

VITICULTURE ZONING OF GRAPE PRODUCTION ZONES FOR GI ARMENIAN BRANDY BASED ON VINE ROOTSTOCKS



2026

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TECHNICAL ASSISTANCE FOR THE DEVELOPMENT OF
THE GEOGRAPHICAL INDICATION "ARMENIAN BRANDY"

PROJECT INFORMATION

PROJECT TITLE:

Technical Assistance for the Development of the Geographical Indication “Armenian Brandy”

CONTRACT NUMBER:

2024/454-624

COUNTRY:

Republic of Armenia

FUNDING:

European Union

CONTRACTING AUTHORITY:

The European Union, represented by the European Union Delegation to the Republic of Armenia

CONTRACTOR:

Expertise France Groupe AFD (40, boulevard de Port-Royal 75005 Paris, France) in consortium with DMI Associates (21, rue Longue 69001 Lyon, France)

PROJECT BENEFICIARIES:

Ministry of Economy of Republic of Armenia, Vine and Wine Foundation of Armenia, etc.

DURATION:

20 June 2024 – 19 June 2026

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INTRODUCTION

Armenia is one of the world's historically significant viticultural regions, where grape cultivation, wine production and the use of indigenous grapevine genetic resources are deeply embedded in the agricultural, cultural and economic identity of the country. Archaeological discoveries at the Areni-1 cave complex, including a wine press, fermentation and storage vessels, grape remains and associated winemaking equipment dated to around 4100–4000 BC, provide some of the earliest reliable evidence of organized wine production known to date. This long continuity of viticulture gives Armenian grape production not only economic importance, but also exceptional cultural and genetic value.

This Viticulture Zoning of Grape Production Zones for GI Armenian Brandy Based on Vine Rootstocks (hereinafter: zoning) has been prepared within the project Technical Assistance for the Development of the Geographical Indication "Armenian Brandy", funded by the European Union and implemented by Expertise France in partnership with DMI Associates. Its purpose is to provide a scientific, spatially explicit and practically applicable basis for future decision-making in Armenian viticulture, particularly in the context of grape production zones intended for Armenian brandy. The zoning extends the terroir-based zoning approach by integrating the suitability assessment of selected vine rootstocks within the defined grape production zones of Armenia. Six widely used rootstocks were analyzed: Riparia × Rupestris 3309 C, Berlandieri × Rupestris Ruggeri 140, Berlandieri × Riparia 420A, Berlandieri × Rupestris 1103 Paulsen, Berlandieri × Riparia Kober 5BB, and Berlandieri × Riparia Teleki 5C.

The preparation of this zoning is particularly important because grapevines in most Armenian grape production zones are still traditionally cultivated on their own roots. This practice is part of the country's viticultural heritage and has been possible due to the historical absence, limited presence, or uneven distribution of phylloxera in many vineyard areas. However, this situation cannot be considered permanently secure. In some zones, such as Tavush, vineyards are already cultivated on rootstocks, while official phytosanitary reporting has recorded the presence of *Daktulosphaira vitifoliae* in Armenia. The EPPO Global Database reported grape phylloxera as present in three Armenian provinces in the quarantine pest update for Armenia.

The historical experience of Europe clearly demonstrates why this issue requires strategic attention. Grape phylloxera, a small root- and leaf-feeding insect native to North America, was introduced into Europe in the nineteenth century and radically changed the history of viticulture. Historical records indicate that phylloxera appeared in southern France in the early 1860s and that its presence on dead gvine roots was officially confirmed in 1868. From there, it spread rapidly across European wine regions, causing severe vineyard decline and forcing one of the most important technological changes in modern viticulture: the grafting of European *Vitis vinifera* cultivars onto resistant or tolerant North American rootstocks.

The reason for this change was biological and agronomic. European *Vitis vinifera* vines are highly susceptible to the root-feeding form of phylloxera, while several American *Vitis* species developed different levels of tolerance or resistance through long co-evolution with the pest. For this reason, American species such as *Vitis riparia*, *Vitis rupestris* and *Vitis berlandieri*, as well as their hybrids, became the foundation of modern rootstock breeding and global grafted viticulture.

Nevertheless, the introduction of rootstocks is not simply a question of resistance to phylloxera. Rootstocks strongly influence vine vigour, rooting depth, water and nutrient uptake, drought tolerance, tolerance to soil salinity, adaptation to soil texture, soil depth, erosion conditions and, very importantly, tolerance to lime and carbonate-rich soils. This is particularly relevant for Armenia, where many grape production areas are characterized by calcareous soils and variable calcium carbonate content. In such conditions, the wrong rootstock can lead to poor vine establishment, reduced nutrient availability, lime-induced chlorosis, excessive or insufficient vigour, and lower vineyard longevity. Therefore, the selection of rootstocks must be based on the combined assessment of local soil, topographic and environmental conditions, rather than on general recommendations.

Recent molecular and genomic research on grape phylloxera has further emphasized that this pest should not be viewed only through the simple question of whether it is present or absent. Population-genomic studies have shown that phylloxera populations differ genetically, that invasion routes can be reconstructed through DNA analysis, and that different populations may have different adaptive potential. A major genome study found that

the global invasion of grape phylloxera likely originated from the upper Mississippi River region in North America and spread through Europe to other wine-growing regions; the same study included Armenian phylloxera material among introduced populations and reported that populations from Germany, Austria, Romania and Armenia were tightly clustered with Mississippi Valley populations.

These findings are highly relevant for Armenia. They indicate that future phytosanitary risk assessment should consider not only the geographical spread of phylloxera, but also the biological and genetic characteristics of phylloxera populations. In practical terms, this means that the potential spread of phylloxera in Armenia could require a gradual transition from own-rooted vines to grafted vines in vulnerable areas. Such a transition must be prepared in advance, because emergency decisions made after widespread vineyard decline would be more expensive, less precise and less effective.

Recent molecular work led by Ms. Margaryan, PhD has shown that phylloxera in Armenia should not be viewed only as a question of presence or absence. For the first time, phylloxera populations in Armenia were genotyped, and more than 100 new genotypes were collected and sequenced. The results indicate that the phylloxera detected in one Armenian wine-growing area is not the same as the populations historically known from Tavush or Artsakh but was most probably introduced through imported planting material during the 2000s. This finding highlights the need for systematic monitoring, strict control of propagation material, and careful evaluation of rootstocks adapted to the specific environmental conditions of each Armenian grape production zone/wine-growing area.

For this reason, the zoning provides an important decision-support tool for identifying which rootstocks may be most appropriate in different Armenian grape production zones/wine-growing areas. The analysis does not assume that one rootstock is universally suitable for all sites. On the contrary, each rootstock was evaluated according to its specific ecological and agronomic requirements. The modelling approach integrates topographic indicators, including elevation, slope and terrain exposure, with key soil indicators such as potassium, phosphorus, humus, pH, calcium carbonate content, stoniness, texture, erosion, soil depth and soil genus. By combining these indicators in a GIS-based multi-factor model, the zoning identifies spatial patterns of potential suitability for each rootstock.

This approach follows the same applied logic used in other viticultural zoning and rootstock recommendation projects led by Mr. Jakšić (Team Leader of the project) in different wine-growing regions in Europe: rootstock selection should be locally adapted, scientifically justified and directly useful for vineyard planning. The goal is not only to produce maps, but to transform complex environmental data into practical recommendations that can support future vineyard establishment, vineyard renewal, nursery planning, and national preparedness in case grafting becomes necessary on a larger scale.

The importance of this zoning is also connected with the preservation of Armenia's grapevine genetic resources. Armenia has conserved an extensive and valuable diversity of grapevine germplasm. A comprehensive molecular characterization study of Armenian grapevine resources collected 492 samples from more than 120 locations and showed that Armenia preserved a wide range of grapevine genetic diversity despite geographical isolation and limited material exchange.

The value of this genetic heritage is further confirmed by recent DNA-based research on Armenian wild vines. A study of Armenian *Vitis sylvestris* analyzed 196 wild genotypes, including 148 newly collected unique wild genotypes and 48 previously collected wild individuals, and found high genetic diversity and important breeding potential. The same research emphasized that wild grapes are endangered across their distribution areas and that preservation measures are necessary to maintain their genetic integrity and survival.

If phylloxera were to spread more widely into Armenian own-rooted vineyards, the risk would therefore not be limited to production losses. It could also threaten old vineyards, rare local varieties, unique genotypes, and valuable genetic resources that are important for future breeding, adaptation to climate change, resistance to diseases, and the preservation of Armenian viticultural identity. For this reason, preventive zoning, rootstock suitability analysis, conservation of local germplasm, sanitary monitoring and the establishment of appropriate grafting strategies must be considered as parts of one integrated national approach.

The zoning should be understood as a forward-looking tool. It does not imply that all Armenian vineyards must immediately be converted to grafted vines. Rather, it provides the knowledge base needed to act rationally if the spread of phylloxera accelerates, if new vineyard areas are planned, or if national policy decides to introduce grafting as a protective measure in specific zones. It also provides guidance for selecting rootstocks that are not only resistant to phylloxera, but also compatible with Armenian soils, terrain, water regimes and production objectives.

This publication can be used by a wide range of stakeholders. At the national level, it can support state institutions, ministries, phytosanitary authorities, agricultural policy makers and decision-makers responsible for rural development, land use planning and viticultural strategy. At the professional and technical level, it can be used by research institutions, universities, advisory services, GIS specialists, nurseries, certification bodies and laboratories involved in grapevine health and propagation material. At the production level, it can support brandy grape producers, winegrowers, vineyard investors, cooperatives, wineries, brandy companies and local municipalities in planning vineyard establishment, vineyard renewal and risk management.

In the event that phylloxera spreads further and the grafting of grapevines becomes necessary in additional grape production zones of Armenia, this zoning can serve as a practical reference for choosing the most suitable rootstocks for specific sites. In that sense, it is both a scientific document and a preparedness instrument: a basis for protecting production, preserving genetic resources, reducing future economic losses, and ensuring the long-term sustainability of Armenian viticulture.

We would like to emphasize that the value of this work lies in its practical application. The maps and recommendations presented here are intended to help Armenia prepare before a crisis occurs, to make informed decisions based on terroir and scientific evidence, and to protect one of the country's most valuable agricultural and cultural resources: the grapevine.

Darko Jakšić, PhD

Team Leader and first author of this zoning, in the name of the authors

The top half of the image features a dark maroon background. In the center, a large, bold, dark maroon number '1' is positioned. Above the number, there is a stylized, lighter maroon archway with intricate scrollwork and floral patterns. The archway is composed of several segments, each with a different pattern, creating a sense of depth and architectural detail.

1

METHODOLOGY FOR RESEARCH, MODELLING, AND MAPPING

1.1 METHODOLOGY FOR THE ANALYSIS OF TOPOGRAPHIC INDICATORS

Topographic terroir factors were analyzed to quantify terrain characteristics relevant to vine rootstock suitability across the territory of Armenia. A 30-meter resolution Digital Elevation Model (DEM), derived from the Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global dataset, was used as the primary input layer. This dataset provides consistent national coverage and sufficient spatial detail for viticultural spatial analysis.

Based on the DEM, three key topographic indicators were derived within a GIS environment: elevation, slope, and terrain exposure (aspect), using standard terrain analysis tools and raster-based geomorphometric functions (ArcGIS / QGIS). Elevation was extracted directly from the DEM, while slope was calculated as the rate of change in elevation using a 3×3 moving window and local surface gradients. Terrain exposure (aspect) was determined as the compass direction of the maximum rate of elevation change, expressed in degrees from 0° to 360°.

For each of the analyzed vine rootstocks, suitability classes were defined for each topographic factor using a class-based approach. These classes reflect the ecological requirements and adaptability of individual rootstocks to different terrain conditions. Elevation was classified into three suitability levels, slope into five classes based on terrain steepness, and terrain exposure into directional categories representing differences in solar radiation and microclimatic conditions.

The defined classes were subsequently transformed into normalized suitability scores ranging from 0.2 to 1.0, enabling comparison and integration of factors within the spatial modelling framework. The detailed classification schemes and corresponding suitability scores for each rootstock factor are presented in Chapter 3.

1.2. METHODOLOGY FOR THE ANALYSIS OF SOIL INDICATORS

A total of ten soil indicators were included in the analysis: potassium content (K), phosphorus content (P), humus content, soil pH, calcium carbonate content (CaCO_3), soil stoniness, soil texture, soil depth, soil erosion, and soil type (genus). These variables were selected as they represent key physical and chemical soil properties influencing grapevine growth, nutrient availability, water retention, and overall rootstock suitability.

