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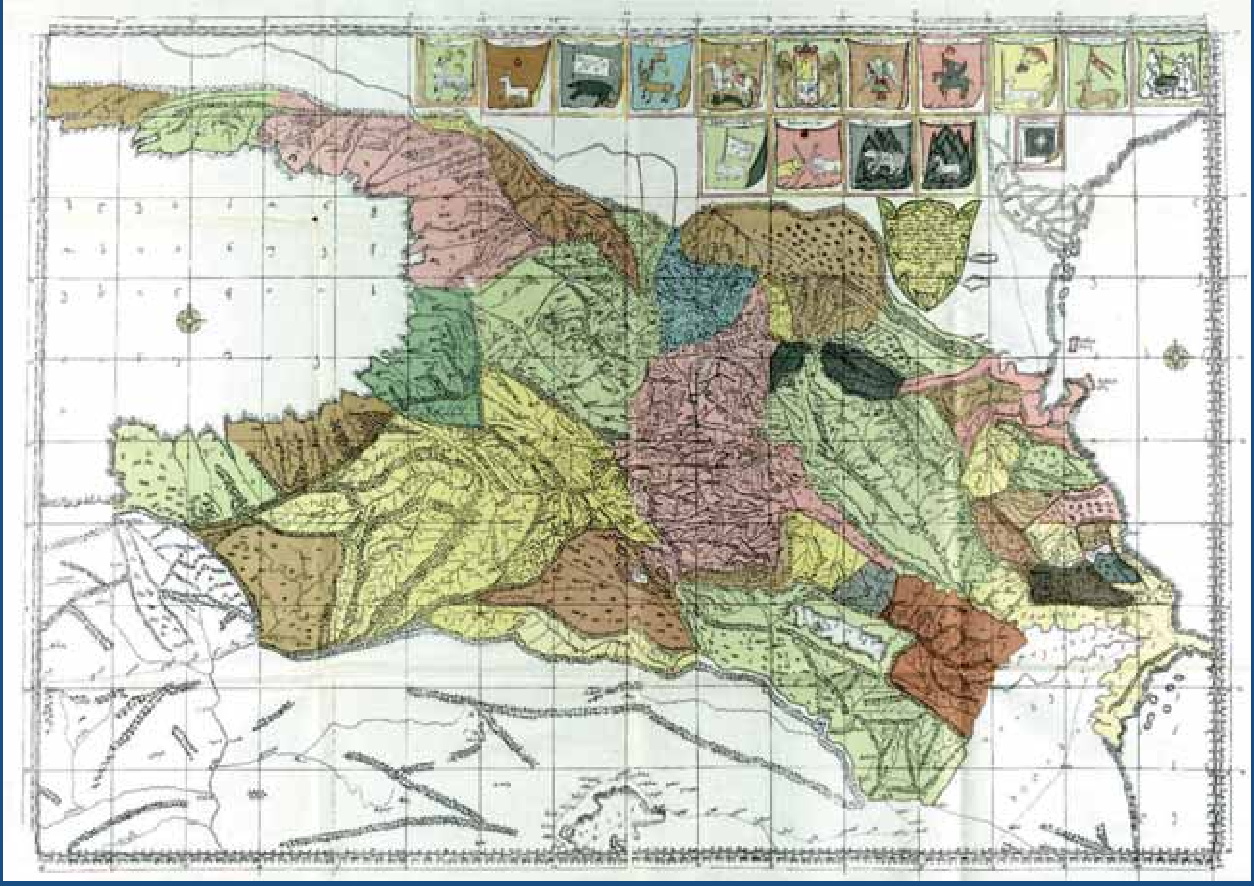
CLIMATE ANALYSIS FOR MODERN GEORGIAN VITICULTURE

A PRACTICAL HANDBOOK FOR VITICULTURISTS



Georgian Wine
National Wine Agency

Tbilisi, 2022

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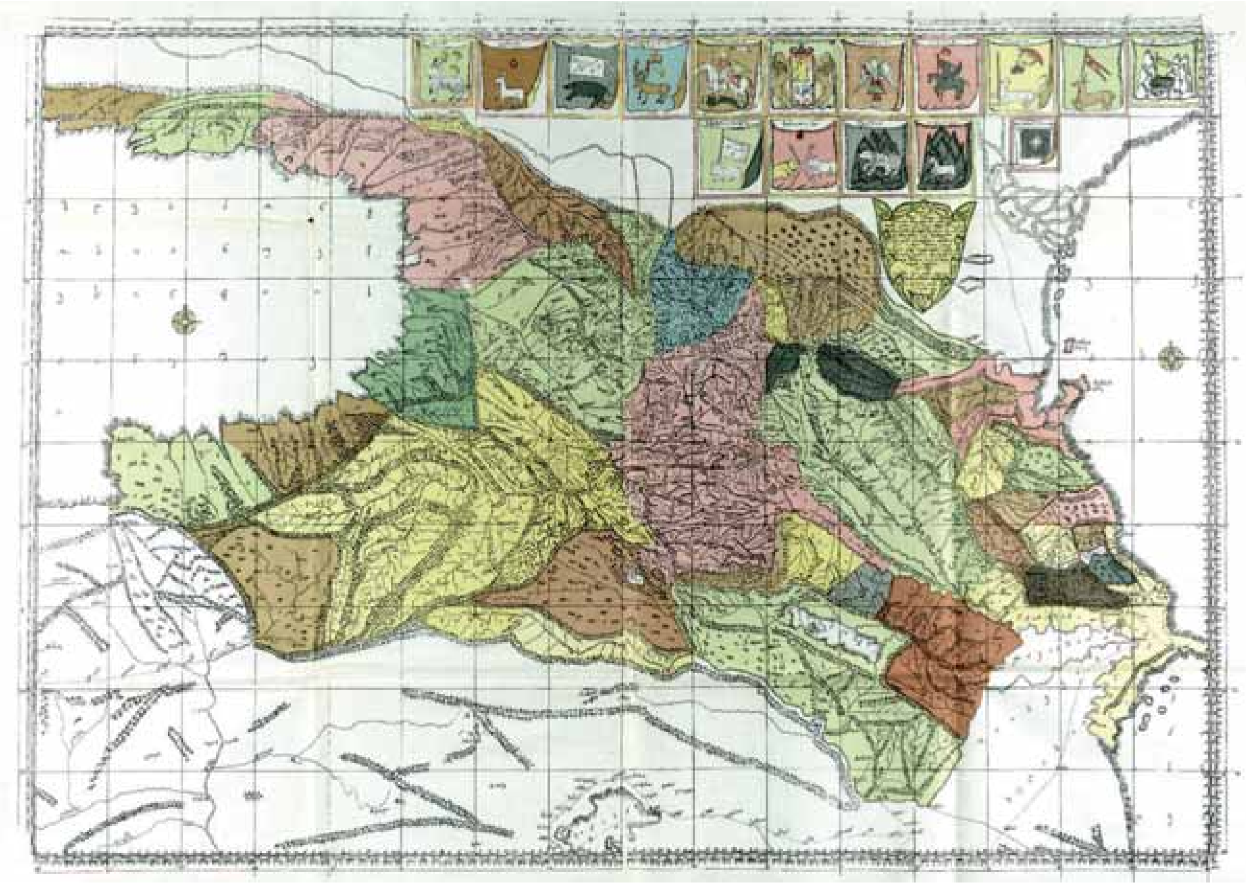

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MINISTRY OF ENVIRONMENTAL PROTECTION
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DEPARTMENT OF HYDROMETEOROLOGY
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In cover page

Newly designed map of Kingdom of Iberia or all Georgian parts, which is located between Ponto and Caspian seas - Map of Georgia by Prince Vakhushti Bagrationi for 1735.

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PRESENTATION

Among crops, viticulture is probably the most linked with the territory as stated by the fact that the regions with an ancient winemaking tradition show original cultivation and oenological models which cannot be reproduced elsewhere. These models are the result of specific adaptive combination of genetic choices (grape varieties), environmental resources (climate and soil), cultural and enological practices in the framework of the evolution of market conditions. This leads us to imagine modern viticulture as a sector that evolves following the needs of the market while maintaining specific attention to the values of tradition.

Georgia, like many countries with an ancient winemaking tradition, is facing a new climate and market scenario. The aim that has guided us in this work of agro-climatic characterization of the Georgian wine-growing regions was to give knowledge elements of the specific climatic resources and limitations in order to guide the choices of the viticultural and enological companies in the definition of new vitivinicultural models aimed at enhancing the specificities of the oldest in the world terroirs.

This book is a collaborative work of researches from Italy and Georgia dedicated to analyze the recent climatic situation of Georgia, to evaluate the agroclimatic conditions of Georgian viticulture and to provide practical support for the viticulturists of the country for planting and managing their vineyards situated in diverse geographic locations taking in account recent trends of climate change.

This handbook is particularly addressed to technicians in viticulture, viticulturists, winemakers, teachers and students in the agricultural fields.

The edition in Georgian language was also issued to promote the local divulgation of this work.

Acknowledgements

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GENERAL INTRODUCTION

One of the main aims of viticulture is to optimize the production process in order to obtain a final product suitable to the oenological objectives in terms of quantity and quality. Vine production is the result of a bulk of metabolic processes fed by photosynthesis and leading to the wide range of organic molecules of bunches, so precious for wine making. Plant metabolism is influenced by different factors, acting in the vineyard through the growing season like the level of solar radiation, the course of air temperature, the availability of water and nutrients in the soil and the presence/strength of biotic and abiotic adversities (insects, cryptogams, weeds, drought, water excess, strong winds, high and low temperatures, hail and so on). By a general point of view, mild environmental stress conditions could improve grape quality by limiting the vegetative vigor and by activating secondary grapes metabolism linked to the synthesis and accumulation of polyphenols and aroma compounds. On the other hand, severe stresses impair grapevines yield and grapes quality. This reference general scheme leads the choices of vine growers in genetics (varieties and rootstocks) and in cropping techniques (plant density, training system, pruning, fertilization, soil management, etc.).

The abovementioned scheme has been the guideline for the analysis carried out by the researchers involved in “Research Project on Georgian Grape and Wine Culture” for the enhancement and improvement of Georgian viticulture. The results of their activities are summarized in this handbook that provides detailed description of the twelve wine-growing Regions of Georgia.

The investigation of the role of the different production factors over a complex territory like Georgia implies high difficulties related not only to the understanding of spatial and temporal variability of the factors but also to the knowledge of the choices of vine growers. In order to overcome these difficulties, the research group adopted tools such as geographic information systems and physical and biological models in order to carry out a quantitative interpretation of the features of the Georgian viticultural terroir. These tools were used to analyze agro-climatic and hydrologic factors that determine the aptitude of the terroir to viticulture. These factors were seen in their relations with physiological, morphological and phenological features of reference varieties, training systems, management practices, enological models, economic aspects, social aspects (growers, consumers and other operators of the vinicultural chain) and history of grapevines and wine.

The final result is a set of guidelines for site selection and its preparation for new vineyard, choice of variety and rootstock, planting typology, plant management and vineyard fertilization.

A series of maps describing agro-climatic resources and imitations of the Georgian viticulture under current climate were presented in the book. This is a set of georeferenced maps with pixel of 0.016°, These maps were released in electronic format compatible with the “state of the art” geographic information systems and, hopefully, they will be the quantitative basis for the future improvements of Georgian viticulture.

Chapter 1

THE CLIMATE OF GEORGIA SURVEY DATA AND METHODS

INTRODUCTION

The climate of Georgia is the result of the combined action of a lot of factors that act at different scales, giving rise to a complex hierarchy of climates ranging from micro to macro scale (Pinna, 1978).

The location at middle latitudes is responsible of the well-known seasonal effects on solar radiation with strong consequences on the whole set of climatic variables (air temperature, precipitation, relative humidity, wind, etc.). Moreover, the closeness to "source regions" exposes Georgia to the action of air masses with peculiar characteristics, namely:

- Polar continental air (Pc), coming from the Cold Pole of the Boreal Hemisphere (the Siberian area). Pc is the coldest air mass that affects Georgia during the winter semester
- Arctic air (A): always cold
- Polar maritime air (Pm): always mild and moist
- Subtropical air (T): always hot.

The **effect of the relief** on the climate[1] is particularly strong because Georgia is a large basin bordered by the Greater Caucasus at North and the Lesser Caucasus at South and opened towards the Black Sea at West and towards the Caspian depression at East. This gives rise to mesoscale effects like foehn-stau[2], orographic enhancement of convection with thunderstorm activity and endo-mountain effects (dry and limpid air, low precipitation. etc.). Orographic effects are particularly relevant on air masses coming from the source regions and driven towards the Georgian area by synoptic atmospheric circulation. For instance, the Greater Caucasus blocks and deflects the Pc cold air flowing from the East European plain which can only penetrate South Caucasus, either either via the Black Sea or via the Caspian (Kotlyakov, & Krenke, 1980). A similar effect occurs for the arctic air that, due due to the barrier effect of the Greater Caucasus, enters enters the Georgian basin in the middle troposphere (above 3000 m of height), destabilizing the hot and humid air mass below it and triggering thunderstorm activity.

Moreover, the **local structure of the relief** (shape, slope, aspect) triggers a lot of local topoclimatic effects on:

- solar radiation: the morphological features of the relief rule the solar radiation amount and quality (ratio between direct and diffuse) received throughout the year by different sites which varies in function of their slope, exposure and orographic horizon
- air temperature and relative humidity: valley floors, affected by nocturnal drainage of cold air coming from mountain peaks and slopes, are characterized by high relative humidity, fogs, frosts and hoarfrosts (cold lake effect); on the other hand, the overhanging slopes are characterized by greater mildness (thermal belt)
- precipitation: precipitation maxima observed when a valley is getting narrow forcing air to lift or when a mountain range is perpendicular to the flow of humid air masses
- wind with land-sea breezes and mountain-valley breezes.

Significant effects are also given by **land covers** that influence the different terms of the surface energy balance (fluxes of short and long wave radiation, turbulent fluxes of sensible and latent heat, flux of heat into the ground), giving relevant effects on surface meteorological variables. For example, a bare soil compared to one covered by vegetation warms much more during the day and cools down more quickly at night.

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[1] The combined effect of the orographic factors on the climate gives rise to the so-called topoclimate.

[2] In its more classical form, the **foehn** is for a warm, dry, downslope wind descending the lee side of a mountain range as a result of synoptic-scale, cross-barrier flow over the range. **Stau** is the accumulation of cloudiness and precipitation on the windward side of a mountain range affected by foehn in its lee side (for a more exhaustive definition of foehn see American Meteorological Society, 2015).

The **large water mass of Black Sea** gives rise to a lot of effects such as the mitigation of temperatures (extremes are mitigated, so the coastal areas have higher average temperatures in winter and lower in summer), the enhancement of winds (land - sea breezes) and a relevant moistening of the atmosphere, able to feed precipitation systems.

Static and Dynamic Climatology

The **general climatic classification** of viticultural areas of Georgia was carried out by means of **Köppen – Geiger** classification system (Köppen and Geiger, 1936) while specific agroclimatic indexes were used to analyse resources and limitations for viticulture (see Chapter 2).

The **yearly precipitation** proposed in the map section highlights the channeling effect of the Colchis relief on humid air masses coming from the Black Sea and the orographic intensification with some precipitation maxima on the windward sides of the relief.

The yearly temperature map (see Chapter 2) shows the strong effect of the relief with an average thermal gradient for Georgia calculated for the full set of processed stations that is summarized in table 1. Higher values and close to those of the free atmosphere (-0.65°C/100 m) are observed in summer instead. Note that the lower gradient is observed in the winter months due to the thermal inversions typical of the lower layers of the air mass. The lowest gradient happens in February, testifying the maximum yearly activity of the Siberian Low.

Table 1.1 – Mean thermal gradient (°C/100 m) for the whole set of stations

Month	Maximum temperature	Minimum temperature
January	-0.47	-0.52
February	-0.45	-0.49
March	-0.58	-0.59
April	-0.56	-0.57
May	-0.63	-0.63
June	-0.61	-0.62
July	-0.63	-0.65
August	-0.65	-0.66
September	-0.59	-0.61
October	-0.54	-0.57
November	-0.52	-0.54
December	-0.5	-0.53

Finally, **hailstorms** frequency is particularly crucial for viticulture. The degree of risk can be roughly assessed on the base of the mean yearly hailstorms map of Georgia from the Climatology Reference Book for the Climate of the Soviet Union (Reference book, 1990). Although obtained with data referred to the period 1891-1980, the map gives an overview of the danger of hail in different viticultural areas of the country.

An overview on dynamic climatology of Georgia can be useful to appreciate its suitability for viticulture.

In **summer**, the Caucasus area is mainly affected by subtropical anticyclones with sunny weather which can be particularly hot due to three effects: (i) strong solar radiation, (ii) adiabatic compressional heating of air parcels that in the anticyclone drop from upper troposphere until the surface and (iii) advection of subtropical air masses. The summer stability can be temporarily broken by phases of thunderstorm activity triggered by the outbreaks of arctic or polar maritime air masses.

In **intermediate seasons** the Georgia area is periodically affected by mobile troughs in the Westerlies and Mediterranean lows that reach the Black Sea and give rise to mesoscale disturbances bringing abundant precipitation over the Colchis, especially along the Black Sea coast and on the windward mountain areas of the inland (Stau effect).

In **winter** Georgia is affected by the western expansion of the Siberian high, the so called European winter monsoon (Lamb, 1977). This phenomenon is the responsible of relevant cold outbreaks. In this context the Surami Ridge is an important climatic divide because the Siberian high dominates during winter at the East of it giving rise to relevant continentality and low precipitation in the Kura river lowland while the Colchis is periodically affected by Black sea disturbances with rain and snow.

CLIMATE CHANGE

There is an increasing awareness that the time variability of the Euro-Mediterranean temperatures in the last two centuries is the result of the overlap of three distinct phenomena:

1. a strong inter-annual variability (sawtooth shaped diagram), as the result of change in frequency and persistence of atmospheric circulation types (Beck et al., 2007);
2. a sixty years cyclicity, as the result of the alternation of cold and warm phases in surface waters of Atlantic Ocean as shown by the index AMO (Atlantic Mutidecadal Oscillation) (Kilbourne, 2014; Alexander et al., 2014; Knudsen et al. 2011). Note that the transition of AMO from cold to warm is forced by some years of strong positive NAO - North Atlantic Oscillation (Mc Carthy et al., 2015) as can be seen from figure 1.1;
3. a positive trend of temperatures since the end of the little Ice Age (around 1850) with the European mean temperature for 1991-2010 that is +1.3 °C higher than in 1851-1860 (increase more relevant than the global one which on the same period was about + 0.85 ° C) (European Environmental Agency, 2016) as described in figure 1.1.

For instance, the strong inter-yearly variability and the presence of multi-decadal cycles during the last centuries is also detectable in the time series of the harvest dates of grapevine available in Switzerland (Meier et al, 2007), Italy (Mariani et al, 2009), Austria (Maurer et al., 2011) and France (Chuine et al., 2004).

The superimposition of the phenomena 2 (sixty years cyclicity with AMO in cold phase) and 3 (positive trends) made the Euro-Mediterranean temperatures of 1951-1987 period move back to values close to those observed during the 1901-1930 period, while the abrupt transition to a positive phase of NAO in 1988 (Mariani et al., 2012) opened a new climatic phase, stabilized by the transition of AMO from cold to warm phase (1994). The main response of surface meteorological variables to this forcing was an abrupt increase in mean annual temperatures for the Western European area observed in 1988 (Mariani et al., 2012).

Temperature and Circulation Indexes Analysis

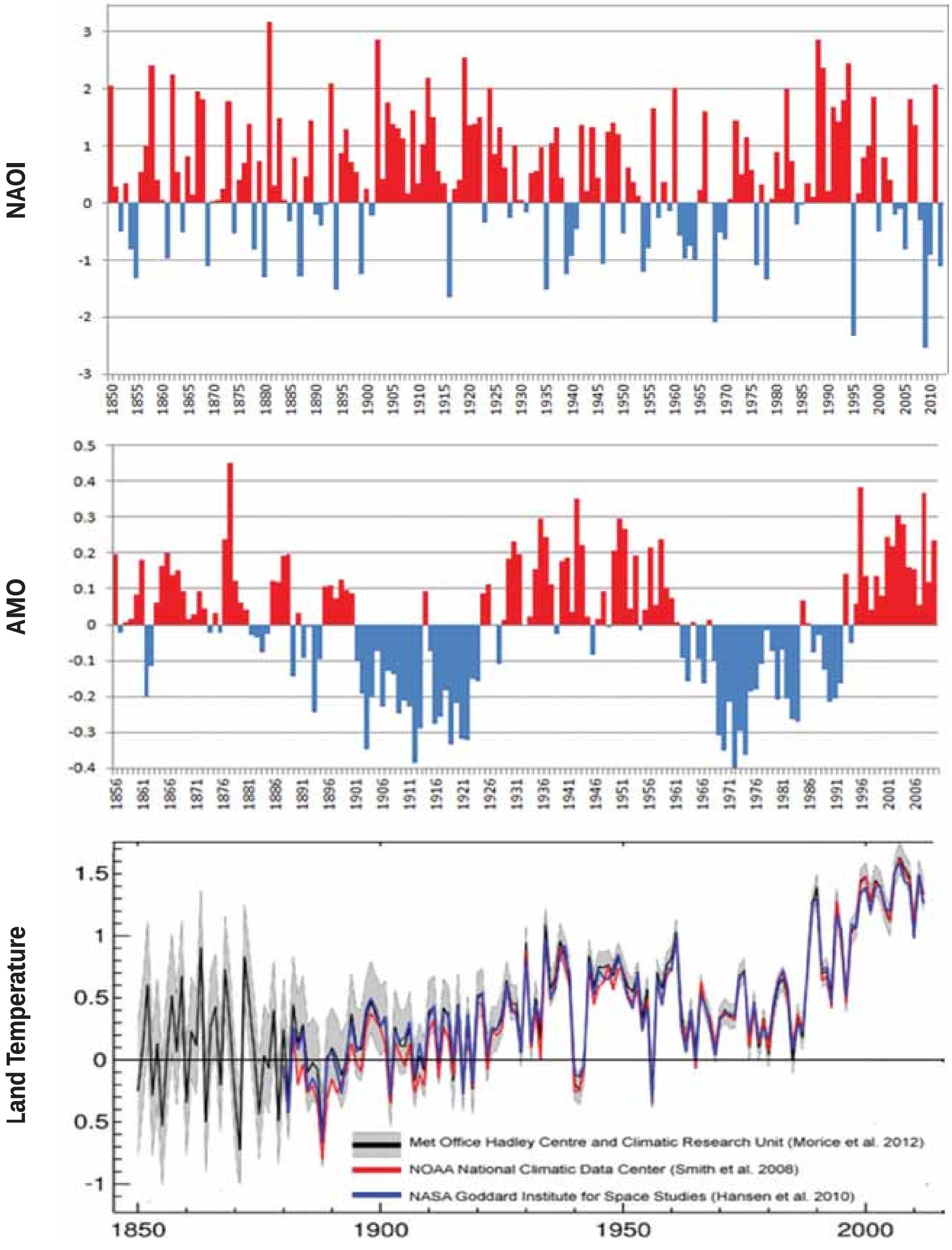


Figure 1.1 – Analysis of circulation indexes and European temperature

Temperature Analysis

In order to check the possible relation between the European climate change of the ’80s and the behavior of air temperatures in Georgia, a change point analysis, performed with the Bai and Perron method (1998), was applied to the yearly mean temperature of the whole set of Georgian stations for the period 1974-2013. The analysis shows that, with a 95% confidence, the breakpoint lies between 1991 and 1997, with 1994 as the most likely year of discontinuity (figure 1.2). The current period (1994-2013) shows an increase of 1.4°C when compared to the previous one (1974-1993). Therefore, **1994 can be considered as the year of an abrupt climate change for Georgia,** with the beginning of the current climatic phase. By consequence the reference period 1994-2013 will be taken into account as representative of the current climatic phase.

As stated before, the result for Western Europe presented by Mariani et al. (2012) shows the presence of a change in yearly mean temperatures that, with a 95% confidence, lies between 1982 and 1991 with **1987 as the most likely year of an climate change for Western Europe**. The current climatic phase (1988-2012) showed an increase of about 1 °C when compared to the 1951-1987.

The delay between Georgia and Western Europe could be considered the effect of the progressive dilution of the Oceanic signal as it moves into the European continent. The result is that the abrupt change in temperatures observed for Georgia is directly related to the transition from a negative to a positive phase of AMO that took place in 1994, a transition triggered by years of strong positive NAO - North Atlantic Oscillation (Mc Carthy et al., 2015).

These results state that large-scale circulation is a primary driver of thermal resources for grapevine, in agreement with the conclusions of Santos et al. (2012).

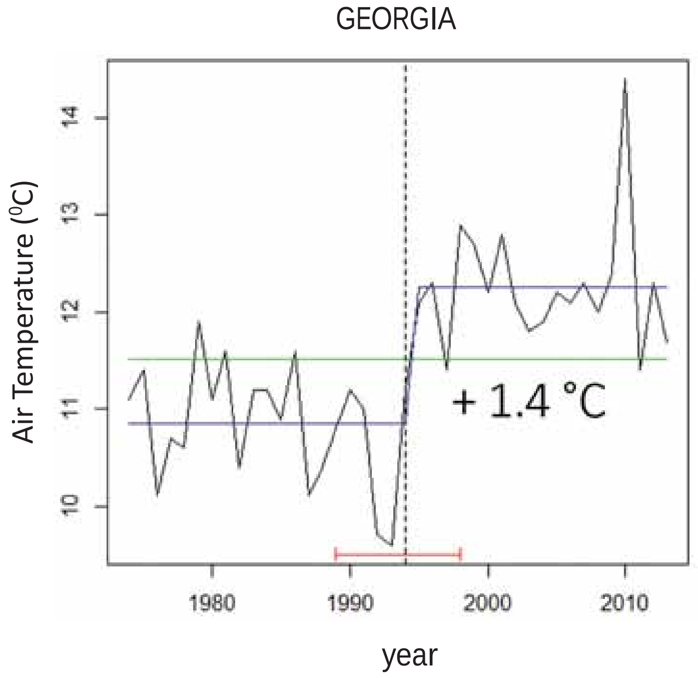


Figure 1.2 – Breakpoint analysis of average yearly temperature for Georgia over the period 1974-2013

SURVEY DATA AND METHODS

General Information

This work is based on daily data of precipitation and maximum and minimum temperature for the period 1974-2013, gauged by 273 weather stations located in Georgia and neighbor Countries and provided by the following sources:

- National Environmental Agency of Georgia – Department of Hydrometeorology.
- ECA&D (the European Climate Assessment & Dataset project).
- US NOAA (Global Surface Summary of the Day).

The agrometeorological/viticultural characterization of Georgia is based on the analysis of data over two periods:

The **1994-2013** reference period, according to the climatological analysis previously presented, defines the current climatic phase. It was adopted for the characterization of climate, thermal indexes and phenology.

The **1974-2013** reference period was adopted for the computation of the extreme events indexes (frosts, summer stress) and for water related indexes (ET0, ETM, ETR, Water Excess Index, Water Shortage Index). The low frequency of extreme events justifies the need of long time series to provide a reliable characterization of those phenomena. A similar argument applies to the the analysis of soil water availability, being driven by precipitation that presents a high interannual variability.

Hereafter follows a brief description of the methods adopted for the agrometeorological/viticultural characterization of Georgia.

Köppen Geiger Classification (reference period 1974-2013)

The Köppen Geiger system is one of the most widely used systems for the classification of the world's climates. On the base of annual and monthly averages of temperature and precipitation (Köppen, 1936, Geiger, 1954), it classifies the Georgian areas in the following types:

- ET – Polar and Alpine climate
- Dfa – Continental fully humid climate with a hot summer
- Dfb - Continental fully humid climate with a warm summer
- Dfc - Continental fully humid climate with a cool summer
- Cfa – Warm temperature fully humid climate with a hot summer
- Cfb - Warm temperature fully humid climate with a warm summer
- Cfc - Warm temperature fully humid climate with a cool summer
- Bsk – Arid steppe cold climate

The classification here presented was kindly provided by climatologist Gizo Gogichaishvili and GIS expert Giorgi Zedgenidze of the Department of Hydrometeorology of National Environmental Agency of Georgia.

Bagnouls Gaussen Diagram (reference period 1974-2013)

The diagram is based on average monthly precipitation, mean temperature and absolute minimum temperature, for the reference period 1974-2013. For each Region, data are referred to the lowest altitudinal belt present in the Region (the altitudinal belt is showed at the top left of the chart). Red line (left Y-axis) is average temperature and Blue line is precipitation (right y-axis scale, twice the left Y-axis scale). Drought conditions are reached when the blue line is below the red line and is highlighted by a red-dotted area. Water excess is reached when the blue line overcomes the 100 mm threshold (solid blu area). The risk of frost is represented by rectangles above the x-axis. Light blue means that the absolute minimum temperature is below 0 °C, while darker blue means that the mean monthly temperature is below the 0°C threshold.

Thermal-Pluviometric Features

Altitudinal Belts

The area suitable for viticulture extends up to 1250 m and is subdivided in five altitudinal belts: 0-250, 250-500, 500-750, 750-1000 and 1000-1250 m. The characterization of viticultural areas is based on this partition.

Yearly Precipitation (1994 – 2013)

Average yearly precipitation, calculated for the current climatic phase on the base of daily fields.

Yearly Maximum Temperature (1994 – 2013)

Average yearly maximum temperature, calculated for the current climatic phase on the base of daily fields.

Yearly Minimum Temperature (1994 – 2013)

Average yearly minimum temperature, calculated for the current climatic phase on the base of daily fields.

Thermal Resources and Limitations

Winkler Index (1994 – 2013)

This index, calculated for the current climatic phase, is given by the sum of growing degree days (GDD) (active temperature with 10°C base) from April 1st to October 31st. The index defines the availability of thermal resources for grapevine growth and the suitability of the studied area to different grape varieties, allowing proper ripening. Average yearly Winkler Index was calculated for the current climatic phase on the base of daily temperature fields for the 1994-2013 period. According to the index viticultural areas were classified in the correspondant Winkler classes, whose charactistics are hereafter listed.

Table 1.2 – *Winkler Index for the viticultural regions*

Winkler class	GDD	Viticultural climate	Vinicultural aptitude
I -	< 850	very cool	Very early ripening grapes for fresh and fruity wines or sparkling wine bases
I	850 - 1400	cool	Early ripening grapes for fresh and fruity wines or sparkling wine bases
II	1400 - 1650	temperate cool	Early ripening grapes for wines to be aged. Medium ripening grapes for white or red wines ready to drink.
III	1650 - 1950	temperate	Medium ripening grapes for white or red wines ready to be aged.
IV	1950 - 2200	temperate warm	Late ripening grapes for white or red wines ready to be aged.
V	2200 - 2700	hot	Late ripening grapes for bodied red wines to be aged.
V +	> 2700	very hot	Very late ripening grapes for bodied red wines to be aged.

Phenological Timing

Beginning of Vegetative Season (1994 – 2013)

The average date of bud break for the current climatic phase, is expressed as day of the year (DOY in the 366). It was obtained by means of a temperature-based model, parametrized for Rkatsiteli variety (Cola et al., 2016, Cola et al., 2012, Mariani et al., 2012).

Day of Beginning of Flowering (1994 – 2013)

The average beginning of flowering for the current climatic phase, is expressed as day of the year (DOY in the range 1-366). It was obtained by means of a temperature-based model, parametrized for Rkatsiteli variety (Cola et al., 2016, Cola et al., 2012, Mariani et al., 2012).

Day of Fruit Set (1994 – 2013)

The average beginning of fruit set for the current climatic phase, is expressed as day of the year (DOY in the range 1-366). It was obtained by means of a temperature-based model, parametrized for Rkatsiteli variety (Cola et al., 2016, Cola et al., 2012, Mariani et al., 2012).

Beginning of Veraison (1994 – 2013)

The average beginning of veraison for the current climatic phase, is expressed as day of the year (DOY in the range 1-366). It was obtained by means of a temperature-based model, parametrized for Rkatsiteli variety (Cola et al., 2016, Cola et al., 2012, Mariani et al., 2012).

Thermal Stress

Summer Stress (1974 – 2013)

The risk of summer stress for the 1974-2013 period is expressed as the percentage of years over the reference period with at least 7 days with maximum temperature above the 35°C threshold. The classes are: Very Low (<3%), Low (3-5%), Medium (5.0-6.7%), High (6.7-10%) and Very high (>10%).

Spring Frost (1974 – 2013)

The risk of spring frost for the 1974-2013 period is expressed as the percentage of years over the reference period with spring minimum temperature below the -2°C threshold. The classes are: Very Low (<3%), Low (3-5%), Medium (5.0-6.7%), High (6.7-10%) and Very high (>10%).

Winter Frost (1974 – 2013)

The risk of winter frost for the 1974-2013 period is expressed as the percentage of years over the reference period with winter minimum temperature below the -15°C threshold. The classes are: Very Low (<3%), Low (3-5%). Medium (5-6.7%), High (6.7-10%) and Very high (>10%).

Water Resources and Limitations

Soil water availability for grapevine is obtained by means of a daily water balance (figure 1.3) that evaluates the input (precipitation)-and the outputs (deep infiltration, runoff, evapotranspiration and the fraction of precipitation that evaporates before reaching the ground). The balance is referred to AWC (Available Water Capacity), the maximum amount of water storable in the soil profile explored by roots and available for grapevine. An AWC of 100 mm was used to describe soils with low water capacity (e.g., soils rich of gravel) or shallow soils or soils with sandy texture), while 200 mm was used to represent soils with high water capacity.

The real evapotranspiration of grapevine is obtained from the reference crop evapotranspiration - ET0 (figure 1.4), expressing the consumption of a lawn of low height (12 cm), regularly covering the ground in order to intercept all the incoming solar radiation, optimally supplied with water and nutrients and not affected by diseases.

The maximum grapevine evapotranspiration ETM (figure 1.4) represents the grapevine water consumption when the plant is optimally supplied with water and nutrients and not affected by diseases. ETM is obtained multiplying ET0 by the crop coefficient – Kc, expressing the percentage of consumption of grapevine compared to the reference crop. Kc values change during the growth season. For instance, a row vineyard during the maximum development of canopy (July) has a Kc in the 0.5-0.7 range, depending of canopy density.

The real grapevine evapotranspiration – ETR (figure 1.4) is obtained by multiplying ETR by by the water stress factor – SF (in the range 0-1), estimated with a model accounting for the stress faced by grapevine when soil water drops below the level of easily available water or when soil water overcomes the field capacity, limiting oxygen availability for roots.

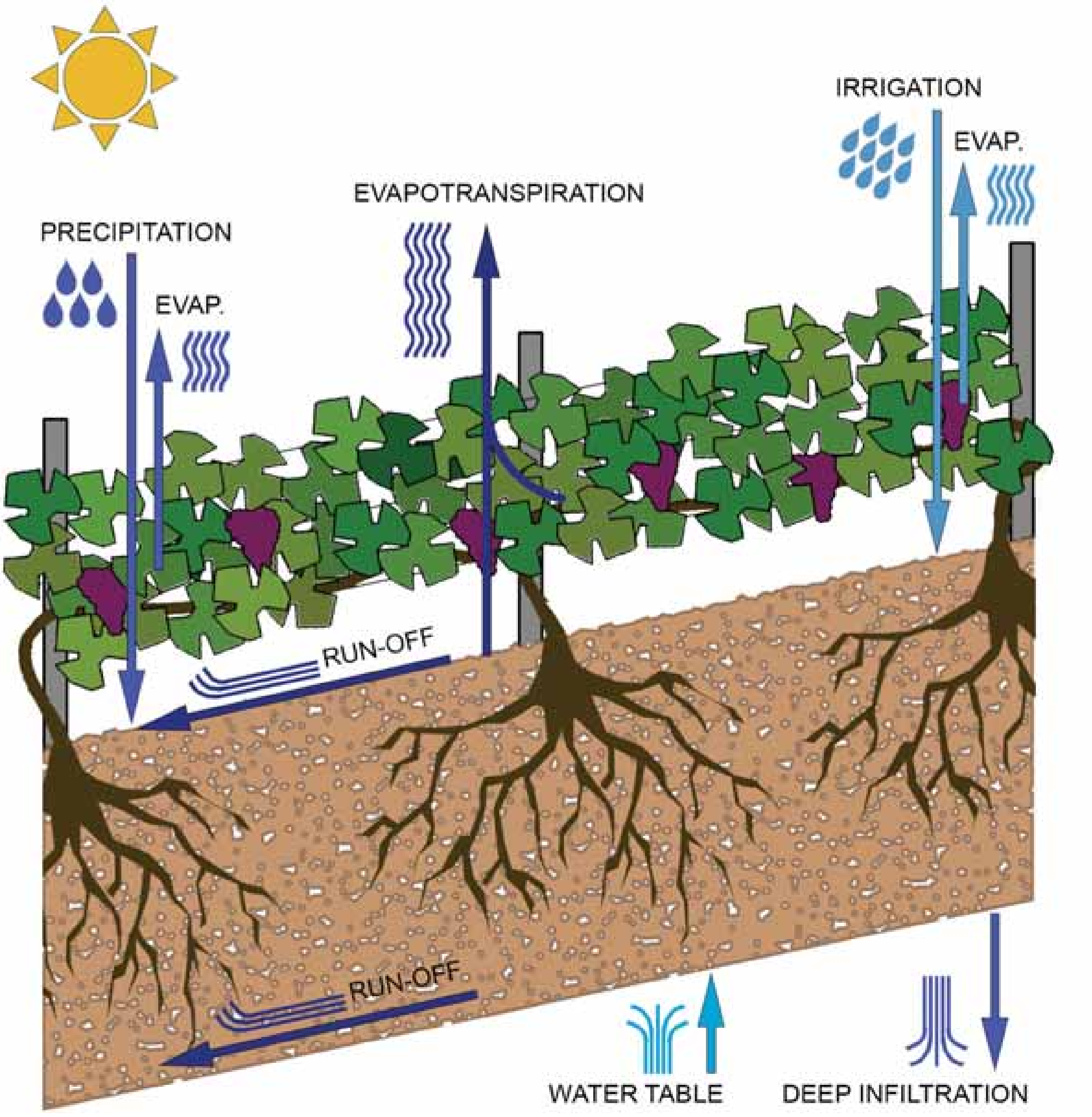


Figure 1.3 – Grapevine water balance: input and outputs of grapevine water balance.

Reference crop Evapotranspiration ET0 (1974 – 2013)

Average yearly ET0 for the 1974-2013 period, calculated by means of the Hargreaves and Samani method (Allen, 1998), based on daily maximum and minimum temperatures.

Maximum Evapotranspiration ETM (1974 – 2013)

Average yearly ETM for the 1974-2013 period, calculated by applying dynamic FAO crop coefficient Kc (Allen et al., 1998).

