelve ISSR markers were used to analyze genetic differences. A total of 247 loci were found. Among these, 238 (96.36%) loci were found to be polymorphic, whereas 9 (3.64%) of loci were found to be monomorphic. Number of allele value (n_a) was calculated 1.96, while the number of effective alleles (n_{ae}) value was 1.3. On the other hand, genetic diversity (h) was found to be 0.2. In conclusion, two main cluster were seen on the

dendrogram. While the genomes of einkorn wheat were included in the main cluster, the other cluster included bread wheat genomes. Moreover, einkorn wheat genomes were divided into two subgroups among themselves. As a result einkorn genomes which grown in Kastamonu and grown in Bolu were divided into two subgroups (107). While the PPB (%) in the study of Özbek and Zencirci (107) was found to be 96.36%, in our study the PPB (%) within the einkorn species was 22%. Although einkorn samples were collected from Bolu and Kastamonu just like the study of Özbek and Zencirci (107), there was no significant differences between them in our study. This may be caused by the different type of marker.

In another study, genetic relationships of 14 einkorn wheat which obtained from Iğdır University were examined with 7 types of ISSR markers. At the end of the study, 68 PB were obtained. Also, the polymorphism rate (P%) average was seen 97.5%. The average genetic diversity (H) value was determined as 0.45, and the average of PIC was determined as 0.34. The average Jaccard similarity value was seen as 0.46, as well. In conclusion, genotypes were grouped in to two clusters in dendrogram (108).

One accession of *T. aestivum*, twelve accessions of *T. dicoccoides*, eight accessions of *T. urartu* and ten accessions of *T. monococcum* ssp. *boeoticum* were used in another study. Thirt-three primer of amplified fragment length polymorphism (AFLP) were tested on wheat species to see genetic differences. Total of 871 polymorphic loci were produced. According to species, *T. monococcum* ssp. *boeoticum* showed 133 loci, *T. urartu* showed 66 loci, and *T. dicoccoides* showed 141 loci. The dendrogram consists of two main clusters. One cluster includes *T. aestivum*, *T. dicoccoides* and *T. urartu*, while the other group includes only *T. monococcum* ssp. *boeoticum*. According to the subgroups, *T. aestivum* and *T. dicoccoides* had closest relationship (109). In our study, einkorn and bread wheat formed two clusters.

In the study of Pour-Aboughadareh et al. (110), total of 180 samples were collected that included *Aegilops umbellulata* Zhuk., *A. cylindrical* Host., *A. crassa* Boiss., *A. speltoides*, *A. caudata* L., Tausch., *A. triuncialis*, *A. neglecta* L., *A. tauschii* Coss., *T. durum*, *T. boeoticum* Boiss., *T. urartu* Gandilyan and *T. aestivum* species. Fifteen SCoT primers were used for polymorphism study. *A. cylindrica*, *A.*

umbellulata, *T. boeoticum* and *T. durum* showed high genetic diversity, while *A. tauschii*, *T. aestivum*, *T. boeoticum*, *T. durum* and *T. urartu* showed close relationship. According to the dendrogram 180 of samples were divided into 8 clusters and 11 subgroups. *Triticum aestivum* and *T. durum* were distributed in a single group (110).

In another polymorphism study, 70 accessions were used including *T. boeoticum*, *T. aestivum* ve *T. durum* species which were taken from different region of Iran. Fifteen SCoT primers were used to characteries genetic polymorphism. There were 166 bands seen and 162 (97.59%) bands were polymorphic. The polymorphism information content (PIC) value was equal to 0.46. As a result of ANOVA, there was 63% genetic difference within, while there was 10% genetic difference between populations. The mean number of alleles (N_a) was 1.58. As a result, *T. durum* and *T. boeoticum* showed lowest relationship. Three main cluster has been seen at the dendrogram. First cluster (C1) further divided into two subgroups included *T. durum* and *T. aestivum*. However, *T. boeoticum* and *T. urartu* were in the other two clusters (C2, C3) (50).