Soil data were obtained from the ARMSIS platform (Armenian Soil Information System), which provides national-scale digital soil information derived from field surveys and laboratory analyses. Chemical soil properties, including potassium content, phosphorus content, humus content, and soil pH, were obtained as raster datasets (TIFF format).

Additional soil indicators, including soil stoniness, soil texture, soil depth, soil erosion, and soil type (genus), were extracted from the same platform in vector format (shapefile – SHP). All datasets were processed within a GIS environment and harmonized for further spatial analysis.

Calcium carbonate content (CaCO_3) was derived through spatial interpolation of point-based data obtained from publicly available sources. The original dataset consisted of georeferenced observations of CaCO_3 content at specific locations. These point data were processed within a GIS environment, where interpolation techniques were applied to generate a continuous raster surface representing the spatial distribution of calcium carbonate content across the study area.

1.3. NETWORK ANALYSIS

Bayesian Network Analysis (BNA) was applied to evaluate the structure and strength of relationships among environmental indicators and to derive weighting coefficients for the rootstock suitability assessment. This approach enables the identification of interdependencies between variables and reduces subjectivity in multi-criteria modelling.

Within the network, two central metrics were calculated for each indicator: Strength and Expected Influence (EI). The Strength metric represents the sum of absolute values of connections between a given variable and all other nodes in the network, reflecting its overall level of interaction. In contrast, Expected Influence accounts for both the magnitude and direction of relationships, expressing the net contribution of each variable within the system. To obtain a single measure of indicator importance, an integrated centrality value was defined as:

$$W_i = | Strength_i | + | Expected Influence_i |$$

The integrated value W_i represents the overall network centrality of each indicator and serves as the basis for determining its relative importance in the suitability model.

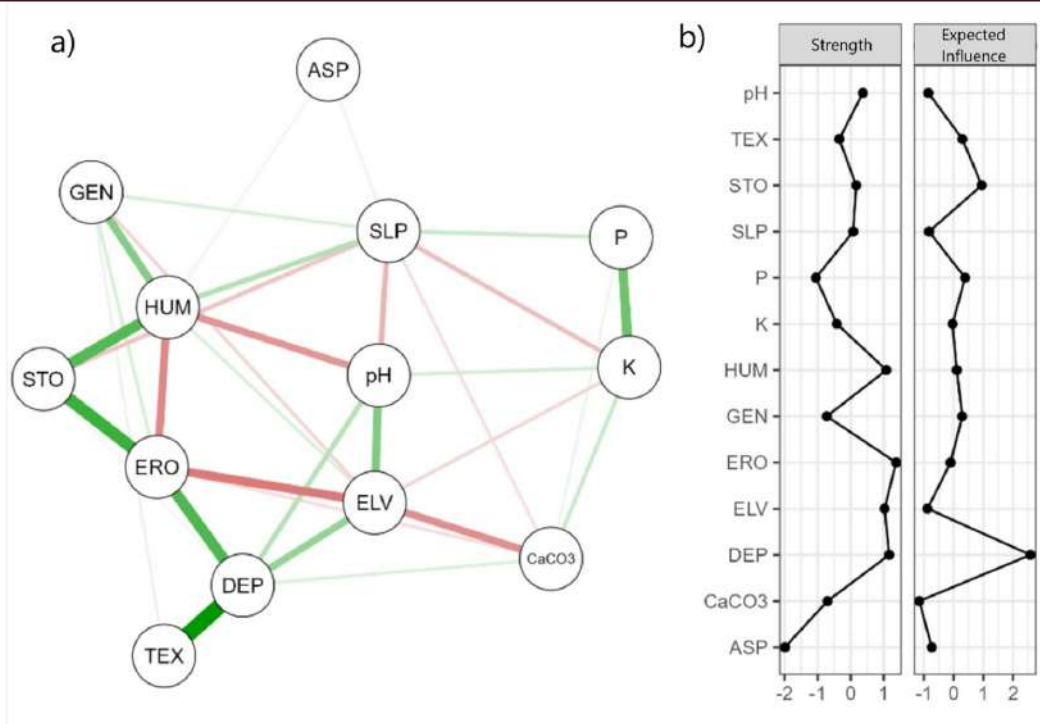
These values were subsequently normalized to derive the final weighting coefficients:

$$W_i = \frac{W_i}{\sum W_i}$$

where $\sum W_i$ represents the sum of integrated values for all indicators.

The resulting weights reflect the relative contribution of each environmental variable in the rootstock suitability assessment and were further used in the spatial modelling process.

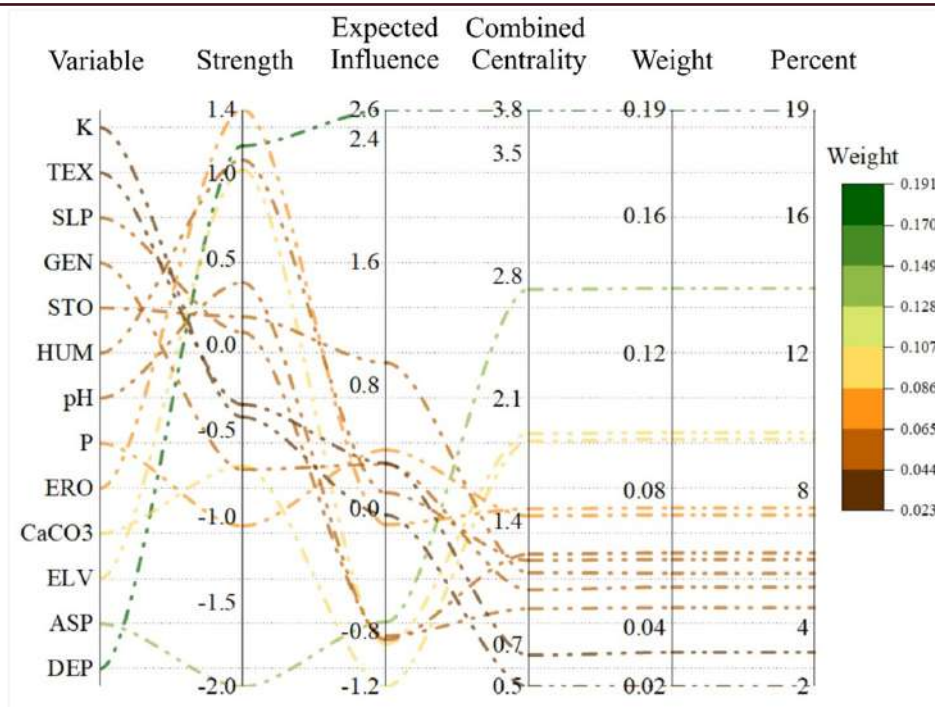
Figure 1.



Bayesian network showing relationships between environmental indicators;

(b) node centrality measures expressed as Strength and Expected Influence.

Figure 2.



Centrality metrics and derived weights of environmental indicators based on Bayesian Network Analysis

STANDARD SCORING FUNCTION (SSF)

To ensure comparability of the data and facilitate further spatial analysis, all environmental indicators were standardized using the Standard Scoring Function (SSF), whereby the values were transformed into normalized suitability scores. This approach enables the integration of heterogeneous environmental variables within a unified modelling framework.

Two types of SSF approaches were applied, depending on the nature of the indicator and the ecological response of the vine rootstocks.

For selected indicators, including soil pH, potassium content, and phosphorus content, a continuous SSF approach was used. In this case, suitability was defined using three types of response functions:

- More is better – $N(x)$
- Less is better – $M(x)$
- Midpoint optimal – $F(x)$

The selection of indicators and the definition of their response function types were based on the CMST conceptual framework. Instead of applying the original discrete CMST scoring scale, indicator values were normalized using Standard Scoring Functions (SSF). Threshold and target values were derived from CMST suitability logic and subsequently adjusted to regional Armenian conditions and dataset characteristics, ensuring methodological consistency while preserving local relevance.

The mathematical formulations for these functions are:

$$N(x) \begin{cases} 1 - 0.9 \frac{X-L}{U-L} & L \leq X \leq U \\ 0.1 & X > U \end{cases}$$

$$M(x) \begin{cases} 0.1 & X < L \\ 1 + 0.9 \frac{X-L}{U-L} + 0.1 & L \leq X \leq U \\ 1 & X > U \end{cases}$$

$$F(x) \begin{cases} 0.1 & X \leq L \\ 0.9 \frac{X-L}{T-L} + 0.1 & L < X \leq T \\ 1 & T < X < U \\ 1 - 0.9 \frac{X-T}{U-T} & X \geq U \end{cases}$$

Where:

- X is the measured value of the indicator,
- L is the lower threshold,
- U is the upper threshold,
- T is the optimal (target) value of the indicator.

The set of topographic, climatic, and soil indicators included in the Standard Scoring Function (SSF) framework, together with their assigned response function types and evaluation rules, is presented in Table 2. For each indicator, the suitability logic (more is better, less is better, or midpoint optimal) and the corresponding target or threshold values used for normalization were defined in accordance with the conceptual CMST model and then adapted to the regional conditions of Armenia and the characteristics of the available dataset. In this way, the CMST suitability principles were operationalized through SSF-based numerical scoring. The table therefore represents the operational basis for applying the SSF method, ensuring consistent, transparent, and reproducible transformation of diverse indicators into standardized suitability scores for subsequent spatial integration and network analysis .

For other indicators, a discrete class-based scoring approach was applied. In this case, each environmental variable was divided into predefined suitability classes (e.g., most suitable, highly suitable, moderately suitable, less suitable, and unsuitable), and each class was assigned a corresponding normalized score, typically ranging from 0.2 to 1.0. This approach was applied to indicators such as elevation, slope, terrain exposure, soil stoniness, soil texture, soil erosion, soil depth, and soil genus.

The definition of suitability classes, optimal ranges, and corresponding scoring rules was based on viticultural knowledge, literature sources, and expert interpretation, while also considering the specific environmental conditions of Armenia.

The resulting standardized indicator layers represent the basis for further spatial analysis and the evaluation of rootstock suitability. Detailed classification schemes and scoring rules for each rootstock and indicator are presented in Chapter 3.

The top half of the image features a dark maroon background. It is decorated with a large, stylized number '2' in the center. Above the '2' is a semi-circular arch containing intricate, lighter-colored scrollwork patterns. Above the arch, there are several triangular shapes of varying sizes, resembling a sunburst or a stylized mountain range.

2

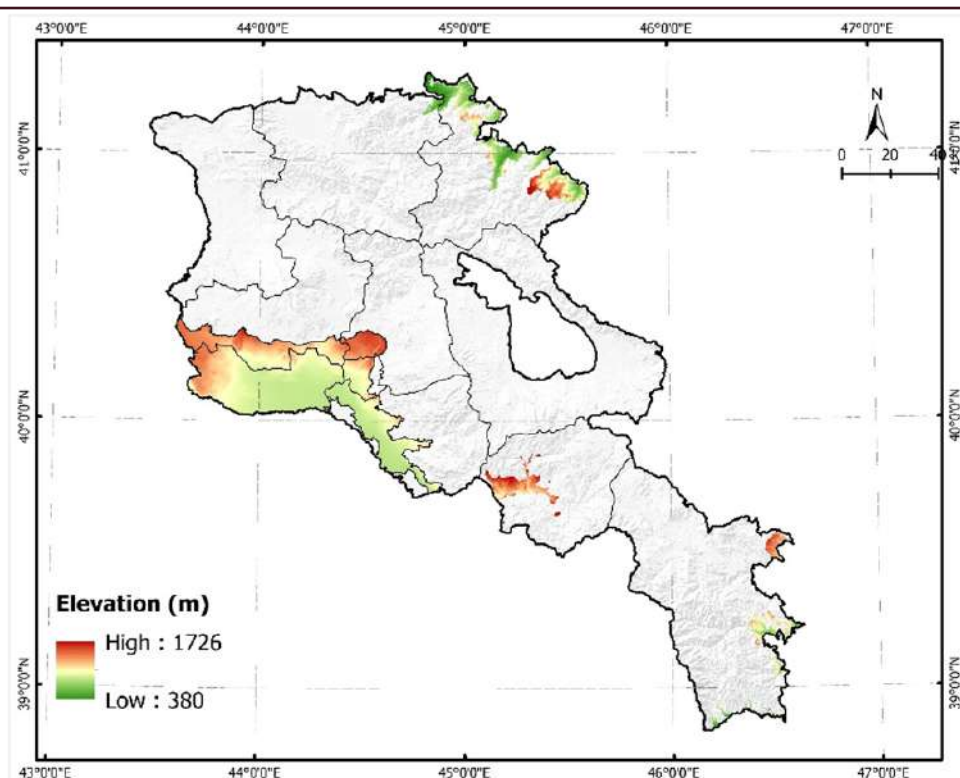
TOPOGRAPHY AND SOIL INDICATORS IN THE GRAPE PRODUCTION ZONE OF ARMENIA

2.1. TOPOGRAPHIC INDICATORS (TERROIR FACTORS) USED FOR VINE ROOTSTOCK ZONING IN THE GRAPE PRODUCTION ZONES OF ARMENIA

2.1.1. ELEVATION

The grape production zones for Armenian brandy are characterized by significant variability in elevation, ranging from approximately 380 m to around 1,726 m above sea level. The lowest elevations are recorded in Tavush, while the highest altitudes are found in Vayots Dzor. The Ararat Valley and Syunik zones are predominantly situated within intermediate elevation belts, with most vineyards located between 500 and 1,400 m. This wide altitudinal range enables pronounced microclimatic variability and supports differentiated grape ripening conditions (Map 1).