Real Evapotranspiration ETR (1974 – 2013)

Average yearly ETR for the 1974-2013 period, calculated multiplying ETM for the strass factor SF, obtained with the daily water balance referred to a single layer soil reservoir (AWC equal to 100 or 200 mm).

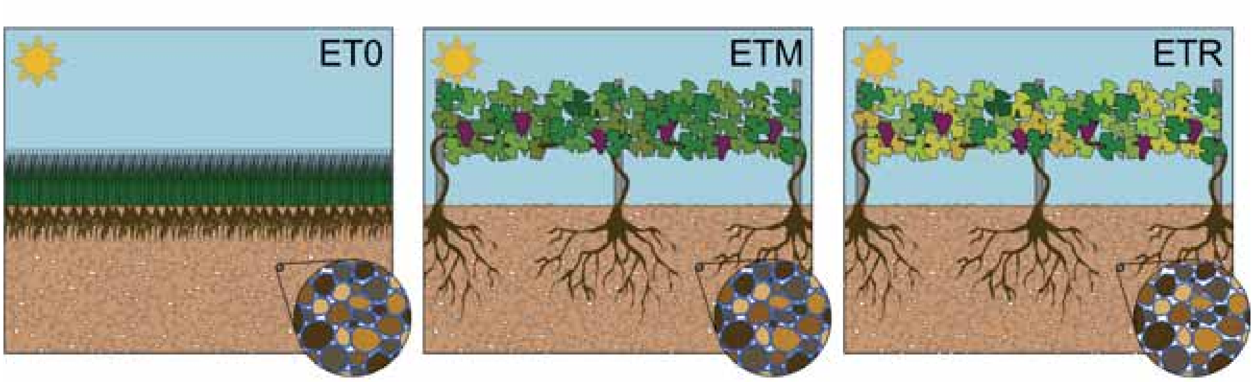


Figure 1.4 – Representation of reference evapotranspiration ET0, maximum grapevine evapotranspiration ETM and real grapevine evapotranspiration ETR.

Water Excess (1974 – 2013)

The average yearly sum of the stress factor SF caused by water excess in the soil, calculated for the 1974-2013 period.

Water Shortage (1974 – 2013)

The average yearly sum of the stress factor SF caused by water shortage in the soil, calculated for the 1974-2013 period.

Chapter 2

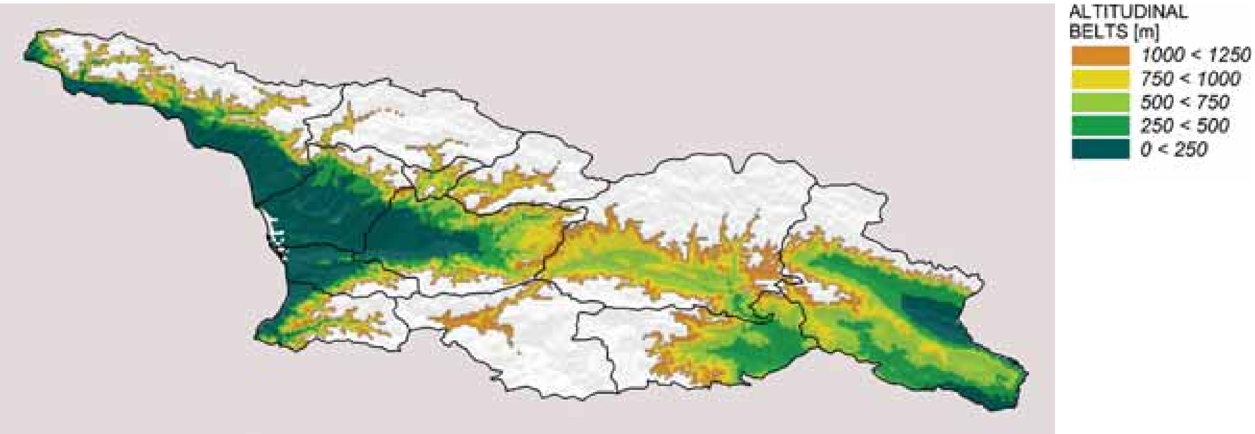
AGROCLIMATIC MAPS FOR SUISTAINABLE VITICULTURAL MODELS

Section 1

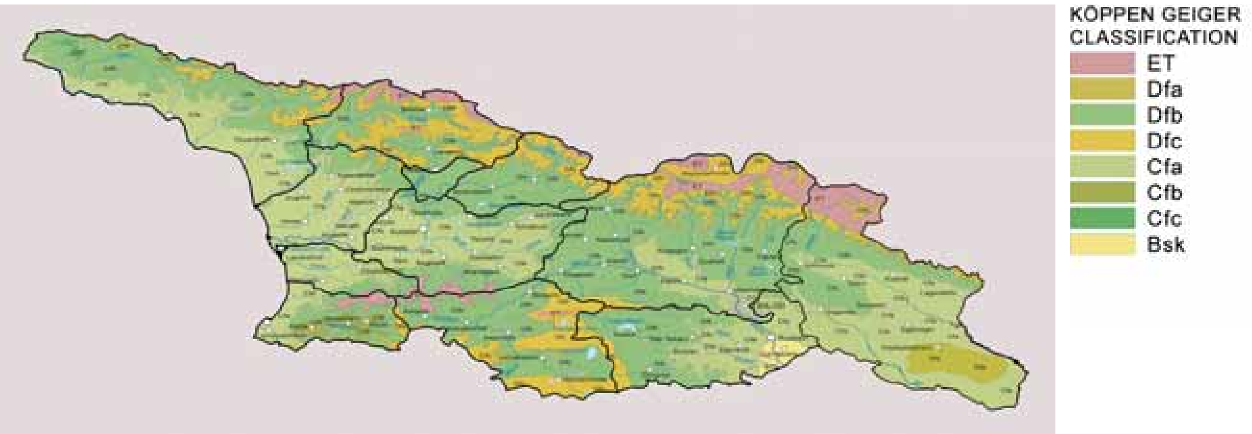
NATIONAL MAPS

AGROCLIMATIC AND HYDROLOGICAL MAPS OF GEORGIA

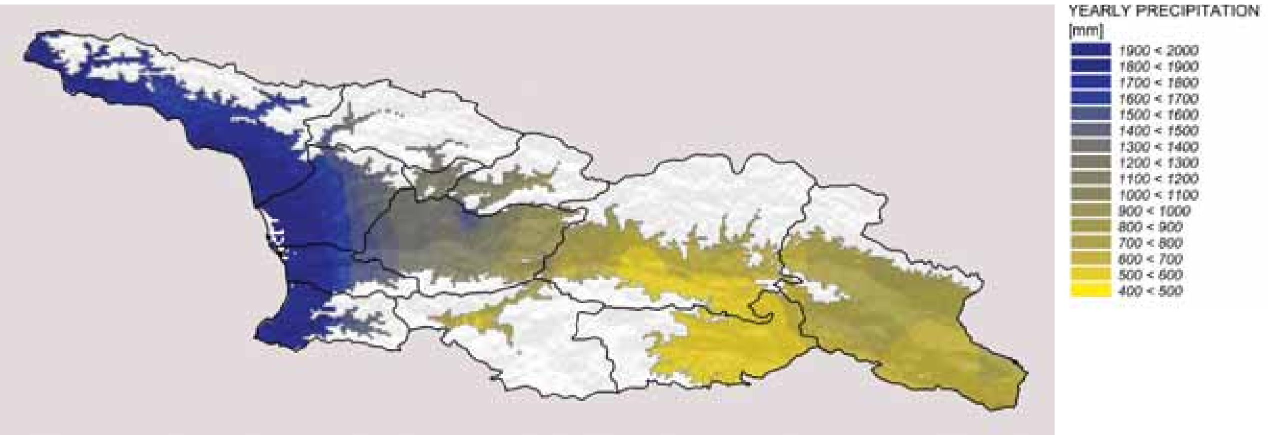
Viticultural Areas of Georgia



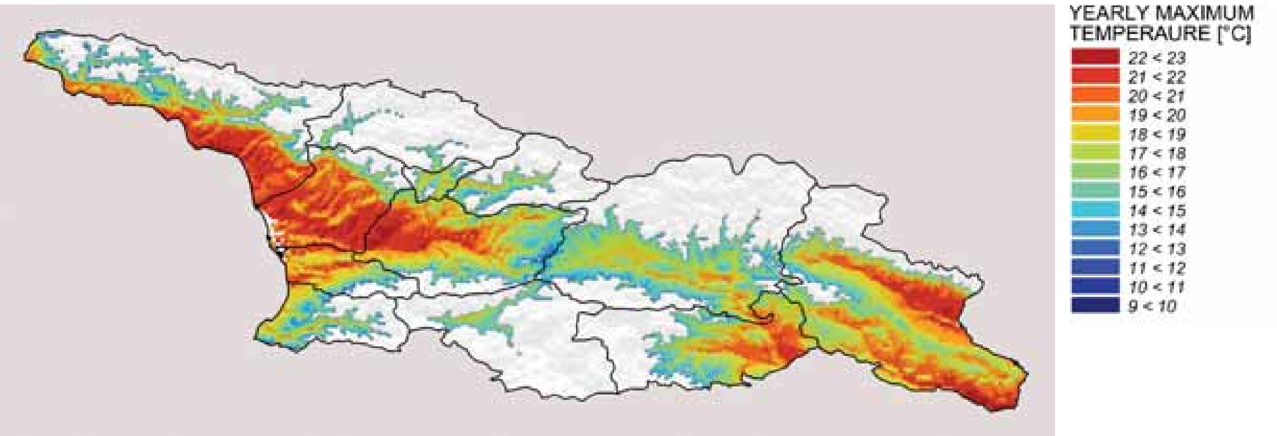
Altitudinal Belts of Viticultural Area



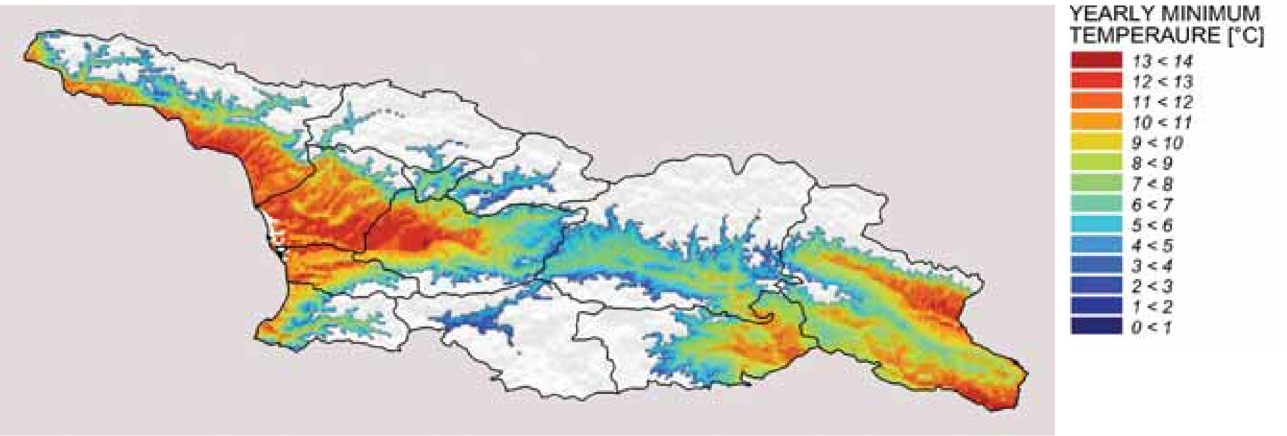
Köppen Geiger Classification



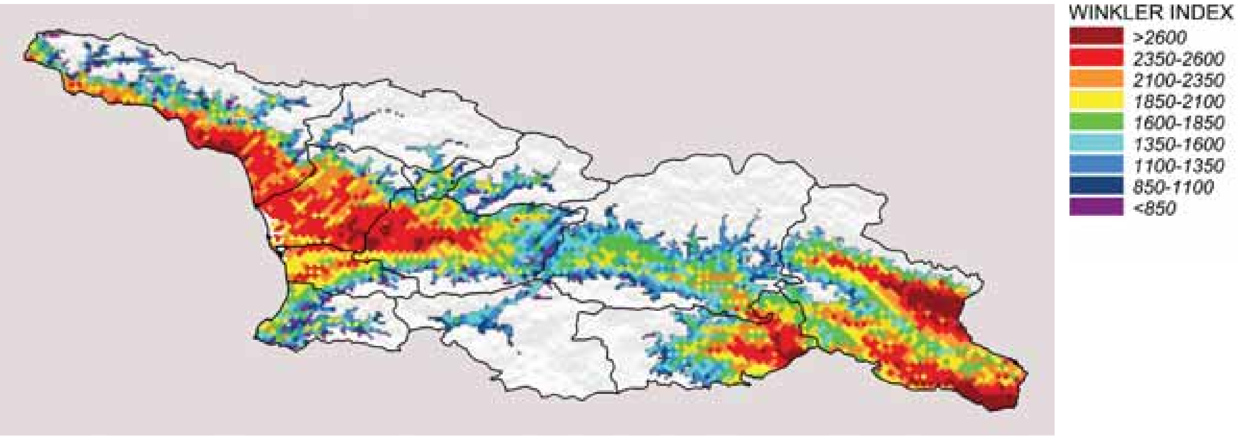
Yearly Precipitation (1994 – 2013)



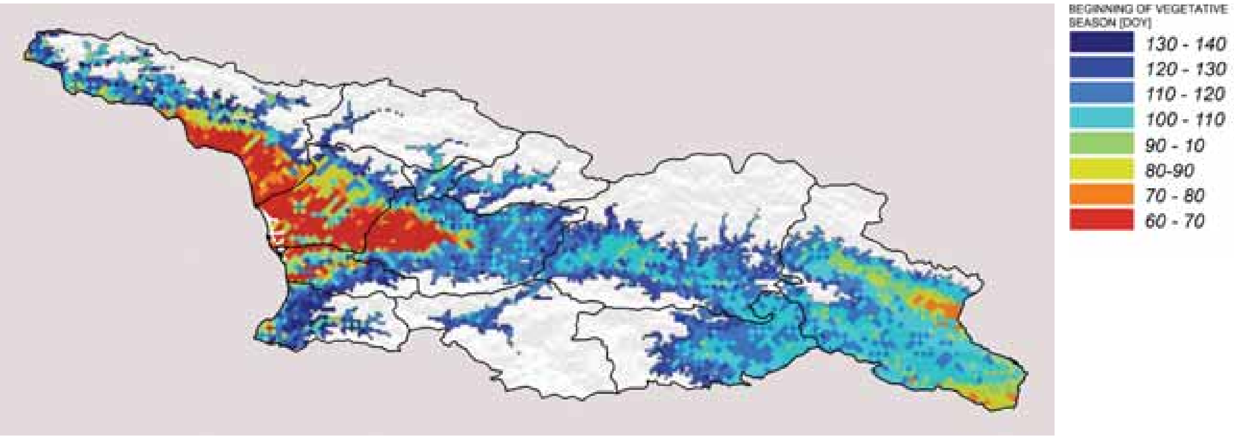
Yearly Maximum Temperature (1994 – 2013)



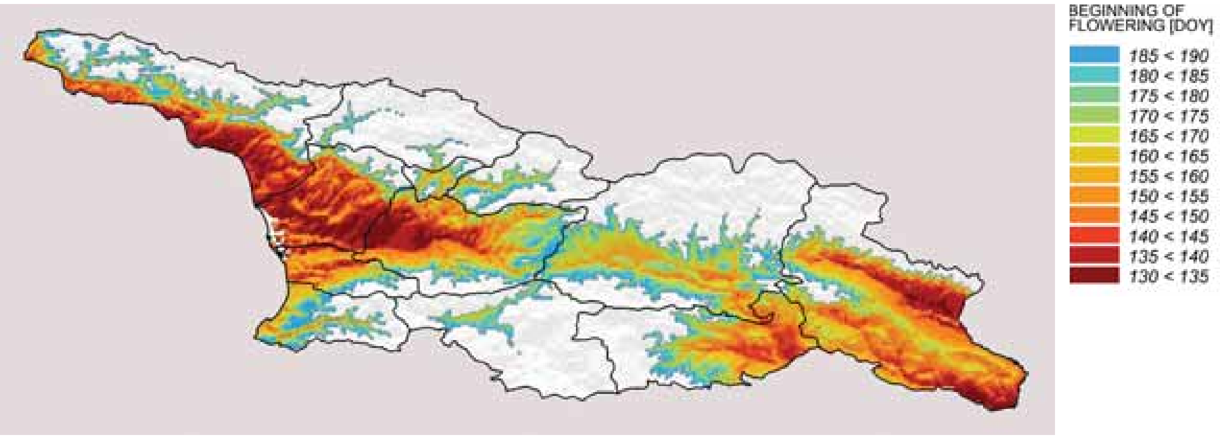
Yearly Minimum Temperature (1994 – 2013)



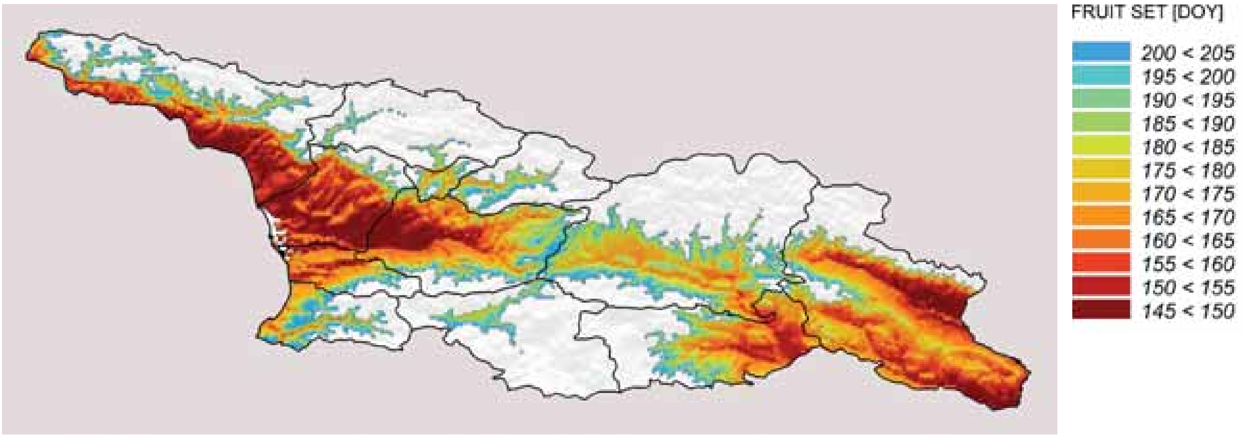
Winkler Index (1994 – 2013)



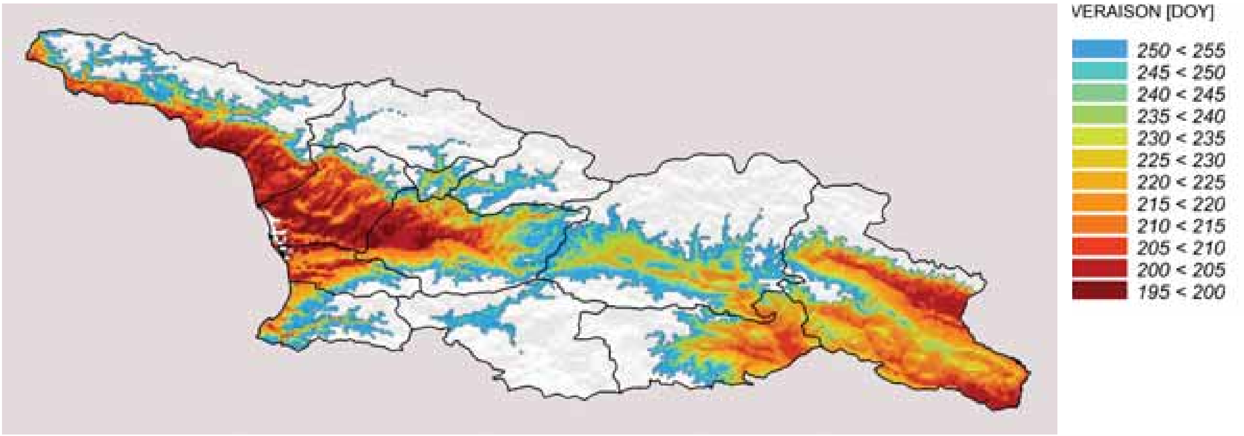
Beginning of Vegetative Season (1994 – 2013)



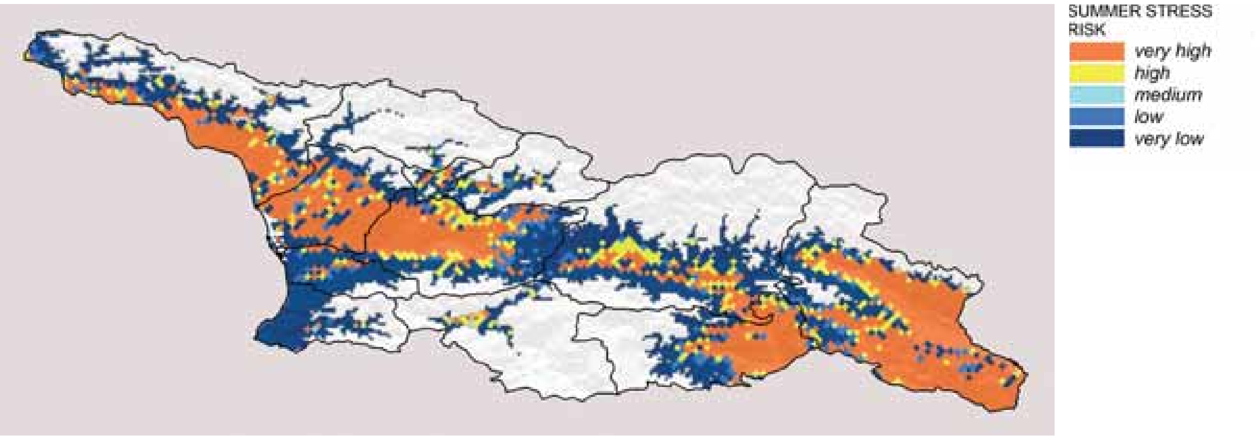
Beginning of Flowering (1994 – 2013)



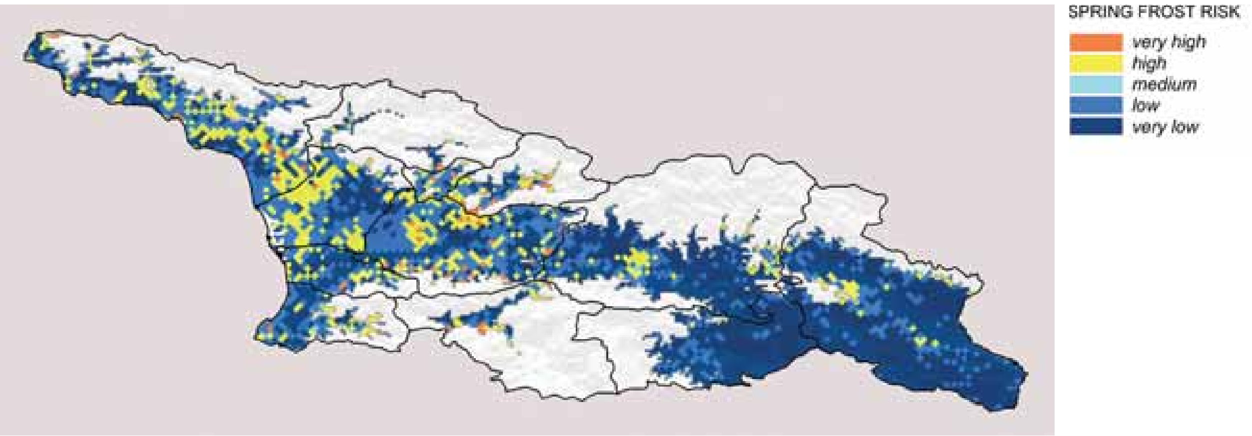
Beginning of Fruit Set (1994 – 2013)



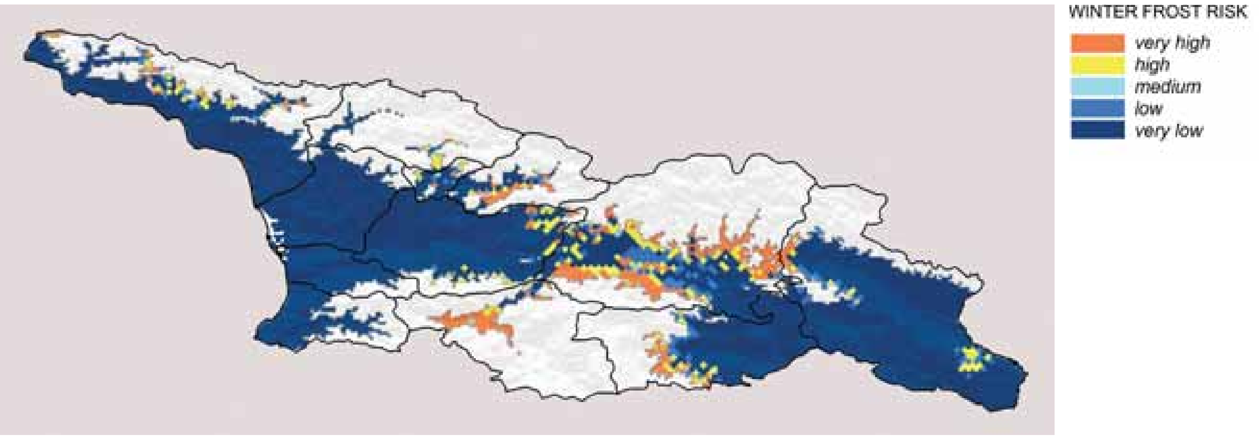
Beginning of Veraison (1994 – 2013)



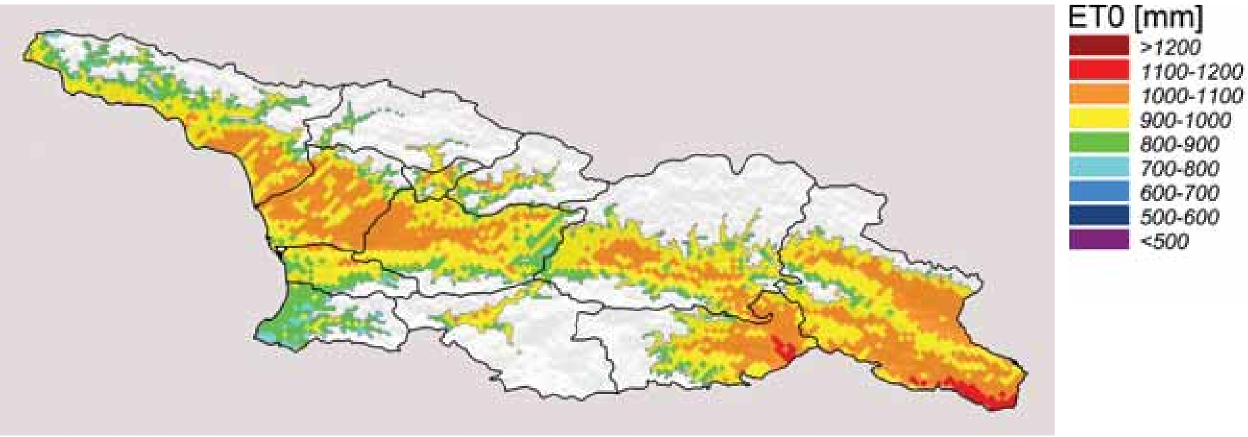
Summer Stress (1974 – 2013)



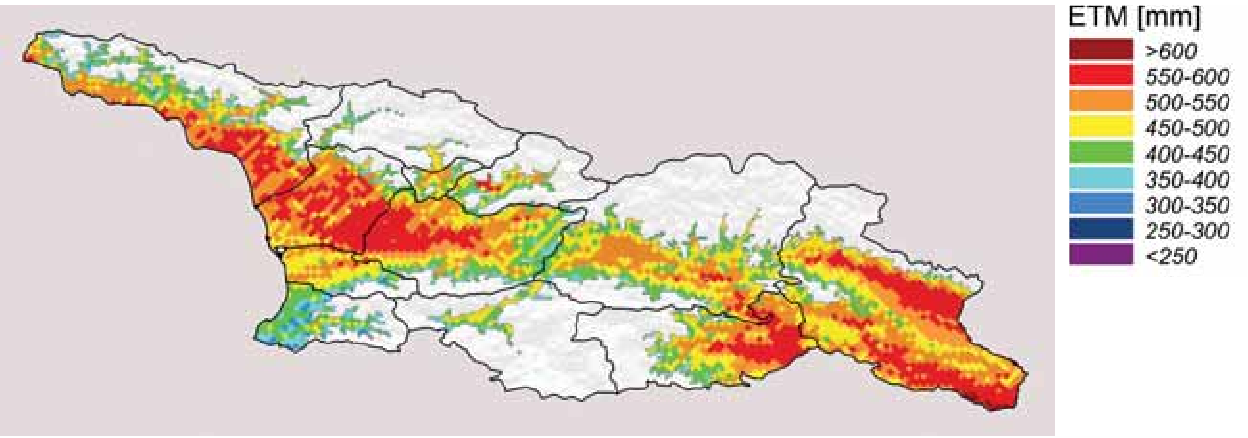
Spring Frost (1974 – 2013)



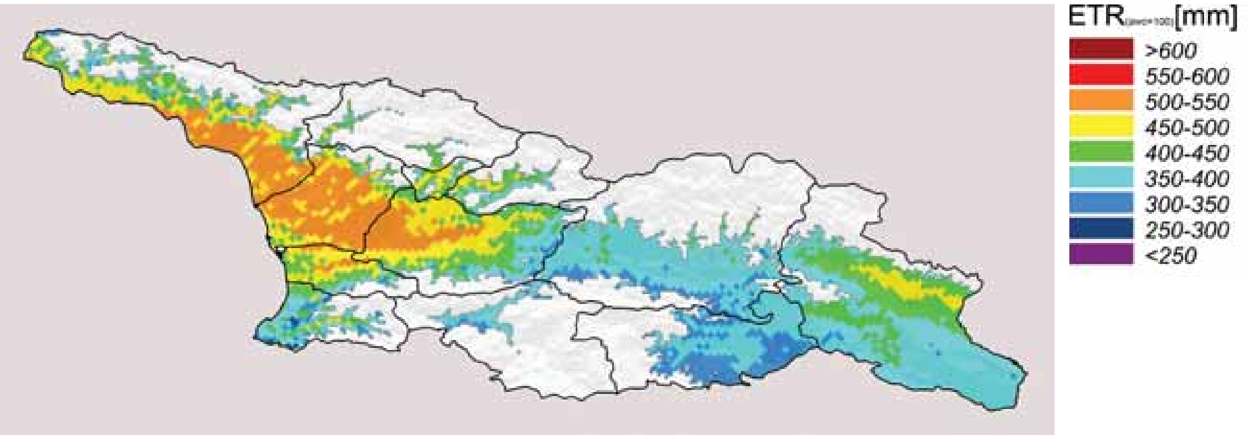
Winter Frost (1974 – 2013)



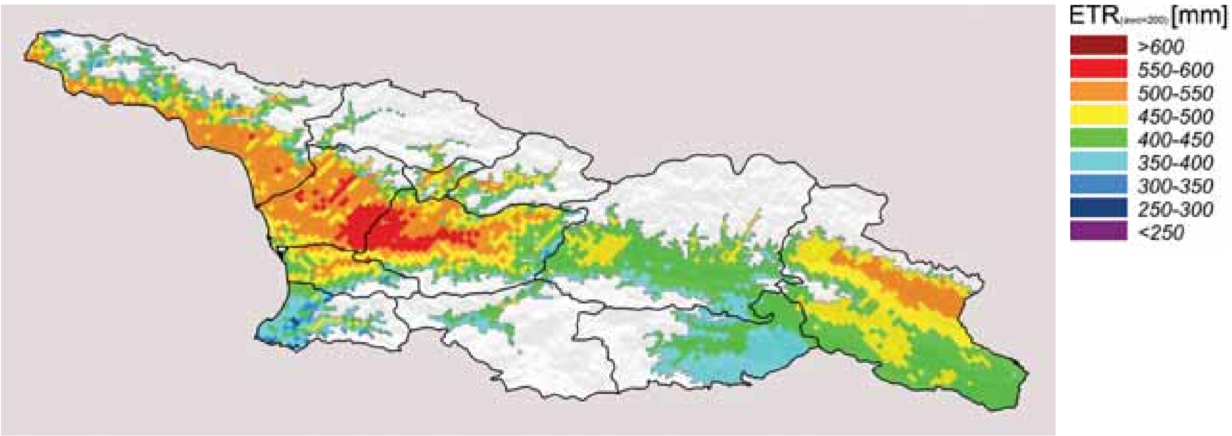
Reference Evapotranspiration ET0 (1974 – 2013)



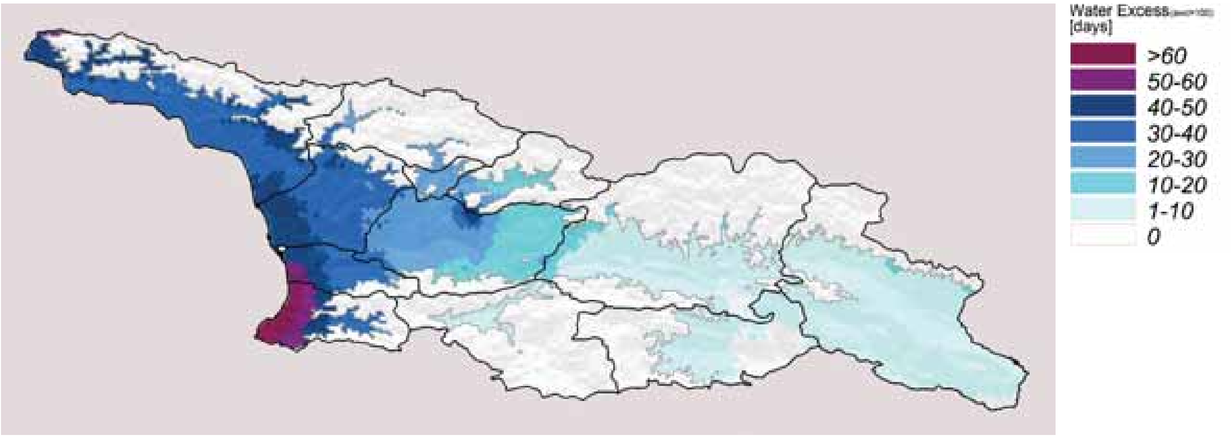
Maximum Evapotranspiration ETM (1974 – 2013)



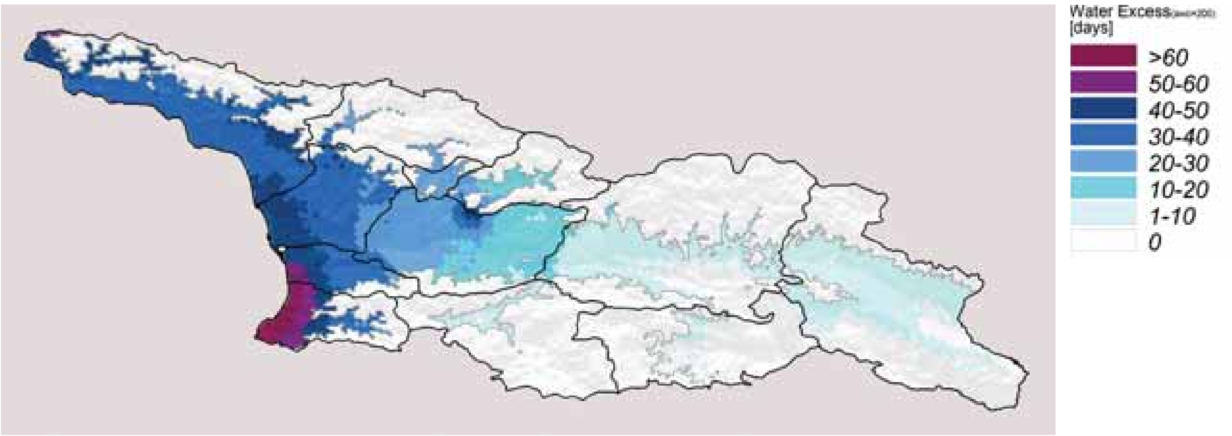
Real Evapotranspiration ETR (AWC = 100 mm) (1974 – 2013)



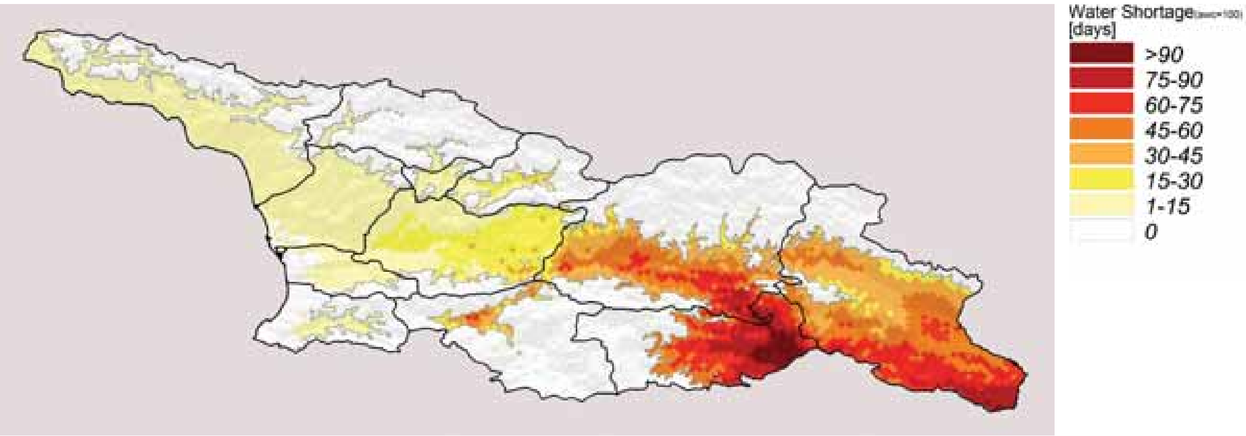
Real Evapotranspiration ETR (AWC = 200 mm) (1974 – 2013)



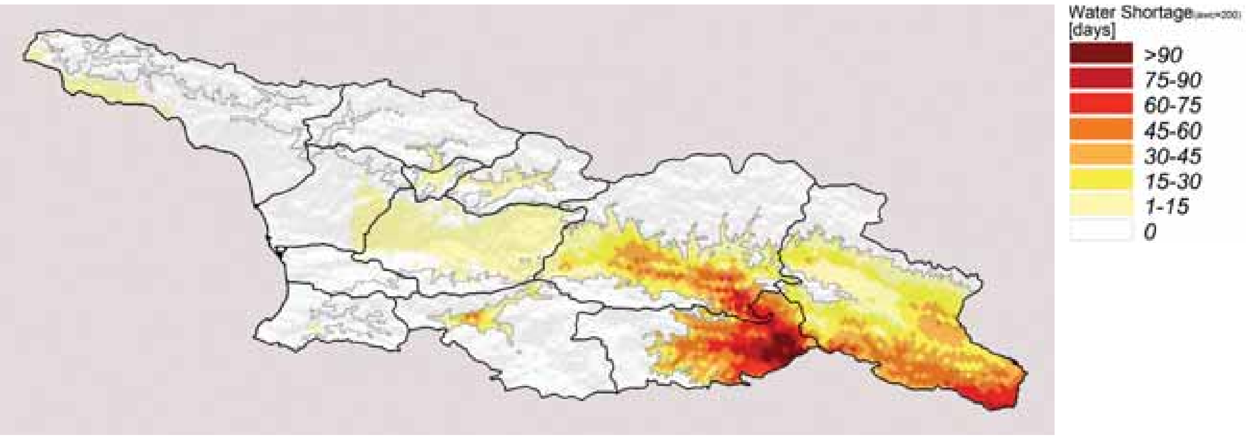
Water Excess (AWC = 100 mm) (1974 – 2013)



Water Excess (AWC = 200 mm) (1974 – 2013)



Water Shortage (AWC = 100 mm) (1974 – 2013)



Water Shortage (AWC = 200 mm) (1974 – 2013)

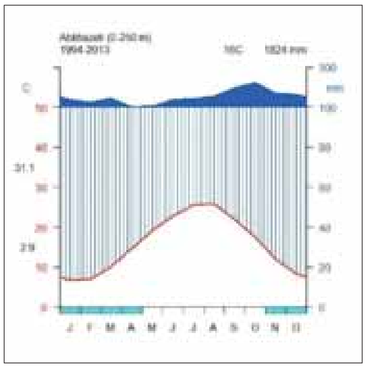
Section 2

REGIONAL MAPS

ABKHAZETI

Köppen Geiger Classification

Bagnouls – Gaussen Diagram (0-250 m altitudinal belt)



The area suitable for viticulture is mainly characterized by a Köppen climatic type Cfa with transition to Dfb at the highest elevations.