Another genetic polymorphism study was conducted in China. Total of nineteen accession were examined included *Thinopyrum* Á. Löve, *Triticum* L. and *Hordeum* L. genera. Seventeen SCoT markers created 144 bands. Ninety-five bands were amplified and 81 of them showed polymorphic (85.3 %) for *Thinopyrum* species, while 97 bands were amplified and 83 of them showed polymorphic (85.6 %) for *Triticum* species. The mean observed alleles was 8.5 in *Thinopyrum* and *Triticum* species. While the average PIC value of *Thinopyrum* species was 0.716, this value was 0.682 for *Triticum* species. Beside these, PIC values among species vary between 0.374 and 0.890. Three clusters were formed in the dendrogram. The closest relationship was seen between *Triticum* and *Thinopyrum*, whereas *Hordeum* was found to be distantly related to other species. In one of the subgroups, *T. monococcum*, *T. aestivum* ssp. *spelta* and *T. aestivum* ssp. *aestivum* were closely related with each other (47). In our study, bread wheat and einkorn showed 62% similarity.

Polymorphism studies of 51 accessions, including different species of the *Aegilops* and *Triticum* genera obtained from Iraq, were studied. Eighteen different

SCoT markers were used and 139 bands were formed, 129 of these bands showed polymorphic for accessions. On the other hand, average PIC value was calculated as 0.56. Species formed three main groups in the dendrogram. While *T. boeoticum*, *T. dicoccoides*, *T. aestivum*, *A. triuncialis* L. were included in Group 1, *A. lorentii* Hochst. was included in Group 3, and other *Aegilops* species were included in Group 2. According to this dendrogram, it was seen that the A genomes were clustered together (52).

When local varieties are grown in the same environment for a long time, the seeds degenerate or get tired. Yield capacity does not change, however quality decreases and some characteristic features get lost. To avoid this situation, farmers exchange seeds among themselves. Because of this seed exchange, which has become traditional for farmers, gene diversity increases and germplasm expands. In this study, genetic polymorphism may not have been found between einkorn populations, as seeds may not be exchanged and always may be grown in same region by farmers in Bolu.

5.3 Geographic Information Systems and Remote Sensing

Topographic (elevation, slope, aspect), climate (precipitation, maximum-minimum-mean temperatures and bioclimate), soil (bulk density, coarse fragment, sand, silt, clay, CEC, nitrogen, organic carbon, pH, great soil groups and land use capability) and CORINE (land use/cover) complementary database (raster maps) of Bolu province were created. Moreover, Great Soil Groups and Land suitability was examined by using KHGM data. Such a study has not been conducted before for Bolu province.

In today's conditions, agriculture is not only a strategic sector but also an element of national security. Therefore, it is essential to manage and plan the resources to be used in agricultural production correctly. Resource management and planning in agriculture is a complex process that requires the evaluation of many different components together. Within the scope of the thesis study, a model has been developed to evaluate heterogeneous data with different functions in order to facilitate this complex process. With this model, the ecological suitability of IZA wheat in Bolu province was modulated, calculated, mapped and classified. Using

yield and the environmental variables strongly effective on yield, a yield model of IZA wheat that shows potential growing areas was developed by multiple regression and mapped by GIS at the end of this study. Among Bolu districts, Göynük, Mudurnu, Seben, Mengen, Yeniçağa and Bolu center have lands that can be considered as suitable regions for planting to IZA. In this thesis, IZA wheat suitability map was created. The points showing the sampling areas of IZA wheat populations were overlayed on the IZA wheat suitability map. Thus, it has been seen that the majority of the areas where IZA wheat is currently grown have been selected appropriately. Moreover, the IZA wheat suitability map has also revealed the existence of other potential areas where cultivation areas can be expanded efficiently and safely. Therefore, developed map has created an important data source for more accurate cultivation plans of IZA wheat in Bolu. The results also showed that Bolu province has a significant amount of potential area (1887.9 km²) for IZA wheat cultivation. This area is 22.71% of the province's total area (8313 km²).