Map 1.



Elevation of the
Grape Production
Zone of Armenia

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO ELEVATION

Elevation was applied to define rootstock suitability using a class-based approach. All analyzed rootstocks show a uniform response, with optimal conditions at elevations up to 1000 m. The range between 1000 and 1500 m is considered moderately suitable, reflecting increasing climatic limitations.

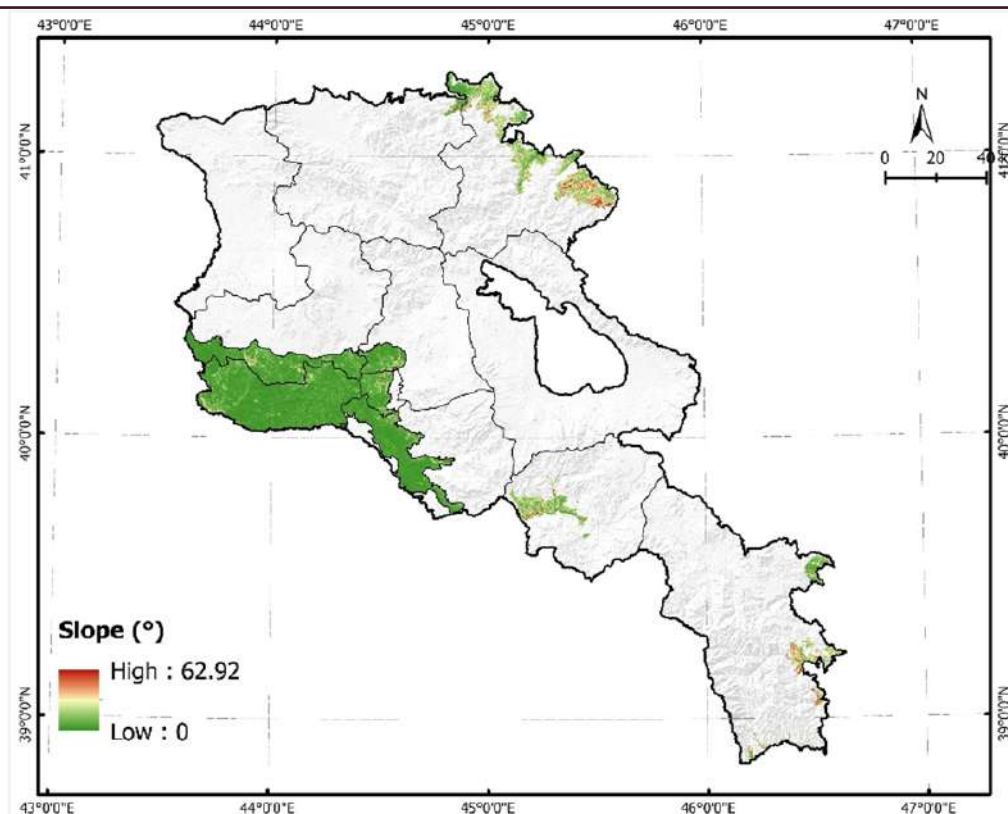
Elevations above 1500 m are classified as unsuitable due to reduced thermal conditions and shorter growing seasons. The consistent classification across all rootstocks indicates that elevation acts as a limiting factor rather than a differentiating one within the study area (Table 1).

Table 1. Class-Based Normalized Suitability Scores for Elevation for Different Vine rootstocks

Rootstock	SSF type	Most suitable - 1	Moderately suitable – 0.6	Unsuitable – 0.2
R x R 3309 C	Stepwise discrete (normalized)	≤ 1000 m	> 1000 – 1500 m	> 1500 m
B x R Rugeri 140	Stepwise discrete (normalized)	≤ 1000 m	> 1000 – 1500 m	> 1500 m
B x R 420A	Stepwise discrete (normalized)	≤ 1000 m	> 1000 – 1500 m	> 1500 m
B x R 1103 Paulsen	Stepwise discrete (normalized)	≤ 1000 m	> 1000 – 1500 m	> 1500 m
B x R Kober 5BB	Stepwise discrete (normalized)	≤ 1000 m	> 1000 – 1500 m	> 1500 m
B x R Teleki 5C	Stepwise discrete (normalized)	≤ 1000 m	> 1000 – 1500 m	> 1500 m

2.1.2. SLOPE

The grape production zones for Armenian brandy are characterized by pronounced variability in terrain slope, ranging from flat areas (0°) to very steep gradients exceeding 60°. The gentlest terrain is found in the Ararat Valley, where slopes up to 5° dominate, while the steepest conditions are recorded in Vayots Dzor, with maximum values reaching approximately 62.92°. The Tavush and Syunik zones are predominantly characterized by hilly to mountainous relief, with a significant share of slopes exceeding 12°.

Map 2.

Slope of the Grape
Production Zone of
Armenia

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO SLOPE

Slope was applied to define rootstock suitability using a class-based approach. All analyzed rootstocks show a uniform response, with the most suitable conditions on gentle slopes between 0° and 3°. Slopes above 3° are considered highly suitable, while those exceeding 5° fall into the moderately suitable category, reflecting gradually increasing terrain constraints.

Slopes above 8° are classified as less suitable, whereas slopes exceeding 12° are considered unsuitable due to limitations related to vineyard management, erosion risk, and reduced mechanization potential. The consistent classification across all rootstocks indicates that slope represents a limiting factor rather than a differentiating one within the study area (Table 2).

Table 2. Class-Based Normalized Suitability Scores for Slope for Different Vine Rootstocks

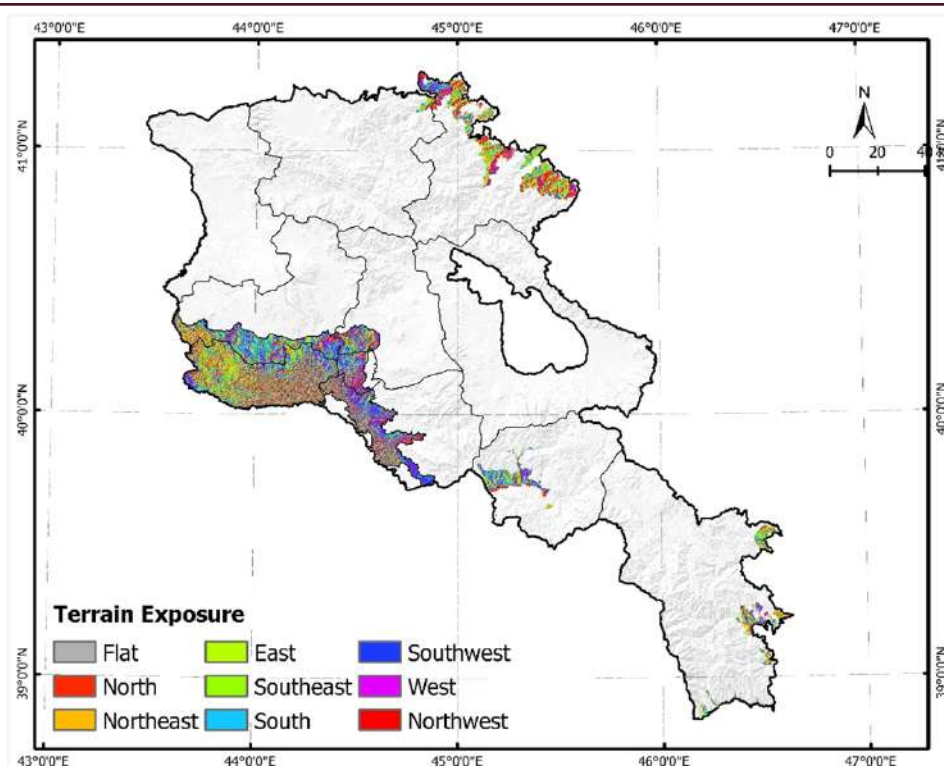
Rootstock	SSF type	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6	Less suitable – 0.4	Unsuitable – 0.2
R x R 3309 C	Stepwise discrete (normalized)	0-3	>3	>5	>8	>12
B x R Rugeri 140	Stepwise discrete (normalized)	0-3	>3	>5	>8	>12
B x R 420A	Stepwise discrete (normalized)	0-3	>3	>5	>8	>12
B x R 1103 Paulsen	Stepwise discrete (normalized)	0-3	>3	>5	>8	>12
B x R Kober 5BB	Stepwise discrete (normalized)	0-3	>3	>5	>8	>12
B x R Teleki 5C	Stepwise discrete (normalized)	0-3	>3	>5	>8	>12

2.1.3. TERRAIN EXPOSURE

The grape production zones for Armenian brandy are characterized by diverse terrain exposure, with all orientations represented. However, southern, southeastern, and southwestern exposures are generally the most dominant across all zones. The highest share of southern exposure is observed in Vayots Dzor (23.66%) and the Ararat Valley (20.99%), while southeastern exposure is particularly pronounced in Syunik (19.11%).

The Tavush zone exhibits a more balanced distribution of exposures, with slightly higher shares of southeastern (15.97%) and southern (14.21%) orientations. In contrast, Ararat Valley and Vayots Dzor show a clearer dominance of southern-oriented slopes, while Syunik is characterized by a relatively even distribution, with southeastern and southern exposures being the most represented.

This variability in terrain exposure contributes to differences in solar radiation, heat accumulation, and microclimatic conditions, thereby influencing grape ripening dynamics and overall viticultural potential (Map 3).



Terrain Exposure of the Grape Production Zone of Armenia.

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO TERRAIN EXPOSURE

Terrain exposure was applied to define rootstock suitability using a class-based approach. Unlike elevation and slope, the results indicate certain differences in suitability patterns among the analyzed rootstocks. Southeastern and southwestern exposures are generally identified as the most suitable, particularly for $R \times R$ 3309 C, $B \times R$ 420A, $B \times R$ Kober 5BB, and $B \times R$ Teleki 5C, as they provide favorable solar radiation and thermal conditions.

For some rootstocks, such as $B \times R$ Ruggeri 140 and $B \times R$ 1103 Paulsen, southern exposure represents the most suitable category, while southeastern and southwestern orientations are classified as highly suitable. East, west, and flat terrains are generally considered moderately to highly suitable, depending on the rootstock, indicating relatively balanced microclimatic conditions.

Northeastern and northwestern exposures are consistently classified as less suitable, while northern exposure is considered unsuitable for all analyzed rootstocks due to reduced solar radiation and lower heat accumulation. These results suggest that terrain exposure plays a more differentiated role in rootstock suitability compared to other topographic factors, primarily through its influence on microclimatic conditions.