Precipitation is plentiful during the whole year with an average annual value between 1600 and 2000 mm.

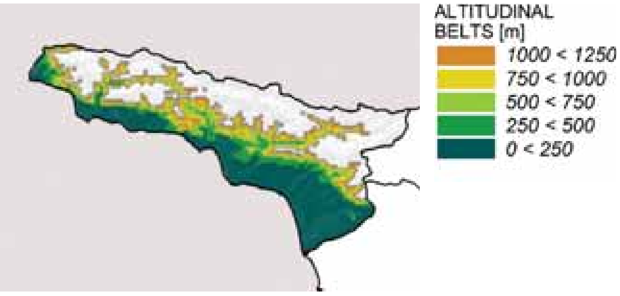
The Bagnouls – Gaussen diagram highlights the excess of precipitation along the whole year, with absence of dry season.

The climatic risk of temperature below the critical threshold of -15°C is significant only for higher elevations.

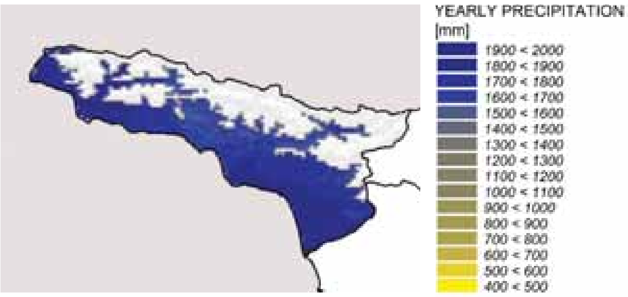
The thunderstorm activity in summer gives a significant hail risk (1 to 3 hail days per year)

THERMO-PLUVIOMETRIC FEATURES

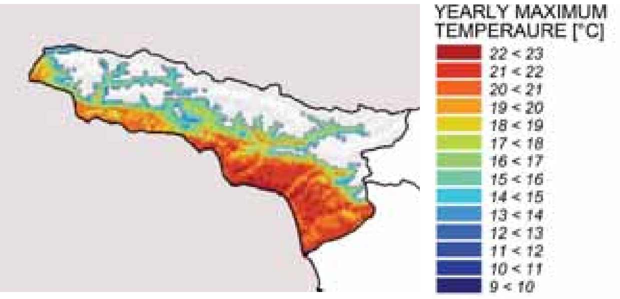
Altitudinal Belts



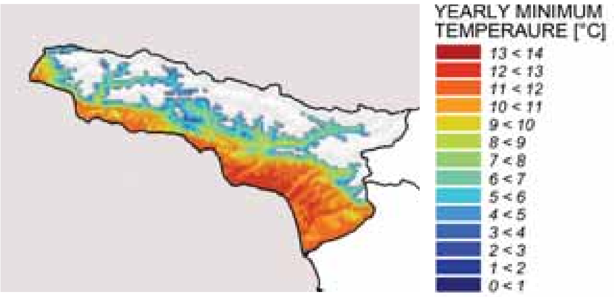
Yearly Precipitation (1994 – 2013)



Yearly Maximum Temperature (1994 – 2013)

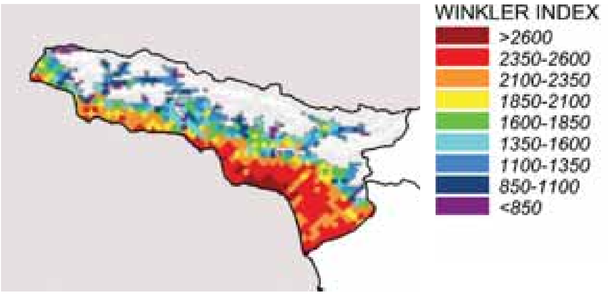


Yearly Minimum Temperature (1994 – 2013)

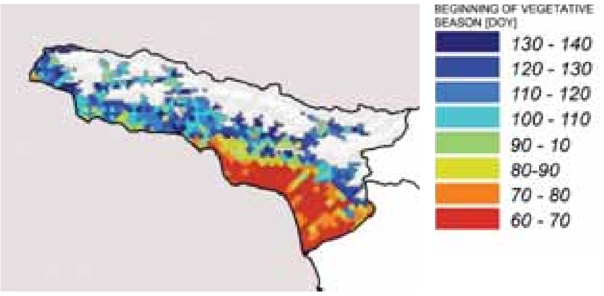


THERMAL RESOURCES AND LIMITATIONS

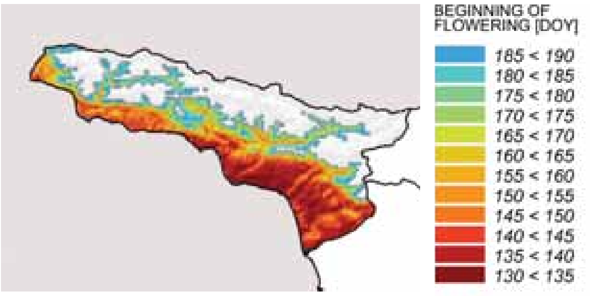
Winkler Index
(1994 – 2013)



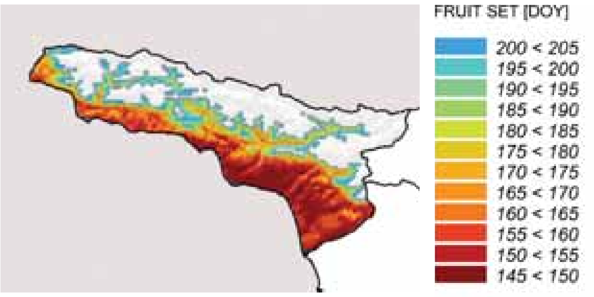
Beginning of Vegetative Season
(1994 – 2013)



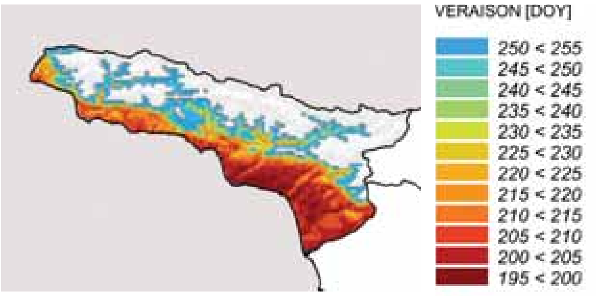
Beginning of Flowering
(1994 – 2013)



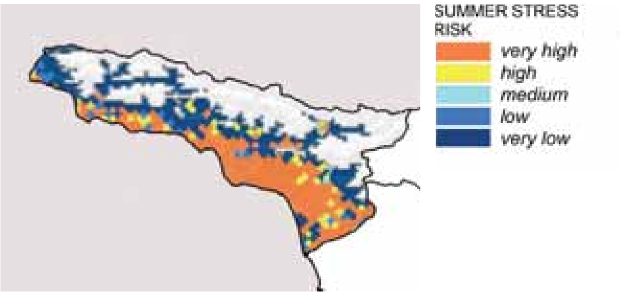
Fruit Set
(1994 – 2013)



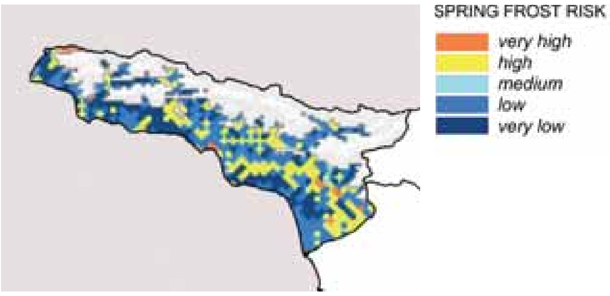
Beginning of Veraison
(1994 – 2013)



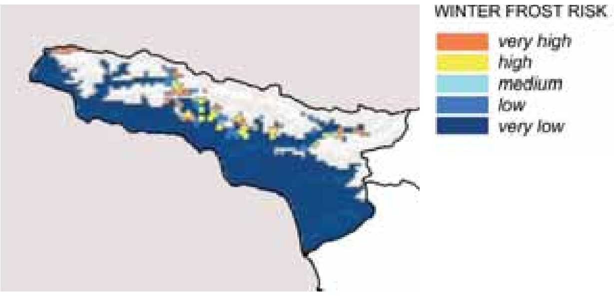
Summer Stress
(1974 – 2013)



Spring Frost
(1974 – 2013)

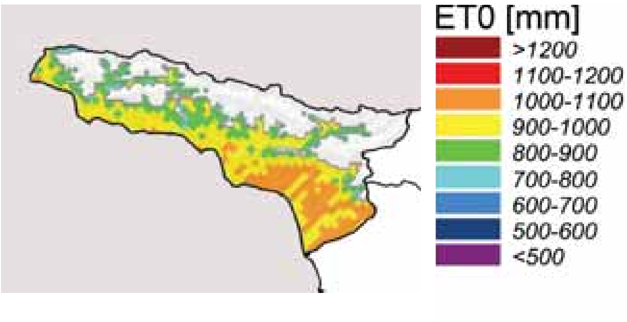


Winter Frost
(1974 – 2013)

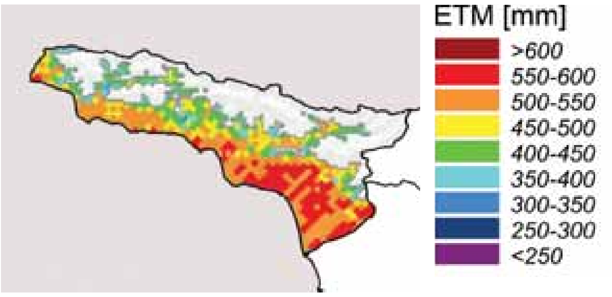


WATER RESOURCES AND LIMITATIONS

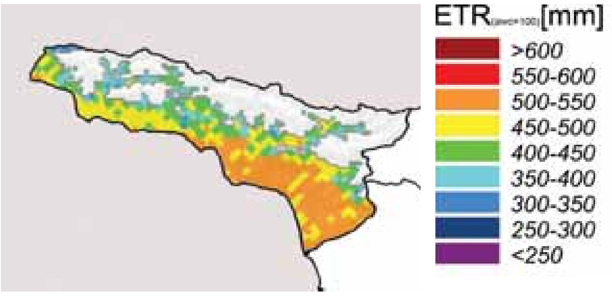
Reference Evapotranspiration ET0
(1974 – 2013)



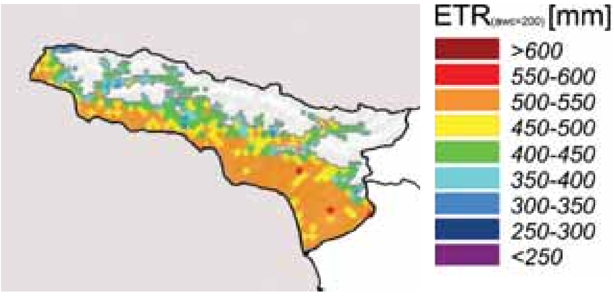
Maximum Evapotranspiration ETM
(1974 – 2013)



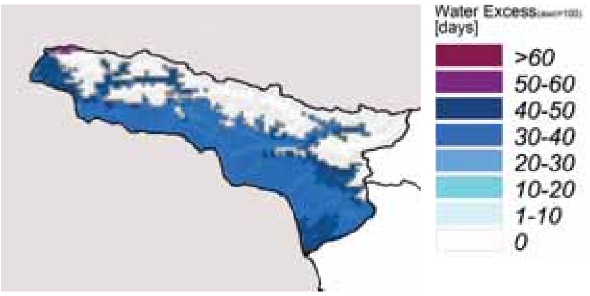
Real Evapotranspiration ETR (AWC = 100 mm)
(1974 – 2013)



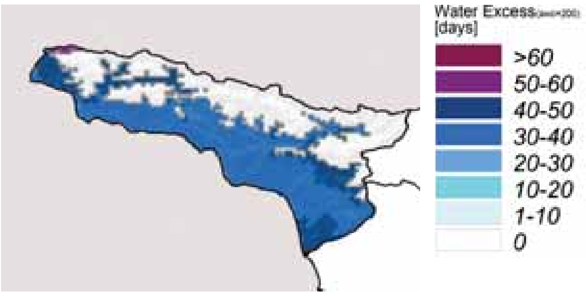
Real Evapotranspiration ETR (AWC = 200 mm)
(1974 – 2013)



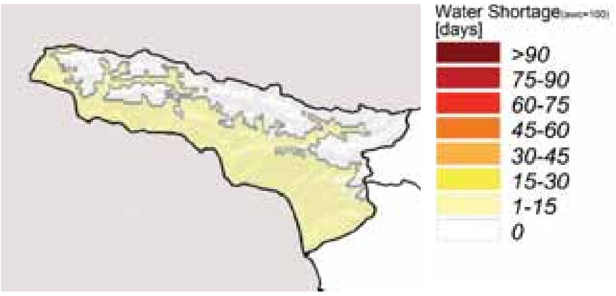
Water Excess (AWC = 100 mm)
(1974 – 2013)



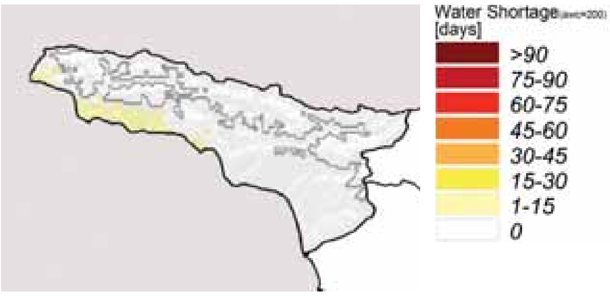
Water Excess (AWC = 200 mm)
(1974 – 2013)



Water Shortage (AWC = 100 mm)
(1974 – 2013)



Water Shortage (AWC = 200 mm)
(1974 – 2013)



Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0 - 250	50.3	early	IV - V	very low	very low - high
250 - 500	9.5	early	IV	very low	very low - high
500 - 750	13.2	medium	II	low - high	very low - high
750 - 1000	15.0	late	I	high	very low - high
1000 - 1250	11.9	late	< I	very high	very low - high

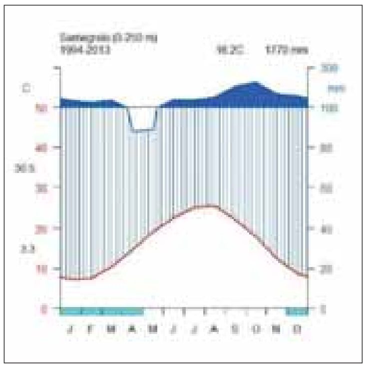
Elevation belt (m)	Risk of summer light - thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0 - 250	very high	very low - low	medium	high
250 - 500	very high	very low - low	medium	high
500 - 750	very low	very low - low	medium	high
750 - 1000	very low	very low - low	medium	high
1000 - 1250	very low	very low - low	medium	high

Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0 - 250	12	low	1.2	16	3 - 4	0
250 - 500	12	low	1.2	16	3 - 4	0
500 - 750	10	medium	1.0	14	2 - 3	100
750 - 1000	10	medium	1.0	12	2 - 3	100
1000 - 1250	8	high	0.8	10	2 - 3	100

SAMEGRELO

Köppen Geiger Classification

Bagnouls – Gaussen Diagram (0-250 m altitudinal belt)



The viticultural area belongs to the coastal area of the Black Sea and is mainly characterized by the Köppen climatic type Cfa with transition to Dfb at the highest elevations.

Precipitation is plentiful during the whole year with an average annual precipitation between 1200 and 2000 mm in the vine area.

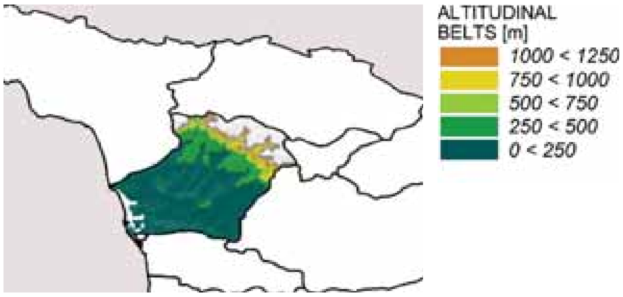
The Bagnouls – Gaussen diagram highlights the excess of precipitation along most part of the year, with the absence of dry season.

The climatic risk of temperature below the critical threshold of -15°C is very low for the last 40 years.

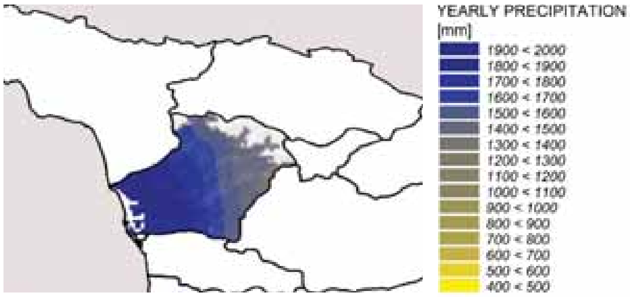
The thunderstorm activity in summer gives a significant hail risk (1 - 3 hail days per year).

THERMAL-PLUVIOMETRIC FEATURES

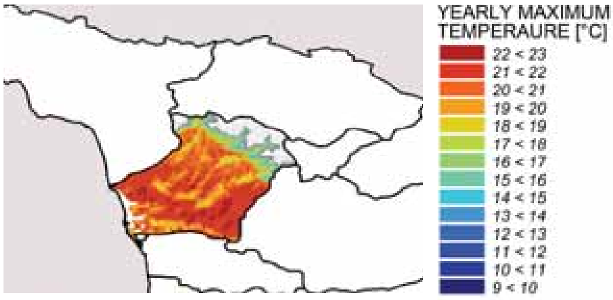
Altitudinal Belts



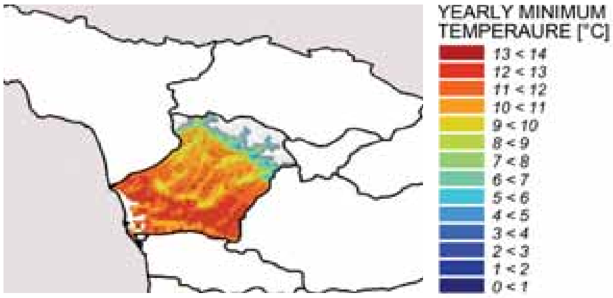
Yearly Precipitation (1994 – 2013)



Yearly Maximum Temperature (1994 – 2013)

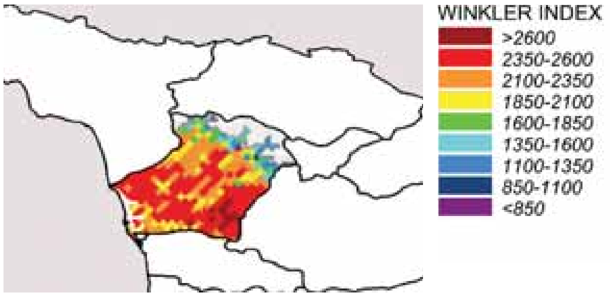


Yearly Minimum Temperature (1994 – 2013)

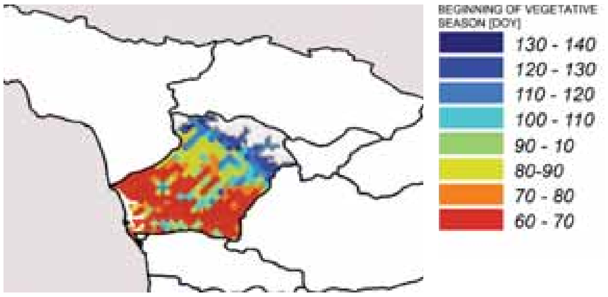


THERMAL RESOURCES AND LIMITATIONS

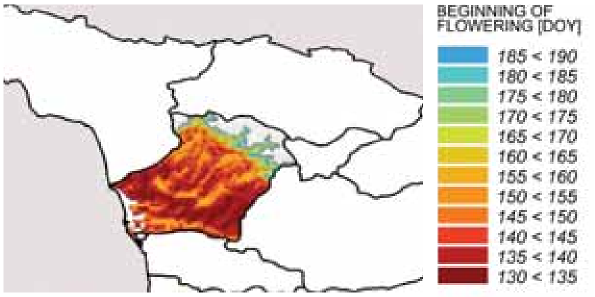
Winkler Index
(1994 – 2013)



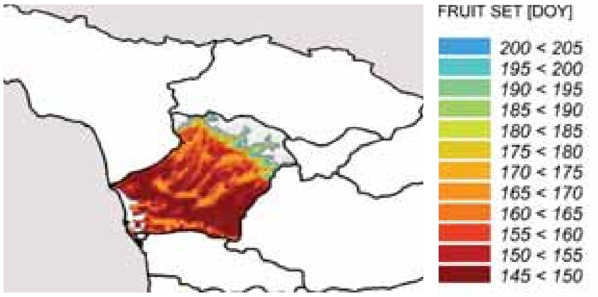
Beginning of Vegetative Season
(1994 – 2013)



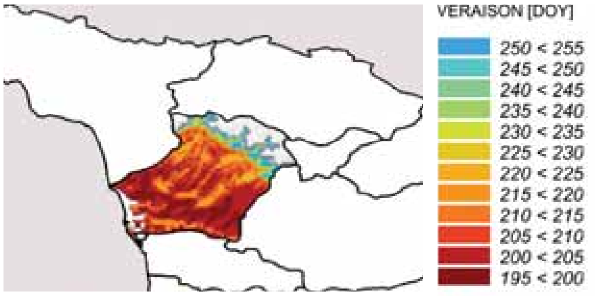
Beginning of Flowering
(1994 – 2013)



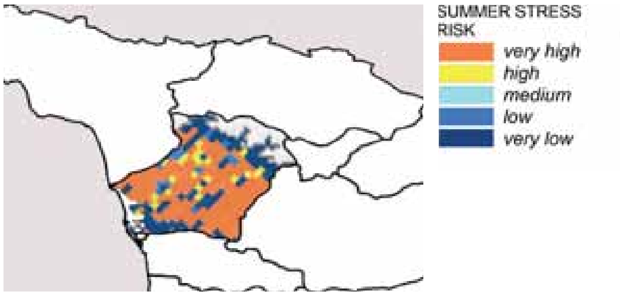
Fruit Set
(1994 – 2013)



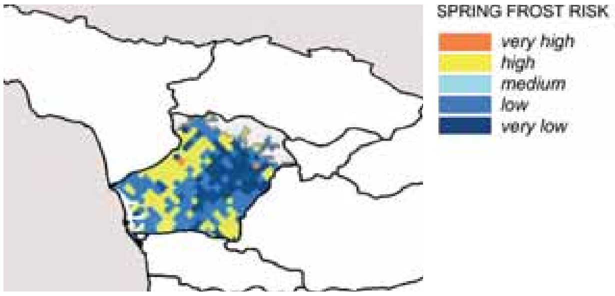
Beginning of Veraison
(1994 – 2013)



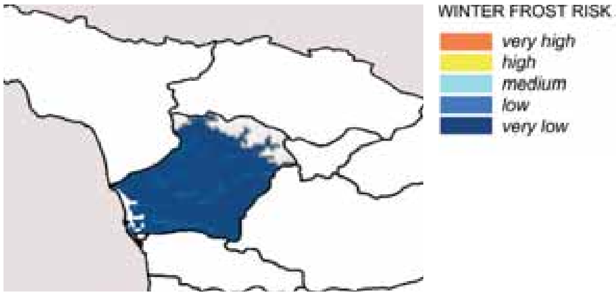
Summer Stress
(1974 – 2013)



Spring Frost
(1974 – 2013)

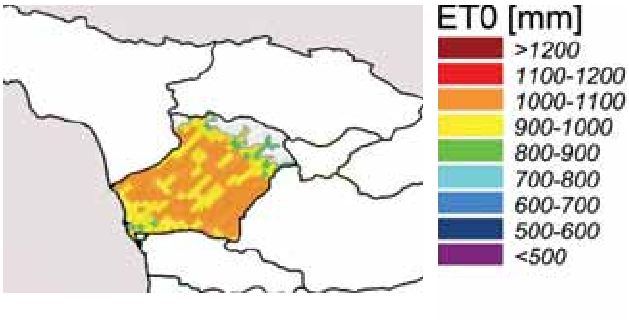


Winter Frost
(1974 – 2013)

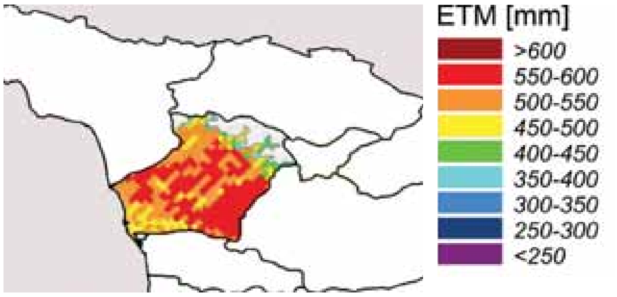


WATER RESOURCES AND LIMITATIONS

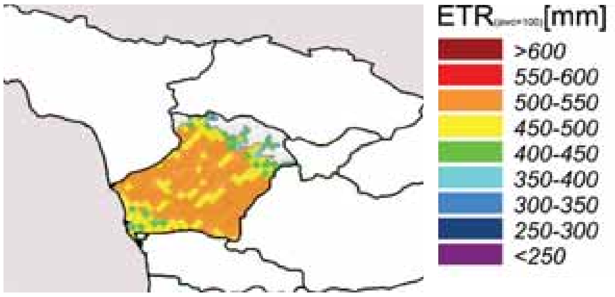
Reference Evapotranspiration ET0 (1974 – 2013)



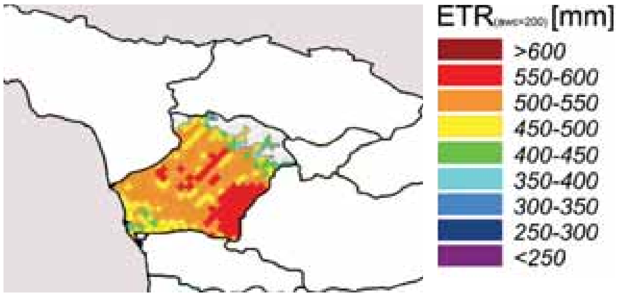
Maximum Evapotranspiration ETM (1974 – 2013)



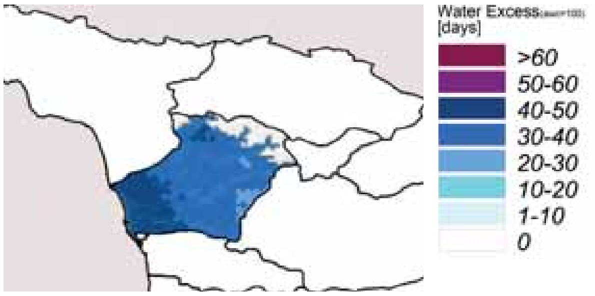
Real Evapotranspiration ETR (AWC = 100 mm) (1974 – 2013)



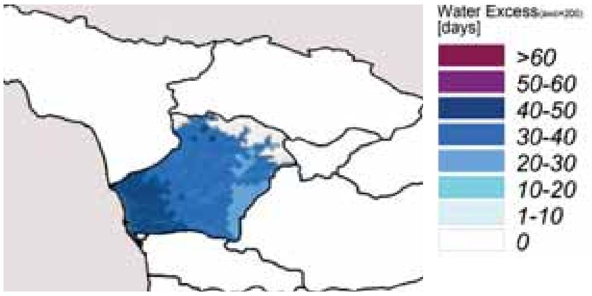
Real Evapotranspiration ETR (AWC = 200 mm) (1974 – 2013)



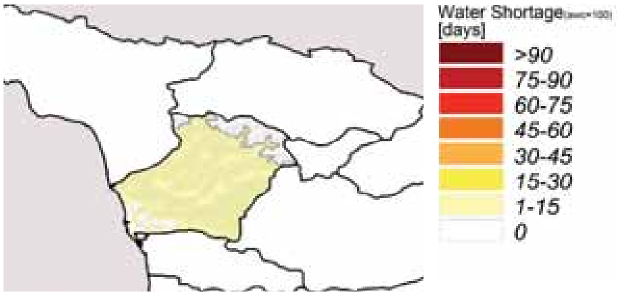
Water Excess (AWC = 100 mm) (1974 – 2013)



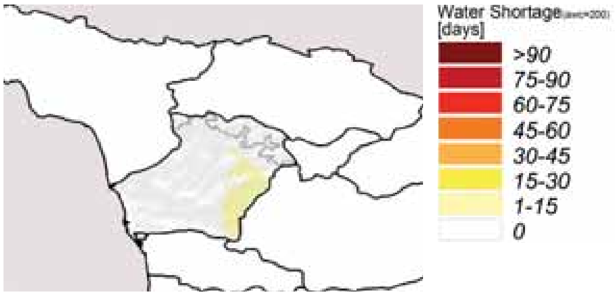
Water Excess (AWC = 200 mm) (1974 – 2013)



Water Shortage (AWC = 100 mm) (1974 – 2013)



Water Shortage (AWC = 200 mm) (1974 – 2013)



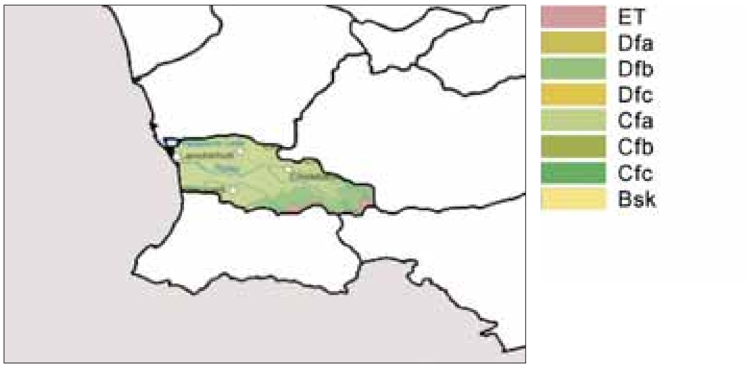
Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0 - 250	72.5	early	IV - V	low - very low	low - high
250 - 500	15.3	early	IV - V	low - very low	low - high
500 - 750	3.8	medium	III	low - very low	low - high
750 - 1000	4.4	late	II	low - very low	low - high
1000 - 1250	4.1	late	I	low - very low	low - high

Elevation belt (m)	Risk of summer light - thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0 - 250	very high	very low - low	medium	high
250 - 500	very low - very high	very low - low	medium	high
500 - 750	very low - very high	very low - low	medium	high
750 - 1000	low - very low	very low - low	medium	high
1000 - 1250	low - very low	very low - low	medium	high

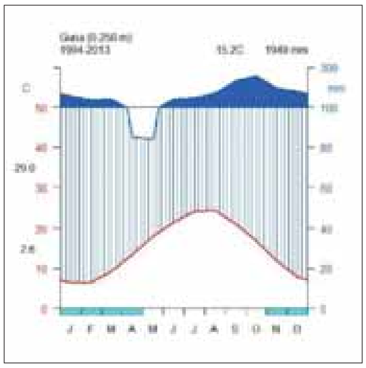
Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0 - 250	12	low	1.2	16	3 - 4	0
250 - 500	12	low	1.2	16	3 - 4	0 - 100
500 - 750	10	medium	1.0	12	2 - 3	0 - 100
750 - 1000	8	high	0.8	10	2 - 3	100
1000 - 1250	6	high	0.8	8	2	100

GURIA

Köppen Geiger Classification



Bagnouls – Gaussen Diagram (0-250 m altitudinal belt)



The viticultural area belongs to the coastal area of the Black Sea and is mainly characterized by the Köppen climatic type Cfa with transition to Dfb at the highest elevations.

Precipitation is plentiful during the whole year with an average annual precipitation between 1400 and 2000 mm.

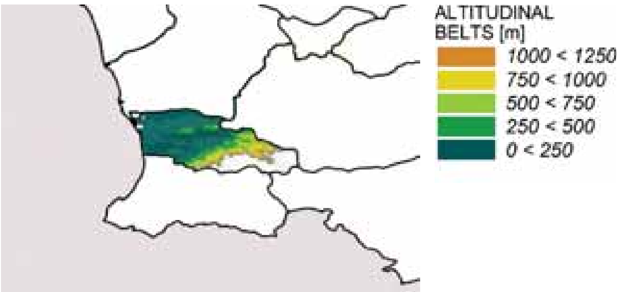
The Bagnouls – Gaussen diagram highlights consistent excess of precipitation along most part of the year, with the absence of dry season.

The climatic risk of temperature below the critical threshold of -15 °C is very low for the last 40 years.

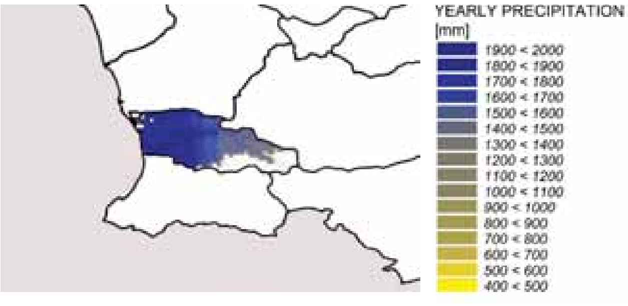
The thunderstorm activity in summer gives a significant hail risk (1 - 2 hail days per year).