6. CONCLUSIONS AND RECOMMENDATIONS

The elevation, climate, soil and land use characteristics of Bolu province were investigated in this study. Elevation values were examined by using ASTER DEM data, climate values were examined by using CHELSA data, topographic structure was examined by using ISRIC data, and land cover and use were examined by using the Corin database. At the same time, the agro-morphological characteristics of local wheat varieties grown in Bolu were observed, as well. In the continuation of these studies, the effects of ecological variables (topographic, climatic and soil) on agro-morphological characteristics of wheat species were examined. A model was created with these data, and the most suitable (potential) areas were determined. Through the model created, potential areas for planting in the desired regions can be selected in future studies. Polymorphism studies were also studied. There was no high degree of polymorphism found among IZA populations. This may be because they grew in the same region, and seeds were not exchanged by farmers.

7. REFERENCES

Vancouver citation system was used in this thesis.

1. Harlan JR. The living fields: our agricultural heritage: Cambridge University Press; 1998.
2. van Zeist W, de Roller GJ. Plant remains from Asikli Höyük, a pre-pottery Neolithic site in central Anatolia. *Vegetation History and Archaeobotany*. 1995;4:179-85.
3. Karagöz A, Zencirci N, Tan A, Taşkın T, Köksel H, Sürek M, et al. Bitki genetik kaynaklarının korunması ve kullanımı. Türkiye Ziraat Mühendisliği VII Teknik Kongresi. 2010;11(15):155-77.
4. Onur M, Ceylan F. Heritage of the Anatolian geography: registered varieties of ancestral wheat (siyez, gacer, and menceki). *Journal of Ethnic Foods*. 2023;10(1):36.
5. WWF-Türkiye. Türkiye'nin buğday atlası. 2016.
6. Gökçöl M. Türkiye'nin Buğdayları. Tom II İstanbul. 1939.
7. Özberk F, Karagöz A, Özberk İ, Ayhan A. Buğday genetik kaynaklarından yerel ve kültür çeşitlerine; Türkiye'de buğday ve ekmek. *Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi*. 2016;25(2):218-33.
8. Altay F. Eskişehir Ziraat Araştırma Enstitüsünün kuruluşu ve yaptığı çalışmalar II. *TÜRKTOB*. 2012;4:64-7.
9. Chantret N, Salse J, Sabot F, Rahman S, Bellec A, Laubin B, et al. Molecular basis of evolutionary events that shaped the hardness locus in diploid and polyploid wheat species (*Triticum* and *Aegilops*). *The Plant Cell*. 2005;17(4):1033-45.
10. Feldman M, Lupton G, Miller T. Evolution of crops. Longman Scientific London; 1995.
11. Tanksley SD, McCouch SR. Seed banks and molecular maps: unlocking genetic potential from the wild. *science*. 1997;277(5329):1063-6.
12. Aslan D, Aktaş H, Ordu B, Zencirci N. Evaluation of bread and einkorn wheat under *in vitro* drought stress. *The J Animal Plant Sci*. 2017;27(6):1974-83.
13. Aslan D, Ordu B, Zencirci N. Einkorn wheat (*Triticum monococcum* ssp. *monococcum*) tolerates cold stress better than bread wheat (*Triticum aestivum* L.) during germination. *Biotech Studies*. 2016.
14. Hidalgo A, Brandolini A. Nutritional properties of einkorn wheat (*Triticum monococcum* L.). *Journal of the Science of Food and Agriculture*. 2014;94(4):601-12.
15. Thakur P, Kumar S, Malik JA, Berger JD, Nayyar H. Cold stress effects on reproductive development in grain crops: an overview. *Environmental and Experimental Botany*. 2010;67(3):429-43.
16. Nezhadahmadi A, Prodhan ZH, Faruq G. Drought tolerance in wheat. *The Scientific World Journal*. 2013;2013.
17. Pinheiro HA, DaMatta FM, Chaves AR, Fontes EP, Loureiro ME. Drought tolerance in relation to protection against oxidative stress in clones of *Coffea canephora* subjected to long-term drought. *Plant science*. 2004;167(6):1307-14.