Table 3. Class-Based Normalized Suitability Scores for Terrain Exposure for Different Vine rootstocks

Rootstock	SSF type	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6	Less suitable – 0.4	Unsuitable – 0.2
R x R 3309 C	Stepwise discrete (normalized)	Southeast and Southwest	East, West and Flat	South	Northeast and Northwest	North
B x R Rugeri 140	Stepwise discrete (normalized)	South	Southeast, Southwest and Flat	East and West	Northeast and Northwest	North
B x R 420A	Stepwise discrete (normalized)	Southeast and Southwest	South and Flat	East and West	Northeast and Northwest	North
B x R 1103 Paulsen	Stepwise discrete (normalized)	South	Southeast, Southwest and Flat	East and West	Northeast and Northwest	North
B x R Kober 5BB	Stepwise discrete (normalized)	Southeast and Southwest	South and Flat	East and West	Northeast and Northwest	North
B x R Teleki 5C	Stepwise discrete (normalized)	Southeast and Southwest	South and Flat	East and West	Northeast and Northwest	North

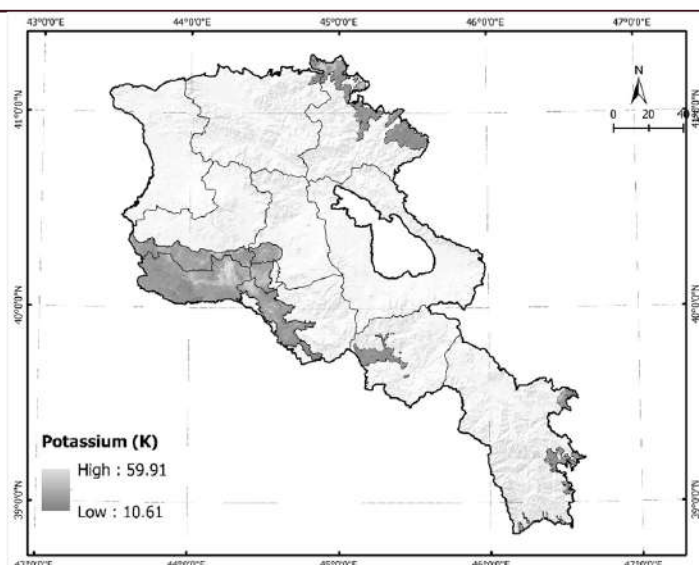
2.2. SOIL INDICATORS (TERROIR FACTORS) USED FOR VINE ROOTSTOCK ZONING IN THE GRAPE PRODUCTION ZONES OF ARMENIA

2.2.1. POTASSIUM CONTENT (K)

The grape production zones for Armenian brandy are characterized by variability in soil potassium content, ranging approximately from 10.61 to 59.91 mg/100 g. The highest variability is observed in the Ararat Valley, while other zones show more uniform distributions.

In most production zones, potassium levels are predominantly within the 20–30 mg/100 g range, particularly in Vayots Dzor, Tavush, and Syunik, where this class clearly dominates. In the Ararat Valley, the prevailing range is slightly broader, with most soil falling between 20 and 40 mg/100 g. Areas with low potassium content (≤ 20 mg/100 g) are limited across all zones, while higher values (>40 mg/100 g) occur only locally.

This distribution indicates generally adequate to favorable potassium availability for grapevine growth, supporting processes such as water regulation, stress resistance, and sugar accumulation, although localized variability may require site-specific soil management (Map 4).

Map 4.

Potassium Content (K) of the Grape Production Zone of Armenia

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO POTASSIUM CONTENT (K)

Potassium content was used to define rootstock suitability using a midpoint optimal approach. The results indicate similar response patterns among the analyzed rootstocks, with optimal potassium ranges generally defined between 25 and 40 mg/100 g. For most rootstocks (R × R 3309 C, B × R 420A, B × R Kober 5BB, and B × R Teleki 5C), suitability increases with increasing potassium content above 25 mg/100 g, while values approaching 40 mg/100 g remain within the optimal range.

For B × R Ruggeri 140, a slightly higher threshold is defined, with optimal values above 30 mg/100 g, whereas B × R 1103 Paulsen shows a broader tolerance, with suitability increasing above 20 mg/100 g. In all cases, potassium levels exceeding the upper threshold (40 mg/100 g) are associated with decreasing suitability, indicating potential nutrient imbalance or reduced efficiency.

Overall, the results suggest that moderate to moderately high potassium levels provide the most favorable conditions for rootstock performance, while both low and excessive concentrations may limit suitability.

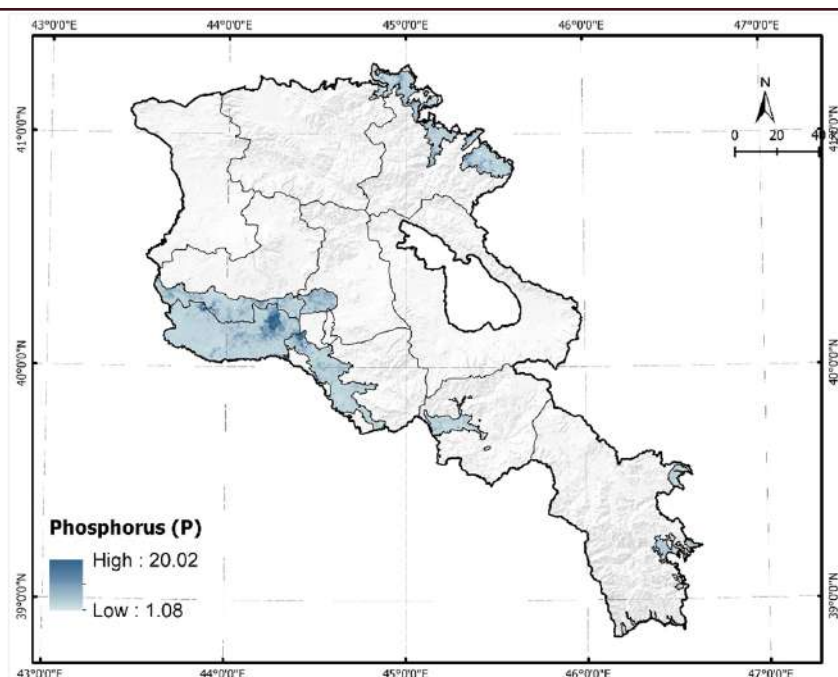
Table 4. Potasium Content (K) Based Scoring Rules for Different Vine rootstocks

Rootstock	SSF type	Definition / Rule
R x R 3309 C	Optimum	Optimal value: >25 – 40; ≤40: less is better; >25: more is better
B x R Rugeri 140	Optimum	Optimal value: >30 – 40; ≤40: less is better; >30: more is better
B x R 420A	Optimum	Optimal value: >25 – 40; ≤40: less is better; >25: more is better
B x R 1103 Paulsen	Optimum	Optimal value: >20 – 40; ≤40: less is better; >20: more is better
B x R Kober 5BB	Optimum	Optimal value: >25 – 40; ≤40: less is better; >25: more is better
B x R Teleki 5C	Optimum	Optimal value: >25 – 40; ≤40: less is better; >25: more is better

2.2.2. PHOSPHORUS CONTENT (P)

The grape production zones for Armenian brandy are characterized by generally low to moderate phosphorus content, ranging approximately from 1.08 to 20.02 mg/100 g. The lowest values are observed in the Ararat Valley and Syunik zones, where most soils fall into low phosphorus classes, while slightly higher and more uniform levels are present in Vayots Dzor and Tavush.

Across all zones, the dominant phosphorus classes are typically below 5 mg/100 g, indicating limited natural availability of this nutrient. Only small and localized areas exhibit higher phosphorus content above 5 mg/100 g. This distribution suggests that phosphorus availability is generally a limiting factor for grapevine growth, given its essential role in root development, energy transfer, and grape ripening. As a result, soil management practices, particularly targeted fertilization, may be required to ensure optimal vine performance and grape quality (Map 5).



Phosphorus Content
(K) of the Grape
Production Zone of
Armenia

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO PHOSPHORUS CONTENT (P)

Phosphorus content was used to define rootstock suitability using a midpoint optimal approach. The results indicate relatively consistent response patterns among the analyzed rootstocks, with optimal phosphorus values generally defined within the range of 15 to 25 mg/100 g. For most rootstocks (R × R 3309 C, B × R Rugeri 140, and B × R 420A), suitability increases with increasing phosphorus content above 15 mg/100 g, while values approaching 25 mg/100 g remain within the optimal range.

Slight variations are observed among specific rootstocks, with B × R 1103 Paulsen showing optimal suitability above 20 mg/100 g, and B × R Kober 5BB and B × R Teleki 5C above 18 mg/100 g. In all cases, phosphorus levels exceeding 25 mg/100 g are associated with decreasing suitability.

Overall, the results indicate that moderate phosphorus availability provides the most favorable conditions for rootstock performance, while both low and excessive levels may limit vine development and productivity.

Table 5. Phosphorus (P) Based Scoring Rules for Different Vine rootstocks

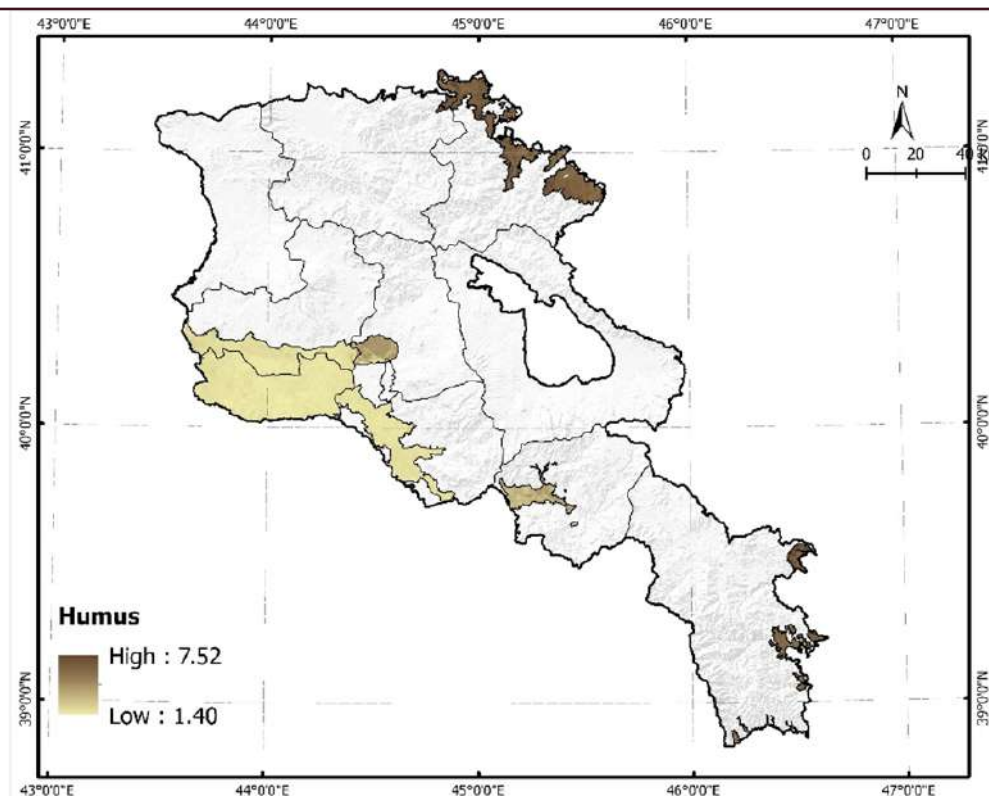
Rootstock	SSF type	Definition / Rule
R x R 3309 C	Optimum	Optimal value: >15 – 25; ≤25: less is better; >15: more is better
B x R Rugeri 140	Optimum	Optimal value: >15 – 25; ≤25: less is better; >15: more is better
B x R 420A	Optimum	Optimal value: >15 – 25; ≤25: less is better; >15: more is better
B x R 1103 Paulsen	Optimum	Optimal value: >20 – 25; ≤25: less is better; >20: more is better
B x R Kober 5BB	Optimum	Optimal value: >18 – 25; ≤25: less is better; >18: more is better
B x R Teleki 5C	Optimum	Optimal value: >18 – 25; ≤25: less is better; >18: more is better

2.2.3. HUMUS CONTENT

The grape production zones for Armenian brandy are characterized by variability in humus content, ranging approximately from 1.4% to over 7.5%. The lowest values are observed in the Ararat Valley, where soils are predominantly poor in organic matter, while higher humus levels are typical for Tavush and Syunik, where values frequently exceed 5%. Vayots Dzor shows intermediate conditions, with most soils ranging between 2% and 5%. Across the zones, Ararat Valley is dominated by low humus content (1–2%), whereas Tavush and Syunik are characterized by a predominance of higher organic matter levels. Vayots Dzor exhibits a balanced distribution, with moderate to relatively high humus content.

This variability reflects differences in soil fertility and structure, as humus plays a key role in nutrient availability, water retention, and soil stability. While higher humus content generally supports improved soil conditions, very high levels may also promote excessive vegetative growth, requiring appropriate vineyard management (Map 6).

Map 6.