THERMAL-PLUVIOMETRIC FEATURES

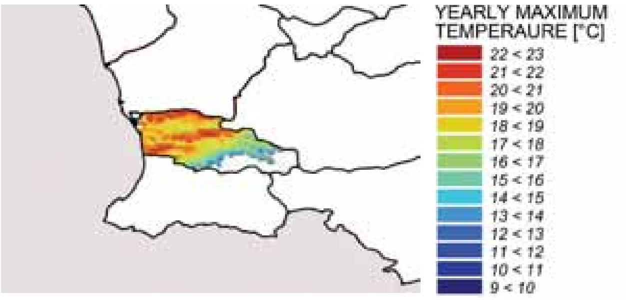
Altitudinal Belts



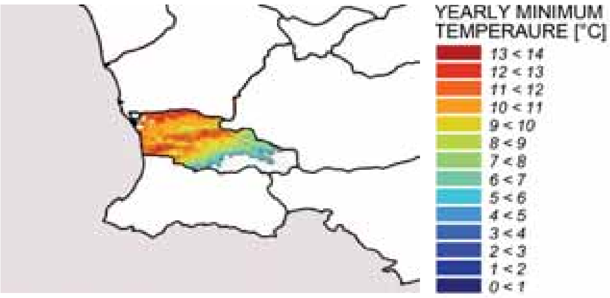
Yearly Precipitation (1994 – 2013)



Yearly Maximum Temperature (1994 – 2013)

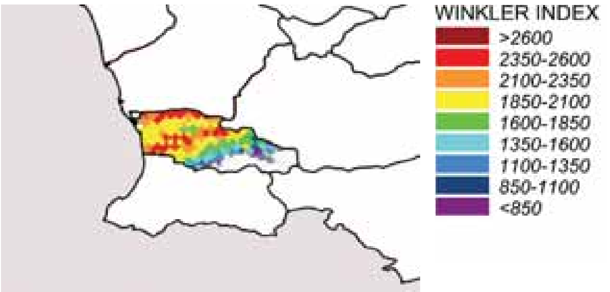


Yearly Minimum Temperature (1994 – 2013)

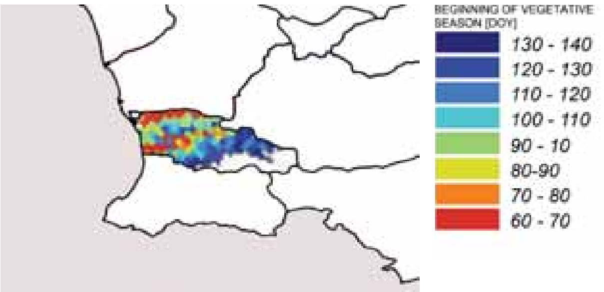


THERMAL RESOURCES AND LIMITATIONS

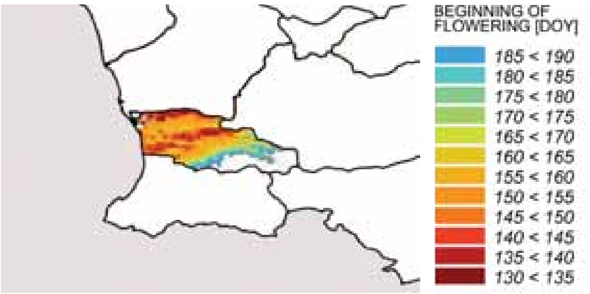
Winkler Index
(1994 – 2013)



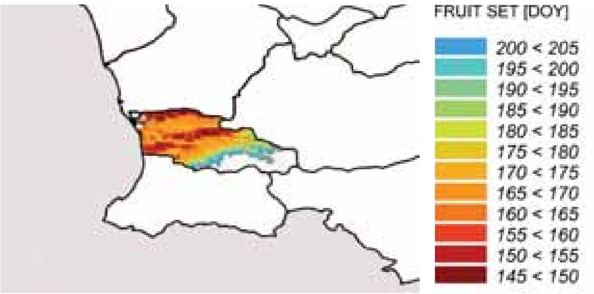
Beginning of Vegetative Season
(1994 – 2013)



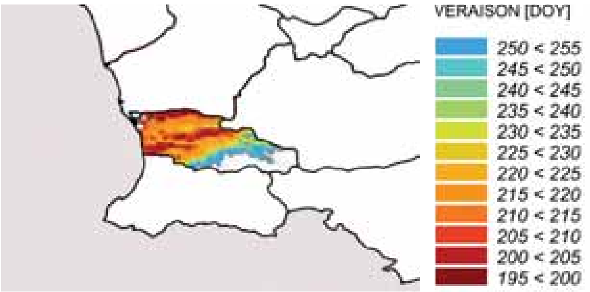
Beginning of Flowering
(1994 – 2013)



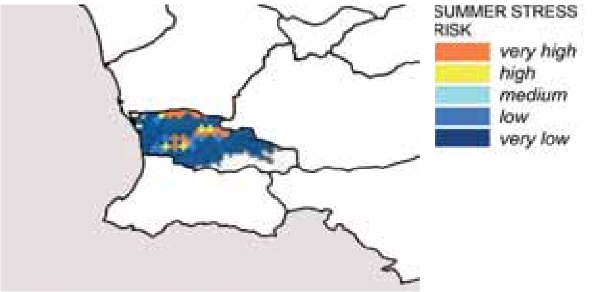
Fruit Set
(1994 – 2013)



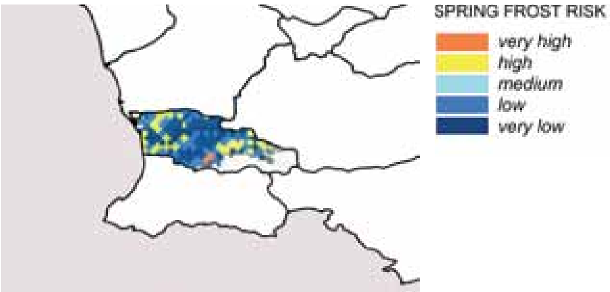
Beginning of Veraison
(1994 – 2013)



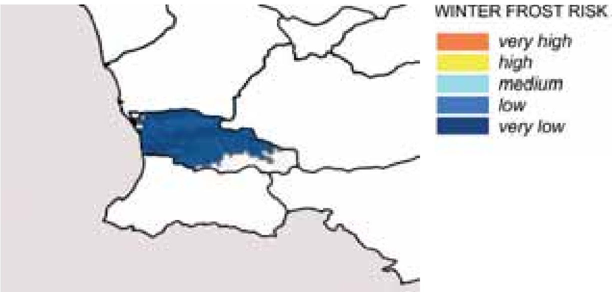
Summer Stress
(1974 – 2013)



Spring Frost
(1974 – 2013)

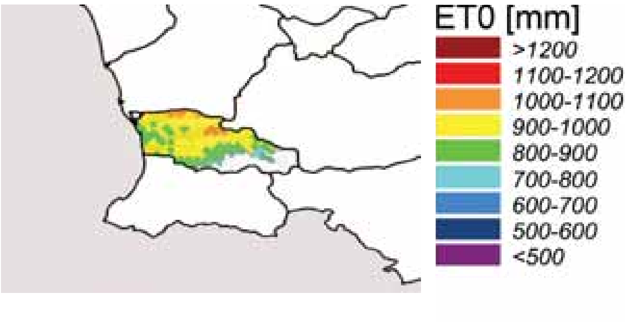


Winter Frost
(1974 – 2013)

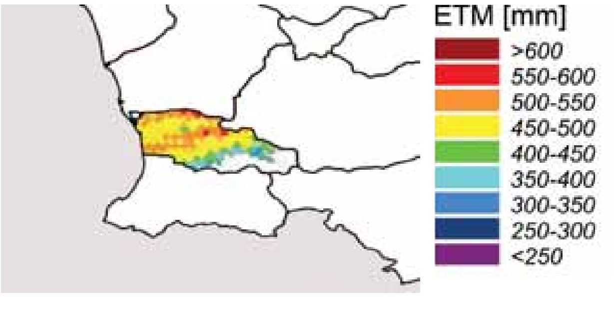


WATER RESOURCES AND LIMITATIONS

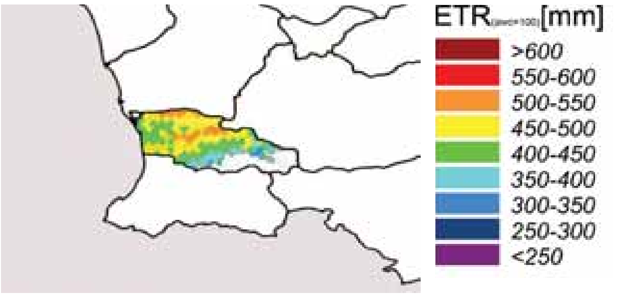
Reference Evapotranspiration ET0 (1974 – 2013)



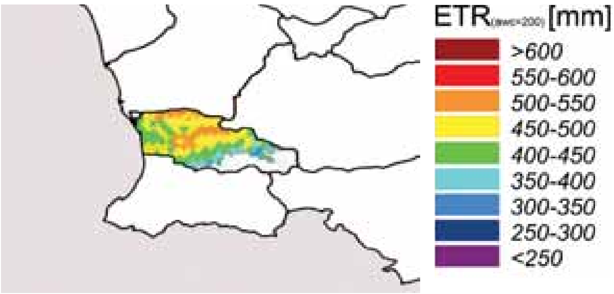
Maximum Evapotranspiration ETM (1974 – 2013)



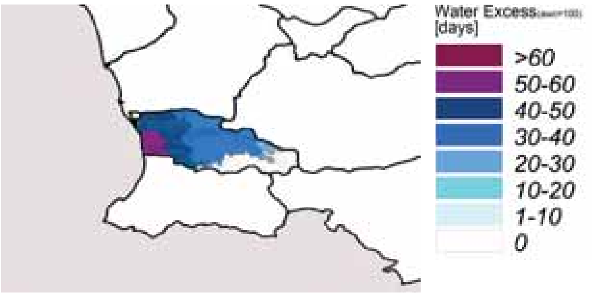
Real Evapotranspiration ETR (AWC = 100 mm) (1974 – 2013)



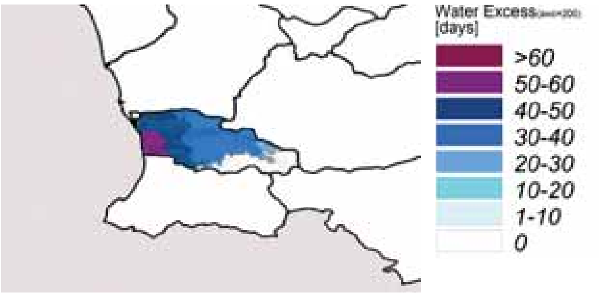
Real Evapotranspiration ETR (AWC = 200 mm) (1974 – 2013)



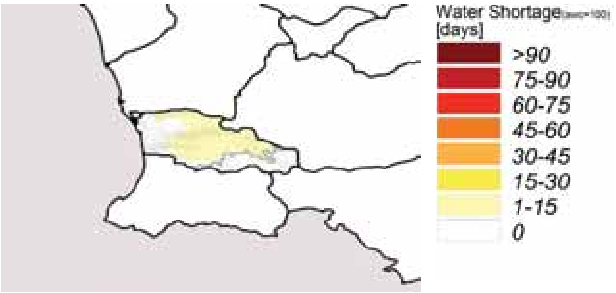
Water Excess (AWC = 100 mm) (1974 – 2013)



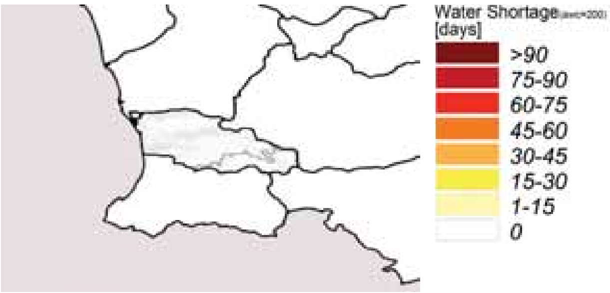
Water Excess (AWC = 200 mm) (1974 – 2013)



Water Shortage (AWC = 100 mm) (1974 – 2013)



Water Shortage (AWC = 200 mm) (1974 – 2013)

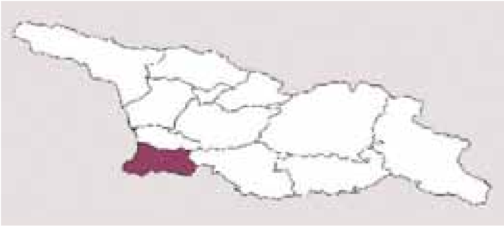


Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0 - 250	64.9	early	IV - V	very low	very low - high
250 - 500	14.2	early	III - IV	low	very low - high
500 - 750	6.7	medium	III	low	very low - high
750 - 1000	7.5	late	I - II	low	very low - high
1000 - 1250	6.7	late	I	low	very low - high

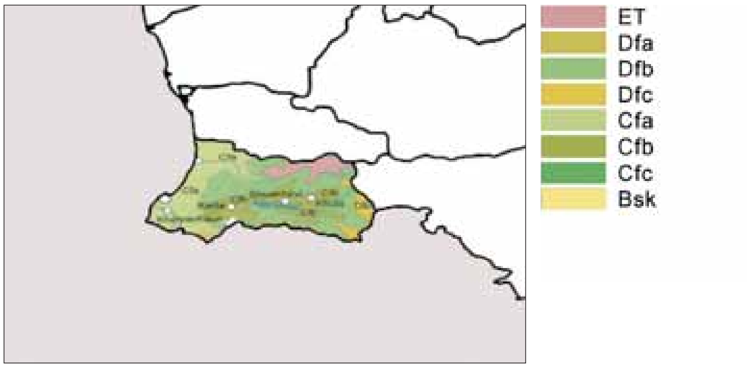
Elevation belt (m)	Risk of summer light - thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0 - 250	medium	very low	medium - high	very high
250 - 500	low	very low	medium - high	very high
500 - 750	very low	very low	medium - high	very high
750 - 1000	very low	very low	medium - high	very high
1000 - 1250	very low	very low	medium	very high

Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0 - 250	12	low	1.2	16	3 - 4	50
250 - 500	10	medium	1.0	12	2 - 3	100
500 - 750	8	high	0.8	10	2 - 3	100
750 - 1000	6	high	0.8	8	2	100
1000 - 1250	6	high	0.8	8	2	100

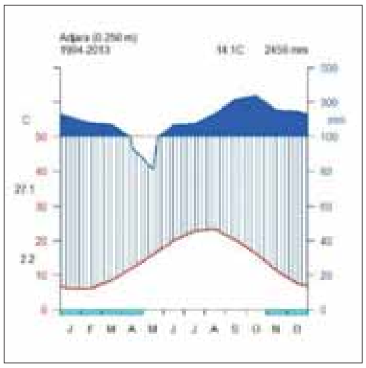
ADJARA



Köppen Geiger Classification



Bagnouls – Gaussen Diagram (0-250 m altitudinal belt)



The viticultural area belongs to the coastal area of the Black Sea and is characterized by the Köppen climatic type Cfa with transition to with transition to Cfb above 500 m asl in the Adjaristskali river valley and to Dfb at the highest elevations.

Precipitation is plentiful during the whole year with an average annual precipitation between 1400-2000 mm.

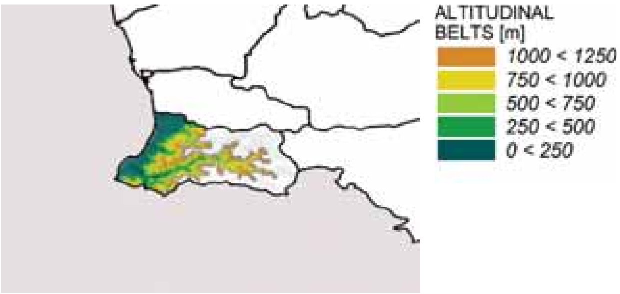
The Bagnouls – Gaussen diagram highlights consistent excess of precipitation along most part of the year, with the absence of dry season.

The climatic risk of temperature below the critical threshold of -15°C is very low.

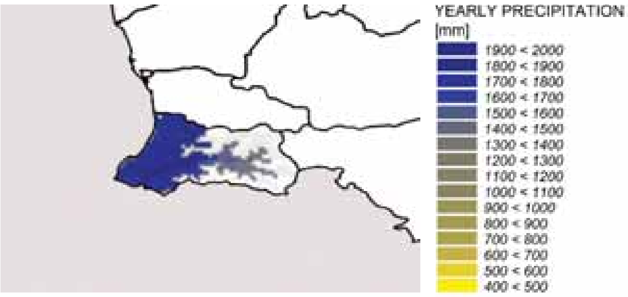
The thunderstorm activity in summer gives a significant hail risk (1 - 3 hail days per year).

THERMAL-PLUVIOMETRIC FEATURES

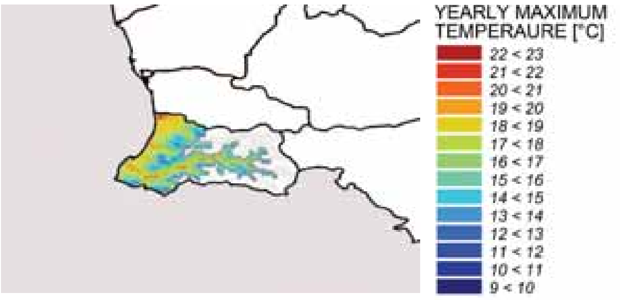
Altitudinal Belts



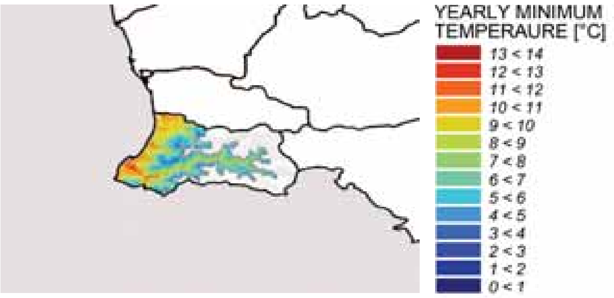
Yearly Precipitation (1994 – 2013)



Yearly Maximum Temperature (1994 – 2013)

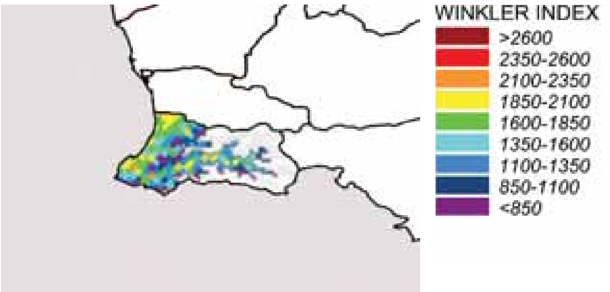


Yearly Minimum Temperature (1994 – 2013)

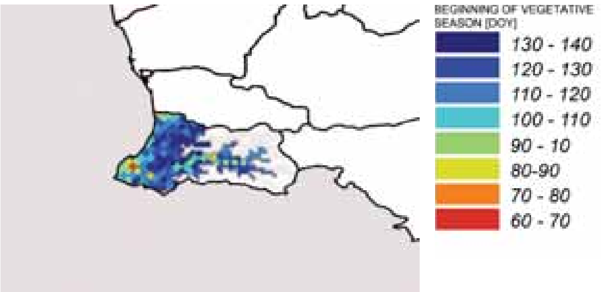


THERMAL RESOURCES AND LIMITATIONS

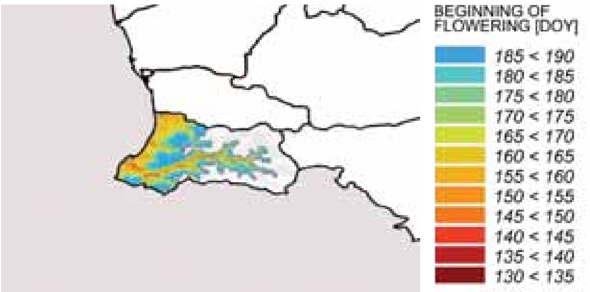
Winkler Index
(1994 – 2013)



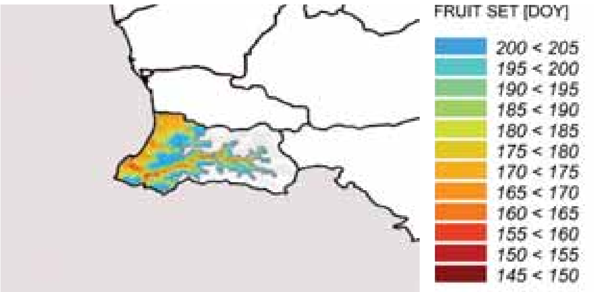
Beginning of Vegetative Season
(1994 – 2013)



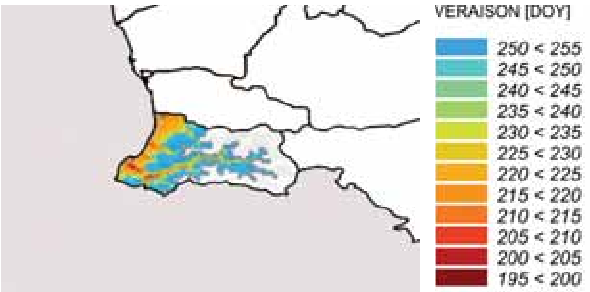
Beginning of Flowering
(1994 – 2013)



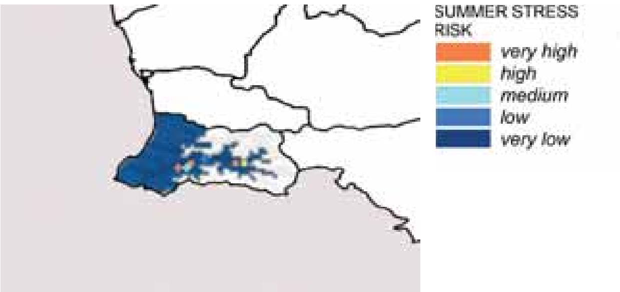
Fruit Set
(1994 – 2013)



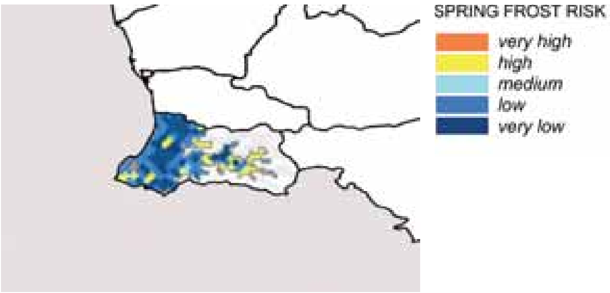
Beginning of Veraison
(1994 – 2013)



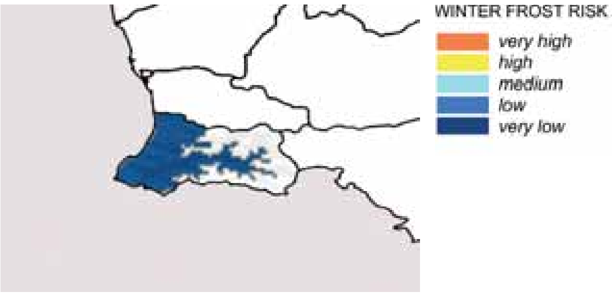
Summer Stress
(1974 – 2013)



Spring Frost
(1974 – 2013)

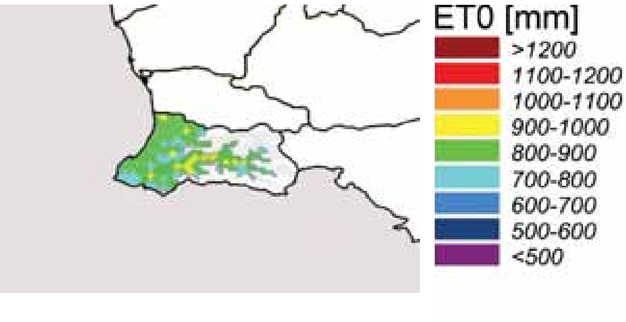


Winter Frost
(1974 – 2013)

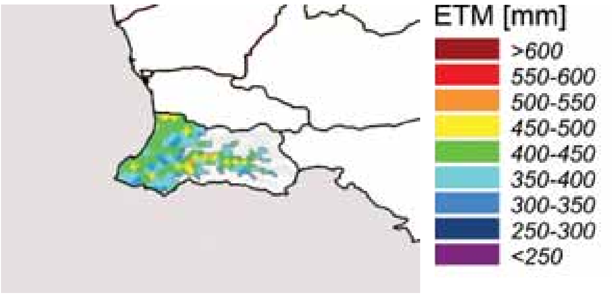


WATER RESOURCES AND LIMITATIONS

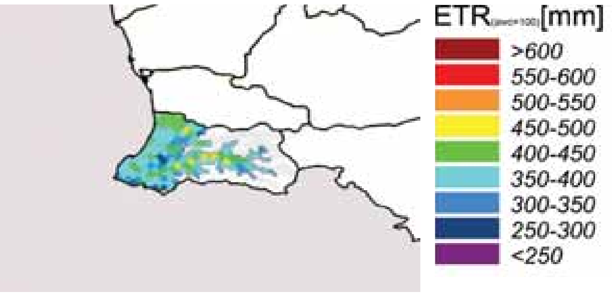
Reference Evapotranspiration ET0
(1974 – 2013)



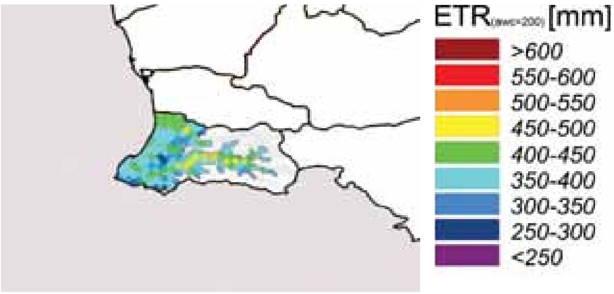
Maximum Evapotranspiration ETM
(1974 – 2013)



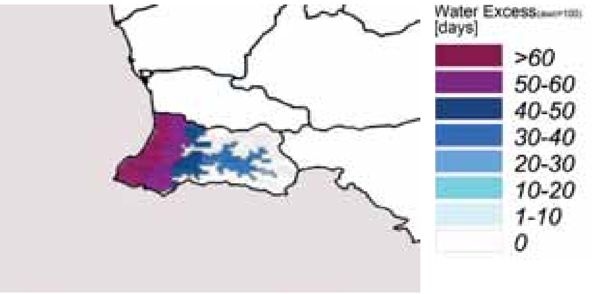
Real Evapotranspiration ETR (AWC = 100 mm)
(1974 – 2013)



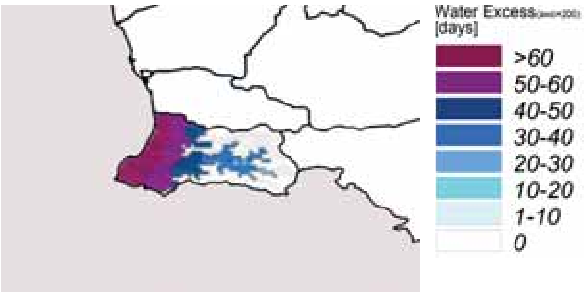
Real Evapotranspiration ETR (AWC = 200 mm)
(1974 – 2013)



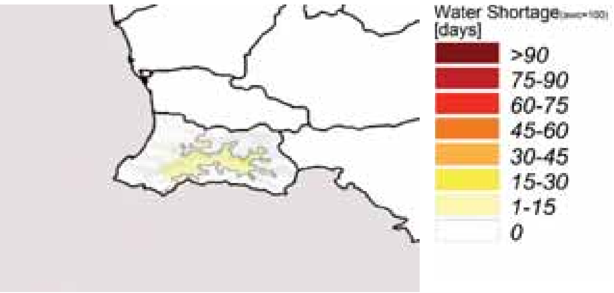
Water Excess (AWC = 100 mm)
(1974 – 2013)



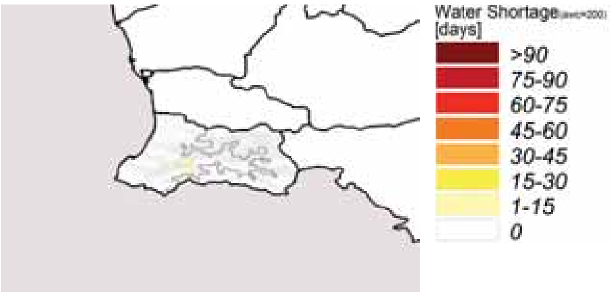
Water Excess (AWC = 200 mm)
(1974 – 2013)



Water Shortage (AWC = 100 mm)
(1974 – 2013)



Water Shortage (AWC = 200 mm)
(1974 – 2013)



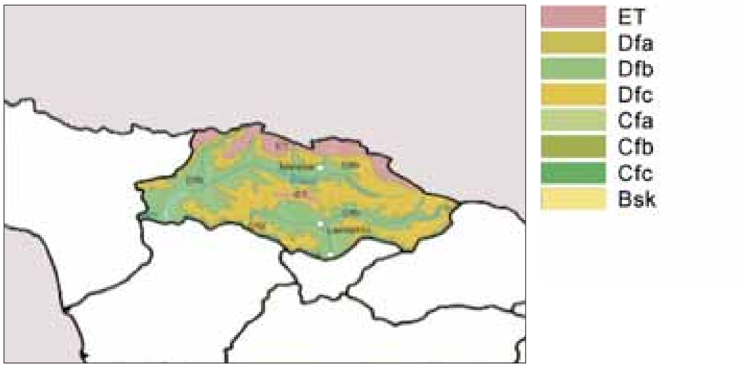
Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0 - 250	25.4	early	III	low - very low	very low - low
250 - 500	16.7	early	III	low - very low	very low - low
500 - 750	18.8	medium	II	low - very low	very low - high
750 - 1000	11.6	late	II	low - very low	very low - high
1000 - 1250	27.5	late	I	low - very low	very low - high

Elevation belt (m)	Risk of summer light - thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0 - 250	very low - low	very low	medium	very high
250 - 500	very low - low	very low	medium	very high
500 - 750	very low - low	very low - low	medium	very high
750 - 1000	very low - low	very low - low	medium	very high
1000 - 1250	very low - low	very low - low	medium	very high

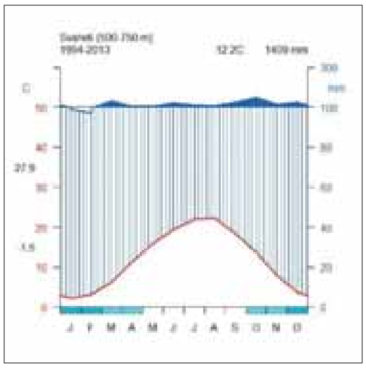
Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0 - 250	10	medium	1.0	12	2 - 3	50
250 - 500	10	medium	1.0	12	2 - 3	50
500 - 750	8	high	0.8	10	2 - 3	100
750 - 1000	8	high	0.8	10	2 - 3	100
1000 - 1250	6	high	0.8	8	2	100

SVANETI

Köppen Geiger Classification



Bagnouls – Gaussen Diagram
(500-750 m altitudinal belt)



The Svaneti region belongs to the southern slopes of the Greater Caucasus chain and the area potentially suitable for viticulture is limited to the lower altitudes which are characterized by a Köppen climatic type Dfb.

Precipitation is well distributed throughout the year with average annual values mainly between 1200 and 1600 mm, with a gradual decrease with the increase of the altitude (endo-alpine effect).

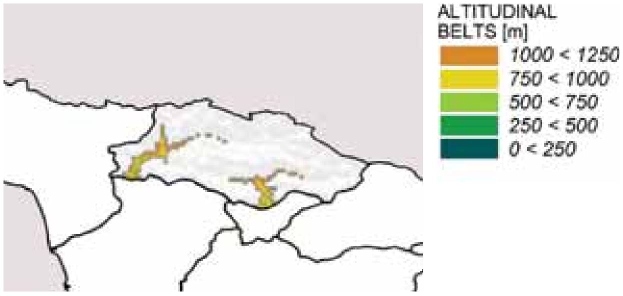
The Bagnouls – Gaussen diagram highlights light excess of precipitation along most part of the year, with the absence of dry season.

The risk of temperatures below -15°C in the Enguri and Tskhenistskali valleys is strongly affected by land morphology.

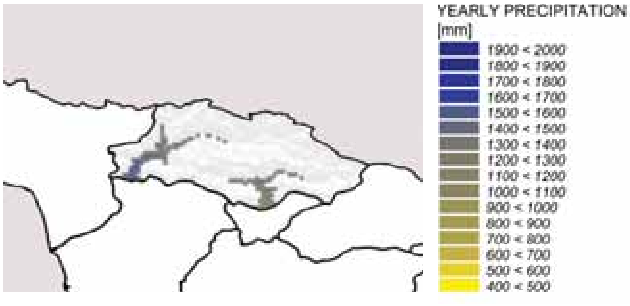
The thunderstorm activity in summer gives a significant hail risk (2 - 3 hail days per year).

THERMAL-PLUVIOMETRIC FEATURES

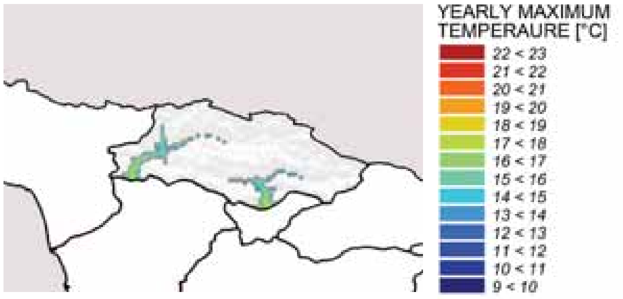
Altitudinal Belts



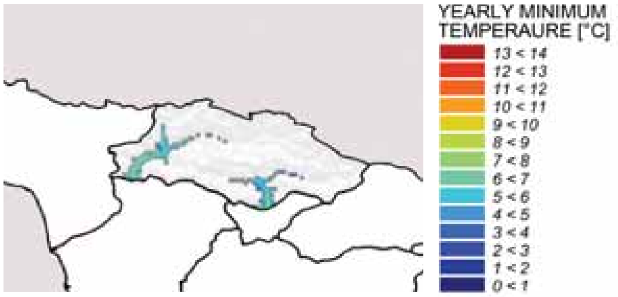
Yearly Precipitation
(1994 – 2013)



Yearly Maximum Temperature
(1994 – 2013)

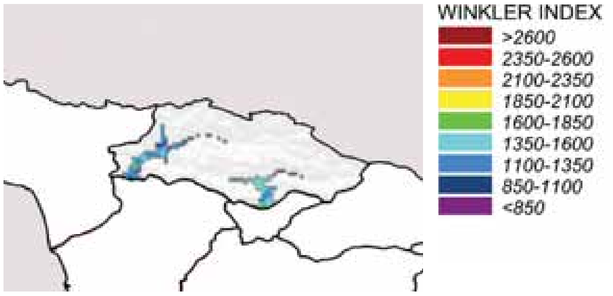


Yearly Minimum Temperature
(1994 – 2013)

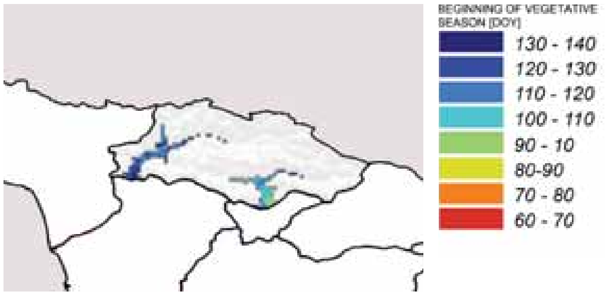


THERMAL RESOURCES AND LIMITATIONS

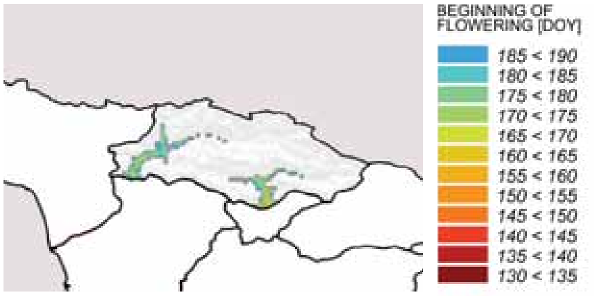
Winkler Index (1994 – 2013)



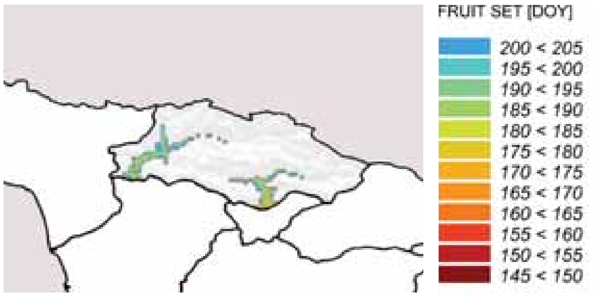
Beginning of Vegetative Season (1994 – 2013)



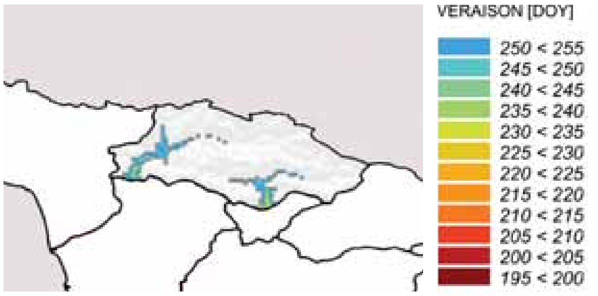
Beginning of Flowering (1994 – 2013)



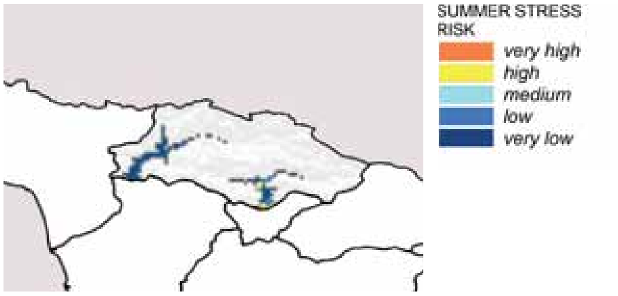
Fruit Set (1994 – 2013)



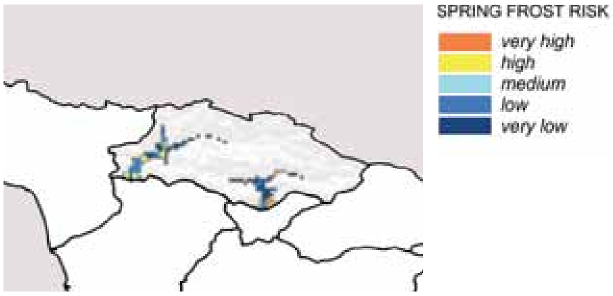
Beginning of Veraison (1994 – 2013)



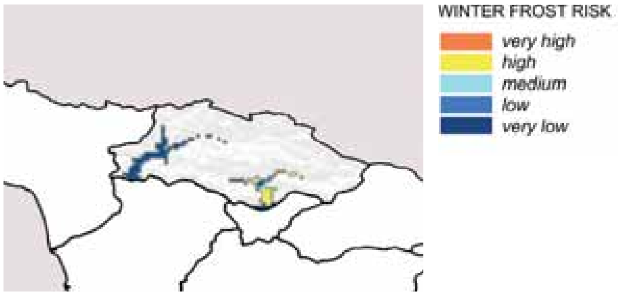
Summer Stress (1974 – 2013)



Spring Frost (1974 – 2013)

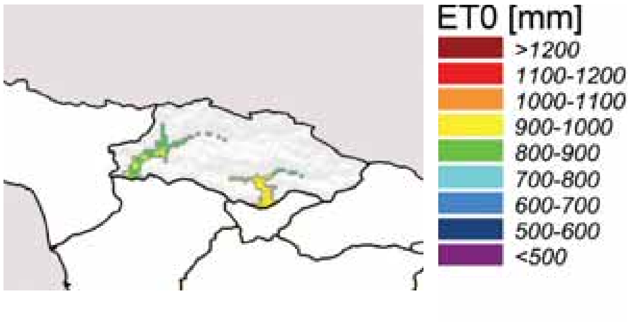


Winter Frost (1974 – 2013)

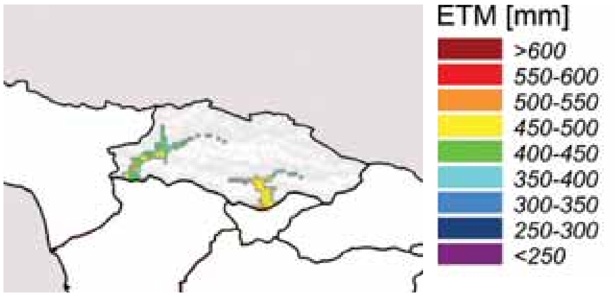


WATER RESOURCES AND LIMITATIONS

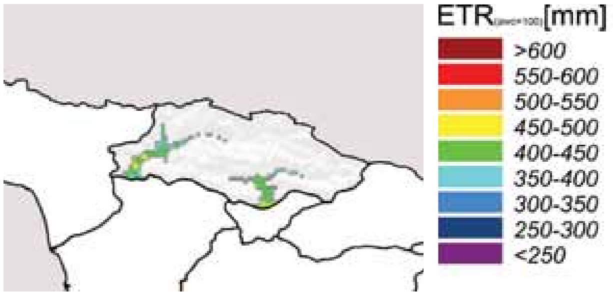
Reference Evapotranspiration ET0 (1974 – 2013)



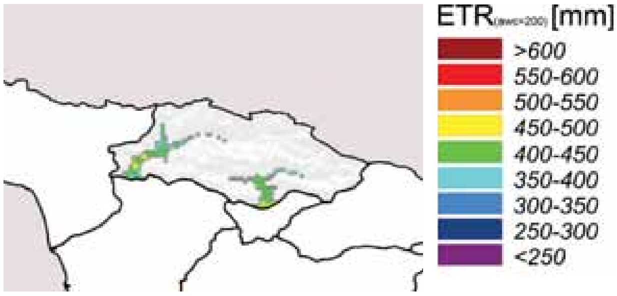
Maximum Evapotranspiration ETM (1974 – 2013)



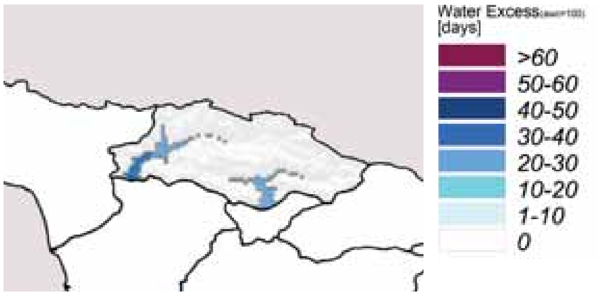
Real Evapotranspiration ETR (AWC = 100 mm) (1974 – 2013)



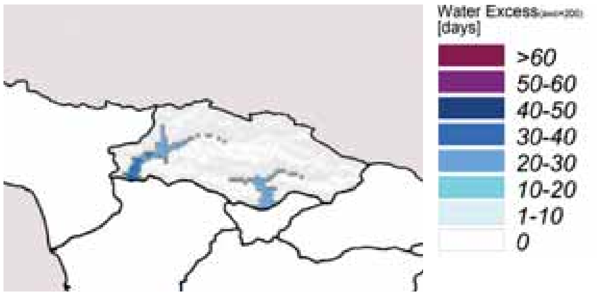
Real Evapotranspiration ETR (AWC = 200 mm) (1974 – 2013)



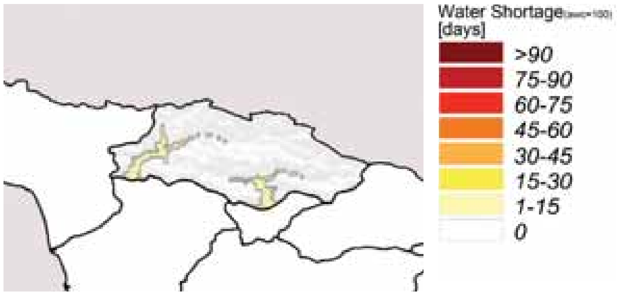
Water Excess (AWC = 100 mm) (1974 – 2013)



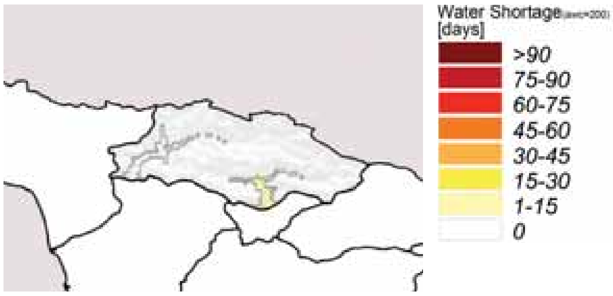
Water Excess (AWC = 200 mm) (1974 – 2013)



Water Shortage (AWC = 100 mm) (1974 – 2013)



Water Shortage (AWC = 200 mm) (1974 – 2013)



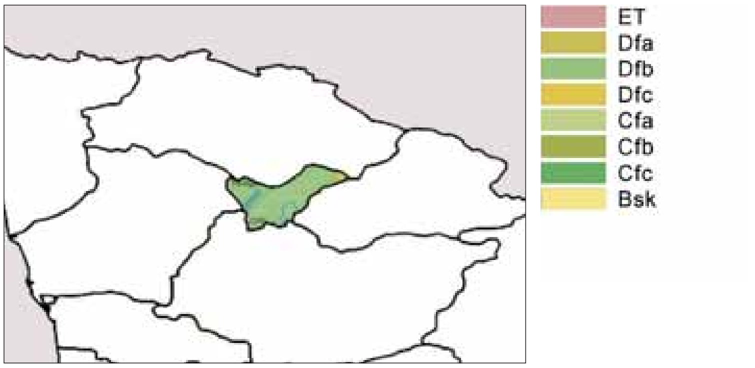
Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0 - 250	-	-	-	-	-
250 - 500	-	-	-	-	-
500 - 750	7.5	medium	III	very low - high	very low - high
750 - 1000	30.0	late	II	very low - high	very low - high
1000 - 1250	62.5	late	I	very low - high	very low - high

Elevation belt (m)	Risk of summer light - thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0 - 250	-	-	-	-
250 - 500	-	-	-	-
500 - 750	very low (high)	very low	medium	high
750 - 1000	very low (high)	very low	medium	high
1000 - 1250	very low (high)	very low	medium	high

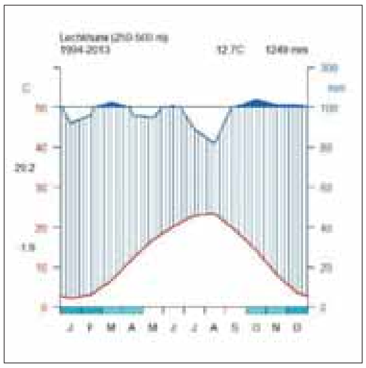
Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0 - 250	-	-	-	-	-	-
250 - 500	-	-	-	-	-	-
500 - 750	10	medium	1.0	12	2 - 3	50
750 - 1000	8	high	0.8	10	2 - 3	100
1000 - 1250	6	high	0.8	8	2	100

LECHKHUMI

Köppen Geiger Classification



Bagnouls – Gaussen Diagram
(250-500 m altitudinal belt)



The Lechkhumi region belongs to the southern slopes of the Greater Caucasus chain and the area potentially suitable for viticulture is characterized by a Köppen climatic type Dfb.