18. Karakas FP, Keskin CN, Agil F, Zencirci N. Profiles of vitamin B and E in wheat grass and grain of einkorn (*Triticum monococcum* spp. *monococcum*), emmer (*Triticum dicoccum* ssp. *dicoccum* Schrank.), durum (*Triticum durum* Desf.), and bread wheat (*Triticum aestivum* L.) cultivars by LC-ESI-MS/MS analysis. *Journal of Cereal Science*. 2021;98:103177.
19. Coates PM, Paul MC, Blackman M, Blackman MR, Cragg GM, Levine M, et al. *Encyclopedia of Dietary Supplements* (Online): CRC press; 2004.
20. McCormick DB. Riboflavin. *Present knowledge in nutrition*. 2012;280-92.
21. Tahiliani AG, Beinlich CJ. Pantothenic acid in health and disease. *Vitamins and Hormones*. 1991;46:165-228.
22. Bailey LB, Caudill MA. Folate. 2012. 321-42 p.
23. Shahidi F, De Camargo AC. Tocopherols and tocotrienols in common and emerging dietary sources: occurrence, applications, and health benefits. *International Journal of Molecular Sciences*. 2016;17(10):1745.
24. Lachman J, Hejtmánková K, Kotíková Z. Tocols and carotenoids of einkorn, emmer and spring wheat varieties: Selection for breeding and production. *Journal of Cereal Science*. 2013;57(2):207-14.
25. Karakas FP, Keskin CN, Agil F, Zencirci N. Phenolic composition and antioxidant potential in Turkish einkorn, emmer, durum, and bread wheat grain and grass. *South African Journal of Botany*. 2022;149:407-15.
26. Yönel O, Özdil S. Çölyak hastalığı. *Güncel Gastroenteroloji*. 2014;18(1):93-100.
27. Geisslitz S, Wieser H, Scherf KA, Koehler P. Gluten protein composition and aggregation properties as predictors for bread volume of common wheat, spelt, durum wheat, emmer and einkorn. *Journal of Cereal Science*. 2018;83:204-12.
28. Hidalgo A, Brandolini A, Ratti S. Influence of genetic and environmental factors on selected nutritional traits of *Triticum monococcum*. *Journal of agricultural and food chemistry*. 2009;57(14):6342-8.
29. Erba D, Hidalgo A, Bresciani J, Brandolini A. Environmental and genotypic influences on trace element and mineral concentrations in whole meal flour of einkorn (*Triticum monococcum* L. subsp. *monococcum*). *Journal of cereal Science*. 2011;54(2):250-4.
30. Moshawih S, Abdullah Juperi RaNA, Paneerselvam GS, Ming LC, Liew KB, Goh BH, et al. General health benefits and pharmacological activities of *Triticum aestivum* L. *Molecules*. 2022;27(6):1948.
31. Rajoria A, Mehta A, Mehta P, Ahirwal L, Shukla S. Phytochemical analysis and estimation of major bioactive compounds from *Triticum aestivum* L. grass with antimicrobial potential. *Pak J Pharm Sci*. 2015;28(6):2221-5.
32. Marrelli M, Sprovieri P, Conforti F, Statti G. Phytochemical content and antioxidant activity of ancient majorca and carosella (*Triticum aestivum* L.) Wheat Flours. *Agronomy*. 2021;11(6):1217.
33. Tangüler H, Eleroğlu H, Özer EA, Işıklı Develi N. Unutulmak üzere olan geleneksel tatlımız: Uğut. *Türk Tarım - Gıda Bilim ve Teknolojisi Dergisi*. 2015;3(7):604-9.
34. (GEF) GEF. Turkey-In-Situ Conservation of Genetic Diversity Project, Project Document, 11295-TU, February, 1993, Washington, D.C. : World Bank Group. . 1993.