Humus Content of
the Grape Production
Zone of Armenia

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO HUMUS CONTENT

The results indicate both common patterns and certain differences among the analyzed rootstocks. For most rootstocks (R × R 3309 C, B × R 1103 Paulsen, B × R Kober 5BB, and B × R Teleki 5C), the most suitable humus range is between 2% and 3%, while slightly higher values (3–5%) are considered highly suitable. Moderate suitability is associated with lower humus levels (1–2%), whereas both very low ($\leq 0.5\%$) and excessively high ($> 5\%$) humus contents are classified as less suitable or unsuitable.

Some variation is observed for specific rootstocks. B × R Ruggeri 140 shows optimal suitability at slightly lower humus levels (1–2%), with both lower and higher values reducing suitability. In contrast, B × R 420A exhibits the highest suitability at higher humus content (3–5%), indicating a preference for more fertile soils.

Overall, the results suggest that moderate humus content provides the most favorable conditions for rootstock performance, while both deficient and excessive organic matter levels may limit vine growth and balance (Table 6).

Table 6. Class-Based Normalized Suitability Scores for Humus Content for Different Vine rootstocks

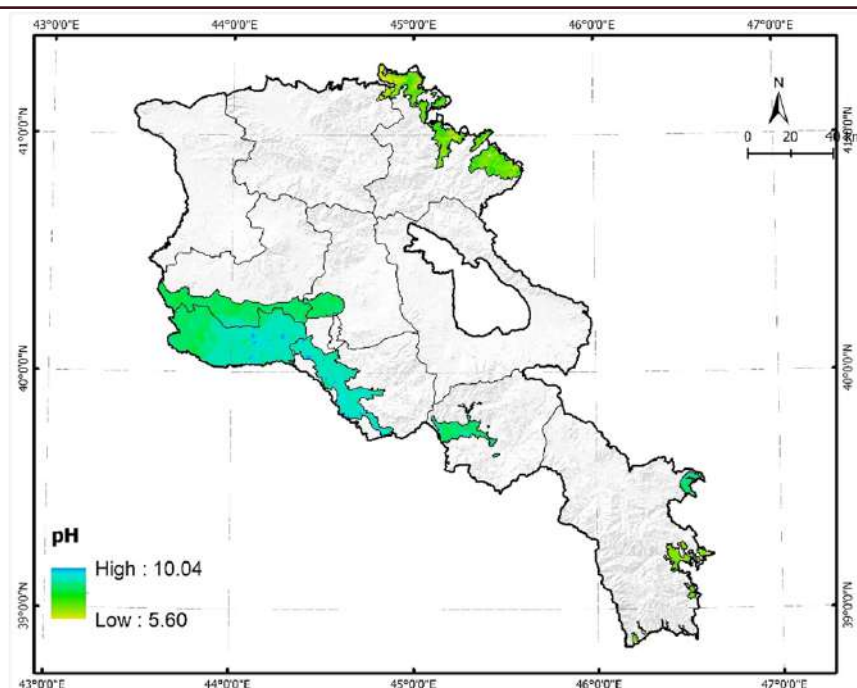
Rootstock	SSF type	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6	Less suitable – 0.4	Unsuitable – 0.2
R x R 3309 C	Stepwise discrete (normalized)	> 2 - 3	> 3 - 5	> 1 - 2	> 5 i > 0.5-1	≤ 0.5
B x R Rugeri 140	Stepwise discrete (normalized)	> 1 - 2	> 2 - 3 i > 0.5 - 1	> 3 - 5	≤ 0.5	> 5
B x R 420A	Stepwise discrete (normalized)	> 3 - 5	> 2 - 3	> 1 - 2	> 5 i > 0.5-1	≤ 0.5
B x R 1103 Paulsen	Stepwise discrete (normalized)	> 2 - 3	> 3 - 5	> 1 - 2	> 5 i > 0.5-1	≤ 0.5
B x R Kober 5BB	Stepwise discrete (normalized)	> 2 - 3	> 3 - 5	> 1 - 2	> 5 i > 0.5-1	≤ 0.5
B x R Teleki 5C	Stepwise discrete (normalized)	> 2 - 3	> 3 - 5	> 1 - 2	> 5 i > 0.5-1	≤ 0.5

2.2.4. PH

The grape production zones for Armenian brandy are characterized by a wide range of soil pH conditions, approximately from 5.6 to over 10.0. The most alkaline conditions are observed in the Ararat Valley, while Tavush exhibits slightly acidic to neutral soils, and Vayots Dzor and Syunik are predominantly neutral to moderately alkaline.

Across all zones, the dominant pH range generally falls between 5.5 and 8.2, which is considered suitable for grapevine cultivation. Areas with higher alkalinity (above 8.2) are present, particularly in the Ararat Valley and partially in other zones, while strongly alkaline soil (>9) are limited.

This variability in soil reaction influences nutrient availability and vine performance, as slightly acidic to neutral conditions are generally optimal, whereas higher pH values may reduce the availability of certain nutrients and require appropriate soil management (Map 7).



pH of the Grape
Production Zone of
Armenia

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO PH

Soil pH was used to define rootstock suitability using a midpoint optimal approach. The results indicate similar response patterns among the analyzed rootstocks, with optimal pH values generally ranging between 6.5 and 7.2, corresponding to neutral to slightly acidic conditions. Suitability increases as pH values approach this optimal range from lower levels, while values above the upper threshold lead to decreasing suitability.

Slight differences are observed for specific rootstocks. R × R 3309 C shows optimal suitability at a slightly lower range (6.0–7.0), while most other rootstocks (B × R Ruggeri 140, B × R 420A, B × R 1103 Paulsen, B × R Kober 5BB, and B × R Teleki 5C) are best adapted to the 6.5–7.2 range.

Extremely acidic and strongly alkaline soils are excluded for all rootstocks, with lower limits generally around pH 4.5–5.5 and upper limits between 8.0 and 9.0, depending on the rootstock. Overall, the results indicate that neutral to slightly acidic soil conditions provide the most favorable environment, while deviations toward extreme pH values significantly reduce suitability (Table 7).

Table 7. pH Based Scoring Rules for Different Vine rootstocks

Rootstock	SSF type	Definition / Rule	Excluded
R x R 3309 C	Optimum	Optimal value: >6.0 – 7.0; ≤6.0: more is better; >7.0: less is better	< 4.5 and > 8.0
B x R Rugeri 140	Optimum	Optimal value: >6.5 – 7.2; ≤6.5: more is better; >7.2: less is better	< 4.5 and > 9.0
B x R 420A	Optimum	Optimal value: >6.5 – 7.2; ≤6.5: more is better; >7.2: less is better	< 5.5 and > 9.0
B x R 1103 Paulsen	Optimum	Optimal value: >6.5 – 7.2; ≤6.5: more is better; >7.2: less is better	< 4.5 and > 9.0
B x R Kober 5BB	Optimum	Optimal value: >6.5 – 7.2; ≤6.5: more is better; >7.2: less is better	< 4.5 and > 9.0
B x R Teleki 5C	Optimum	Optimal value: >6.5 – 7.2; ≤6.5: more is better; >7.2: less is better	< 4.5 and > 8.2

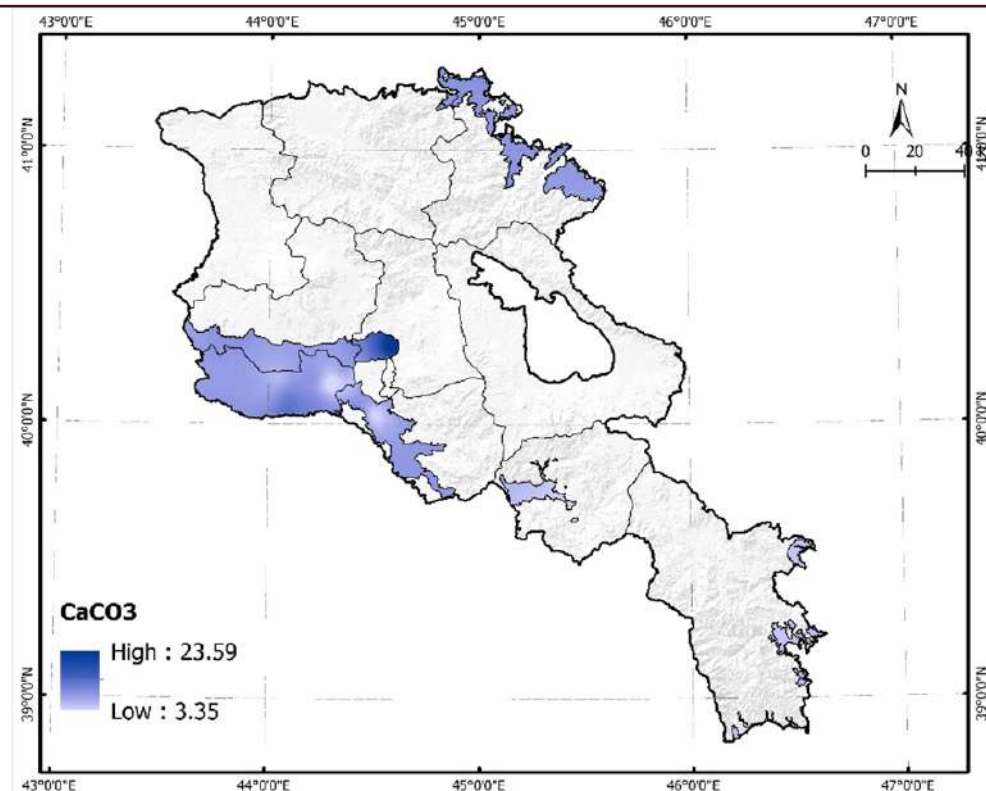
2.2.5. CALCIUM CARBONATE CONTENT (CaCO₃)

The grape production zones for Armenian brandy are characterized by moderate to high variability in calcium carbonate (CaCO₃) content, ranging approximately from 3.3% to 23.6%. Higher CaCO₃ concentrations are predominantly observed in the central and western parts of the production areas, while lower values occur in more localized zones.

The spatial distribution indicates that most vineyard areas are characterized by moderate to elevated carbonate content, which is typical for semi-arid viticultural environments. Such conditions can influence soil structure, water retention, and nutrient availability, particularly affecting the availability of micronutrients such as iron.

Overall, the observed CaCO₃ levels suggest generally suitable conditions for grapevine cultivation, although higher carbonate concentrations may require careful rootstock selection and soil management to prevent potential nutrient imbalances (Map 8).

Map 8.



Calcium Carbonat
Content (CaCO₃) of
the Grape Production
Zone of Armenia

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO CALCIUM CARBONATE CONTENT

Calcium carbonate content was used to define rootstock suitability using a class-based approach. The results indicate both common patterns and distinct differences among the analyzed rootstocks. For most rootstocks (B × R 420A, B × R 1103 Paulsen, B × R Kober 5BB, and B × R Teleki 5C), the most suitable CaCO₃ range is between

5% and 10%, while slightly lower (2–5%) and moderately higher values (10–15%) are considered highly suitable. Moderate suitability is associated with very low carbonate content ($\leq 2\%$), whereas higher levels (15–30%) are classified as less suitable, and values above 30% as unsuitable.

A different pattern is observed for R × R 3309 C, which shows optimal suitability at lower CaCO₃ levels (2–5%), indicating greater preference for less calcareous soils. In contrast, B × R Ruggeri 140 demonstrates the highest suitability at higher carbonate levels (10–15%), reflecting greater tolerance to calcareous conditions.

Overall, the results suggest that moderate CaCO₃ content provides the most favorable conditions for most rootstocks, while both very low and especially high carbonate levels may limit suitability depending on rootstock tolerance (Table 9).