Precipitation is well distributed throughout the year with average annual values between 1200 and 1400 mm, with a gradual decrease with the increase of the altitude (endo-alpine effect).

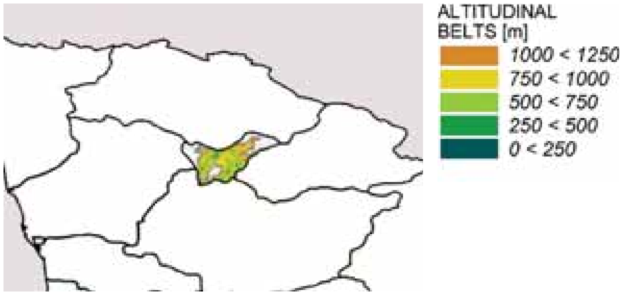
The Bagnouls – Gaussen diagram highlights light water excess in March, October, November and December with absence of dry season.

The climatic risk of temperature below the critical threshold of -15°C ranges between very low and very high.

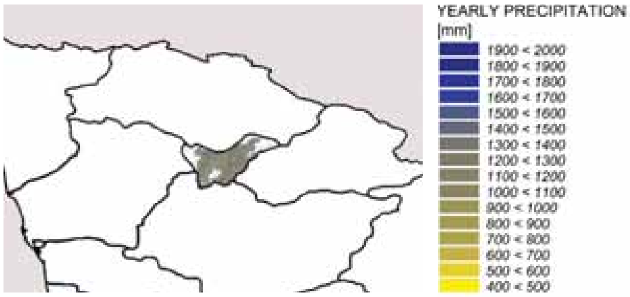
The thunderstorm activity in summer gives a significant hail risk (2 - 3 hail days per year).

THERMAL-PLUVIOMETRIC FEATURES

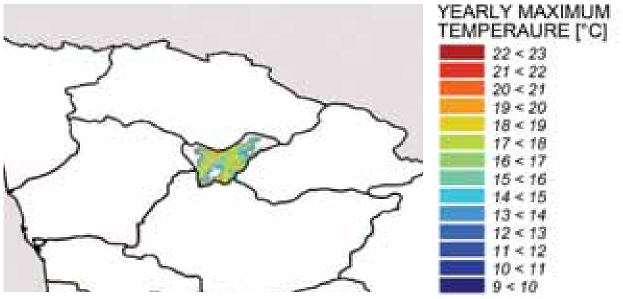
Altitudinal Belts



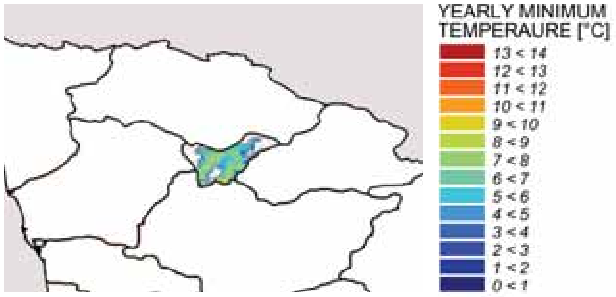
Yearly Precipitation
(1994 – 2013)



Yearly Maximum Temperature
(1994 – 2013)

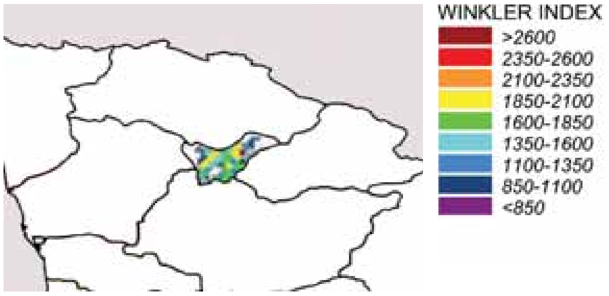


Yearly Minimum Temperature
(1994 – 2013)

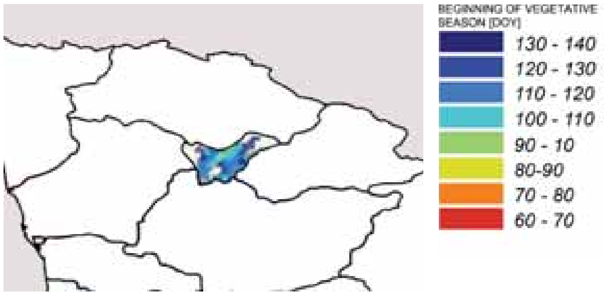


THERMAL RESOURCES AND LIMITATIONS

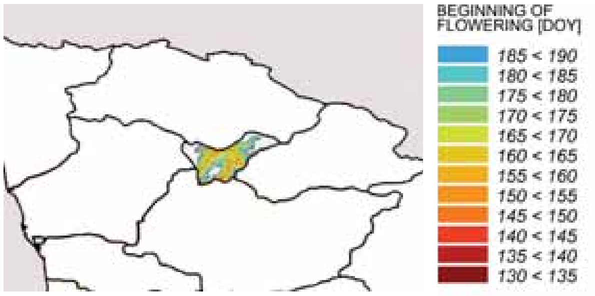
Winkler Index
(1994 – 2013)



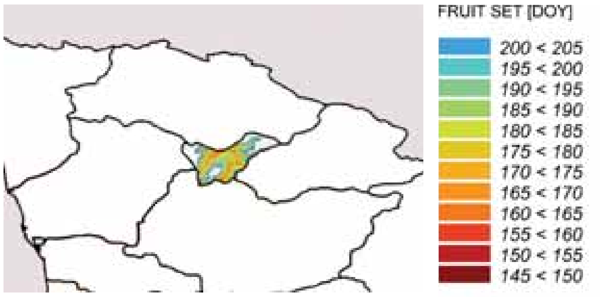
Beginning of Vegetative Season
(1994 – 2013)



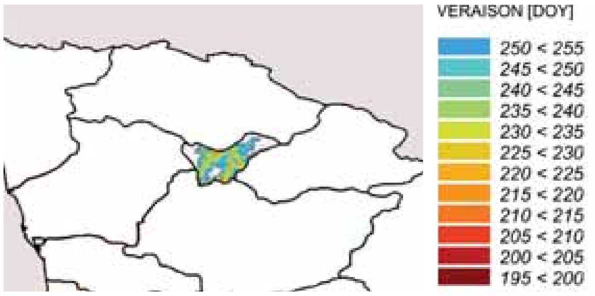
Beginning of Flowering
(1994 – 2013)



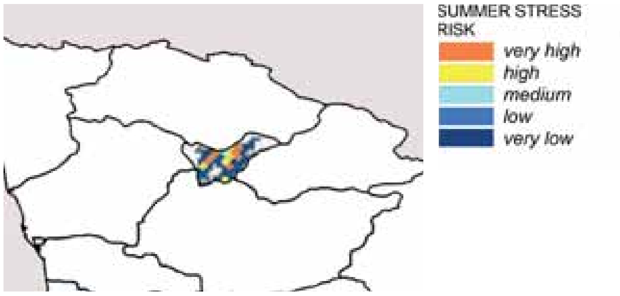
Fruit Set
(1994 – 2013)



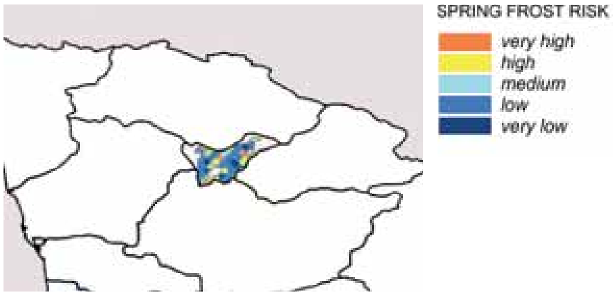
Beginning of Veraison
(1994 – 2013)



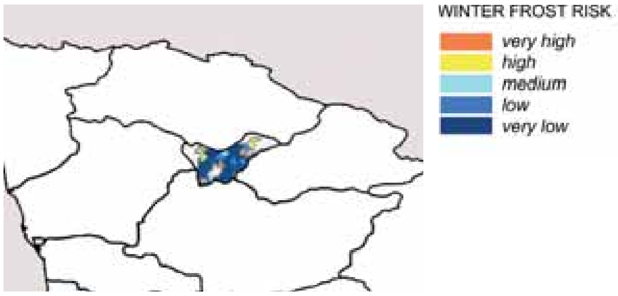
Summer Stress
(1974 – 2013)



Spring Frost
(1974 – 2013)

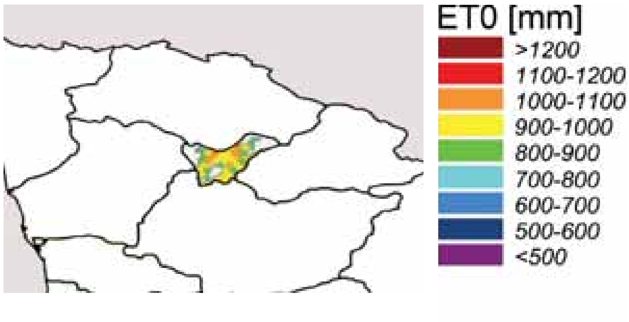


Winter Frost
(1974 – 2013)

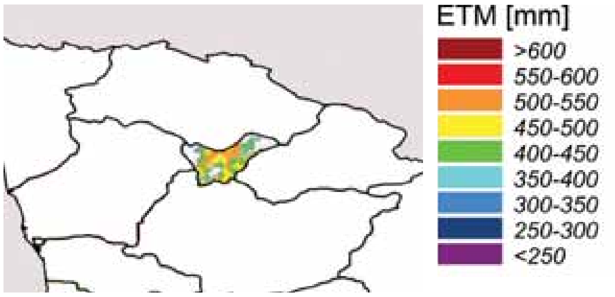


WATER RESOURCES AND LIMITATIONS

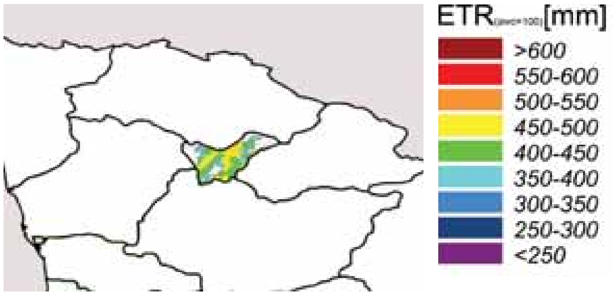
Reference Evapotranspiration ET0
(1974 – 2013)



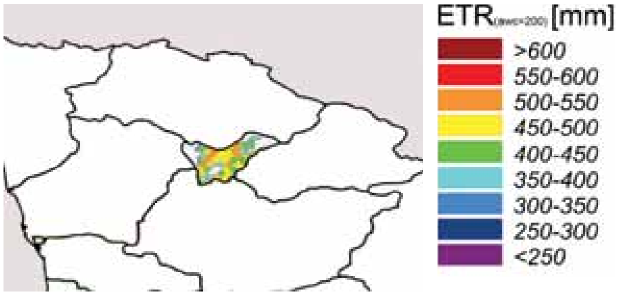
Maximum Evapotranspiration ETM
(1974 – 2013)



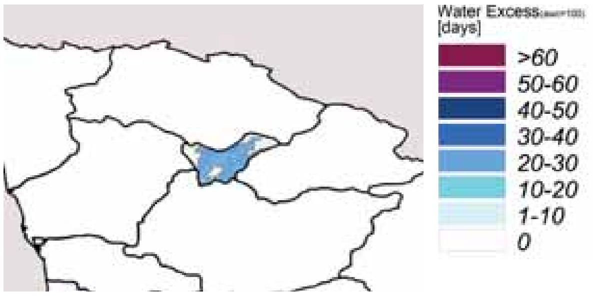
Real Evapotranspiration ETR (AWC = 100 mm)
(1974 – 2013)



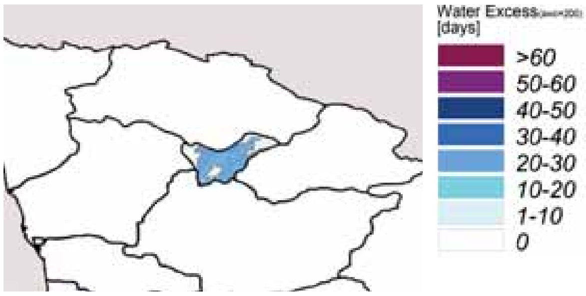
Real Evapotranspiration ETR (AWC = 200 mm)
(1974 – 2013)



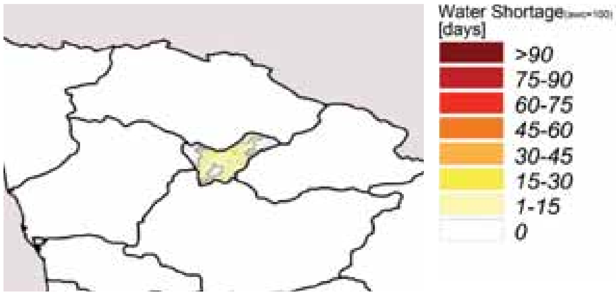
Water Excess (AWC = 100 mm)
(1974 – 2013)



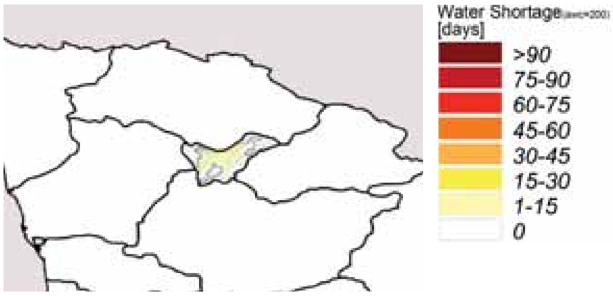
Water Excess (AWC = 200 mm)
(1974 – 2013)



Water Shortage (AWC = 100 mm)
(1974 – 2013)



Water Shortage (AWC = 200 mm)
(1974 – 2013)



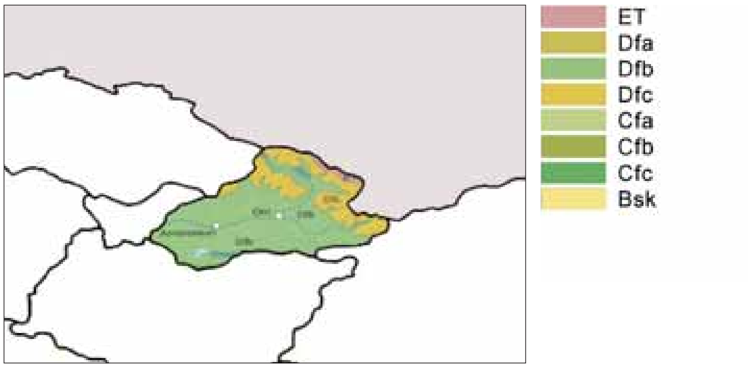
Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0 - 250	-	-	-	-	-
250 - 500	2.3	medium	III	very low	low
500 - 750	34.9	medium	III	very low	low
750 - 1000	30.2	late	II	low - high	low
1000 - 1250	32.6	late	I	low - high	medium - very high

Elevation belt (m)	Risk of summer light - thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0 - 250	-	-	-	-
250 - 500	high - very high	very low - low	medium	high
500 - 750	high - very high	very low - low	medium	high
750 - 1000	very low	very low - low	medium	high
1000 - 1250	very low	very low - low	medium	high

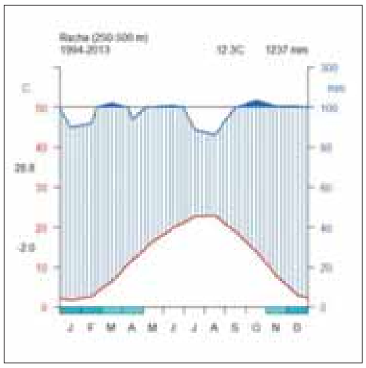
Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0 - 250	-	-	-	-	-	-
250 - 500	10	medium	1.0	12	2 - 3	50
500 - 750	10	medium	1.0	12	2 - 3	50
750 - 1000	8	high	0.8	10	2 - 3	100
1000 - 1250	6	high	0.8	8	2	100

RACHA

Köppen Geiger Classification



Bagnouls – Gaussen Diagram (250-500 m altitudinal belt)



The Racha region belongs to the southern slopes of the Greater Caucasus chain and the area potentially suitable for viticulture is limited to the lower altitudes which are characterized by a Köppen climatic type Dfb (Rioni valley).

Precipitation is well distributed throughout the year with average annual values between 1000 and 1400 mm, showing a gradual decrease with the increase of the altitude (endo-alpine effect).

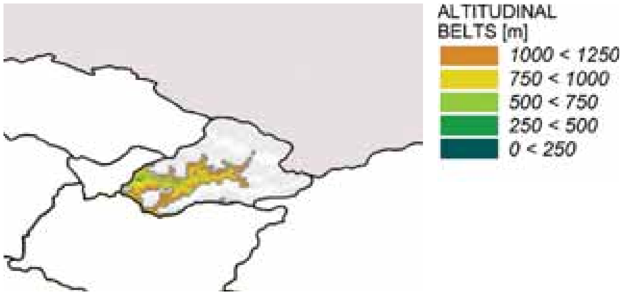
The Bagnouls – Gaussen diagram highlights light water excess in March, October, November and December with absence of dry season.

The climatic risk of temperature below the critical threshold of -15°C ranges from very low to very high.

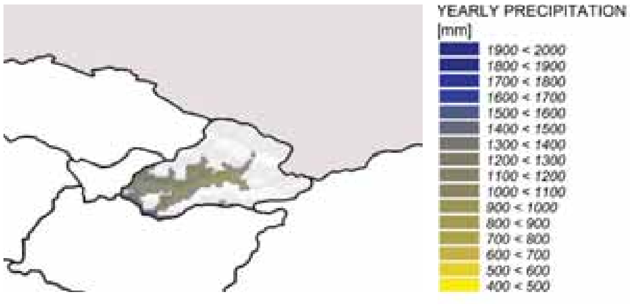
The thunderstorm activity in summer gives a significant hail risk (2 - 3 hail days per year).

THERMAL-PLUVIOMETRIC FEATURES

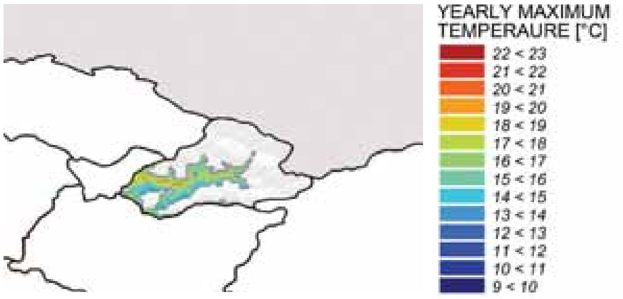
Altitudinal Belts



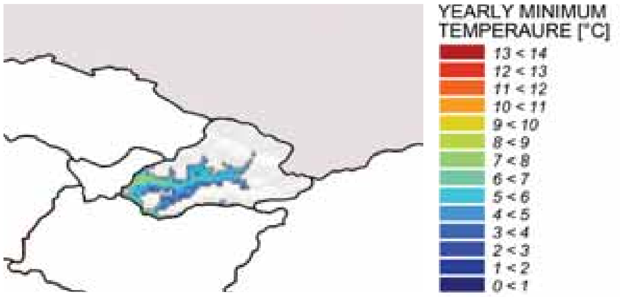
Yearly Precipitation (1994 – 2013)



Yearly Maximum Temperature (1994 – 2013)

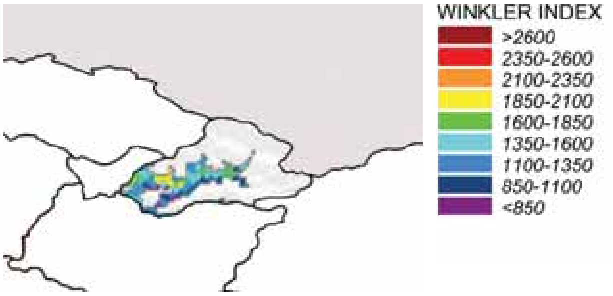


Yearly Minimum Temperature (1994 – 2013)

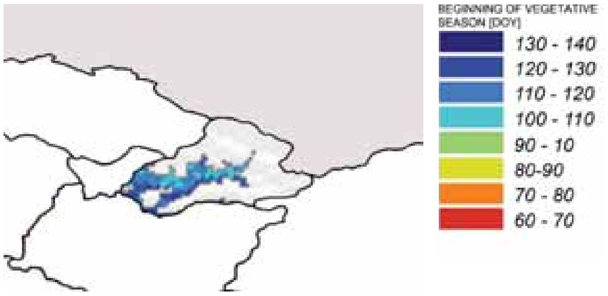


THERMAL RESOURCES AND LIMITATIONS

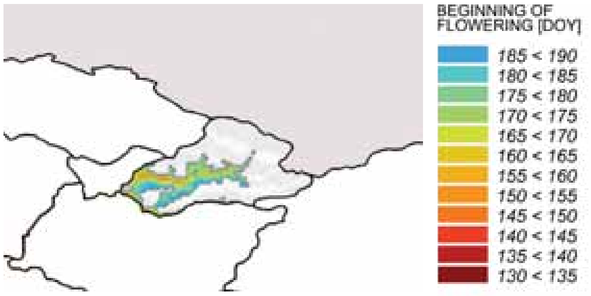
Winkler Index (1994 – 2013)



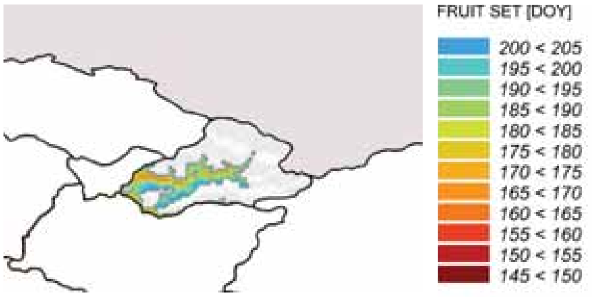
Beginning of Vegetative Season (1994 – 2013)



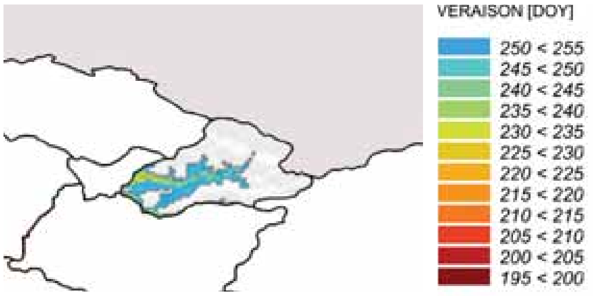
Beginning of Flowering (1994 – 2013)



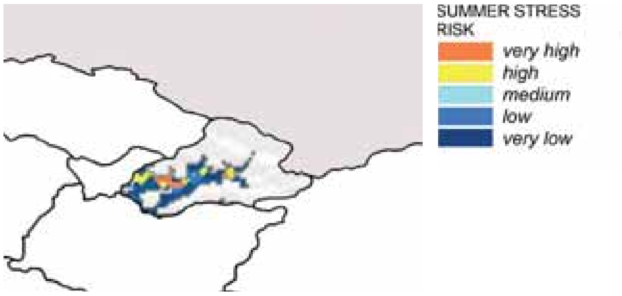
Fruit Set (1994 – 2013)



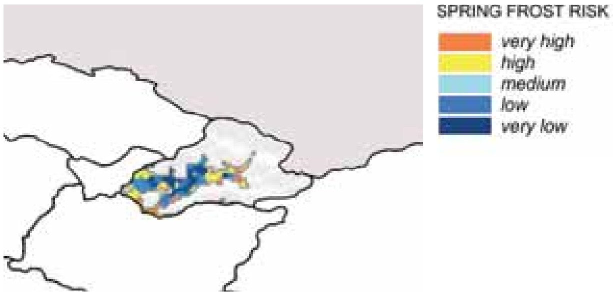
Beginning of Veraison (1994 – 2013)



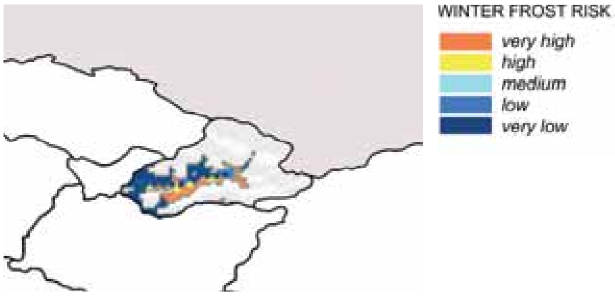
Summer Stress (1974 – 2013)



Spring Frost (1974 – 2013)

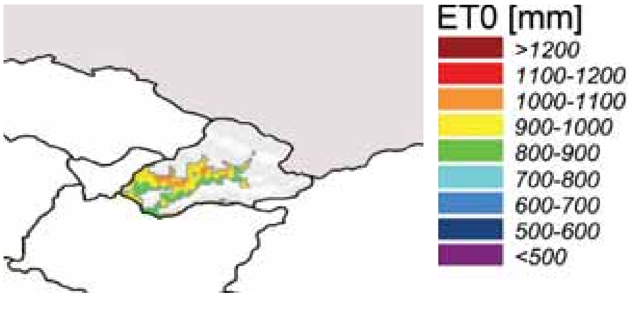


Winter Frost (1974 – 2013)

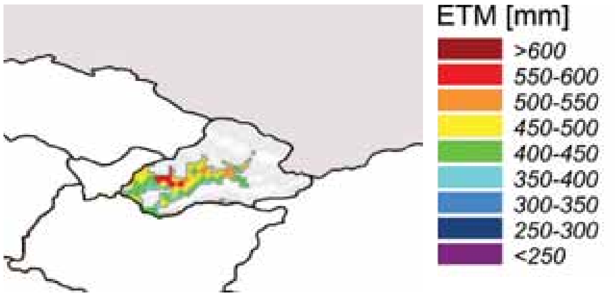


WATER RESOURCES AND LIMITATIONS

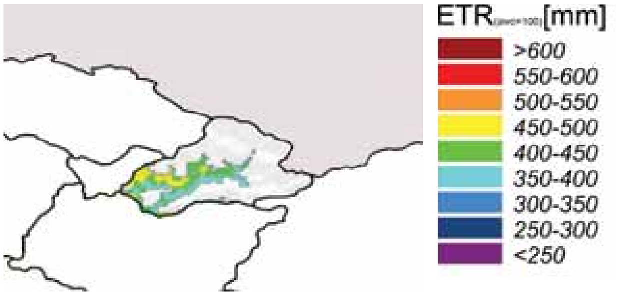
Reference Evapotranspiration ET0 (1974 – 2013)



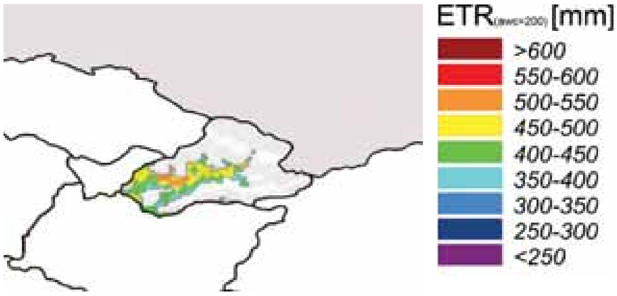
Maximum Evapotranspiration ETM (1974 – 2013)



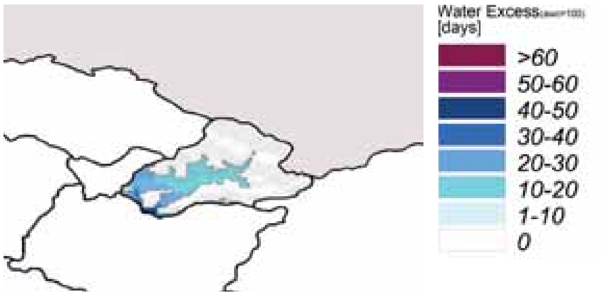
Real Evapotranspiration ETR (AWC = 100 mm) (1974 – 2013)



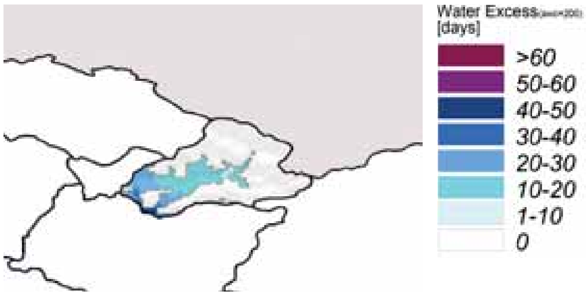
Real Evapotranspiration ETR (AWC = 200 mm) (1974 – 2013)



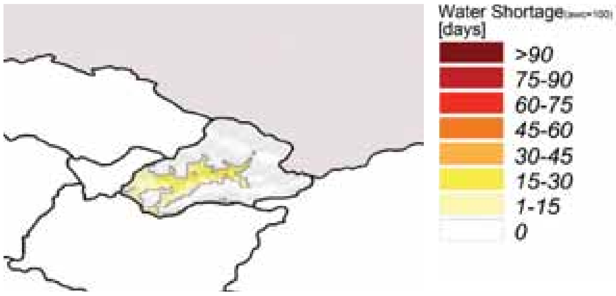
Water Excess (AWC = 100 mm) (1974 – 2013)



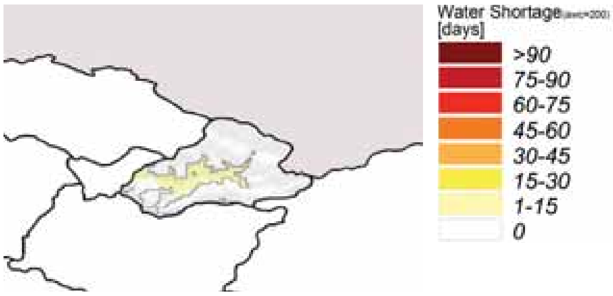
Water Excess (AWC = 200 mm) (1974 – 2013)



Water Shortage (AWC = 100 mm) (1974 – 2013)



Water Shortage (AWC = 200 mm) (1974 – 2013)



Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0-250	-	-	-	-	-
250-500	1.6	medium	II -III	very low	low - high
500-750	7.8	late	II- III	very low - very high	very low - very high
750-1000	37.5	late	II	very low - very high	very low - very high
1000-1250	53.1	late	I	very low - very high	very low - very high

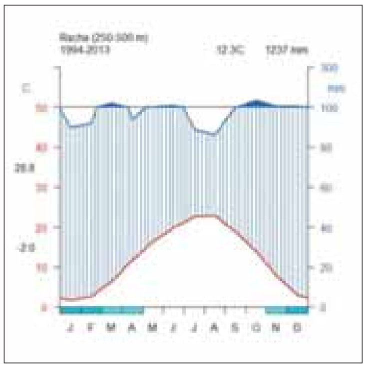
Elevation belt (m)	Risk of summer light-thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0-250	-	-	-	-
250-500	high - very high	very low - low	low - medium	low
500-750	very low - low - (high)	very low - low	low - medium	low
750-1000	very low - low - (high)	very low - low	low - medium	low
1000-1250	very low - low - (high)	very low - low	low - medium	low

Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0-250	-	-	-	-	-	-
250-500	10	medium	1.0	12	2-3	50
500-750	10	medium	1.0	12	2-3	50
750-1000	8	high	0.8	10	2-3	100
1000-1250	6	high	0.8	8	2	100

IMERETI

Köppen Geiger Classification

Bagnouls – Gaussen Diagram (250-500 m altitudinal belt)



The Imereti region belongs to the southern slopes of the Greater Caucasus chain, to the Western slopes of Likhi mountain chain and on the northern slopes of the Lesser Caucasus mountain chain. The area potentially suitable for viticulture is limited to the lower altitudes which are characterized by a Köppen climatic type Cfa with transition to Dfb at the highest altitudes.

Precipitation is well distributed throughout the year with average annual values between 800 and 1600 mm, with a negative gradient from West to East.

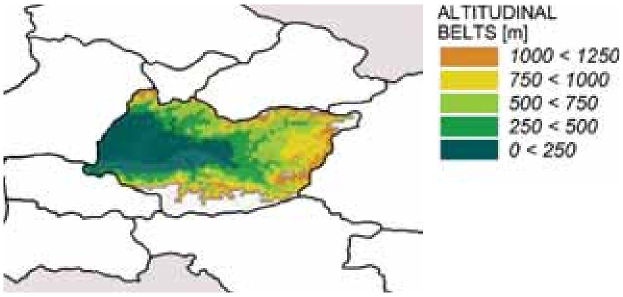
The Bagnouls – Gaussen diagram highlights continuous water excess from November to March with absence of dry season.

The climatic risk of temperature below the critical threshold of -15°C is very low at lower altitudes with a steep increase at highest altitudes.

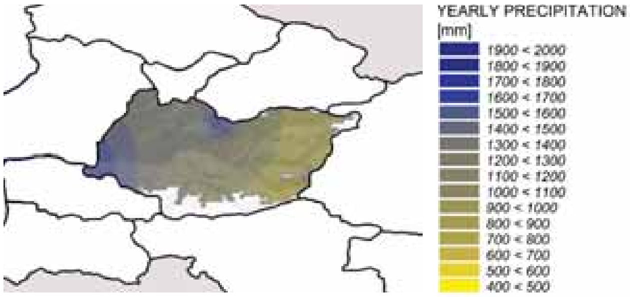
The thunderstorm activity in summer gives a generally low hail risk (about 1 hail day per year).