35. Negri V, Tiranti B. Effectiveness of in situ and ex situ conservation of crop diversity. What a *Phaseolus vulgaris* L. landrace case study can tell us. *Genetica*. 2010;138:985-98.
36. Özberk İ, Atay S, Altay F, Cabi E, Özkan H, Atlı A. Türkiye'nin buğday atlası. İstanbul: WWF-Türkiye. 2016:5-84.
37. Karagöz A. In situ conservation of plant genetic resources in Ceylanpınar State Farm. Zencirci, N, Z Kaya, Y Anikster and WT Adams (eds). 1998.
38. Karagöz A, Zencirci N, Tan A, Taşkın T, Köksel H, Sürek M, et al. Bitki genetik kaynaklarının korunması ve kullanımı, Türkiye Ziraat Mühendisliği VII. Teknik Kongresi. 2010.
39. Doğan H. Coğrafi Bilgi Sistemleri ve Uzaktan Algılamanın tarımsal amaçlı kullanımı, 1. Uluslararası Uzay Sempozyumu, Ankara. 2001.
40. Arslan N. 2010 uluslararası biyoçeşitlilik yılı münasebetiyle tarımsal biyoçeşitlilik ve yerel çeşitlerin/ekotiplerin önemi. *Ziraat Mühendisliği*. 2010(354):4-9.
41. T.C. Tarım ve Orman Bakanlığı DKvMPGMD. Korunan Alan İstatistikleri, 2022 İstatistikî Tablolar <https://www.tarimorman.gov.tr/DKMP/Menu/18/Korunan-Alan-Istatistikleri2022> [updated 30 October 2023].
42. Dogan HM, Dogan M, Celep F. Recent innovations brought by geographic information systems and remote sensing in vegetation and flora studies in Turkey. *Bocconea*. 2012;24:61-7.
43. Gorji AM, Poczar P, Polgar Z, Taller J. Efficiency of arbitrarily amplified dominant markers (SCoT, ISSR and RAPD) for diagnostic fingerprinting in tetraploid potato. *American journal of potato research*. 2011;88:226-37.
44. Rai MK. Start codon targeted (SCoT) polymorphism marker in plant genome analysis: current status and prospects. *Planta*. 2023;257(2):34.
45. Satya P, Karan M, Jana S, Mitra S, Sharma A, Karmakar P, et al. Start codon targeted (SCoT) polymorphism reveals genetic diversity in wild and domesticated populations of ramie (*Boehmeria nivea* L. Gaudich.), a premium textile fiber producing species. *Meta gene*. 2015;3:62-70.
46. Collard BC, Mackill DJ. Start codon targeted (SCoT) polymorphism: a simple, novel DNA marker technique for generating gene-targeted markers in plants. *Plant molecular biology reporter*. 2009;27:86-93.
47. Guo J, Yu X, Yin H, Liu G, Li A, Wang H, et al. Phylogenetic relationships of *Thinopyrum* and *Triticum* species revealed by SCoT and CDDP markers. *Plant Systematics and Evolution*. 2016;302:1301-9.
48. Seyedimoradi H, Talebi R, Fayaz F. Geographical diversity pattern in Iranian landrace durum wheat (*Triticum turgidum*) accessions using start codon targeted polymorphism and conserved DNA-derived polymorphism markers. *Environmental and Experimental Biology*. 2016;14(2).
49. Etminan A, Pour-Aboughadareh A, Mohammadi R, Ahmadi-Rad A, Noori A, Mahdavian Z, et al. Applicability of start codon targeted (SCoT) and inter-simple sequence repeat (ISSR) markers for genetic diversity analysis in durum wheat genotypes. *Biotechnology and Biotechnological Equipment*. 2016;30(6):1075-81.
50. Pour-Aboughadareh A, Ahmadi J, Mehrabi A, Etminan A, Moghaddam M. Assessment of genetic diversity among Iranian *Triticum* germplasm using agro-morphological traits and start codon targeted (SCoT) markers. *Cereal Research Communications*. 2017;45(4):574-86.