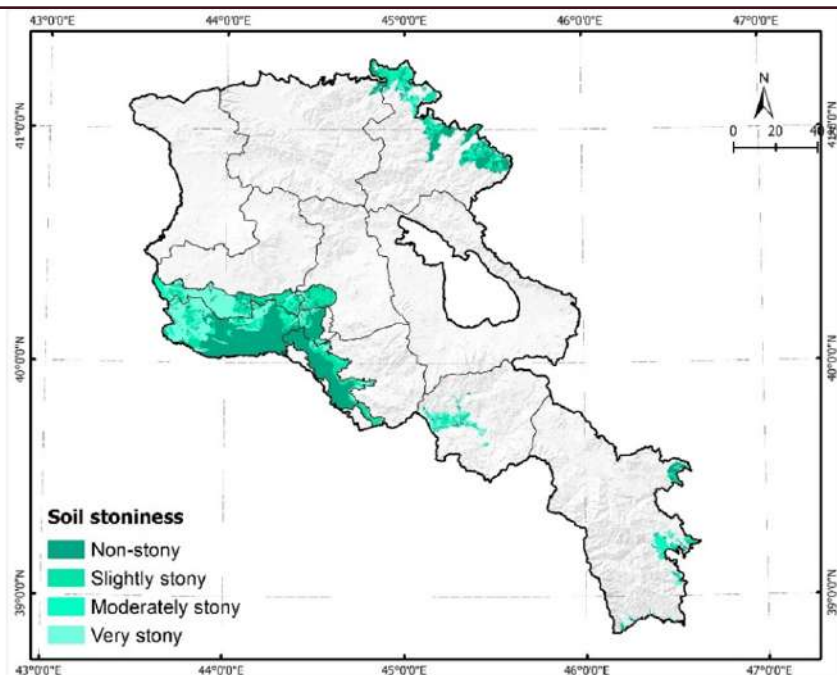
Table 8. Class-Based Normalized Suitability Scores for CaCO₃ Content for Different Vine rootstocks

Rootstock	SSF type	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6	Less suitable – 0.4	Unsuitable – 0.2
R × R 3309 C	Stepwise discrete (normalized)	> 2 - 5	≥ 0 - 2 and >5 – 10	> 10 - 15	> 15 - 30	> 30
B × R Rugeri 140	Stepwise discrete (normalized)	> 10 - 15	> 5 – 10	> 2 - 5	≥ 0 - 2 and > 15 - 30	> 30
B × R 420A	Stepwise discrete (normalized)	>5 - 10	> 2 - 5 and >10 – 15	≥ 0 - 2	> 15 - 30	> 30
B × R 1103 Paulsen	Stepwise discrete (normalized)	>5 - 10	> 2 - 5 and >10 – 15	≥ 0 - 2	> 15 - 30	> 30
B × R Kober 5BB	Stepwise discrete (normalized)	>5 - 10	> 2 - 5 and >10 - 15	≥ 0 - 2	> 15 - 30	> 30
B × R Teleki 5C	Stepwise discrete (normalized)	>5 - 10	> 2 - 5 and >10 - 15	≥ 0 - 2	> 15 - 30	> 30

2.2.6. SOIL STONINESS

The grape production zones for Armenian brandy are characterized by notable variability in soil stoniness. Non-stony soils dominate the study area, covering 44.09% of the total surface, indicating generally favorable conditions for vineyard establishment and mechanized cultivation.

Very stony soils represent a significant proportion of 26.09%, reflecting the presence of shallow, coarse-textured soils, particularly in more rugged and mountainous areas. Slightly stony soils account for 17.57% of the area, while moderately stony soils cover 12.25% (Map 9).

Soil Stoniness of the
Grape Production
Zone of Armenia

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO SOIL STONINESS

Soil stoniness was used to define rootstock suitability using a class-based approach. The results indicate clear differences in response among the rootstocks analyzed. Nonstony and slightly stony soils are generally highly suitable for most rootstocks, particularly for R × R 3309 C and B × R 420A.

Rootstocks such as B × R Ruggeri 140 and B × R 1103 Paulsen demonstrate higher suitability in moderately to very stony soils, where they reach the highest suitability class. In contrast, their suitability decreases in non-stony conditions.

B × R Kober 5BB shows the highest suitability in non-stony and slightly stony soils, while maintaining good performance in moderately stony conditions and reduced suitability in very stony soils (Table 9).

Table 9. Class-Based Normalized Suitability Scores for Soil stoniness for Different Vine rootstocks

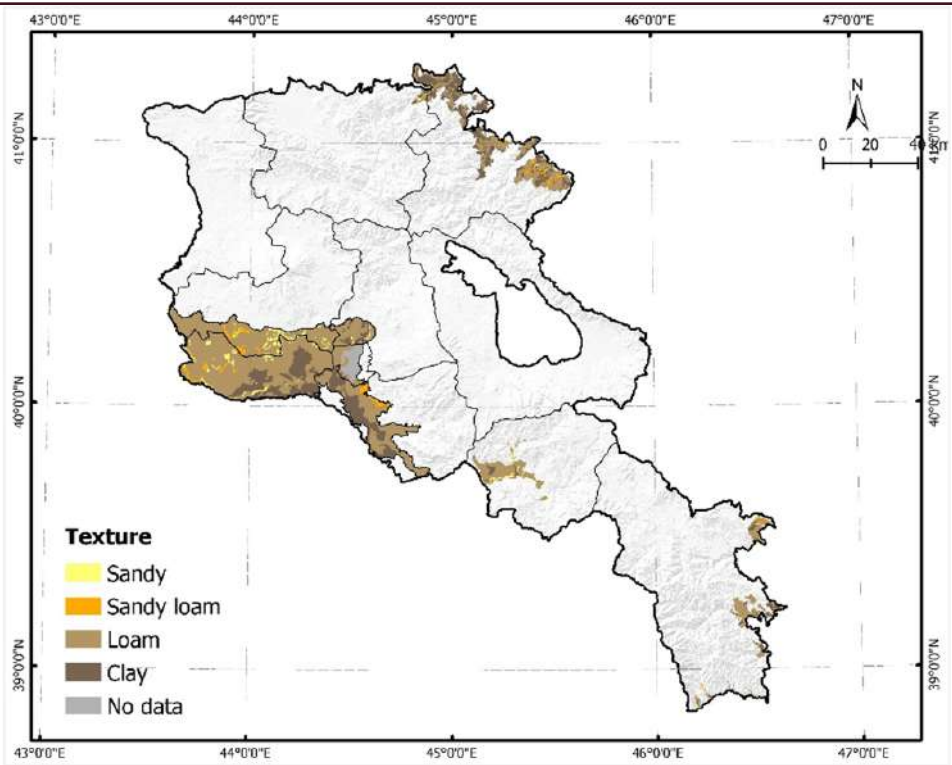
Rootstock	SSF type	Non-stony	Slightly stony	Moderately stony	Very stony
R x R 3309 C	Stepwise discrete (normalized)	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8	Moderately suitable – 0.6
B x R Rugeri 140	Stepwise discrete (normalized)	Less suitable – 0.4	Highly suitable – 0.8	Most suitable - 1	Most suitable - 1
B x R 420A	Stepwise discrete (normalized)	Highly suitable – 0.8	Highly suitable – 0.8	Moderately suitable – 0.6	Less suitable – 0.4
B x R 1103 Paulsen	Stepwise discrete (normalized)	Moderately suitable – 0.6	Highly suitable – 0.8	Most suitable - 1	Most suitable - 1
B x R Kober 5BB	Stepwise discrete (normalized)	Most suitable - 1	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6
B x R Teleki 5C	Stepwise discrete (normalized)	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6	Less suitable – 0.4

2.2.7. SOIL TEXTURE

The grape production zones for Armenian brandy are predominantly characterized by loam soils, which cover 69.90% of the total area. These soils represent the dominant textural class and provide balanced physical properties, including favorable water retention, aeration, and nutrient availability.

Clay soils account for 23.62% of the area and are mainly distributed in specific zones, contributing to higher water-holding capacity but potentially limiting drainage and aeration. Sandy and sandy loam soil are significantly less represented, covering 3.40% and 3.09% of the area, respectively, and occur only in localized patches (Map 10).

Map 10.



Soil Texture of the Grape Production Zone of Armenia

SUITABILITY SCORING VINE ROOTSTOCKS ACCORDING TO SOIL TEXTURE

Soil texture was used to define rootstock suitability using a class-based approach. The results indicate that loam soil represents the most suitable conditions for most rootstocks, including R × R 3309 C, B × R 420A, B × R Kober 5BB, and B × R Teleki 5C.

Rootstocks such as B × R Ruggeri 140 and B × R 1103 Paulsen show the highest suitability in very gravelly/sandy and sandy loam soils, indicating better adaptation to lighter, well-drained textures. In contrast, clay soil is generally less suitable for most rootstocks, although B × R Kober 5BB shows high tolerance and optimal performance in such conditions (Table 10).

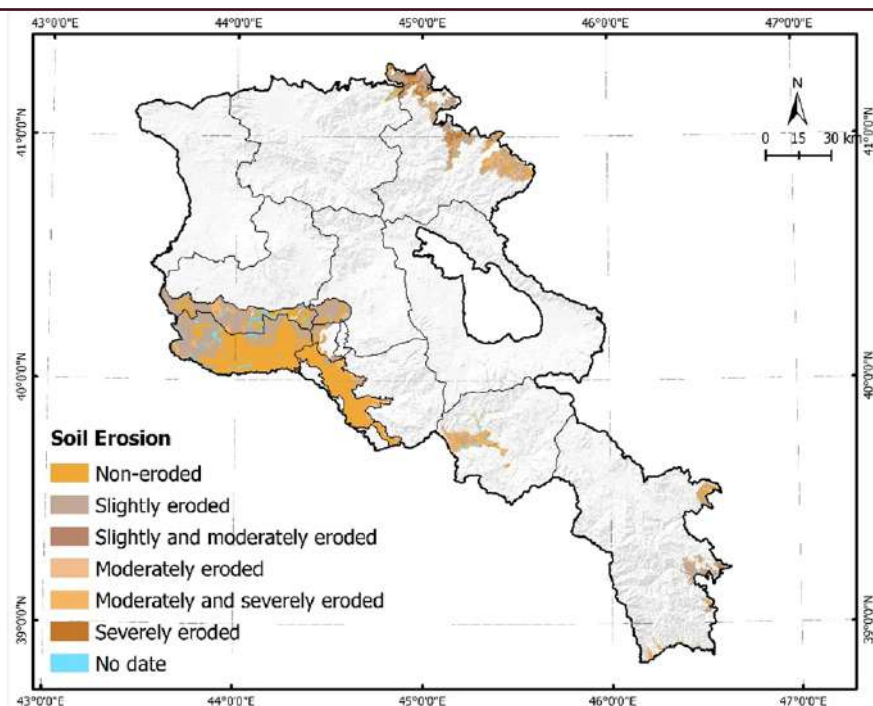
Table 10. Class-Based Normalized Suitability Scores for Soil Texture for Different Vine rootstocks

Rootstock	SSF type	Very gravelly / sand	Clay	Loam	Sandy loam
R x R 3309 C	Stepwise discrete (normalized)	Unsuitable – 0.2	Moderately suitable – 0.6	Most suitable - 1	Less suitable – 0.4
B x R Rugeri 140	Stepwise discrete (normalized)	Most suitable - 1	Less suitable – 0.4	Highly suitable – 0.8	Most suitable - 1
B x R 420A	Stepwise discrete (normalized)	Unsuitable – 0.2	Highly suitable – 0.8	Most suitable - 1	Less suitable – 0.4
B x R 1103 Paulsen	Stepwise discrete (normalized)	Most suitable - 1	Less suitable – 0.4	Highly suitable – 0.8	Most suitable - 1
B x R Kober 5BB	Stepwise discrete (normalized)	Less suitable – 0.4	Most suitable - 1	Most suitable - 1	Less suitable – 0.4
B x R Teleki 5C	Stepwise discrete (normalized)	Less suitable – 0.4	Highly suitable – 0.8	Most suitable - 1	Less suitable – 0.4

2.2.8. SOIL EROSION

The grape production zones for Armenian brandy are characterized by varying degrees of soil erosion, with non-eroded soils covering the largest share of 44.55% of the total area. Slightly eroded soil also represents a significant proportion (41.14%), indicating that most of the vineyards are located under relatively stable soil conditions.

Moderately eroded soils account for 3.70%, while areas affected by both moderate and severe erosion cover 7.60% of the area. Severely eroded soils are limited, representing only 2.91%, and transitional classes such as slightly to moderately eroded soils are negligible (0.09%) (Map 11).

Map 11.

Soil Erosion of the
Grape Production
Zone of Armenia

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO SOIL EROSION

Soil erosion was evaluated using a class-based suitability approach, distinguishing between non-eroded, slightly eroded, slightly to moderately eroded, moderately eroded, and moderately to severely eroded soils. The results indicate distinct differences in rootstock responses to varying erosion intensity.

Most rootstocks, including R × R 3309 C, B × R 420A, B × R Kober 5BB, and B × R Teleki 5C, show the highest suitability in non-eroded soils, with suitability gradually decreasing as erosion intensity increases. These rootstocks are therefore more sensitive to soil degradation and perform best under stable soil conditions.

In contrast, B × R Ruggeri 140 and B × R 1103 Paulsen demonstrate the highest suitability in moderately to severely eroded soils, indicating greater tolerance to degraded and structurally altered soil environments. Slightly eroded soils are generally classified as highly suitable across all rootstocks, representing transitional conditions with limited constraints.