THERMAL-PLUVIOMETRIC FEATURES

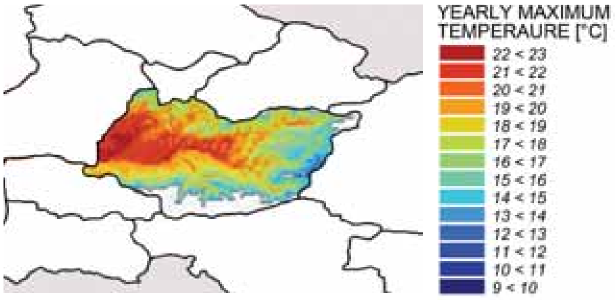
Altitudinal Belts



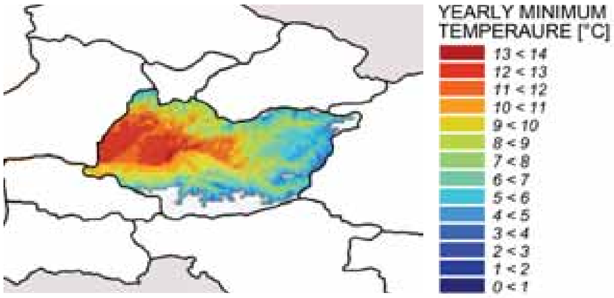
Yearly Precipitation (1994 – 2013)



Yearly Maximum Temperature (1994 – 2013)

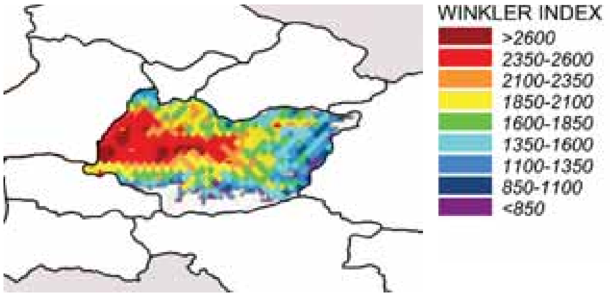


Yearly Minimum Temperature (1994 – 2013)

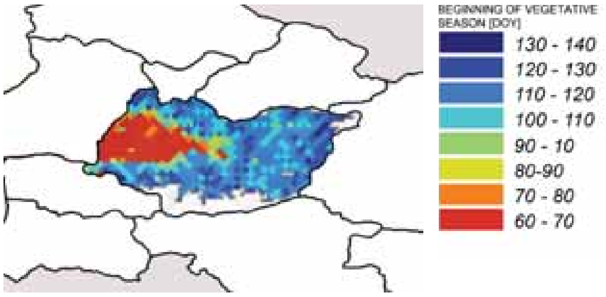


THERMAL RESOURCES AND LIMITATIONS

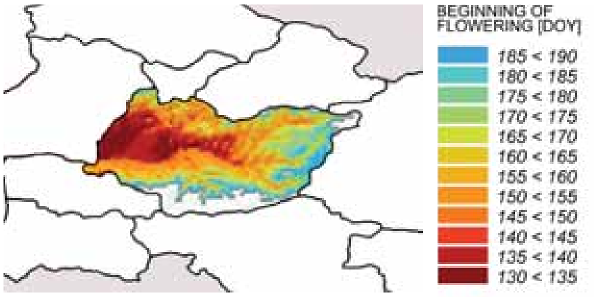
Winkler Index
(1994 – 2013)



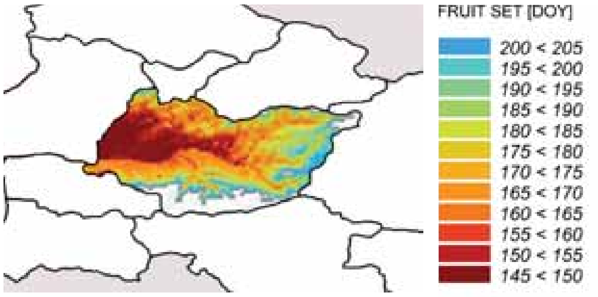
Beginning of Vegetative Season
(1994 – 2013)



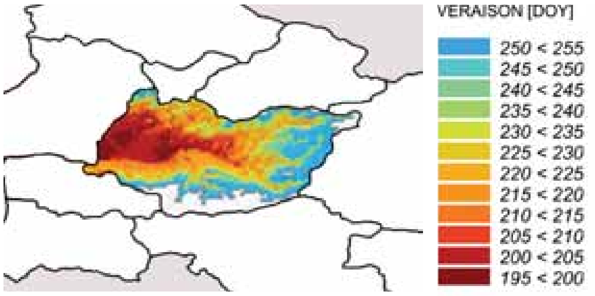
Beginning of Flowering
(1994 – 2013)



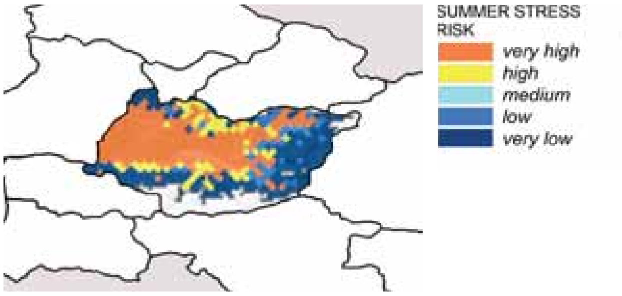
Fruit Set
(1994 – 2013)



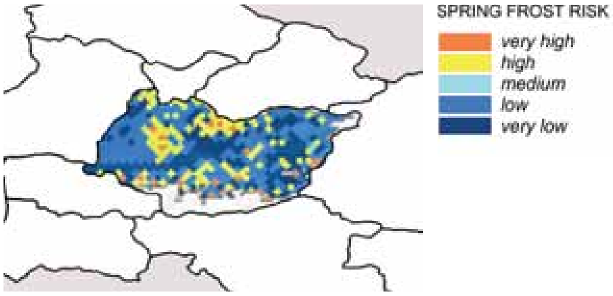
Beginning of Veraison
(1994 – 2013)



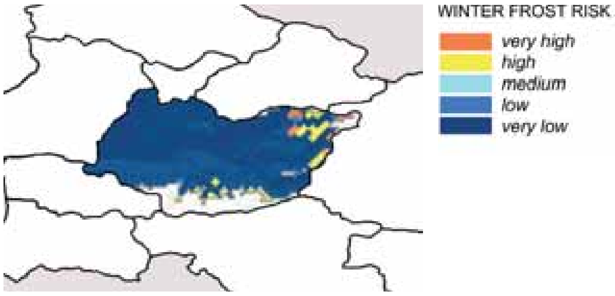
Summer Stress
(1974 – 2013)



Spring Frost
(1974 – 2013)

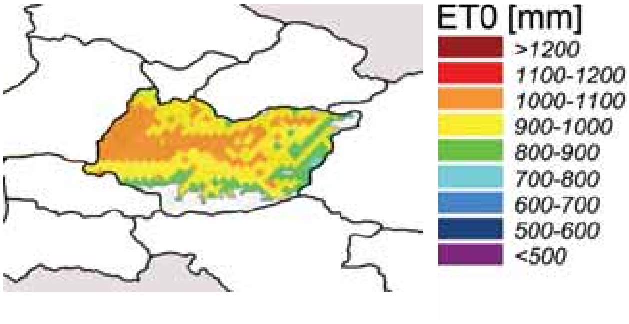


Winter Frost
(1974 – 2013)

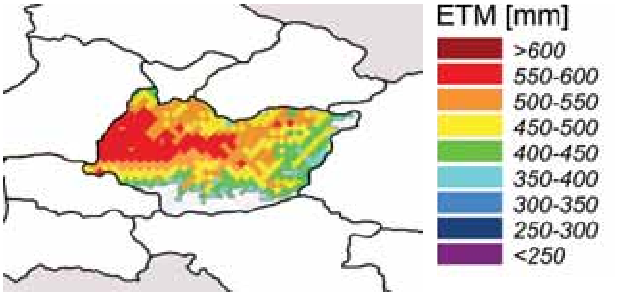


WATER RESOURCES AND LIMITATIONS

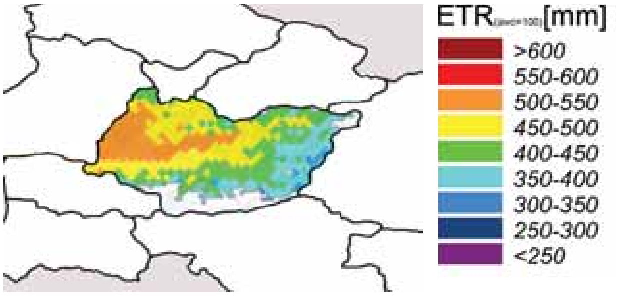
Reference Evapotranspiration ET0 (1974 – 2013)



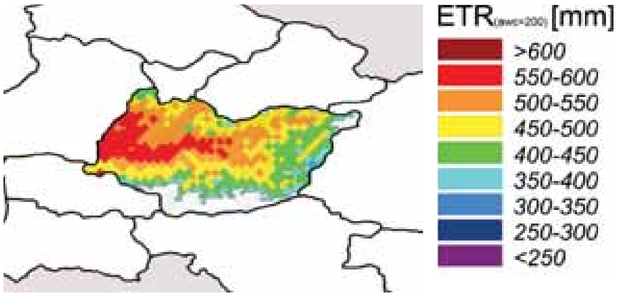
Maximum Evapotranspiration ETM (1974 – 2013)



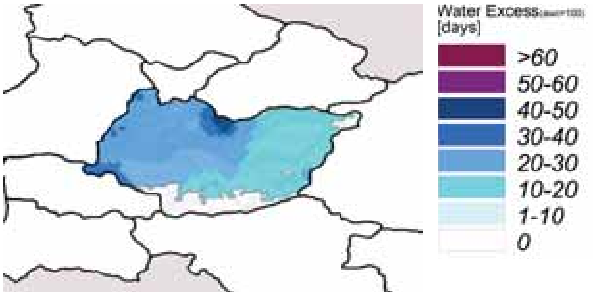
Real Evapotranspiration ETR (AWC = 100 mm) (1974 – 2013)



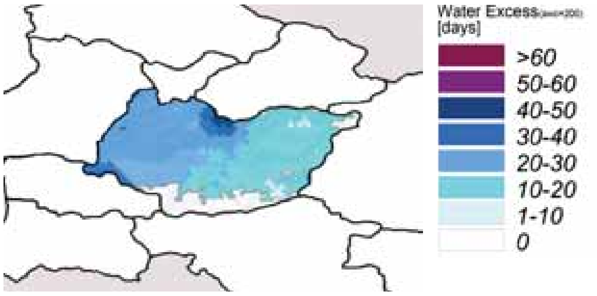
Real Evapotranspiration ETR (AWC = 200 mm) (1974 – 2013)



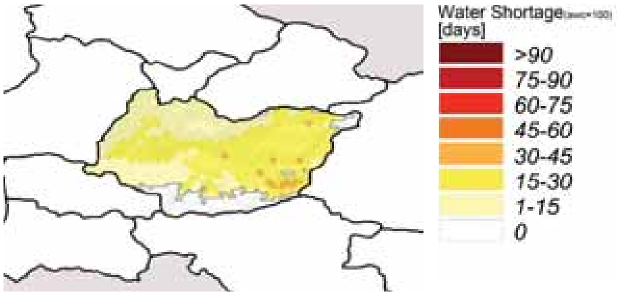
Water Excess (AWC = 100 mm) (1974 – 2013)



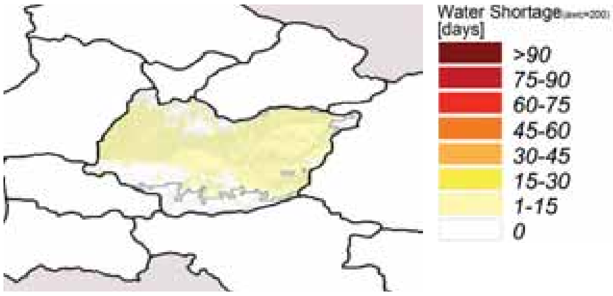
Water Excess (AWC = 200 mm) (1974 – 2013)



Water Shortage (AWC = 100 mm) (1974 – 2013)



Water Shortage (AWC = 200 mm) (1974 – 2013)



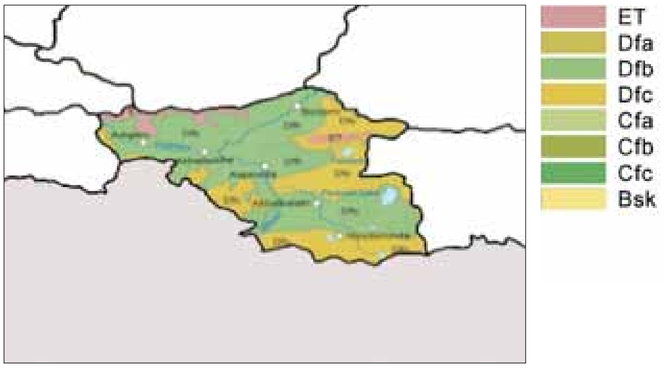
Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0 - 250	30.4	early	V	very low	very low - very high
250 - 500	18.3	early	IV	low	very low - very high
500 - 750	25.4	medium	III	low	very low - very high
750 - 1000	15.0	late	I	low	very low - very high
1000 - 1250	10.9	late	I	low - very high	very low - very high

Elevation belt (m)	Risk of summer light - thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0 - 250	very high	very low	low - medium	high
250 - 500	high - very high	very low	low - medium	high
500 - 750	very low - very high	very low	low - medium	high
750 - 1000	very low - very high	very low - medium	low - medium	high
1000 - 1250	very low	very low - medium	low - medium	high

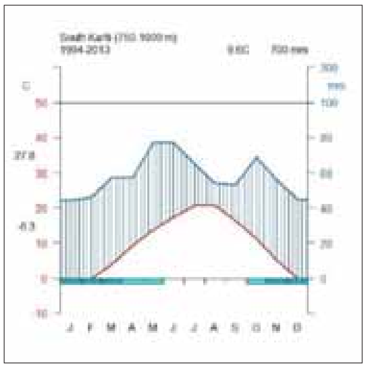
Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0 - 250	12	low	1.2	16	3 - 4	0
250 - 500	12	low	1.2	16	3 - 4	0
500 - 750	8	medium	1.0	10	2 - 3	100 - 0
750 - 1000	6	high	0.8	8	2	100 - 0
1000 - 1250	6	high	0.8	8	2	100

MESKHETI

Köppen Geiger Classification



Bagnouls – Gaussen Diagram (750-1000 m altitudinal belt)



The Meskheti region belongs to the northern slopes of the Lesser Caucasus mountain chain and the area potentially suitable for viticulture is limited to the lower altitudes characterized by a Köppen climatic type Dfb.

Average annual precipitation is between 400 and 800 mm with a winter minimum.

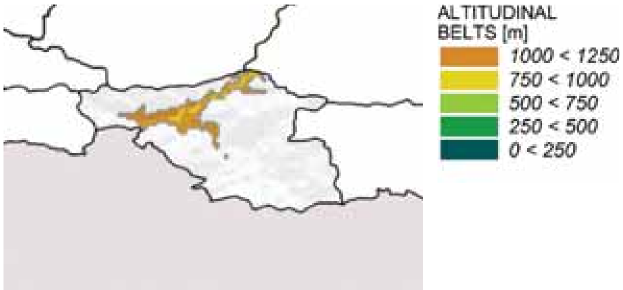
The Bagnouls – Gaussin diagram highlights absence of both dry season and periods of precipitation excess.

The climatic risk of temperature below the critical threshold of -15°C ranges between very low and very high.

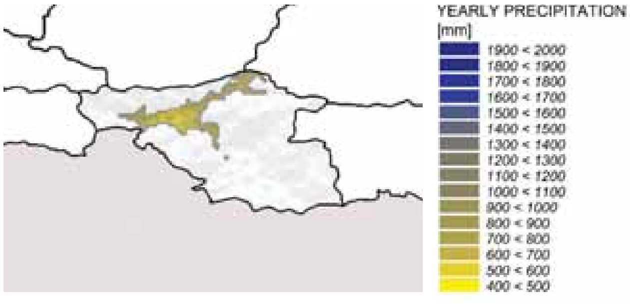
The thunderstorm activity in summer gives a significant hail risk (about 4-6 hail days per year).

THERMAL-PLUVIOMETRIC FEATURES

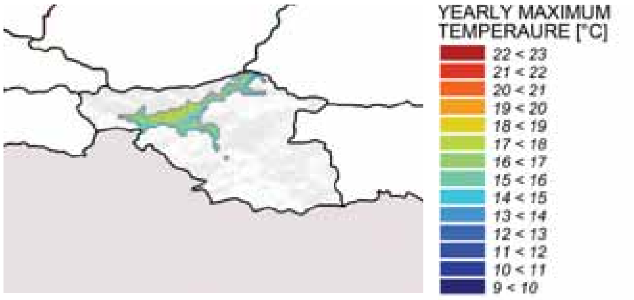
Altitudinal Belts



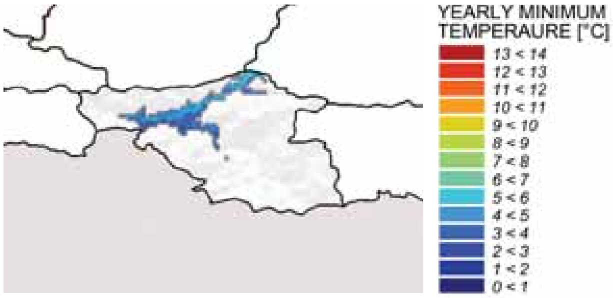
Yearly Precipitation (1994 – 2013)



Yearly Maximum Temperature (1994 – 2013)

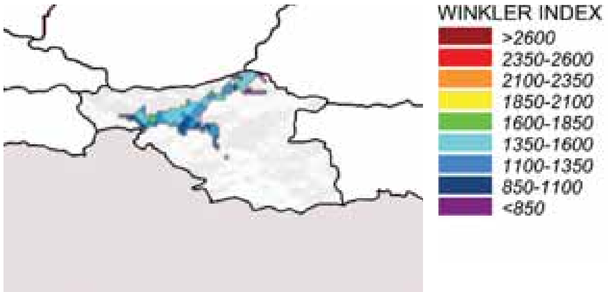


Yearly Minimum Temperature (1994 – 2013)

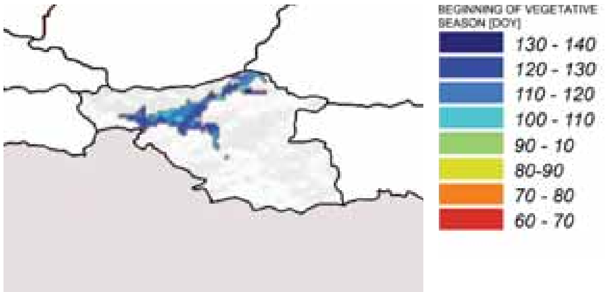


THERMAL RESOURCES AND LIMITATIONS

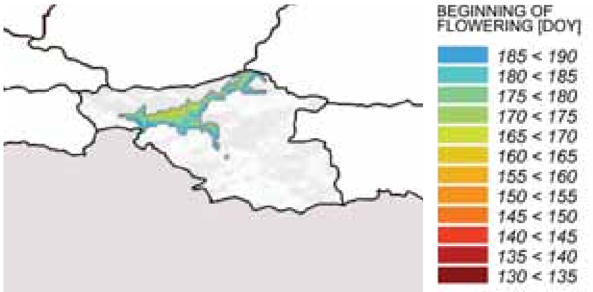
Winkler Index
(1994 – 2013)



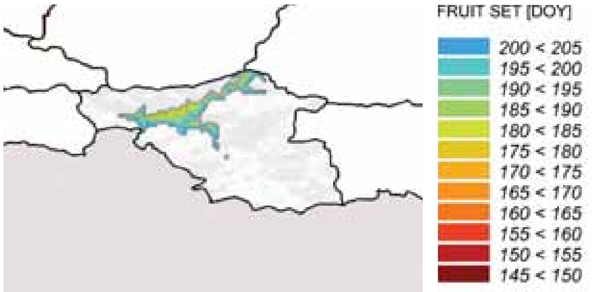
Beginning of Vegetative Season
(1994 – 2013)



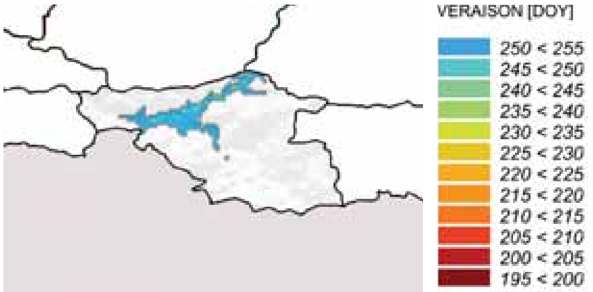
Beginning of Flowering
(1994 – 2013)



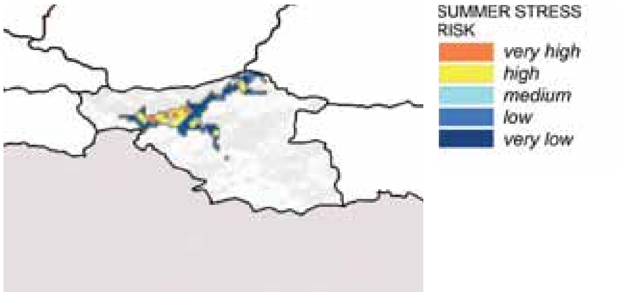
Fruit Set
(1994 – 2013)



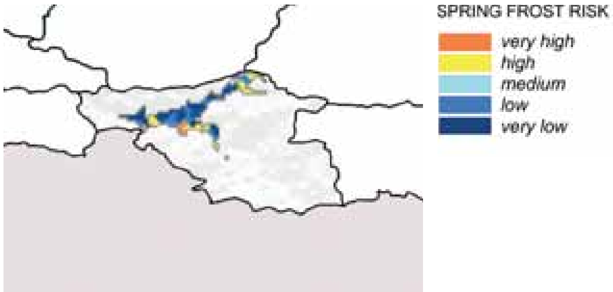
Beginning of Veraison
(1994 – 2013)



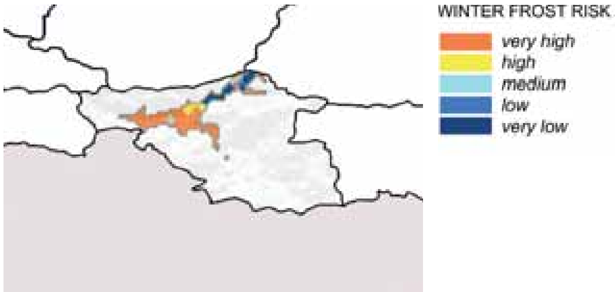
Summer Stress
(1974 – 2013)



Spring Frost
(1974 – 2013)

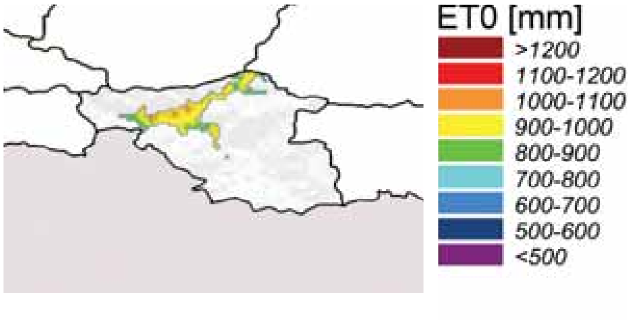


Winter Frost
(1974 – 2013)

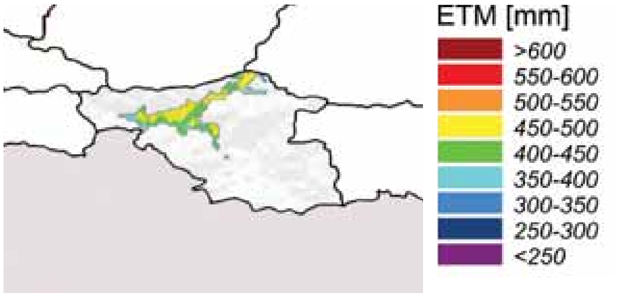


WATER RESOURCES AND LIMITATIONS

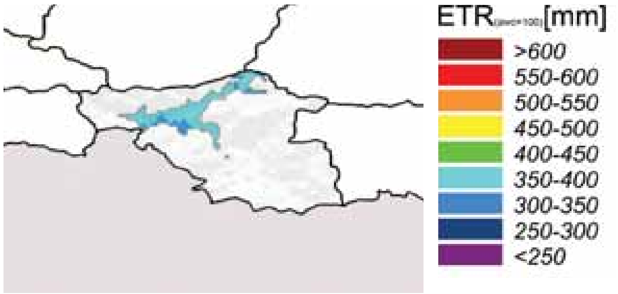
Reference Evapotranspiration ET0 (1974 – 2013)



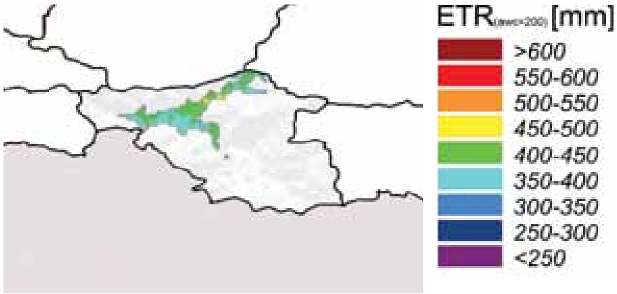
Maximum Evapotranspiration ETM (1974 – 2013)



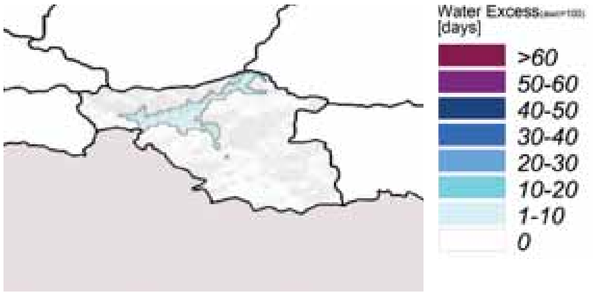
Real Evapotranspiration ETR (AWC = 100 mm) (1974 – 2013)



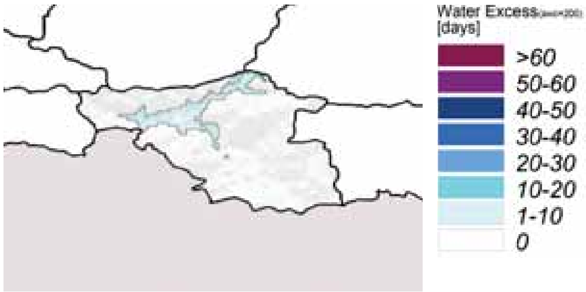
Real Evapotranspiration ETR (AWC = 200 mm) (1974 – 2013)



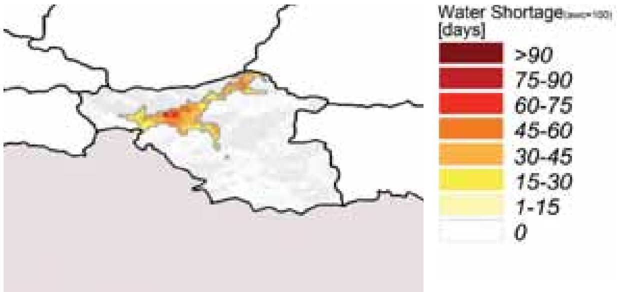
Water Excess (AWC = 100 mm) (1974 – 2013)



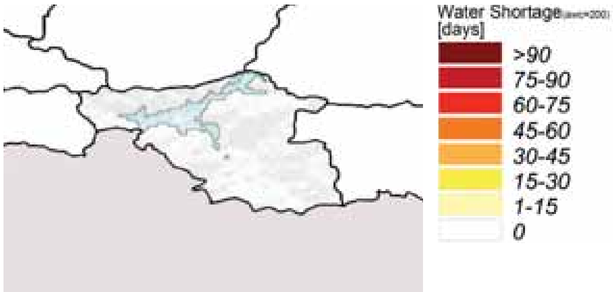
Water Excess (AWC = 200 mm) (1974 – 2013)



Water Shortage (AWC = 100 mm) (1974 – 2013)



Water Shortage (AWC = 200 mm) (1974 – 2013)



Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0 - 250	-	-	-	-	-
250 - 500	-	-	-	-	-
500 - 750	-	-	-	-	-
750 - 1000	17.3	late	I	very low - very high	very low - very high
1000 - 1250	82.7	late	I	very low - very high	very low - very high

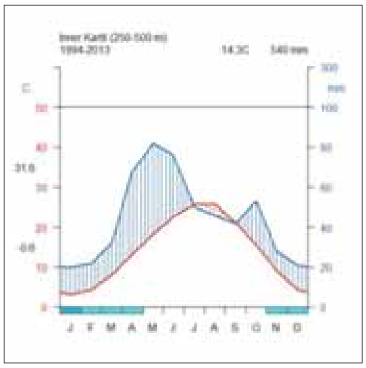
Elevation belt (m)	Risk of summer light - thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0 - 250	-	-	-	-
250 - 500	-	-	-	-
500 - 750	-	-	-	-
750 - 1000	very low - very high	low - medium	low	high
1000 - 1250	very low - very high	low - medium	low	high

Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0 - 250	-	-	-	-	-	-
250 - 500	-	-	-	-	-	-
500 - 750	-	-	-	-	-	-
750 - 1000	6	high	0.8	8	2	100 - 0
1000 - 1250	6	high	0.8	8	2	100 - 0

INNER KARTLI

Köppen Geiger Classification

Bagnouls – Gaussen Diagram
(250-500 m altitudinal belt)



The Inner Kartli region belongs to the sSouthern slopes of the Greater Caucasus mountain chains and to the Northern slopes of the Lesser Caucasus mountain chain and the area potentially suitable for viticulture is limited to the lower altitudes which are characterized by a Köppen climatic type Cfa with transition to Dfb at the highest altitudes.

The annual precipitation is between 400 and 1000 mm.

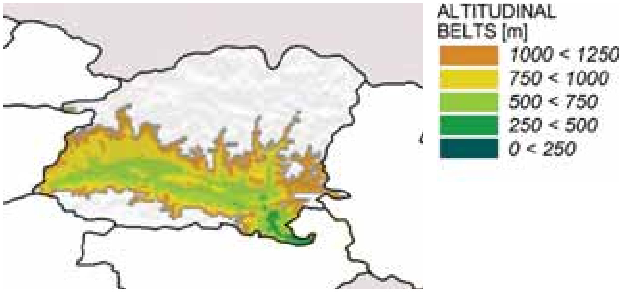
The Bagnouls – Gaussin diagram highlights absence of periods of precipitation excess and a light dry period in August.

The climatic risk of temperature below the critical threshold of -15°C ranges from very low to very high depending on altitude and the other morphological features.

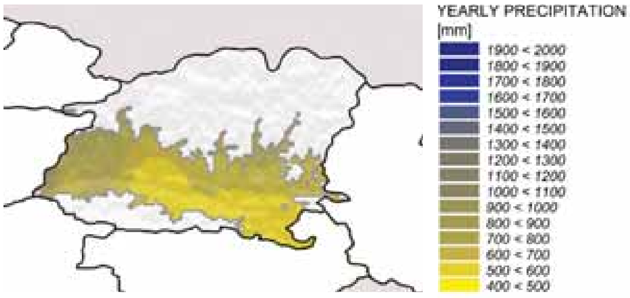
The thunderstorm activity in summer gives a generally low hail risk (about 1 hail day per year).

THERMAL-PLUVIOMETRIC FEATURES

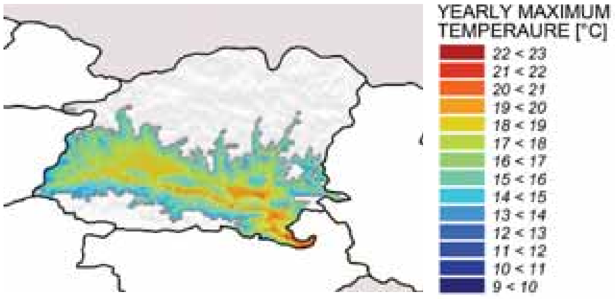
Altitudinal Belts



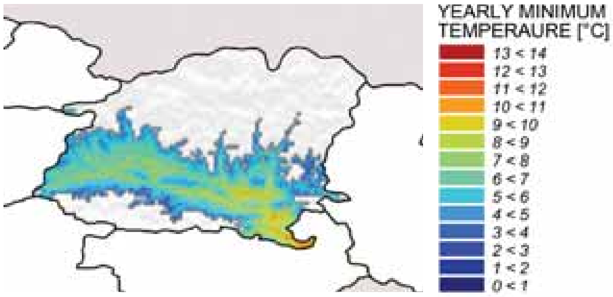
Yearly Precipitation
(1994 – 2013)



Yearly Maximum Temperature
(1994 – 2013)

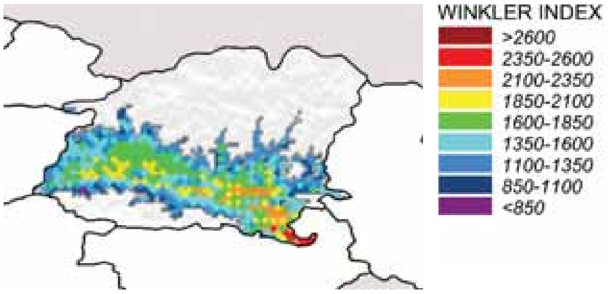


Yearly Minimum Temperature
(1994 – 2013)

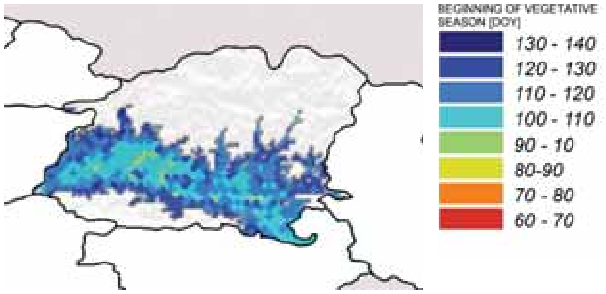


THERMAL RESOURCES AND LIMITATIONS

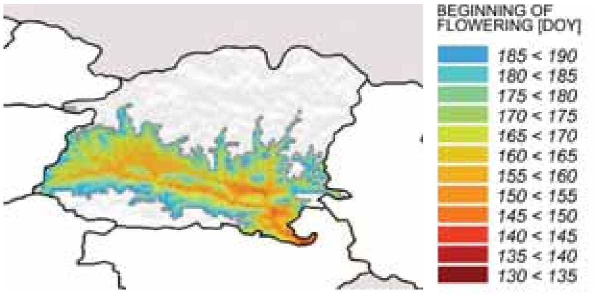
Winkler Index
(1994 – 2013)



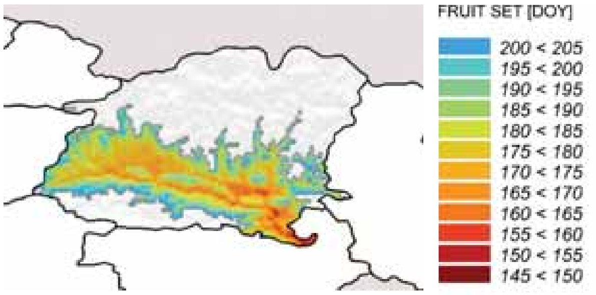
Beginning of Vegetative Season
(1994 – 2013)



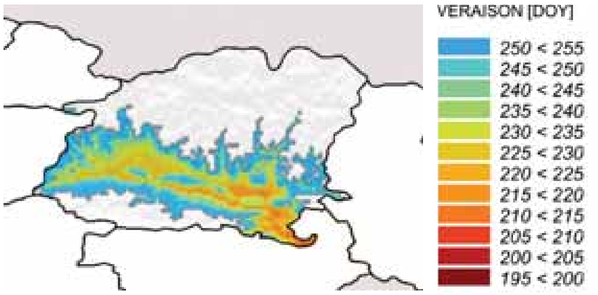
Beginning of Flowering
(1994 – 2013)



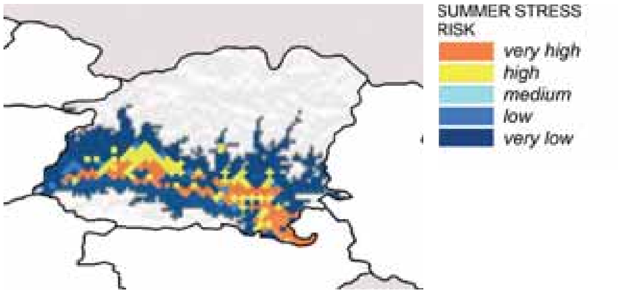
Fruit Set
(1994 – 2013)



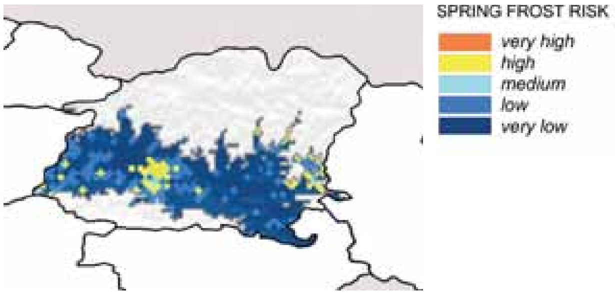
Beginning of Veraison
(1994 – 2013)



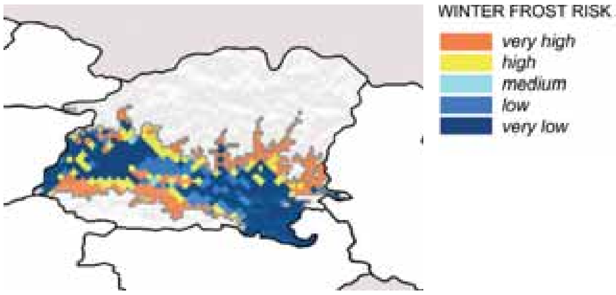
Summer Stress
(1974 – 2013)



Spring Frost
(1974 – 2013)

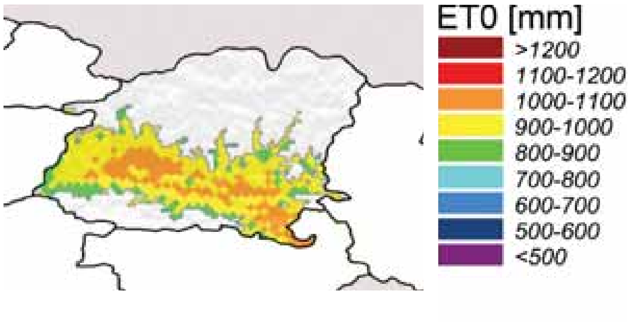


Winter Frost
(1974 – 2013)