51. Gholamian F, Etminan A, Changizi M, Khaghani S, Gomarian M. Assessment of genetic diversity in *Triticum urartu* Thumanjan ex Gandilyan accessions using start codon targeted polymorphism (SCoT) and CAAT-box derived polymorphism (CBDP) markers. *Biotechnology & Biotechnological Equipment*. 2019;33(1):1653-62.
52. Ahmad N. Assessment of genetic relation for *Aegilops* and *Triticum* possessing different genome-bearing species using start codon targeted marker. *Genetic Resources and Crop Evolution*. 2023;1-15.
53. Gençtan ABT. Bazı fotosentez organlarının ekmeklik buğdayda verim unsurları üzerine etkileri. *Tekirdağ Ziraat Fakültesi Dergisi*. 2009;6(2):137-48.
54. Mahmood N, Chowdhry MA. Removal of green photosynthetic structures and their effect on some yield parameters in bread wheat. *Kokohama Foundation for the Advancement of Life Sciences*. 1997.
55. Araus JL, Tapia L. Photosynthetic gas exchange characteristics of wheat flag leaf blades and sheaths during grain filling: the case of a spring crop grown under Mediterranean climate conditions. *Plant physiology*. 1987;85(3):667-73.
56. Demir F, Topal A. Konya koşullarında buğday genotiplerinde yatmanın verim ve kaliteye etkisi. *Bahri Dağdaş Bitkisel Araştırma Dergisi*. 2020;9(2):113-21.
57. Reitz LP, Salmon SC. Hard red winter wheat improvement in the Plains: A 20-year summary: US Department of Agriculture; 1959.
58. Berry P, Sterling M, Spink J, Baker C, Sylvester-Bradley R, Mooney S, et al. Understanding and reducing lodging in cereals. *Advances in agronomy*. 2004;84(04):215-69.
59. Laude H, Pauli AW. Influence of lodging on yield and other characters in winter wheat. *Agronomy Journal*. 1956;48(10):452-5.
60. Simmons S, Oelke E, Wiersma J, Lueschen W, Warnes D. Spring wheat and barley responses to ethephon. *Agronomy Journal*. 1988;80(5):829-34.
61. Liu H, Shi Z, Ma F, Xu Y, Han G, Zhang J, et al. Identification and validation of plant height, spike length and spike compactness loci in common wheat (*Triticum aestivum* L.). *BMC Plant Biology*. 2022;22(1):1-17.
62. GDM. Downloadable Data & Files: Political Map of Turkey (Turkish Civil Administrative Boundaries) in ESRI shp format. General Directorate of Mapping. 2023 [Available from: <https://www.harita.gov.tr/urun/turkiye-mulki-idare-sinirlari/232>].
63. Sensoy S, Demircan M, Ulupinar Y, Balta I. Climate of Turkey. Turkish State Meteorological Service: Ankara. 2016.
64. Peterson A. Köppen Climate Types of Turkey (in svg format). 2016 [Available from: https://upload.wikimedia.org/wikipedia/commons/5/55/Turkey_K%C3%B6ppen.svg].
65. Köppen W. Klassifikation der Klimate nach Temperatur, Niederschlag und Jahresablauf (Classification of climates according to temperature, precipitation and seasonal cycle). *Petermanns Geogr Mitt*. 1918;64:193-203, 43-48.
66. Anonymous. Köppen climate classification 2023 [Available from: https://en.wikipedia.org/wiki/K%C3%B6ppen_climate_classification#cite_ref-4].
67. GDM. Official Statistics: Seasonal Normals for Provinces 1991-2020. General Directorate of Meteorology. 2022 [Available from: <https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=undefined&m=BOLU>].