Overall, the results suggest that soil erosion has a differentiated impact on rootstock performance, with certain rootstocks showing resilience to erosion-affected conditions, while others require more stable, non-degraded soils for optimal performance.

Table 11. Class-Based Normalized Suitability Scores for Soil Erosion for Different Vine rootstocks

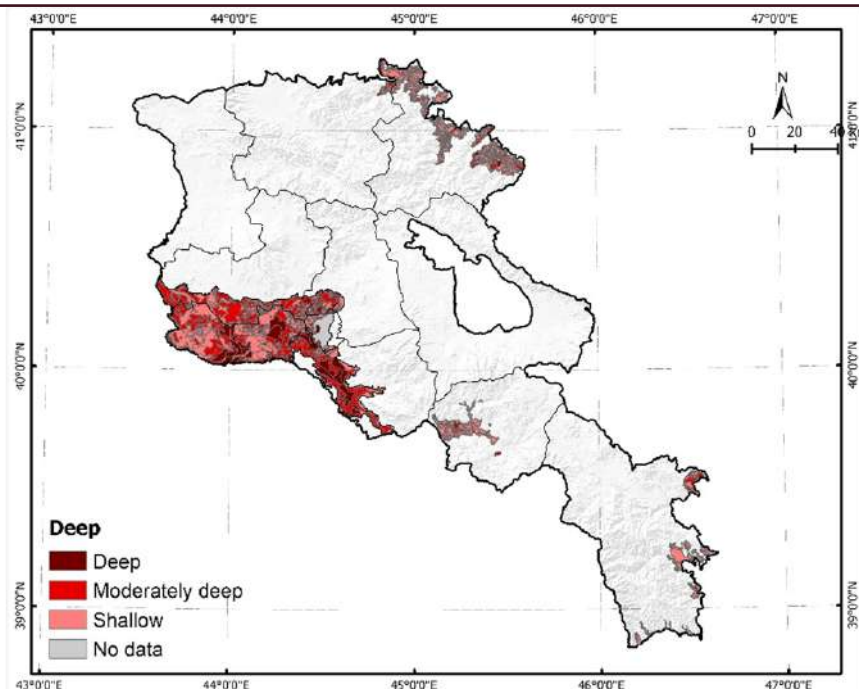
Rootstock	SSF type	Non-eroded	Slightly eroded	Slightly & moderately eroded	Moderately eroded	Moderately & severely eroded
R x R 3309 C	Stepwise discrete (normalized)	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6	Less suitable – 0.4	Unsuitable – 0.2
B x R Rugeri 140	Stepwise discrete (normalized)	Moderately suitable – 0.6	Highly suitable – 0.8	Most suitable - 1	Most suitable - 1	Most suitable - 1
B x R 420A	Stepwise discrete (normalized)	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6	Less suitable – 0.4	Unsuitable – 0.2
B x R 1103 Paulsen	Stepwise discrete (normalized)	Moderately suitable – 0.6	Highly suitable – 0.8	Most suitable - 1	Most suitable - 1	Most suitable - 1
B x R Kober 5BB	Stepwise discrete (normalized)	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6	Less suitable – 0.4	Unsuitable – 0.2
B x R Teleki 5C	Stepwise discrete (normalized)	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6	Less suitable – 0.4	Unsuitable – 0.2

2.2.9. SOIL DEPTH

The grape production zones for Armenian brandy are characterized by considerable variability in soil depth. Shallow soils dominate the study area, covering 50.15% of the total surface, indicating that a significant proportion of vineyards are established under conditions of limited soil volume and reduced water storage capacity.

Moderately deep soils account for 34.63% of the area and represent intermediate conditions, providing a balance between root penetration, water availability, and nutrient storage. Deep soils are less represented, covering 15.23% of the total area, and are mainly found in localized zones where more favorable conditions for root development and water retention are present (Map 12).

Map 12.



Soil Depth of the
Grape Production
Zone of Armenia

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO SOIL DEPTH

Soil depth was evaluated using a class-based suitability approach, distinguishing between deep, moderately deep, and shallow soils. The results indicate clear differences in rootstock responses depending on soil depth conditions.

Most rootstocks, including R × R 3309 C, B × R 420A, B × R Kober 5BB, and B × R Teleki 5C, show the highest suitability in deep soils, with suitability gradually decreasing toward moderately deep and shallow conditions. In contrast, B × R Ruggeri 140 and B × R 1103 Paulsen demonstrate the highest suitability in shallow soils, indicating better adaptation to limited soil depth and potentially constrained rooting conditions.

Moderately deep soils are consistently classified as highly suitable across all rootstocks, representing balanced conditions for root development and water availability. Overall, the results suggest that soil depth plays a differentiated role in rootstock performance, with some rootstocks better adapted to shallow soils, while others perform optimally under deeper soil conditions.

Table 12. Class-Based Normalized Suitability Scores for Soil Depth for Different Vine rootstocks

Rootstock	SSF type	Deep	Moderately deep	Shallow
R x R 3309 C	Stepwise discrete (normalized)	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6
B x R Rugeri 140	Stepwise discrete (normalized)	Moderately suitable – 0.6	Highly suitable – 0.8	Most suitable - 1
B x R 420A	Stepwise discrete (normalized)	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6
B x R 1103 Paulsen	Stepwise discrete (normalized)	Moderately suitable – 0.6	Highly suitable – 0.8	Most suitable - 1
B x R Kober 5BB	Stepwise discrete (normalized)	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6
B x R Teleki 5C	Stepwise discrete (normalized)	Most suitable - 1	Highly suitable – 0.8	Moderately suitable – 0.6

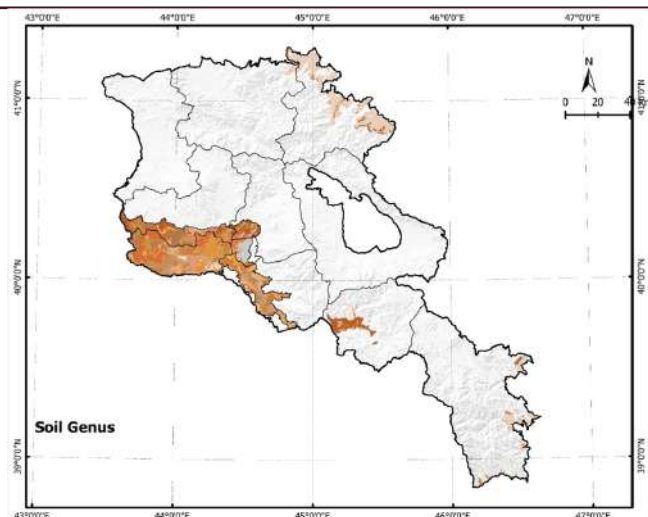
2.2.10. SOIL GENUS

The grape production zones for Armenian brandy are characterized by a high diversity of soil types (genus), reflecting complex soil-forming processes and heterogeneous environmental conditions across the study area. Among the identified soil groups, the most dominant category is “transformed to steppe”, covering 20.22% of the total area, followed by various rubble-stony soil types, including “rubble-stony at places calcic-cemented and undeveloped” (12.19%) and “rubble-stony” (10.92%). These soil types indicate widespread occurrence of shallow, skeletal, and structurally heterogeneous soils.

Additional soil groups such as “rubble-stony transformed” (6.53%), “rubble-stony at places calcic-cemented deep-gypsic” (6.95%), and “deep profile” soils (5.35%) contribute to the overall variability of soil conditions. Alluvial soils (4.13%) and pebble-related soils (3.21–4.71%) are also present, mainly in localized areas, indicating zones with different depositional and hydrological characteristics.

Less represented soil types include calcic, non-calcic, sodic, and various solonetz–solonchak combinations, each contributing to the overall mosaic of soil conditions but covering relatively small proportions individually.

Overall, the spatial distribution of soil genus highlights the complexity of soil environments within Armenian grape production zones, where a mixture of developed, transformed, and skeletal soils creates highly variable conditions for vine growth. This heterogeneity plays an important role in rootstock selection, as different soil types impose distinct constraints related to water availability, rooting depth, salinity, and soil structure (Map 13).



Soil Genus of the
Grape Production
Zone of Armenia

Legend 1. Soil Genus Map Legend

Genus	
Alluvial	Pebble
Clay-malm	Pebble transformed
Deep profile	Residual calcic
Deep-calcic	Residual calcic transformed
Deep-fused	Residual saturated lithogenic-clastic
Deep-fused, in places solonetz-solonchak	Rubble-stony
Deep-solonchak sodic-chloride	Rubble-stony at places calcic-cemented and undeveloped
Deep-solonetz-solonchak	Rubble-stony at places calcic-cemented deep-gypsic
Deep-solonetz-solonchak sodic	Rubble-stony transformed
Deep-solonetz-solonchak sodic-chloride	Rubble-stony weakly-differentiated
In places deep-solonetz-solonchak	Sodic-chloride
Low calcic	Sodic-sulphate-chloride
Marl sodic-chloride	Transformed to clay
Mealy-calcic	Transformed to gleyic
Non-calcic	Transformed to meadow
Non-calcic moderately humic	Transformed to steppe
Non-developed	Weakly-differentiated
Paleohydromorphic	No data

SUITABILITY SCORING OF VINE ROOTSTOCKS ACCORDING TO SOIL GENUS

Soil genus was evaluated using a class-based suitability approach, revealing pronounced differences in rootstock responses depending on soil type.

Alluvial, deep profile, and non-calcic soils are generally classified as most suitable for most rootstocks, indicating favorable conditions for vine development. Similarly, soils such as “transformed to meadow” and “low calcic” also show high suitability across several rootstocks.

In contrast, saline and sodic soil types (e.g., solonetz–solonchak and sodic-chloride groups) are consistently classified as unsuitable, reflecting strong limitations related to salinity and soil structure.

Rootstocks such as B × R Ruggeri 140 and B × R 1103 Paulsen show higher suitability in skeletal and stony soils (e.g., pebble and rubble-stony types), while other rootstocks generally perform better in more developed and deeper soil types.

Overall, the results highlight that soil genus exerts a strong influence on rootstock suitability, with significant variability depending on soil formation processes, structure, and chemical characteristics.

Table 13. Class-Based Normalized Suitability Scores for Soil Genus for Different Vine rootstocks

Genus	R x R 3309 C	B x R Rugeri 140	B x R 420A	B x R 1103 Paulsen	B x R Kober 5BB	B x R Teleki 5C
Alluvial	Most suitable - 1	Moderately suitable – 0.6	Most suitable - 1	Moderately suitable – 0.6	Most suitable - 1	Most suitable - 1
Clay-malm	Moderately suitable – 0.6	Less suitable – 0.4	Highly suitable – 0.8	Less suitable – 0.4	Highly suitable – 0.8	Highly suitable – 0.8
Deep profile	Most suitable - 1	Moderately suitable – 0.6	Most suitable - 1	Moderately suitable – 0.6	Most suitable - 1	Most suitable - 1
Deep-calcic	Moderately suitable – 0.6	Most suitable - 1	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8
Deep-fused	Highly suitable – 0.8	Moderately suitable – 0.6	Highly suitable – 0.8	Moderately suitable – 0.6	Highly suitable – 0.8	Highly suitable – 0.8
Deep-fused, in places solonetz-solonchak	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Unsuitable – 0.2
Deep-solonchak sodic-chloride	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Unsuitable – 0.2
Deep-solonetz-solonchak	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Unsuitable – 0.2
Deep-solonetz-solonchak sodic	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Unsuitable – 0.2
Deep-solonetz-solonchak sodic-chloride	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Unsuitable – 0.2
In places deep-solonetz-solonchak	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Unsuitable – 0.2
Low calcic	Highly suitable – 0.8	Most suitable - 1	Most suitable - 1	Highly suitable – 0.8	Most suitable - 1	Most suitable - 1
Marl sodic chloride	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Unsuitable – 0.2
Mealy-calcic	Moderately suitable – 0.6	Most suitable - 1	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8
Non-calcic	Most suitable - 1	Moderately suitable – 0.6	Most suitable - 1	Moderately suitable – 0.6	Most suitable - 1	Most suitable - 1
Non-calcic moderately humic	Most suitable - 1	Moderately suitable – 0.6	Most suitable - 1	Moderately suitable – 0.6	Most suitable - 1	Most suitable - 1
Non-developed	Moderately suitable – 0.6	Highly suitable – 0.8	Moderately suitable – 0.6	Highly suitable – 0.8	Moderately suitable – 0.6	Moderately suitable – 0.6
Paleohydromorphic	Highly suitable – 0.8	Less suitable – 0.4	Moderately suitable – 0.6	Less suitable – 0.4	Highly suitable – 0.8	Moderately suitable – 0.6
Pebble	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Less suitable – 0.4
Pebble transformed	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Less suitable – 0.4
Residual calcic	Moderately suitable – 0.6	Most suitable - 1	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8
Residual calcic tranformed	Moderately suitable – 0.6	Most suitable - 1	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8
Residual saturated lythogenic-clastic	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Less suitable – 0.4
Rubble-stony	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Less suitable – 0.4
Rubble-stony at places calcic-cemented and undeveloped	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Highly suitable – 0.8	Less suitable – 0.4	Less suitable – 0.4
Rubble-stony at places calcic-cemented deep-gypsic	Unsuitable – 0.2	Highly suitable – 0.8	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Unsuitable – 0.2
Rubble-stony transformed	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Less suitable – 0.4
Rubble-stony weakly-differentiated	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Most suitable - 1	Less suitable – 0.4	Less suitable – 0.4
Sodic chloride	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Unsuitable – 0.2
Sodic-sulphate-chloride	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Less suitable – 0.4	Unsuitable – 0.2	Unsuitable – 0.2
Transformed to clay	Moderately suitable – 0.6	Moderately suitable – 0.6	Moderately suitable – 0.6	Moderately suitable – 0.6	Moderately suitable – 0.6	Moderately suitable – 0.6
Transformed to gleyic	Highly suitable – 0.8	Less suitable – 0.4	Moderately suitable – 0.6	Less suitable – 0.4	Highly suitable – 0.8	Moderately suitable – 0.6
Transformed to meadow	Most suitable - 1	Moderately suitable – 0.6	Most suitable - 1	Moderately suitable – 0.6	Most suitable - 1	Most suitable - 1
Transformed to steppe	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8	Highly suitable – 0.8
Weakly differentiated	Moderately suitable – 0.6	Highly suitable – 0.8	Moderately suitable – 0.6	Highly suitable – 0.8	Moderately suitable – 0.6	Moderately suitable – 0.6