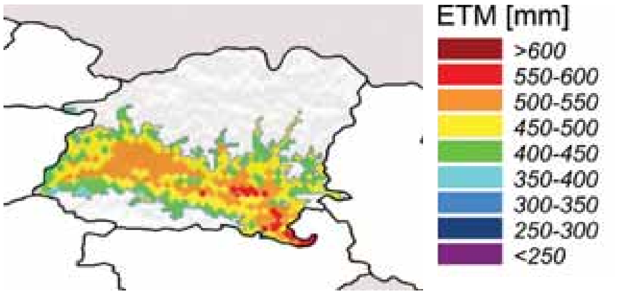


WATER RESOURCES AND LIMITATIONS

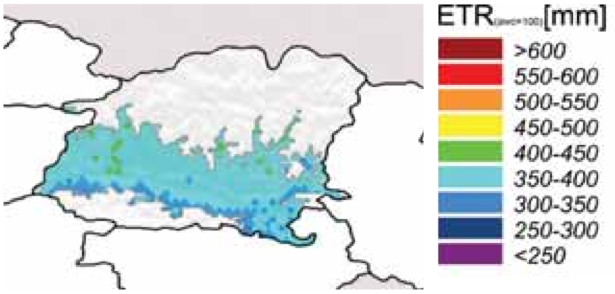
Reference Evapotranspiration ET0
(1974 – 2013)



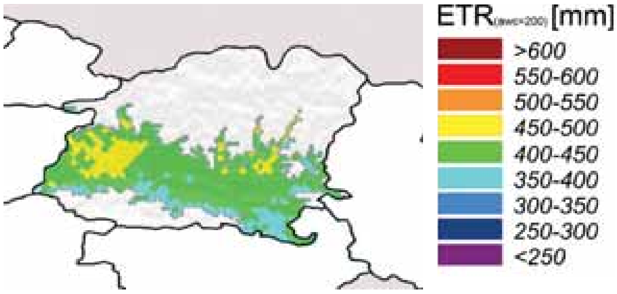
Maximum Evapotranspiration ETM
(1974 – 2013)



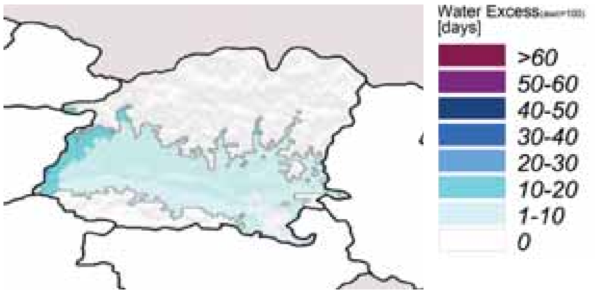
Real Evapotranspiration ETR (AWC = 100 mm)
(1974 – 2013)



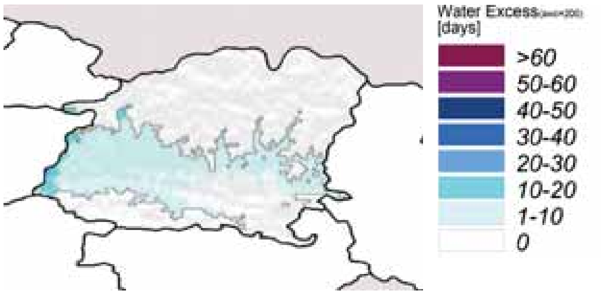
Real Evapotranspiration ETR (AWC = 200 mm)
(1974 – 2013)



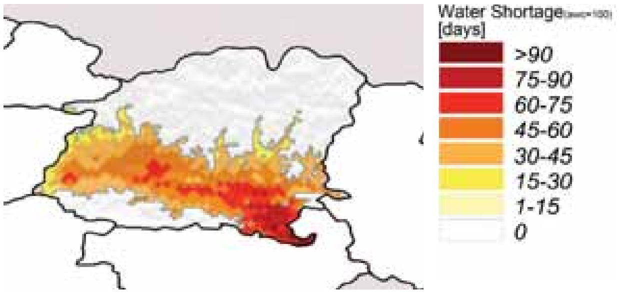
Water Excess (AWC = 100 mm)
(1974 – 2013)



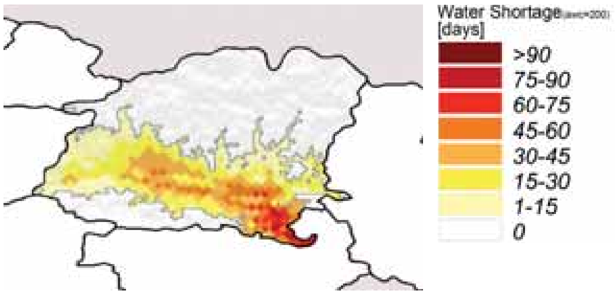
Water Excess (AWC = 200 mm)
(1974 – 2013)



Water Shortage (AWC = 100 mm)
(1974 – 2013)



Water Shortage (AWC = 200 mm)
(1974 – 2013)



Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0 - 250	-	-	-	-	-
250 - 500	2.6	medium	III - IV	very low	very low
500 - 750	31.3	medium	II - III	low	very low - high
750 - 1000	33.2	late	II	very low - high	very low - high
1000 - 1250	33.0	late	I	very low - very high	very low - high

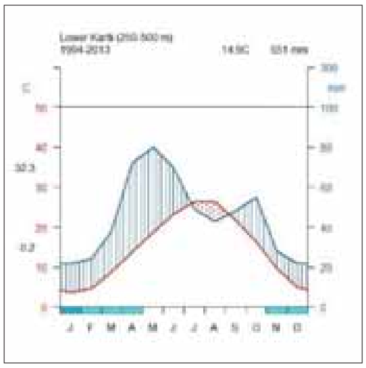
Elevation belt (m)	Risk of summer light - thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0 - 250	-	-	-	-
250 - 500	very high	high - very high	low	high
500 - 750	high - very high	medium	low	high
750 - 1000	very low - high	medium	low	high
1000 - 1250	very low	low	low	high

Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0 - 250	-	-	-	-	-	-
250 - 500	10	medium	1.0	12	2 - 3	0
500 - 750	8	high	0.8	10	2 - 3	0
750 - 1000	6	high	0.8	8	2	100 - 0
1000 - 1250	6	high	0.8	8	2	100

LOWER KARTLI

Köppen Geiger Classification

Bagnouls – Gaussen Diagram (250-500 m altitudinal belt)



The Lower Kartli region belongs to the northern slopes of the Lesser Caucasus mountain chain and the area potentially suitable for viticulture is limited to the lower altitudes which are characterized by a Köppen climatic type Cfa with transition to Dfb at highest elevation and to Bsk at the lowest.

The annual rainfall is between 400 and 800 mm with the main minimum in winter a secondary one in summer.

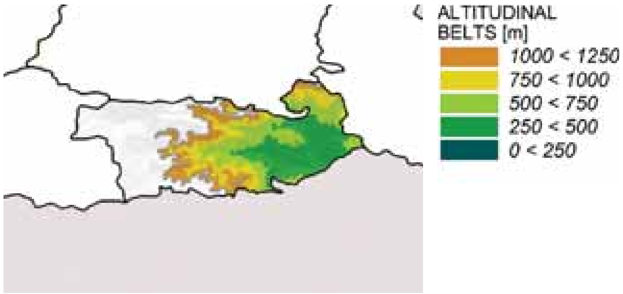
The Bagnouls – Gaussen diagram highlights absence of periods of precipitation excess and a light dry period in July and August.

The climatic risk of descent of minimum temperature below -15 °C ranges from very low to very high depending on altitude and the other morphological features.

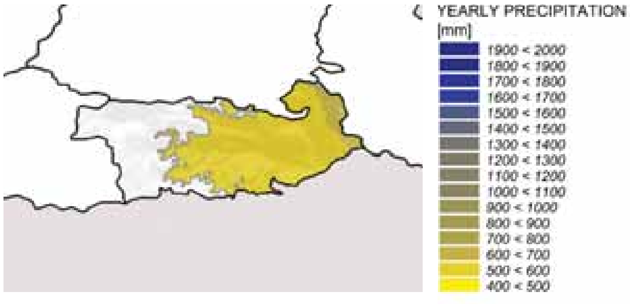
The thunderstorm activity in summer gives a generally low hail risk (about 1 hail day per year).

THERMAL-PLUVIOMETRIC FEATURES

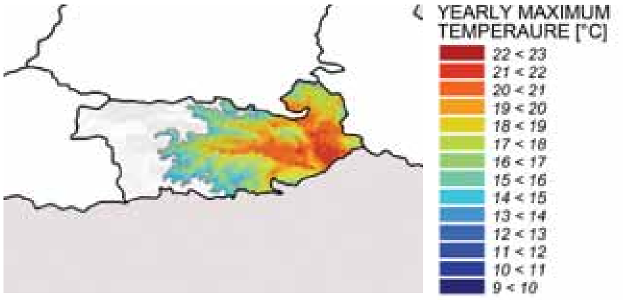
Altitudinal Belts



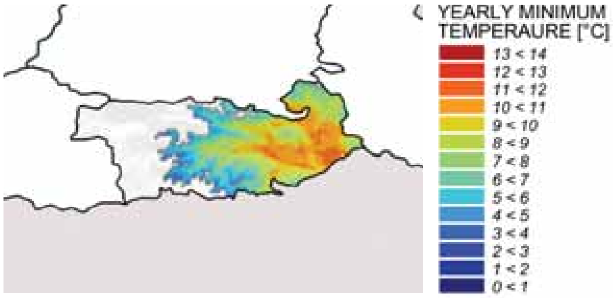
Yearly Precipitation (1994 – 2013)



Yearly Maximum Temperature (1994 – 2013)

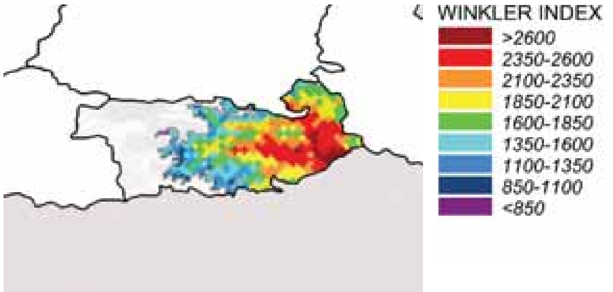


Yearly Minimum Temperature (1994 – 2013)

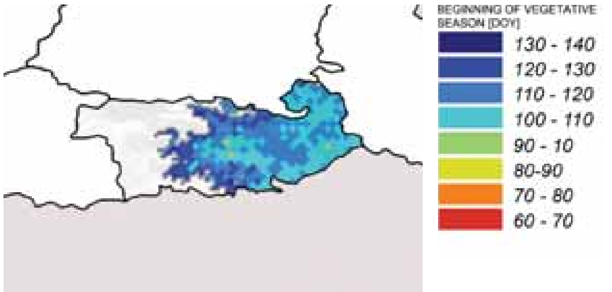


THERMAL RESOURCES AND LIMITATIONS

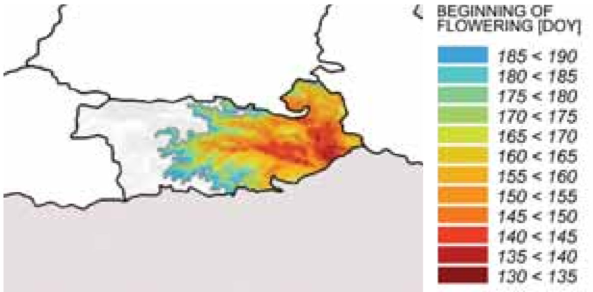
Winkler Index
(1994 – 2013)



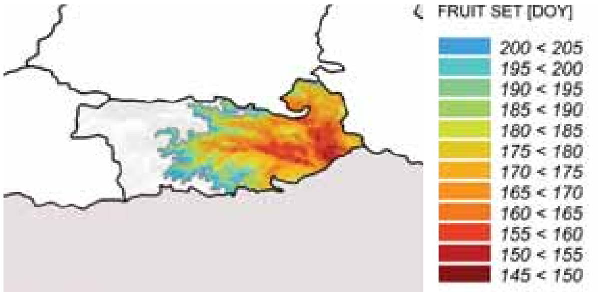
Beginning of Vegetative Season
(1994 – 2013)



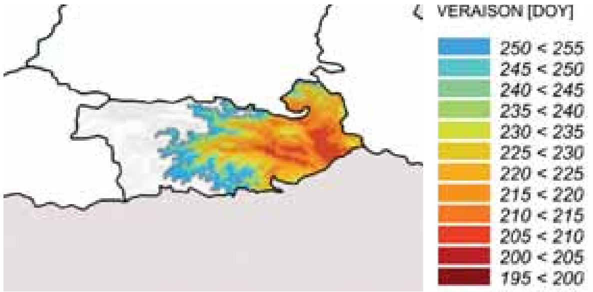
Beginning of Flowering
(1994 – 2013)



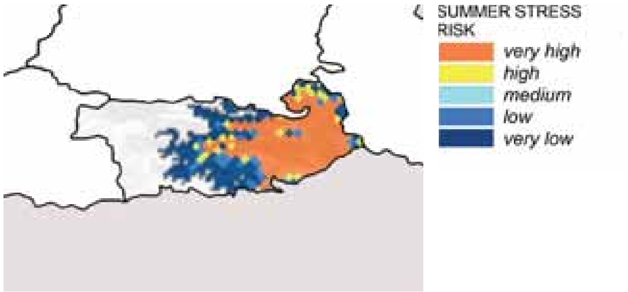
Fruit Set
(1994 – 2013)



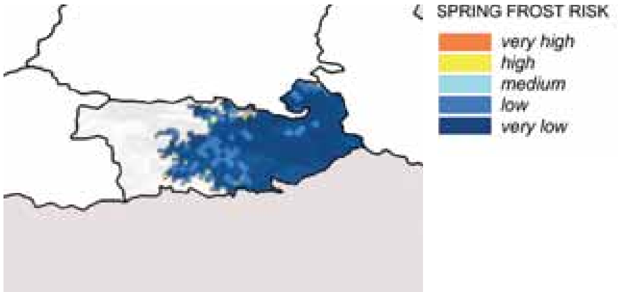
Beginning of Veraison
(1994 – 2013)



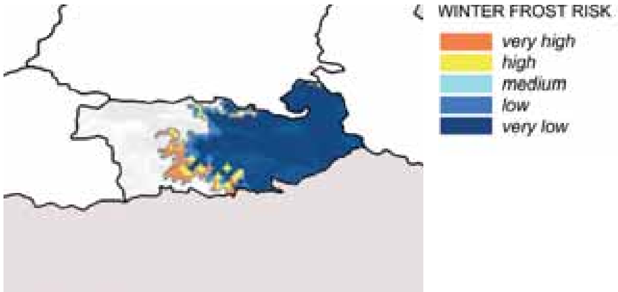
Summer Stress
(1974 – 2013)



Spring Frost
(1974 – 2013)

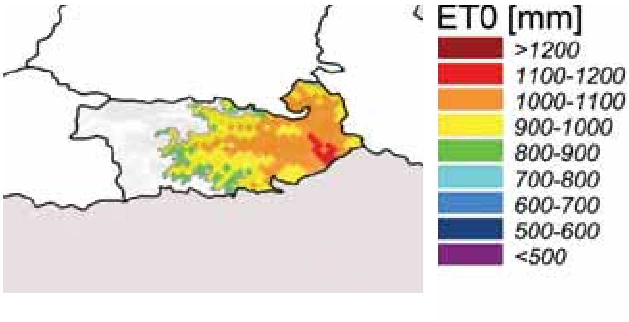


Winter Frost
(1974 – 2013)

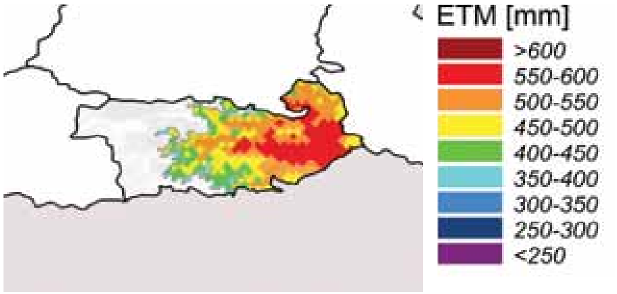


WATER RESOURCES AND LIMITATIONS

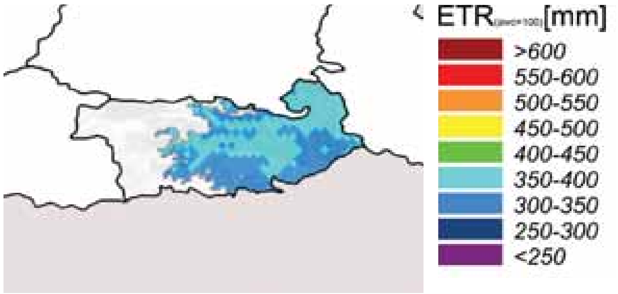
Reference Evapotranspiration ET0 (1974 – 2013)



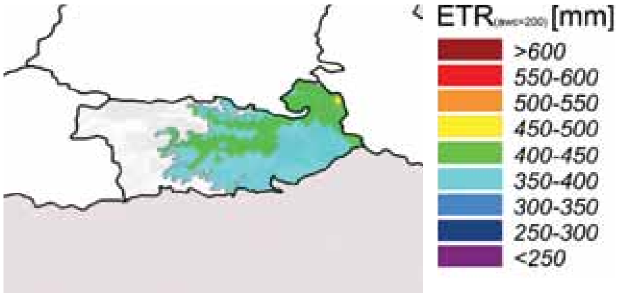
Maximum Evapotranspiration ETM (1974 – 2013)



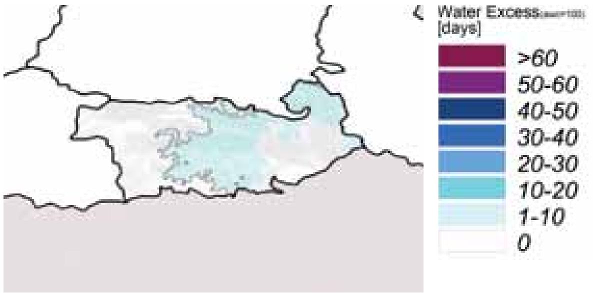
Real Evapotranspiration ETR (AWC = 100 mm) (1974 – 2013)



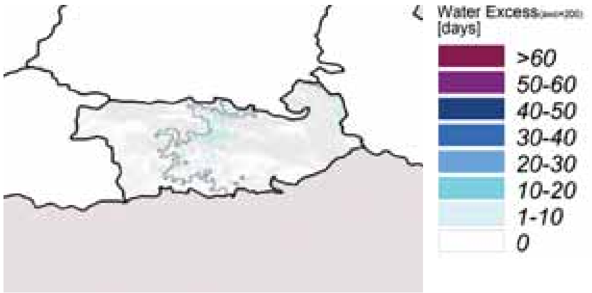
Real Evapotranspiration ETR (AWC = 200 mm) (1974 – 2013)



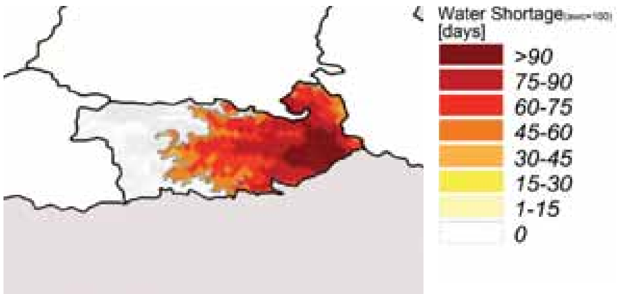
Water Excess (AWC = 100 mm) (1974 – 2013)



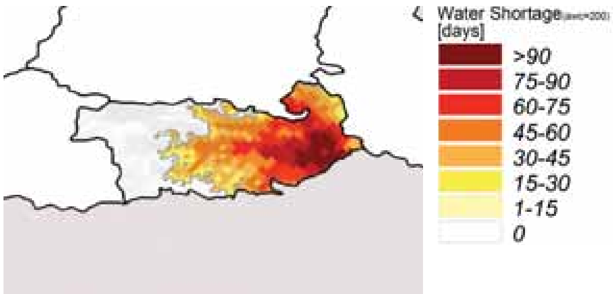
Water Excess (AWC = 200 mm) (1974 – 2013)



Water Shortage (AWC = 100 mm) (1974 – 2013)



Water Shortage (AWC = 200 mm) (1974 – 2013)

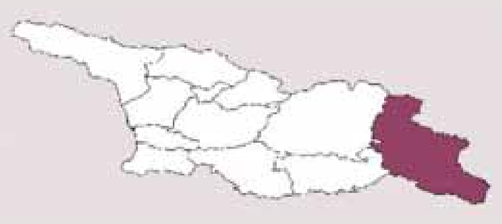


Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0 - 250	-	-	-	-	-
250 - 500	32.3	medium - late	IV - V	very low	very low
500 - 750	25.5	medium - late	III IV	very low	very low - low
750 - 1000	19.1	late	I - II	very low - high	very low - low
1000 - 1250	22.9	late	I - II	very low - very high	very low - low

Elevation belt (m)	Risk of summer light - thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0 - 250	-	-	-	-
250 - 500	very high	high - very high	low	low
500 - 750	low - high	medium	low	low
750 - 1000	very low - high	medium	low	low
1000 - 1250	very low	medium	low	low

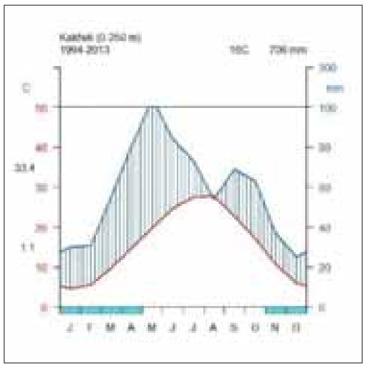
Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0 - 250	-	-	-	-	-	-
250 - 500	10	medium	1.0	12	2 - 3	0
500 - 750	8	high	0.8	10	2 - 3	100 - 0
750 - 1000	6	high	0.8	8	2	100 - 0
1000 - 1250	6	high	0.8	8	2	100

KAKHETI



Köppen Geiger Classification

Bagnouls – Gaussen Diagram (0-250 m altitudinal belt)



The Kakheti region is characterized by a Köppen climatic type Cfa with transition to Dfb and locally to Dfa.

The annual rainfall is between 600 and 1000 mm with the main minimum in winter a secondary one in summer.

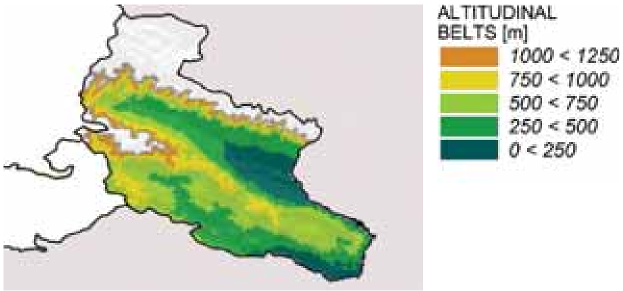
The Bagnouls – Gaussin diagram highlights absence of both dry season and periods of precipitation excess.

The climatic risk of temperature below the critical threshold of -15°C ranges from very low to very high depending on altitude and the other morphological features.

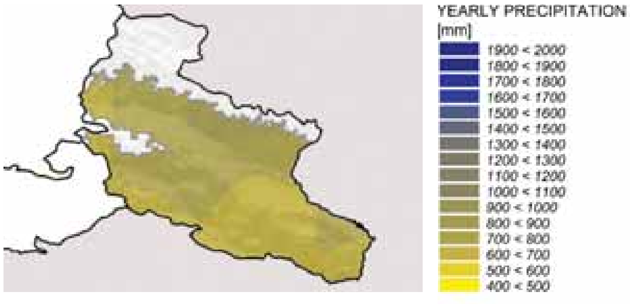
The thunderstorm activity in summer gives a generally low hail risk (about 1 hail day per year).

THERMAL-PLUVIOMETRIC FEATURES

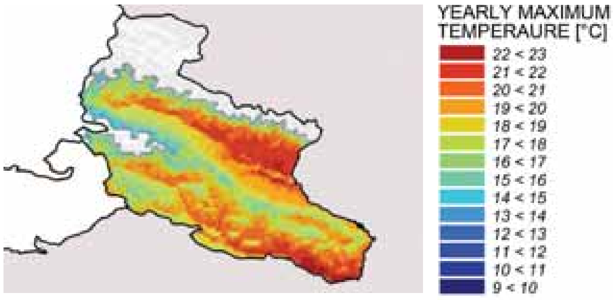
Altitudinal Belts



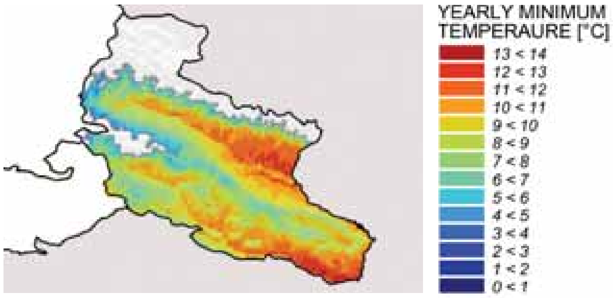
Yearly Precipitation (1994 – 2013)



Yearly Maximum Temperature (1994 – 2013)

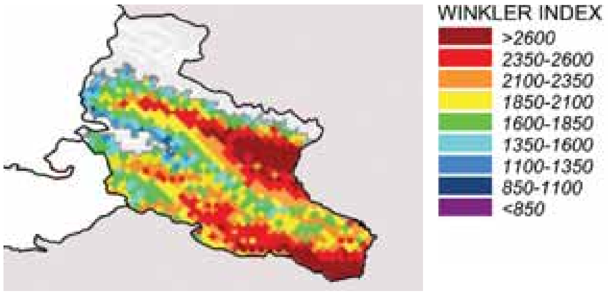


Yearly Minimum Temperature (1994 – 2013)

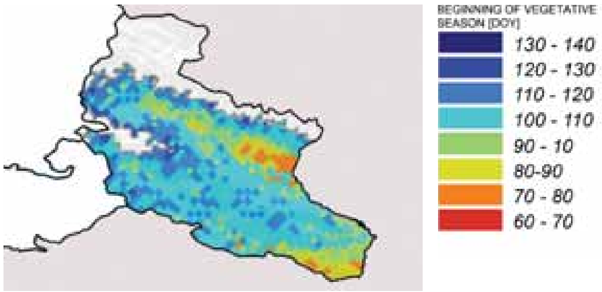


THERMAL RESOURCES AND LIMITATIONS

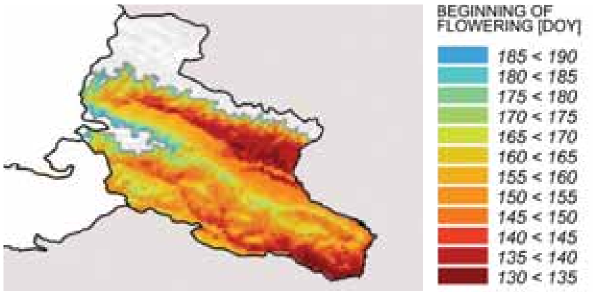
Winkler Index
(1994 – 2013)



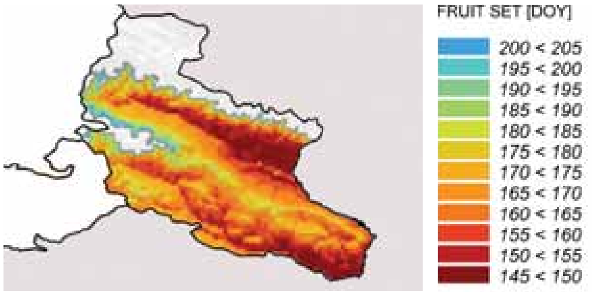
Beginning of Vegetative Season
(1994 – 2013)



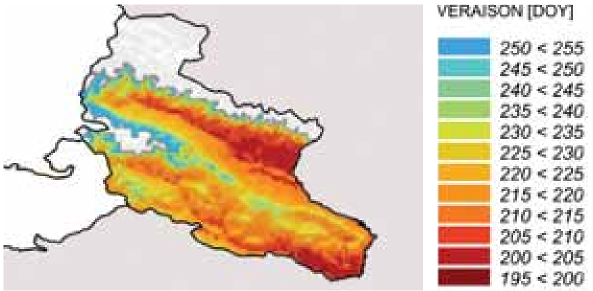
Beginning of Flowering
(1994 – 2013)



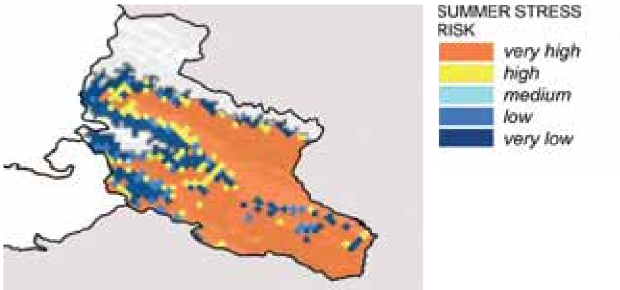
Fruit Set
(1994 – 2013)



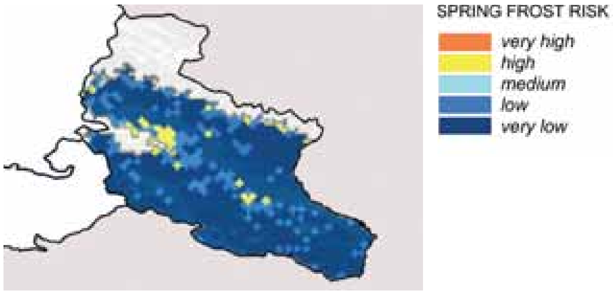
Beginning of Veraison
(1994 – 2013)



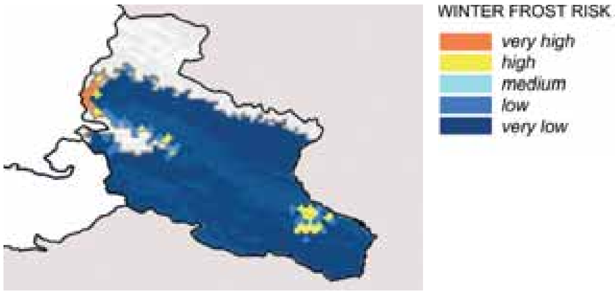
Summer Stress
(1974 – 2013)



Spring Frost
(1974 – 2013)

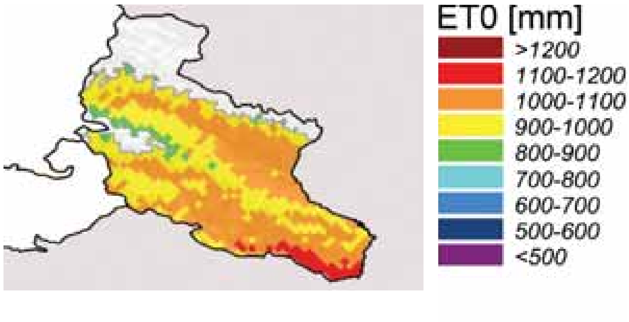


Winter Frost
(1974 – 2013)

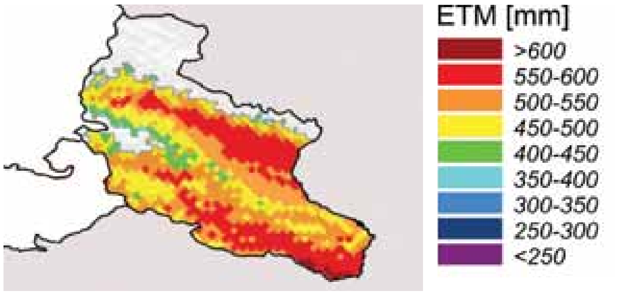


WATER RESOURCES AND LIMITATIONS

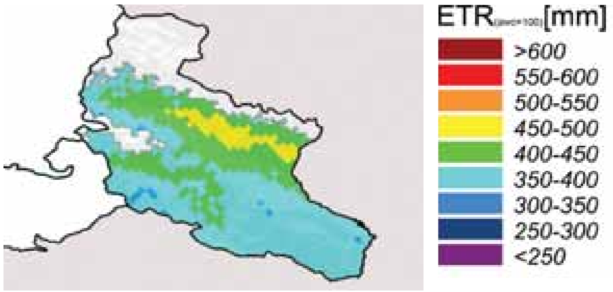
Reference Evapotranspiration ET0 (1974 – 2013)



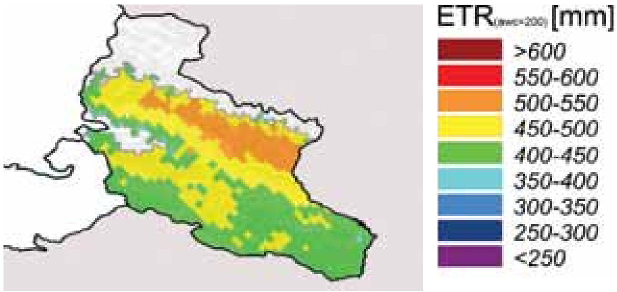
Maximum Evapotranspiration ETM (1974 – 2013)



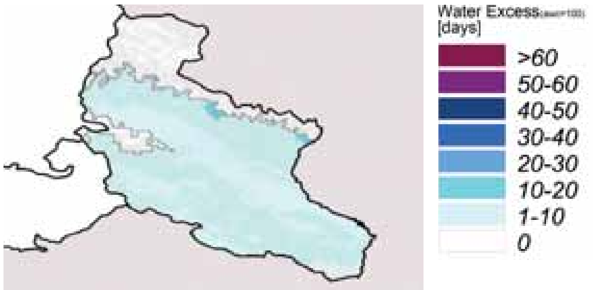
Real Evapotranspiration ETR (AWC = 100 mm) (1974 – 2013)



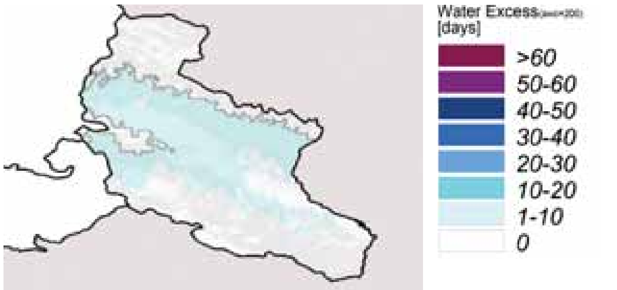
Real Evapotranspiration ETR (AWC = 200 mm) (1974 – 2013)



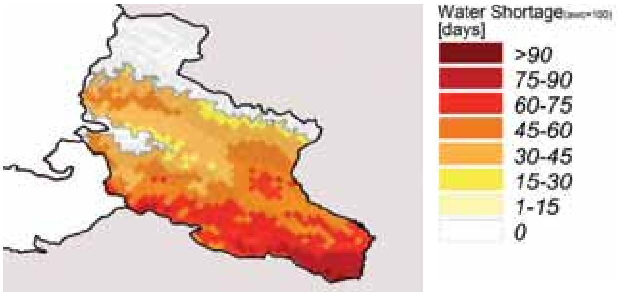
Water Excess (AWC = 100 mm) (1974 – 2013)



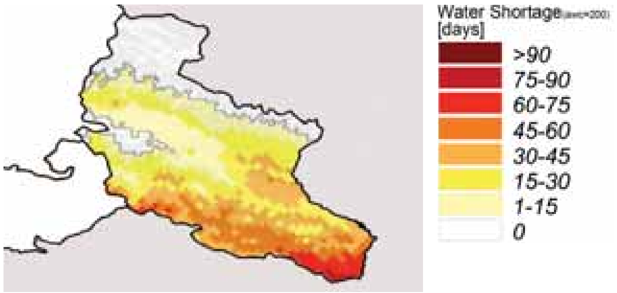
Water Excess (AWC = 200 mm) (1974 – 2013)



Water Shortage (AWC = 100 mm) (1974 – 2013)



Water Shortage (AWC = 200 mm) (1974 – 2013)



Elevation belt (m)	% of the total surface	Phenological timing	Winkler Class	Risk of winter frost	Risk of spring frost
0-250	14.4	early - medium	V	very low	low - very low
250-500	29.9	medium	V	very low	low - very low
500-750	33.0	medium - late	III	low - high	very low - high
750-1000	15.9	late	II	low	very low - high
1000-1250	6.7	late	I	low - very high	very low - high

Elevation belt (m)	Risk of summer light-thermal stress	Risk of summer water stress	Risk of spring water excess	Risk of water excess during ripening
0-250	very high	medium - high	low	low
250-500	very high	medium - high	low	low
500-750	very low - high	medium - high	low	low
750-1000	very low - high	low - medium	low	low
1000-1250	very low	low - medium	low	low

Elevation belt (m)	Target yield (t/ha)	Vine density	Canopy height vs. row distance	Canopy density (shoots/m)	Canopy density (leaf layers)	Exposed bunches (%)
		For Guyot or Spurred Cordon				
0-250	10	medium	1.0	12	2-3	0
250-500	10	medium	1.0	12	2-3	0
500-750	8	high	0.8	10	2-3	100 - 0
750-1000	6	high	0.8	8	2	100 - 0
1000-1250	6	high	0.8	8	2	100

Chapter 3

CONCISE GUIDELINES FOR SUISTAINABLE VITICULTURAL MODELS

The Choice of Variety

The choice of grape variety is the central aspect of the new vineyard design. In Georgia, there are some regulatory constraints. The variety should in fact be listed on the "National Register of Recommended Grapevines Varieties" (Georgian Government, 1998). Moreover, if the vineyard is intended for an appellation of origin wine, the variety must also be included in related production regulation (Sakpatenti, 2020).

In each Georgian viticultural area, there is a traditional assortment of local grapes. These varieties have proved to be very adapted to the soil and climatic condition of the area where they are grown. Moreover, they are highly appreciated by the local viticulturist and wine consumers, by the domestic market and often their wines are also renewed in specific foreign market and sustain important export trades (Chkhartishvili et al. 2016).

For these reasons, in this particular phase of the vinicultural history of Georgia, we recommend maintaining this specific regional varietal assortment and to preserve / reinforce the identity of the Georgian vinicultural system. New varieties might be introduced according to the evolution of the markets needs after careful evaluation by experimental farms as well as by private companies.

The following table lists the recommended and prospective varieties for each Georgian viticultural area.