68. CLC. CORINE Land Cover: 2018. COPERNICUS, Land Monitoring Service. 2018 [Available from: <https://land.copernicus.eu/pan-european/corine-land-cover/clc2018>].
69. TSI. Turkish Statistical Institute, Central Distribution System (cereals and other herbal products of Bolu Province in 2021) 2021 [Available from: <https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr>].
70. Diversity Arrays. Diversity Arrays Technology 2024 [Available from: <https://www.diversityarrays.com>].
71. ESRI. Arc GIS 10.5 Desktop (Software). Environmental System Research Institute, Redlands, California.2016.
72. White B. Esri ArcGIS Desktop Associate Certification Study Guide: For 10.5. Redlands, CA: ESRI; 2018.
73. EARTHDATA. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Terrain Model 1 arc second, Version: 3 (ASTGTM v003). National Aeronautics and Space Administration (NASA) of the United States. 2023 [Available from: <https://lpdaac.usgs.gov/products/astgtmv003/>].
74. ISRIC. World Soil Information, Purpose and Strategy. International Soil Reference and Information Center. 2023 [Available from: <https://www.isric.org/about>].
75. ISRIC. World Data Centre for Soils (WDC-Soils). International Soil Reference and Information Center. 2023 [Available from: <https://www.isric.org/about/world-data-centre-soils-wdc-soils>].
76. ISRIC. Soilgrids Data 2024 [Available from: <https://soilgrids.org/>].
77. WSL. CHELSA – Free climate data at high resolution: Swiss Federal Institute for Forest, Snow and Landscape Research (WSL); 2023 [Available from: <https://www.wsl.ch/en/services-produkte/chelsa-free-climate-data-at-high-resolution/>].
78. Karger DN, Zimmermann NE. Climatologies at High resolution for the Earth Land Surface Areas, CHELSA V2.1: Technical specification. Birmendorf Switzerland: Swiss Federal Research Institute WSL; 2021.
79. WSL. CHELSA - Climate Data 2024 [Available from: <https://envicloud.wsl.ch/#/>].
80. TÜİK. Corine Arazi Örtüsü: Türkiye İstatistik Kurumu, Resmi İstatistik Portalı; 2017 [Available from: <http://www.resmiistatistik.gov.tr/detail/subject/corine-arazi-ortusu/>].
81. Allen P, Bennett K, Heritage B. SPSS statistics version 22: A practical guide: Cengage Learning Australia; 2014.
82. SPSS. IBM SPSS Statistics Software. 22 ed. Chicago: SPSS Inc.; 2013.
83. Rohlf FJ. NTSYS-pc: Numerical Taxonomy and Multivariate Analysis System. 2.1 ed. New York: Exeter Publishing Setauket; 2000.
84. Sokal RR, Rohlf FJ. Biometry: the Principles and Practice of Statistics in Biological Research. 4 ed. New York: W.H. Freeman and Company; 2012. 915 p.
85. Atalay İ. Genel Fiziki Coğrafya. 6 ed. META Basım ve Matbaacılık Hizmetleri, Bornova, İzmir. 2005.
86. Atalay İ. Toprak oluşumu, sınıflandırılması ve coğrafyası. Third ed. Ankara: Çevre ve Orman Bakanlığı; 2006.

87. Coşkun İ, Tekin M, Akar T. Characterization of Turkish diploid and tetraploid hulled wheat lines for some agromorphological traits. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*. 2019;5(2):322-34.
88. Gurcan K, Demirel F, Tekin M, Demirel S, Akar T. Molecular and agro-morphological characterization of ancient wheat landraces of turkey. *BMC plant biology*. 2017;17:1-10.
89. Karahan İ, Sesiz U, Özkan H. Siyez buğday ıslahında kullanılabilecek gen kaynaklarının agromorfolojik karakterizasyonu- (agro-morphological characterization of genetic sources that can be used In einkorn wheat breeding). In: Erkmen O, editor. *Uluslararası Gıda, Tarım Ve Hayvancılık Kongresi*; 19-22 Eylül 2019; Gaziantep/Türkiye 2019. p. 354-9.
90. Uzundzalieva K, Desheva G, Valchinova E, Kyosev B. Comparative evaluation of einkorn accessions (*Triticum monococcum* L.) of some main agricultural characters. *Agro-knowledge Journal*. 2016;17(1):69-80.
91. Konvalina P, Capouchová I, Stehno Z, Moudry J. Agronomic characteristics of the spring forms of the wheat landraces (einkorn, emmer, spelt, intermediate bread wheat) grown in organic farming. *Journal of Agrobiology*. 2010;27(1):9-17.
92. Akçura M, Dokuyucu T, Kara R, Akkaya A. Ekmeklik buğdayda (*Triticum aestivum* L.) verim karakterlerinin çok değişkenli veri analiz yöntemleri ile yorumlanması. *Bitkisel Araştırma Dergisi*. 2004;1(1):32-8.
93. Doğan Y, Kendal E. Diyarbakır koşullarında bazı ekmeklik buğday (*Triticum aestivum* L.) genotiplerinin tane verimi ve bazı kalite özelliklerinin belirlenmesi. *Yüzüncü Yıl University Journal of Agricultural Sciences*. 2013;23(3):199-208.
94. Atar B, Kara B. Comparison of grain yield and some characteristics of hulled, durum and bread wheat genotypes varieties. *Turkish Journal of Agriculture-Food Science and Technology*. 2017;5(2):159-63.
95. Han Ş, Hendek Ertop M. Kastamonu'da üretilen siyez buğdayının (*Triticum monococcum*) bazı kimyasal ve fiziksel özellikleri. *Akademik Gıda*. 2022;20(1):63-70.
96. Ekmeksizozğlu B. Kastamonu yöresinde yetiştirilen siyez (*Triticum monococcum* L.) buğdayının bazı kalite özellikleri ile bazlama ve erişte yapımında kullanımının araştırılması. *Ulusal Tez Merkezi: Ondokuz Mayıs Üniversitesi*; 2016.
97. Kefi S, Kavuncu O, Bıyıklı E, Salantur A, Alyamaç ME, Evlice AK, et al. Morpho-agronomical and nutritional evaluation of cultivated einkorn wheat (*Triticum monococcum* L. ssp. *monococcum*) lines sown in autumn and spring seasons. *Asian Journal of Agriculture and Food Sciences* (ISSN: 2321-1571). 2021;9(1).
98. Aktaş B, İkincikarakaya SÜ. Bazı ekmeklik buğday (*Triticum aestivum* L.) çeşitlerinin çeşit ayırım kriterleri yönünden incelenmesi. *ECSAC'19 Vth European Conference on Science-Artculture*; Ankara. 2019. p. 420-32.
99. Yıldırım GH. Yağışa dayalı koşullarda ileri ekmeklik buğday (*Triticum aestivum* L.) hatlarının uyum yeteneklerinin belirlenmesi. *Ulusal Tez Merkezi: Ordu Üniversitesi*; 2023.
100. Öztürk İ, Avcı R. Ekmeklik buğdayda (*Triticum aestivum* L.) tane verimi ile bazı tarımsal karakterler arası ilişkiler. *Journal of Field Crops Central Research Institute (Turkey)*. 2014;23(2).
101. Baye A, Berihun B, Bantayehu M, Derebe B. Genotypic and phenotypic correlation and path coefficient analysis for yield and yield-related traits in advanced bread wheat (*Triticum aestivum* L.) lines. *Cogent Food and Agriculture*. 2020;6(1):1752603.