Figure 3.1 – Budeshuri tsiteli

Figure 3.2 – Gorula

Table 3.1 – Recommended and prospective varieties for the different Georgian viticultural areas

VITICULTURAL AREAS	RECOMMENDED VARIETIES	
	COLORED	WHITE
Abkhazeti	Amlakhu Kachichi Chkhaveri	Avasirkhva Tsolikouri
Samegrelo	Ojaleshi Chvitiluri	Paneshi Chetchipeshi Tsolikouri
Guria	Aladasturi Chkhaveri Jani Mtevandidi Skhilatubani	Sakmiela Tsolikouri
Adjara	Satsuravi Chkhaveri Aladasturi	Brola Tsolikouri
Lechkhumi	Ojaleshi Orbeluri Usakhelouri Alexandrouli Mujuretuli Kabistoni shavi	Tsulukidzis tetra Tsolikouri
Racha	Alexandrouli Mujuretuli Kabistoni Savi Dzelshavi	Tsolikouri Tsulukidzis (Rachuli) tetra
Imereti	Aladasturi Otskhanuri sapere Dzelshavi Mgaloblishvili Rko shavi	Krakhuna Tsolikouri Tsitska Kapistoni tetri Dondghlabi Kundza
Meskheti	Pinot noir	Goruli mtsvane Khikhvi
Inner Kartli	Tavkveri Shavkapito Saperavi Saperavi budeshuriseburi Danakharuli	Chinuri Goruli mtsvane Gorula Budeshuri tetri Rkatsiteli Rkatsiteli muskaturi
Lower Kartli	Asuretuli shavi Tavkveri Saperavi Saperavi budeshuriseburi	Chinuri Goruli mtsvane Rkatsiteli Rkatsiteli muskaturi
Kakheti	Saperavi Saperavi budeshuriseburi Ikaltos tsiteli Tavkveri Budeshuri tsiteli	Rkatsiteli Mtsvane kakhuri Kisi Khikhvi Rkatsiteli muskaturi Grdzelmtevana Chitistvala

Site Selection and Soil Preparation for a New Vineyard

The choice of a site suitable for a new vineyard is the necessary premise for a profitable viticulture. Several characteristics useful to assess the suitability of the site to viticulture and obtain information useful to support the design and realization of the pre-planting activities of the vineyard are hereafter listed and discussed. This list if obviously non exhaustive because many other features should be evaluated like the closeness to the reference markets and the road network or the availability of irrigation water.

Geo-morphological features

Shape, slope and aspect of the selected field must be evaluated.

Shape refers to the forms of the land surface that influence the movement of fluids like cold air and surface/sub-surface runoff water.

Slope refers to the tangent of the angle of that surface to the horizontal in percent. Flat surfaces or gentle slopes (slope = 5-10%) do not show limitation to mechanization with wheels which is possible only with slope <15%. For slopes from 15 to 25% works are possible only with machinery with caterpillars. Steep slopes are also prone to **erosion by rainfall water**.

Aspect is the prevailing compass direction faced by the slope.

Slope and shape of the surfaces influence runoff of surface waters and **drainage of cold air** from uplands to low-lying surfaces. Concave surfaces or surfaces lying at the bottom of a valley are more exposed that uplands and sloped surfaces to frost risk due to accumulation of cold air that drains downhill.

At the same time slope and shape influence the **runoff of rainfall waters** and is strictly related to soil erosion.

Slope and aspect affect solar radiation received by a given surface that is useful both for photosynthesis and to feed the surface energy balance which affects temperatures and thermal resources for grapevine.

With reference to maximum and minimum temperatures of flat fields, during sunny days the northerly slopes are about 1°C colder and southern surfaces are 1°C warmer. This means for example that southerly slopes in respect to northern ones shows a lower risk of frost and 200-300 more Winkler degrees of thermal resources useful for grapevine. Easterly slopes receive the same quantity of solar radiation of the westerly ones but are generally warmer (ca. + 1°C) because (i) solar radiation received in the morning by easterly surfaces acts on surfaces that are colder than westerly surfaces affected by solar radiation in the afternoon and (ii) easterly surfaces are more exposed to cold wind from Siberian area during the winter semester.

Climate

The quantitative evaluation of climate resources (like temperature, rainfall and soil water), and limitations (probability of critical events like cold air outbreaks, heat waves, drought and water excess) should be carried out by means of the maps produced in this research. These maps are geo-referenced which means that they are suitable to be used as layers of a suitable Geographical Information System. Furthermore, meteorological data gathered in sites close to the selected fields can be also useful. On this latter case it must be taken into account that is important to analyze about **20-30 years of data** (in this particular case 20 years, from 1994 to 2013) of good quality and close to the present in order to evaluate mean and extreme values of each weather variable.

Soil

Pedological features are evaluated through the assessment of the profile of the soil and the chemical-physical analysis carried out on samples representatives of the soil of the vineyard.

The **soil profile** is evaluated by opening trenches deep 1/1.5 m to verify the horizons. The number of trenches to be opened will be of the order of one for each vineyard. For fields with very inhomogeneous soils the survey should thickened by means of core samples taken with appropriate drills. The investigation of the soil profile must be carried out by an experienced soil scientist and is useful to evaluate resources and limitations for grapevine (e.g.: presence of chemical or physical limitations like compacts horizons, near-surface water tables during the whole year or for some limited periods, horizons with high presence of gravel.

Samples for chemical-physical analysis should be taken with spade or shovel removing 5 cm of the top layer of soil and then withdrawing the soil from a layer between 5 and 40 cm deep. The samples taken at several points of the selected field chosen with a random walk will be collected in a bucket and mixed adequately so as to obtain a single sample of the weight of about 1 kg that will be sent to the laboratory for analysis. For large vineyards or inhomogeneous soils it could be profitable to carry out more than one analysis.

Chemical-physical analysis will be referred to gravel, texture, pH, total and active calcium carbonate, organic carbon and organic matter, cation exchange capacity, nitrogen, phosphorus and potassium availability.

Vineyard site preparation

After the selection of a good site, a proper site preparation is a relevant factor for the success of the new vineyard. In this context are of primary importance the following pre-planting activities:

Land clearing. The land where vineyard will be planted has to be cleared of trees, rocks, shrubs, gravel in excess present in the topsoil and so on.

Soil amendment/correction/fertilization. Amendment is related to soil physical properties like texture and structure while correction is related to chemical properties like pH and fertilization consist in give to the soil the appropriate level of nutrients for grapevine.

Soil works: typically soil work consists of a **deep plowing** followed by **harrowing** in order to break the clods. However, the plowing depth should be defined on the base of the pedological profile. This is because it is fundamental:

- to avoid bringing to the surface horizons with unwanted characters (e.g. soil horizons with excess of clay, sand, silt or gravel)
- to break deep horizons that prevent root deepening (e.g. compact layers).

In order to obtain these results is also possible to associate a **surface plowing with subsoilers** that break deep layers. **Soil leveling** is also important to smooth out surface irregularities.

Management of water excess is carried out by means of **field ditches** that have the aim of:

- remove the rainwater exceeding the infiltration rate of the soil
- remove the runoff water in a way quick but compatible with the need to avoid erosion phenomena
- regulate the height of the water table in order to ensure an unsaturated soil layer compatible with viticulture (at least 80 cm during the period of the year when the water table is closest to the surface).

Water table can be also regulated by means of **subsurface drainage.**

Such systems must be designed by an agronomist in order to rightly define the structure of networks of drains or to plan the dimension of ditches (m^3/ha) in function of the most abundant daily rainfall.

Irrigation systems must be defined in areas subject to the risk of significant water stress during the vegetative season and will be planned in function of the availability of irrigation water and quantitative water needs of vineyards.

The Choice of Rootstock

In modern viticulture the role of the rootstock, in addition to offering a protection against Phylloxera and to allow the adaptation of the grapevines to the most different soil and climate conditions, is now complementary to other agronomic tools able to modulate the vegetative growth and the yielding behavior of the grapevines. For this reason, the choice of rootstock plays an extremely important role in enabling the achievement of vegetative and productive balance so important in determining the quality of the grapes.

The rootstock can play an important role in determining vegetative growth, production, water and nutrition status of the vine and for this reason most of the classifications are based on the following characteristics:

- resistance to lime induced iron chlorosis;
- drought resistance;
- induced vigor;
- efficiency in the absorption of nutrients.

But they should not be neglected:

- sensitivity to soil sickness or replanting disease;
- graft affinity
- waterlogging resistance

Resistance to lime induced iron chlorosis. The different rootstocks used today have a wide range of resistance to soil conditions inducing lime induced iron chlorosis. The appropriate choice of rootstock is the most rational way to solve permanently this serious nutritional problem. In the choice of the rootstock in this regard in addition to take account of the ability to resist high concentrations of active limestone, it must also consider other features, and in particular regarding the sensitivity of soil waterlogging. These, especially in the spring period, are due to phenomena of chlorosis, example is the 420A that while presenting a good resistance to limestone (up to 20% of active limestone) but it is sensitive to anoxia phenomena linked to waterlogging, thus entailing phenomena of widespread chlorosis.

Resistance to drought. This is definitely if not the main one of the most important aspect when choosing the rootstock. Qualitative viticulture is realized in land, that for different causes, appear to be deficient from the point of view of water and often do not exist the possibility to carry out irrigation. The good resistance of a rootstock to drought is linked both to the development of its root system and to the water absorption capacity in drought environments. On the other hand it is very important to respect the choice of other factors such as: planting distance, type of training system and cultural practices: soil management, bunch thinning, canopy management, etc.

Induced vigor. The rootstock in modern viticulture plays a crucial role in regulating the development of the plant, so it is always a good rule to use weak rootstock with vigorous varieties and vice versa take more vigorous rootstocks with weaker varieties. The above should still be seen in relation to soil fertility that is decisive in the expression of the plant vegetative-productive balance and other structural variables, and in particular the training system, the type of agronomic management implemented (soil management, fertilization etc.) in relation to the expected wine style.

Efficiency in the absorption of nutrients. Knowledge of the allocation of mineral elements from the soil is essential in choosing the rootstock, as many rootstocks have problems in absorbing certain nutrients. To this must be added the fact that some varieties are more sensitive than others to certain nutritional deficiencies, consequence of this is that these varieties grafted on rootstocks low efficient in absorbing a given nutrient is impaired by serious nutritional deficiency thus leading to negative productive and qualitative results. This is particularly frequent for two nutritional: potassium and magnesium.

Sensitivity to soil sickness (replanting disease). Often the need for immediate replanting does not allow to implement all those agronomic practices needed to favor the restoring of the soil conditions able to avoid those phenomena which go under the name of soil sickness. The cause of this is due to the accumulation in soil of toxins derived from the activity of the roots of the old vineyard. Often the situation is aggravated by the presence of various disease agents and pests (fungi, bacteria, nematodes). All this determines a reduced development of new plant and, with time, the mortality of plants and in general a reduced duration of the new vineyard. An adequate period of rest of the soil, through the cultivation of herbaceous plants such as grasses, after the removal of the old vineyard is a recommended practice, but also the choice of the rootstock is important in these cases. Therefore, in the case of immediate replanting is appropriate to use relatively vigorous rootstocks as the 1103P or 779P that offer greater guarantees to prevent soil sickness phenomena, on the contrary the 420A is not recommended in these cases.

The different characteristics, for the main properties described above, of some of the rootstocks currently commercially available are summarizes in the following table 3.2.

Table 3.2 – List of the main rootstocks available in EU markets and their principal characteristics

Rootstock	Parental species	Vigor	Resistance to			Particularly adapted to soils	Notes
			drought	lime	water logging		
125AA	V. Berlandieri x V. riparia	High	Low	Low	Low	Low in fertility and shallow	Sensible to magnesium deficiency
161-49 C	V. Berlandieri x V. riparia	Low	Low	High	Good	Deep and fertile	
225Ru	V. Berlandieri x V. riparia	High	Good	Good	Low	Deep and low in fertility	
420 A	V. Berlandieri x V. riparia	Low	Good	Good	Low	Silt - clayey, well drained	Unsuitable for replanting
K5BB	V. Berlandieri x V. riparia	High	Good	Good	Good	Clayey and calcareous	
SO4	V. Berlandieri x V. riparia	Medium	Low	Good	Good	Deep and humid	Favor constant yield, hasten ripening
Teleki 5C	V. Berlandieri x V. riparia	Medium	Low	Low	Low	Deep and fertile	Sensible to magnesium deficiency, hasten ripening
110 R	V. Berlandieri x V. rupestris	Medium	Good	Good	Good	Low in fertility and shallow	
1103 P	V. Berlandieri x V. rupestris	More than medium	Good	Good	Good	Clayey, deep and fertile	High resistance to saline soils
140 Ru	V. Berlandieri x V. rupestris	High	High	Very high	Low	Low in fertility and deep	Low affinity with vigorous grape varieties
775 P	V. Berlandieri x V. rupestris	High	Good	Good	Good	Low in fertility and compact	
779 P	V. Berlandieri x V. rupestris	More than medium	Good	Good	Good	More adaptable then 775P	
101-14	V. riparia x V. rupestris	Low	Low	Low	High	Clayey and fertile	Hasten ripening
3309 C	V. riparia x V. rupestris	Low	Low	Low	Low	Deep and well drained	Hasten ripening
41 B	V. vinifera x V. Berlandieri	Low	Good	Very high	Low	Highly calcareous	It may have rooting problems

Planting Typology for Georgian Viticulture

The planting typology refers to the choices of the training system in conjunction with the planting distance and the orientation of the rows. These choices have a significant impact on costs of generation and future management of vineyard.

The choice of the training system must take into account a plurality of managerial aspects especially in relation to the level of mechanization of the future vineyard. The choice should carefully consider:

- the productive target of the vineyard;
- specific varietal characteristics in relation to the habitus of the shoots growth and varietal requirements, in terms of the bunch microclimate;
- consistency between the training system adopted and the mechanization level planned for the management of the vineyard.

Considering the different environmental conditions and vinicultural systems the following training systems are recommended.

Training systems	Notes
Guyot and spurred cordon	Generally recommended
Italian Pergola and Casarsa	Particularly recommended in flat areas with deep soils of the warmer and humid districts for late ripening and late harvested grapes.
Traditional Georgian bush system	Particularly recommended in hilly areas on steep sloped or terraced lands as well as in small vineyards managed with family manual labor.

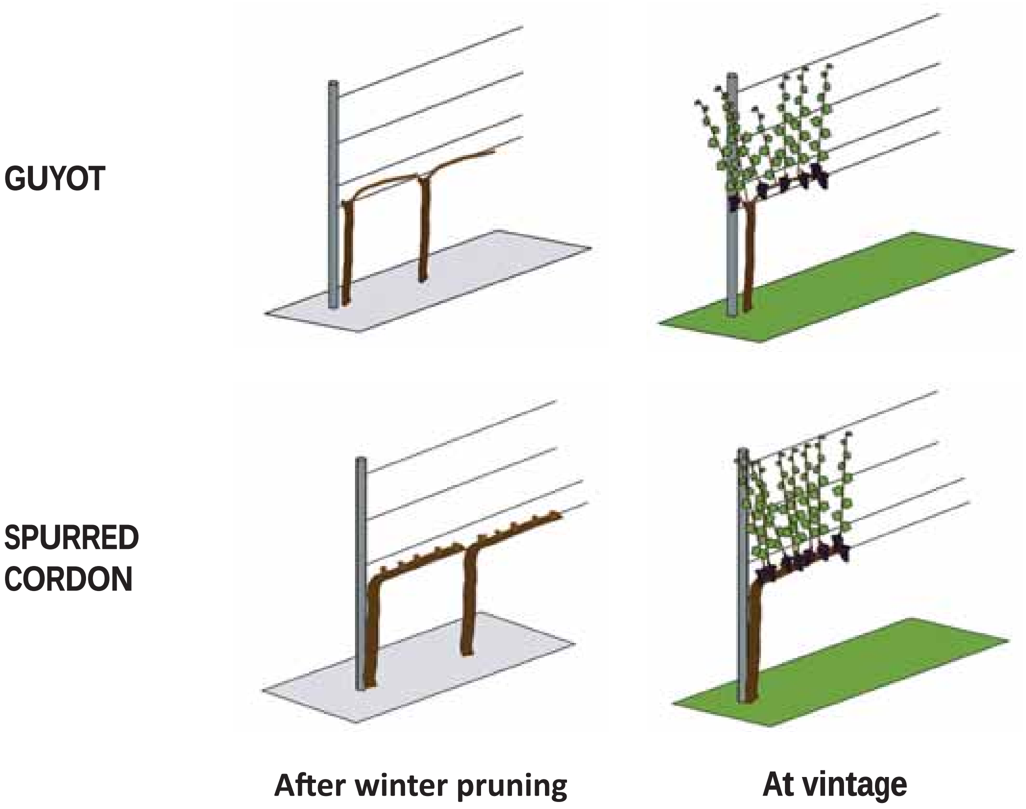


Figure 3.2 – Vine architecture of Guyot and Spurred cordon training systems (from Calò et al. 2006)

Guyot and Spurred cordon systems

They are two well-known training systems characterized by a trunk high around one meter followed by a short spur and a horizontally annually renewed fruiting cane (Guyot system) or by a permanent branch, holding some short spurs (spurred cordon). The canopy is formed by shoot growing upward (vertical shoot positioning). The Guyot system is easier to be formed and managed in respect to the spurred cordon that requires more care for the formation of cordon and the maintenance of the spur efficiency.

The main advantage of the spurred cordon system in respect to the Guyot system is related to the possibility of a partial mechanization of the winter pruning by the use of a pre-pruning machine and, more in general, a lower request of manpower for this cultural technique because spurred cordon does not require the ligation of the annual cane to the main wire. In contrast, it requires a more accurate suckering in spring time to avoid excessive number of sterile shoots on the cordon.

To reach the maximal efficiency of vineyard the following rules should be put into practice:

Row orientation Often the orientation of the rows is imposed by the morphology of the plot. When instead it is possible to choose, it is to be preferred the orientation that allows, in the course of the day, the direct illumination of a first and then the other side of the vegetative-productive wall. This corresponds to the orientation of the rows along the north-south axis. This orientation allows the full canopy exposure to the direct sunlight in the best hours of the day for the photosynthetic activities (mid-morning and mid-afternoon) and protect the bunches by possible excess of radiation during the central part of the day. During the morning it will be well irradiated facade facing east, while the one facing west in the afternoon. This equal distribution of direct radiation on the facades of the row, is paid in energy terms with the loss to the ground, in the middle of the day, of much of the radiation. This is in the bunch microclimate point of view is not unfavorable especially for early maturing varieties because it avoids thermal stress in bunches. In the case where the orientation of the rows cannot follow the north-south orientation, and especially the closer it gets to the east-west, the management of the vegetative-productive wall will have to avoid at the same time, excessive exposure to direct light solar of the bunches exposed to the south, and an excessive shading by foliar layers for the bunches exposed to the North.

Vine density and distances The planting distance must take into account, on the row, the plant vigor expected at that site, and, between the rows, the planned canopy height. The correct choice of the distances will promote uniformity of vegetative-productive wall while avoiding excessive competition between neighboring plants. The correct distance between the rows will avoid phenomena of mutual shading between the rows, however, maximizing the overall interception of the radiation by the vegetation.

Distances should be included in the ranges of the following table.

Table 3.3 – *Vine spacing and density*

Distance between rows (m)	**Vines along rows (m)**				
	0.80	**0.90**	**1.00**	**1.10**	**1.20**
2.20	5682	5051	4545	4132	3788
2.30	5435	4831	4348	3953	3623
2.40	5208	4630	4167	3788	3472

Legend	high density	medium density	low density

Comments

- High density should be adopted in less fertile soils, cooler zones and/or with low vigor varieties;
- Low density should be adopted in soil high in fertility, warmer zones and high vigor varieties.
- Distance between rows should take into consideration the machinery already available and/or to be acquired.
- The highest distance between the vines along the rows should be adopted for varieties low in basal fertility.

Vine, trunk and canopy height. In the end of the shoot growing period and after the shoot trimming, the full height of the vine canopy should be equal or few higher of the distance between the rows.

Comments

- The height of the canopy should be at least 140 cm.
- The trunk height should be between 80 (mandatory for row distance of 220 cm) and 100 cm (possible only for row distance 240).

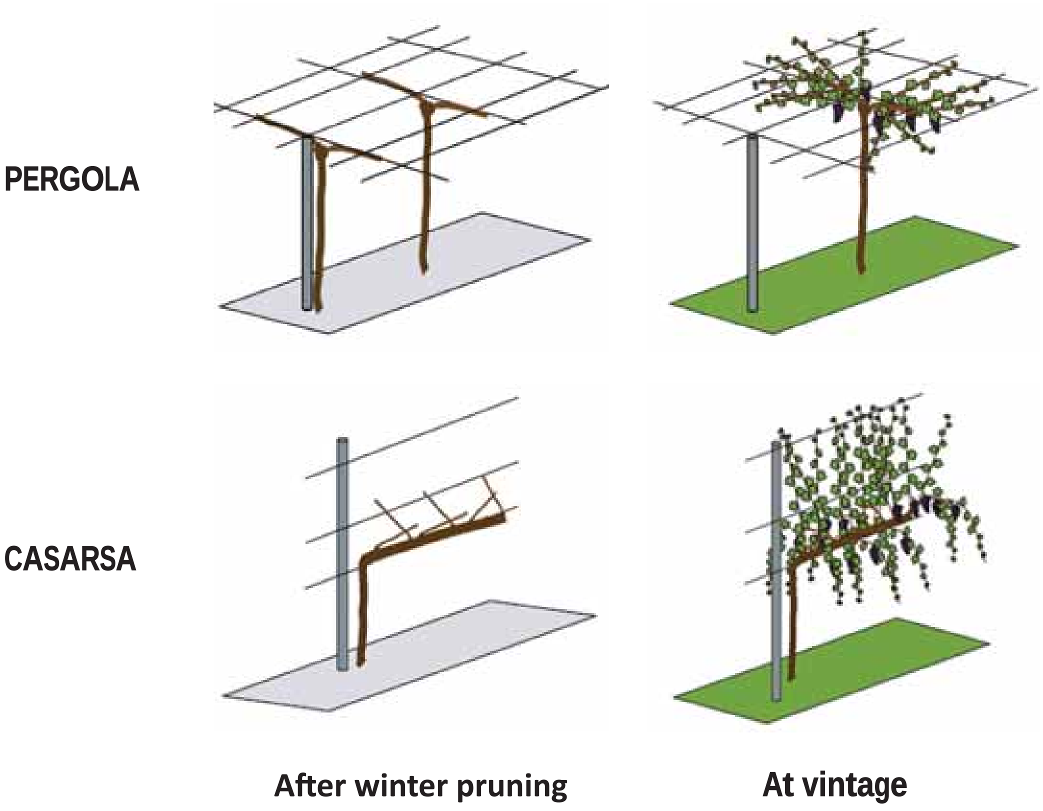


Figure 3.3 – Vine architecture of Pergola and Casarca training systems (from Calò et al. 2006).

Italian (veronese) Pergola system

This training system need soils able to assure a large canopy to the vines. The vines are planted with a distance between rows of 3.20 and 4.00 meters and distance along the row of 50-100 cm with a final density ranging from 2500 to 6250 vine per hectare. The vine is formed by a high trunk (180 cm) from which 2-3 annually renewed fruiting canes are placed horizontally thanks a network of wires to form a plain horizontal canopy. In this training systems the bunches are hanging below the canopy. They are so protected by excess of radiation and are free from possible mechanical damages due to obstacles to their grow for the presence of shoots, wires or other bunches.

Casarsa system

This training system needs soils able to assure a large canopy to the vines. The vines are planted with a distance between rows of 2.80 and 3.30 meters and distance along the row of 90-120 cm with a final density ranging from 2500 to 4000 vine per hectare. The vine is formed by a high trunk (160-170 cm) prolong with a long permanent cordon from which a number of short fruiting canes are inserted. In the classical model 2 or 3 wires are located above the cordon to sustain the basal shoots while the distal shoot will growth downward. In a more simplified model, the wires are missing and all the shoots grow downward. This variant, which allow the mechanical winter pruning and grape harvest is only suitable for grape varieties with an erect or semi erect shoot growth habit.

***Traditional** Georgian bush system*

This form allows high plant density. It is like the Italian "alberello" and the French "gobelet". It consists in a low trunk from which short permanent arms give origin to spurs and short canes. A central pole allows to tie the shoots. This training system permits a high efficiency in the interception of the solar radiation and allow to reach high ratios between foliage and grapes protecting also the bunches from radiative stresses.

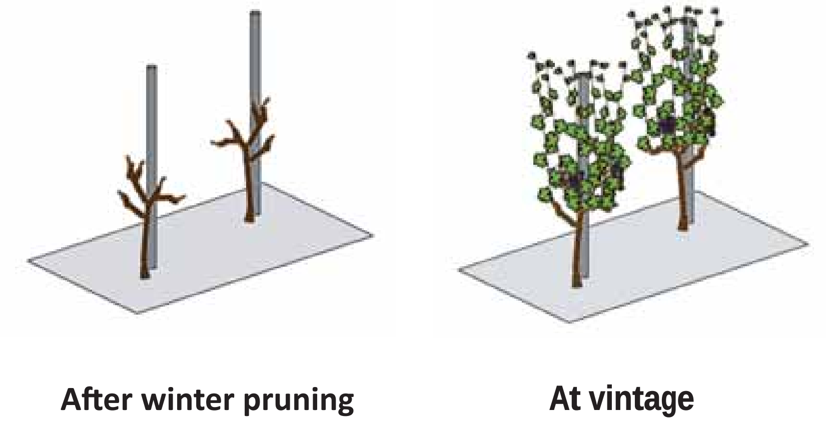


Figure 3.4 – Vine architecture of traditional Georgian bush training system.

Wine Management

The management of the vine refers to a variety of operations including winter pruning and canopy management.

Winter pruning, carried out in the period of dormancy, is intended to maintain the training system, and to set the correct number of buds, which will ensure an appropriate balance between vegetation and production for the next season. It is advisable to prune in late winter in conditions of sunny and windy days to avoid the risk of infections by fungi responsible for trunk diseases.

The canopy management is part of the spring-summer interventions (suckering, shoots thinning, leaf removal, shoots trimming), designed to regulate the development of the foliage and encourage their photosynthetic efficiency, so as to achieve the most suitable thermal and radiative microclimate, in particularly in the area of the bunches, to favor the processes of grape maturation and not foster the development of cryptogams.

Winter pruning intensity defines the buds load per hectare. Among the operations of canopy managements, the most relevant refer to shoot trimming, leaf removal and bunches.

The load of buds per hectare should be calculated on the basis of the following data.

- expected production in term of grapes per hectare;
- vine density in terms of plant per hectare;
- expected blind buds percentage: influenced by the grape variety and the environmental and physiological conditions of the vineyard;
- fertility of shoot: i.e., number of bunches on average brought from each shoot;
- average bunch weight: influenced by the grape variety and the environmental and physiological conditions of the vineyard.

Apart from the value of the plant density that is certain, other data have to be estimated based on past growth and productive performance of the plant, eventually corrected on the basis of the contingent status of vegetation and production potential of plants.

The calculation scheme to define the position of buds is therefore the following.

Expected yield per vine (kg) = *expected yield per hectare (t) x 1000 / number of vines per hectare*
Number of bunches per vine = *expected yield per vine (kg) x 1000 / average bunch weight (g)*
Number of shoots per vine = *number of bunches per vine / fertility of shoots*
Number of buds per vine = *number of shoot per vine / (1- (% blind buds / 100))*

The major problem for the use of this calculation scheme however is the estimation of the required parameters. A local time series data collection should be necessary. Moreover, the expected data should be adjusted year by year according to some preliminary test on bud vitality and fertility.

The following tables make an example for the two most important Georgian grapes.

Table 3.4 – *Main components of the yield function*

Grape variety	blind buds (%)	shoot fertility	bunch average weight (g)	Expected yield (t/ha)
Rkatsiteli B	10	1.25	230	10
Saperavi N	15	1.20	150	8

Table 3.5 – *Yield functions targets in relation to the vine spacing to reach the expected productivity*

Distances		vines/ha	Rkatsiteli B				Saperavi N			
Between rows	on the row		kg/vine	bunches per vine	shoots per vine	buds per vine	kg/vine	bunches per vine	shoots per vine	buds per vine
2.2	0.8	5 682	1.8	7.7	6.1	6.8	1.4	9.4	7.8	9.2
	0.9	5 051	2.0	8.6	6.9	7.7	2.0	13.2	11.0	12.9
	1.0	4 545	2.2	9.6	7.7	8.5	2.2	14.7	12.2	14.4
	1.1	4 132	2.4	10.5	8.4	9.4	2.4	16.1	13.4	15.8
	1.2	3 788	2.6	11.5	9.2	10.2	2.6	17.6	14.7	17.3
2.3	0.8	5 435	1.8	8.0	6.4	7.1	1.8	12.3	10.2	12.0
	0.9	4 831	2.1	9.0	7.2	8.0	2.1	13.8	11.5	13.5
	1.0	4 348	2.3	10.0	8.0	8.9	2.3	15.3	12.8	15.0
	1.1	3 953	2.5	11.0	8.8	9.8	2.5	16.9	14.1	16.5
	1.2	3 623	2.8	12.0	9.6	10.7	2.8	18.4	15.3	18.0
2.4	0.8	5 208	1.9	8.3	6.7	7.4	1.9	12.8	10.7	12.5
	0.9	4 630	2.2	9.4	7.5	8.3	2.2	14.4	12.0	14.1
	1.0	4 167	2.4	10.4	8.3	9.3	2.4	16.0	13.3	15.7
	1.1	3 788	2.6	11.5	9.2	10.2	2.6	17.6	14.7	17.3
	1.2	3 472	2.9	12.5	10.0	11.1	2.9	19.2	16.0	18.8

After setting the number of buds you will need to correct the possible overestimation of vegetative and productive parameters through interventions during the growing season. Among them it is particularly important the thinning of the shoots, especially in the spurred cordon and the bunch thinning.

Thinning of the shoots must be made relatively early in the season (shoots to 10 cm).

Thinning of the bunches must be made in pre-veraison, during the lag phase of berry growth, after estimating the real production load of the vineyard.

Shoot trimming should be generally done at the end of fruit set. In this way it promotes the development of lateral shoots that will provide a younger and efficient leaf area in favor of grape maturation processes. The topping must still leave a length of the shoot above the clusters of at least 80-100 cm, equivalent to 8-10 leaves.

Leaves removal. In general, an early leaves removal (during post flowering - fruit set) associated with the topping of the shoots, in the most fertile sites is considered to be good. Here it is highly likely an intense production of lateral shoots that can quickly rebuild an adequate leaf surface, useful to photosynthetic processes as to the production of suitable leaf layers to shade the grapes in the period of July, August when the thermal excesses suffered by bunches exposed directly to the radiation can damage the clusters themselves. In the less fertile sites early leaves removal will be recommended only when the analysis of the state of the canopy indicates the presence of a high number of leaf layers and an equally high frequency of bunches covered by one or more foliar layers.

Thinning of bunches should be eventually done to balance the production load to the size of the leaf surface exposed vineyard. So, the assessment of the relationship grapes vs. leaf surface per vine is preliminary to decide whether and how thin out the grapes. The most appropriate times to perform the cluster thinning is pre-veraison. Earlier interventions, during the growth of green berries can in fact stimulate the growth of the same berries, partly nullifying the effect of thinning and inducing the production of larger berries. The thinning in the pre-veraison other not to determine an increase in the growth of the berries with respect to the conditions of the plants not thinned out, allows an advance and a greater simultaneity in veraison, and when reports the production load to below the critical threshold of about a kg of grapes per square meter vine leaves, also allows a more precocious and complete technological maturity. Instead, often a more intense phenolic and aromatic maturity is reached for critical thresholds of grapes per leaf area, higher than about a kg of grapes per square meter of vine leaves.

Vineyard Fertilization

Vineyard fertilization has the object to supplement the natural fertility of the soil to make the mineral nutrients necessary for plant growth and grape quality, at such time and in the appropriate amount for production qualitative and quantitative objectives, while minimizing possible environmental impacts resulting from the distribution of fertilizers. It can be via the soil and / or foliar application, and depending on the chosen type of fertilizer, mineral or organic.

Fertilization in a broad sense means the improvement of the agronomic fertility of a soil by means of interventions capable of change for the better the function of water and mineral nutrition and more generally against the habitability of the cultivated species. The more specific target of fertilization is to preserve or establish a nutritional potential of the soil capable of ensuring, in the specific case, the highest economic productivity of the vineyard, consistent with the best qualitative characteristics of grapes, with respect for soil fertility preservation and with minimal environmental impact.

The definition of the fertilization plan should take account of the diagnosis of the nutritional status of the planting and the estimation of the vineyard nutritional requirements.

In turn, the estimation of nutritional status should be based on: soil analysis, leaf analysis, visual analysis of the vegetative and production state and analysis of the quality of grapes.

The analysis of vegetative and production status should be performed every year, and includes:

- an assessment of any symptoms related to deficiencies / nutritional excesses;
- the evaluation of the vegetative development;
- the evaluation of the production load;
- the evaluation of the timing of the autumn leaf fall.
- The grapes qualitative analysis should take into account:
    - sugar title, titratable acidity and pH;
    - level of anthocyanins and polyphenols (red vines);
    - content of yeast assimilable nitrogen (YAN).

The variability of the conditions of the individual vineyard does not allow to define generalized fertilization doses. Instead, fertilization levels should be determined, vineyard by vineyard, to adequately address the specific needs.

Some general lines of intervention, based on diagnostic methods mentioned above, can be summarized as follows.

- If the quantity and the quality levels of production are satisfactory and the nutritional status of plant and soil are normal, the doses of nutrients to be supplied will be determined having regard to the crop nutrient removals.
- If the production or vegetative growth are not adequate and foliar and soil analysis levels are below normal, you need to add an amount of nutrients to enrichment the crop removal doses. In special cases it can be observed an unsatisfactory nutritional status of vineyard, but with nutrient levels in the soil above the threshold of sufficiency. This possibility requires, before changing fertilization, to check whether there are conditions that impede the normal root absorption of nutrients. In these phenomena an important role is played by the soil management. As an example it can be observed in the vineyards where too deep tillage are done.
- Situations in which the nutritional status of the grapevines is adequate and the soil levels exceed the thresholds of sufficiency, require the suspension of fertilization, in order to avoid consumption more than necessary of some elements (consumption of “luxury” for potassium) or excess of plant vigor, always negative for the quality of production.

Nitrogen is the most important element in the nutrition of the vine not only because it regulates plant growth and productivity, but also because it affects the quality of the wine and the activity of yeast in the fermentation. Objective of nitrogen fertilization conducted properly is to adjust the amount of mineral nitrogen readily available at the time in which the plant needs it. This principle is even more important if you highlight the need to minimize the environmental impact of nitrogen fertilization to avoid so that nitrates in the soil and not absorbed by the plants will then be leached in groundwater. Without considering that in any case an excess of nitrogen to the grapevines is reflected on the balance between vegetation and production of the vineyard, favoring vegetative growth at the expense of the ripening of the grapes and sometimes even of production levels.

The setting of the nitrogen fertilization should take into account the following considerations.

- The potential fertility of a soil depends in a first approximation by its depth, texture and level of organic substance. Soil deep, fine in texture and rich in organic matter have a much higher potential fertility of thin soils, of coarse texture and poor in organic matter.

- The spring warming of the soil is important to reactivate the root and the soil microbiological activities. Soils well exposed, drained and with coarse texture heat up more easily with the opposite characteristics are proper of soils which hold more water.
- In the vineyard, in general, the need to increase soil mineral nitrogen availability is prevalent presented in the spring. The critical moment is about a month after the bud break, when the plant nitrogen reserves accumulated during the previous season have been consumed, and the grapevines should support the growth and development by taking the necessary nitrogen from the soil. If this is not able to put at the disposal of the plant in adequate amounts, it is necessary to intervene with the fertilization using readily absorbable mineral nitrogen. Typically, the soils that warm early in spring they can to support these early applications of nitrogen. The need for early nitrogen supply, at about the bud break, are more important in "cold" soils. In the "warm" soils, which in general are the coarsest and less rich in organic matter, the critical moment for the nitrogen nutrition is tending to fall further in the season, or when you approach the flowering - fruit set phase. These soils, in fact, tend to rapidly deplete the mineral nitrogen due to the reduced potential fertility of nitrogen, resulting by the reduced content of organic substance and high vulnerability to nitrogen leaching by the spring rains. For this reason, in these soils it is generally more important to monitor the nutritional status of nitrogen and possibly supply mineral nitrogen in the flowering - fruit set stage.
- A third critical moment for the nitrogen nutrition of the vineyard is at veraison. In this phase resumes the growth of the berry that also accumulates nitrogenous substances in significant quantities. In this time of the year the soil is able to mineralize considerable amount of nitrogen if it is sufficiently provided with organic substance and if it is not too dry. These two limiting conditions may occur in thin and coarse soils, where it may be appropriate, if there is no irrigation, the possibility of foliar treatments with urea at low concentration or nitric nitrogen. In soils fine, deep and sufficiently humid, it should not be required to supply nitrogen.
- After veraison, and during maturation, conditions that can stimulate vegetative activity have to be avoided. A high availability of nitrogen in this part of the season, in addition to delay ripening, especially if the growing area is late, favors the onset of rot and decreases the resistance of the wood to the winter cold.

For the possible supply of phosphorus, potassium and magnesium, according to the already drawn guidelines, the information of the following tables should be followed.

Table 3.6 – Threshold values for the interpretation of the soil availability in phosphorus, potassium, magnesium and boron

Soil analysis index	Low	High
Olsen Phosphorous (ppm* P_2O_5)	< 10	> 30
Exchangeable Potassium (% CEC**)	< 2	> 5
Exchangeable Magnesium (% CEC)	< 3	> 10
Soluble Boron (B ppm)	< 0.1	> 0.5

* ppm = part per million = mg/kg

** CEC = cation exchange capacity

Table 3.7 – Average total nutrient removal (grapes, leaves, pruning wood and old wood) taken with grapes and pruning wood and only with grapes, in vineyards of .varying productions between 7.5 and 15 t/ha

Nutrient	Nutrient removal (kg/ha/year)		
	total	removed by	
		pruning wood and grapes	grapes
Nitrogen (N)	45-80	20-30	12-20
Phosphorus (P_2O_5)	12-22	7-15	5-10
Potassium (K_2O)	55-90	35-60	25-40
Magnesium (MgO)	12-28	6-15	2-5

For the nutritional management of micronutrients, it is particularly important to refer to the leaf analysis and visual inspections. Cases of serious deficiencies are often associated with soil degraded for various reasons, for which it will need to act with soil and corrective measures, as well as with the grass covering practice for its many beneficial effects on soil fertility.

The rapid correction of micronutrients deficiencies has to be implemented with foliar fertilization interventions.

Table 3.8 – Range values for the interpretation of leaf analysis in the Georgian vineyards. Data on dry matter

Sampling time	N %	P %	K %	Ca %	Mg %
Fruit set	2.40-3.70	0.16-0.35	0.70-1.60	2.00-3.70	0.20-0.44
Veraison	1.60-2.90	0.10-0.20	0.50-1.40	2.40-4.20	0.17-0.65

Sampling time	Fe ppm	Mn ppm	B ppm	Zn ppm
Fruit set	50-150	60-140	40-180	20-80
Veraison	60-200	40-180	20-60	5-60

LIST OF ACRONYMS

AWC	available water capacity
DOY	day of the year
ET0	reference crop evapotranspiration
ETM	maximum evapotranspiration
ETR	real evapotranspiration
GDD	growing degree days
GIS	geographic Information System
KC	crop coefficient
SF	water stress factor

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