102. Dabi A, Mekbib F, Desalegn T. Estimation of genetic and phenotypic correlation coefficients and path analysis of yield and yield contributing traits of bread wheat (*Triticum aestivum* L.) genotypes. *International Journal of Natural Resource Ecology and Management*. 2016;1(4):145-54.
103. Feuillet C, Travella S, Stein N, Albar L, Nublat A, Keller B. Map-based isolation of the leaf rust disease resistance gene Lr10 from the hexaploid wheat (*Triticum aestivum* L.) genome. *Proceedings of the National Academy of Sciences*. 2003;100(25):15253-8.
104. Lebedeva T, Peusha H. Genetic control of the wheat *Triticum monococcum* L. resistance to powdery mildew. *Russian Journal of Genetics*. 2006;42:60-6.
105. Sodkiewicz W, Strzembicka A. Application of *Triticum monococcum* for the improvement of triticales resistance to leaf rust (*Puccinia triticina*). *Plant Breeding*. 2004;123(1):39-42.
106. Yildiz A, Hajyzadeh M, Ozbek K, Nadeem MA, Hunter D. Molecular characterisation of the oldest domesticated Turkish einkorn wheat landraces with simple sequence repeat (SSR) markers. *Biotechnology and Biotechnological Equipment*. 2021;35(1):1291-300.
107. Özbek Ö, Zencirci N. Characterization of genetic diversity in cultivated einkorn wheat (*Triticum monococcum* L. ssp. *monococcum*) landrace populations from Turkey as revealed by ISSR. *Russian Journal of Genetics*. 2021;57(6):681-9.
108. Demirel F. Bazı siyez buğdaylarının ISSR Markörleri ile karakterizasyonu. *Journal of Agriculture*. 2020;3(2):33-9.
109. Gülbitti-Onarici S, Sümer S, Özcan S. Determination of phylogenetic relationships between some wild wheat species using amplified fragment length polymorphism (AFLP) markers. *Botanical Journal of the Linnean Society*. 2007;153(1):67-72.
110. Pour-Aboughadareh A, Ahmadi J, Mehrabi AA, Etminan A, Moghaddam M. Insight into the genetic variability analysis and relationships among some *Aegilops* and *Triticum* species, as genome progenitors of bread wheat, using SCoT markers. *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology*. 2018;152(4):694-703.