The top half of the page features a dark maroon background. It is decorated with a large, stylized number '3' in the center. Above the '3' is a semi-circular arch containing intricate, lighter-colored scrollwork patterns. Above the arch, there are several triangular shapes of varying sizes, resembling a sunburst or a stylized crown.

3

**SUITABILITY CLASSIFICATION AND RECOMMENDATIONS
FOR THE VINE ROOTSTOCK
BERLANDIERI × RIPARIA KOBER 5BB
IN THE GRAPE PRODUCTION ZONES OF ARMENIA**

3.1. GENERAL INFORMATION

SYNONYMS AND GENERAL NOTES

Synonyms for the rootstock Berlandieri x Riparia Kober 5BB include Kober 5BB, 5BB, Kober, and others. In Hungary, it is referred to as Berlandieri x Riparia Teleki Kober 5BB.

This rootstock was developed in Klosterneuburg (Austria) by engineer Franz Kober using Teleki's hybrids that inherited more characteristics from the second parent (*Vitis riparia*). It quickly spread from Austria to all countries of Central Europe, as well as to our region, because it is considered one of the "universal rootstocks." It is one of the most widespread rootstocks in the world, especially in cooler wine-growing regions.

SOME BOTANICAL CHARACTERISTICS

The rootstock Berlandieri x Riparia Kober 5BB grows rapidly and produces a vegetatively vigorous plant. Its root system is strong and well-branched, with medium-thick yellow-reddish roots that penetrate deeper soil layers at a geotropic angle of about 50°.

AGROBIOLOGICAL CHARACTERISTICS AND PRODUCTION VALUE OF ROOTSTOCK

Influence on scion vigor: It induces significant vigor in grafted varieties, which may cause negative effects when highly vigorous cultivars are planted on fertile soils.

Influence on berry set: It may lead to poorer berry set in more vigorous varieties grown on fertile soils.
Influence on ripening and grape quality: This varies depending on soil type and climatic conditions. It contributes to regular bearing of grafted varieties and earlier grape ripening. It has a relatively short vegetation period.

Soils: It performs well on various soil types, but is best suited to deep, fertile, loose, and calcareous soils. It is one of the most suitable rootstocks for medium-heavy and moderately moist soils, showing good adaptability to different soil types.

It tolerates high lime content well, allowing vineyards grafted on this rootstock to be established on soils containing up to 40–50% total lime, or 20–21% physiologically active lime. According to some authors, it can tolerate even up to 60% lime in the soil.

Resistance/sensitivity: It shows good resistance to root Phylloxera and is tolerant to nematodes. It is also resistant to low winter temperatures.

Its drought resistance is low, but it is tolerant to soil moisture.

Table 14. Suitability of the rootstock Berlandieri x Riparia Kober 5BB for soils with different characteristics and its susceptibility to deficiencies or excesses of the most important elements/microelements in the soil

Soil characteristics	Adaptability	Chemical element/ microelement in the soil	Susceptibility to deficiencies or excesses
Compact	Good	Deficiency N	Sensitive
Wet	Good	Deficiency K	Sensitive
Dry	Average	Deficiency Mg	Sensitive
Stony (skeletal soils)	Acceptable	Deficiency Fe	Sensitive
Sandy	Good	Excess Cu	Sensitive
Acidic	Acceptable	Deficiency B	Sensitive
Saline	Poor	Deficiency Zn	Sensitive

Rhizogenic properties: It roots very well and produces a high percentage of high-quality vine nursery plants.

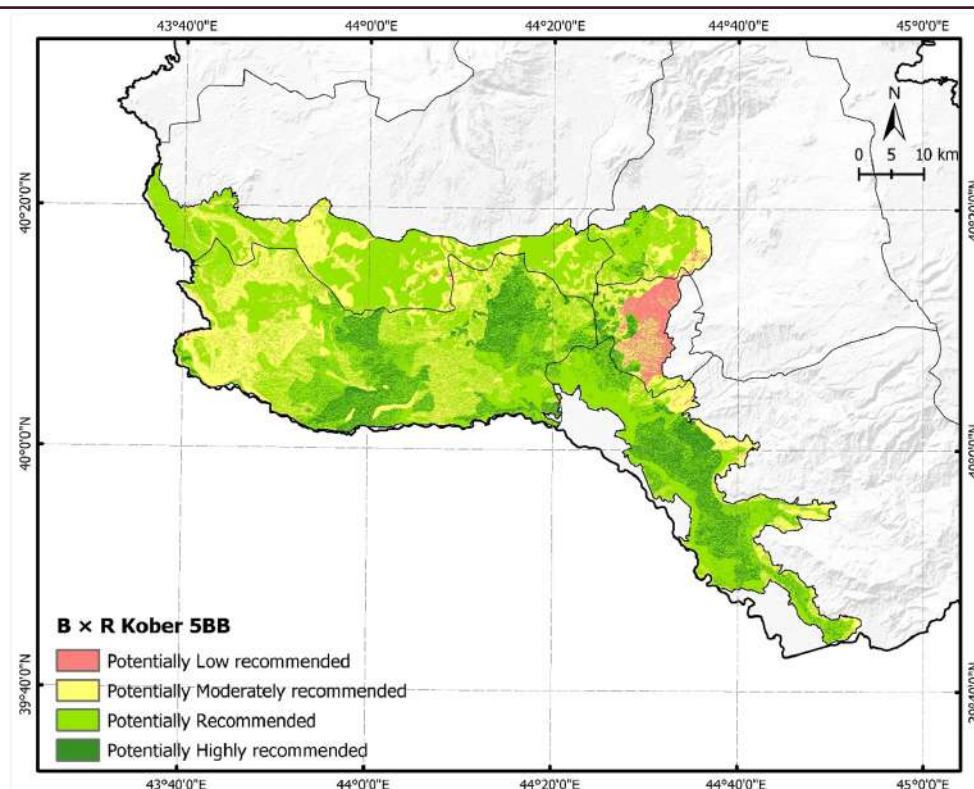
Compatibility: It shows good affinity with all *Vitis vinifera* varieties, which is the main reason for its wide distribution and extensive use in nursery production. In some cases, certain clones of Sauvignon and Cabernet Sauvignon may exhibit incompatibility.

Other important characteristics: It is recommended for northern viticultural regions and is classified among rootstocks that are not suitable for soil or sites with prolonged periods of drought. It adapts well to clay soil.

3.2. POTENTIAL SUITABILITY FOR THE ARARAT VALLEY GRAPE PRODUCTION ZONE

Due to the good adaptability of the Berlandieri × Riparia Kober 5BB rootstock to different soil types, particularly deep, fertile, medium-heavy, and moderately moist calcareous soils, a large part of the territory of the Ararat Valley grape production zones can potentially be recommended for vineyard establishment with this rootstock (Map 14).

According to the results of spatial modelling and suitability classification, approximately 56.37% of the analyzed territory was classified as potentially recommended, while an additional 13.09% was classified as potentially highly recommended for vineyard cultivation with the Kober 5BB rootstock. These areas are mainly characterized by favorable topographic conditions, suitable soil depth, good soil texture, and moderate lime content.



Classification of the territory of the Ararat Valley Grape Production Zone based on potential suitability for vineyard planting with Berlandieri $\times$ Riparia Kober 5BB rootstock

Approximately 27.58% of the territory belongs to the class of potentially moderately recommended areas. These surfaces include soils with less favorable physical and chemical properties, as well as terrains with more pronounced limitations related to slope, erosion, or the content of certain soil elements.

The smallest part of the territory (2.96%) was classified as potentially slightly recommended, characterized by less favorable conditions for successful grapevine cultivation with this rootstock, such as shallow, drier, or more skeletal soils, as well as more pronounced terrain and soil limitations (Table 15).

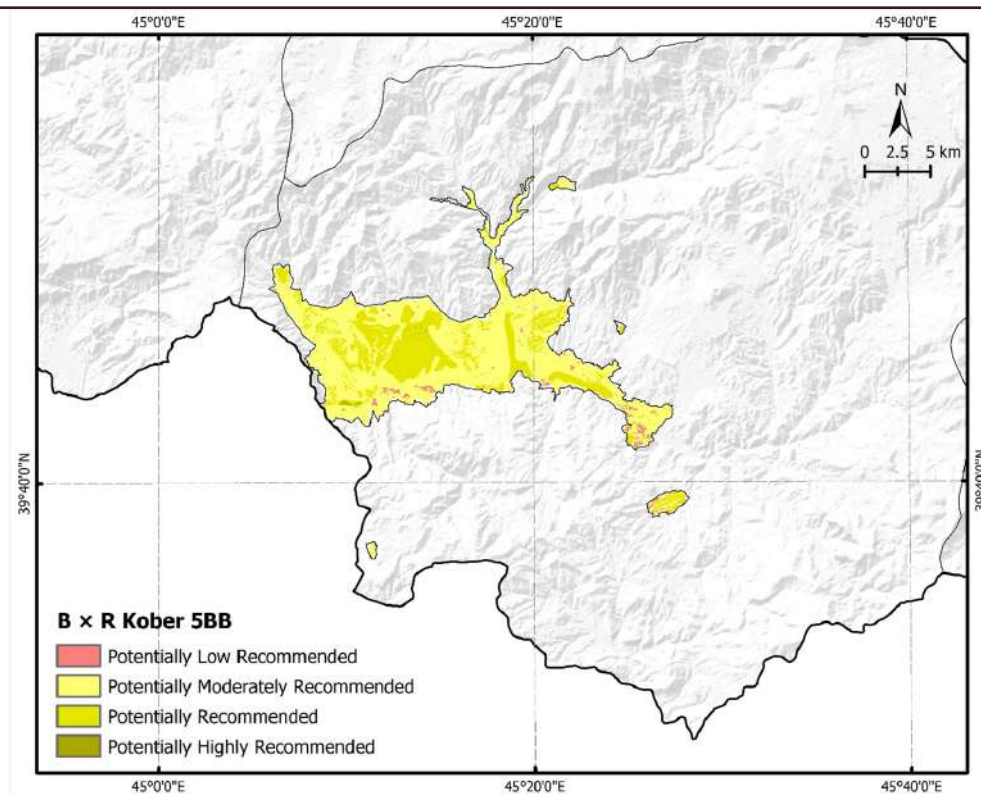
Table 15. Spatial distribution of potential suitability classes for Kober 5BB rootstock in the Ararat Valley Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	7.99	2.96
Potentially Moderately Recommended	74.47	27.58
Potentially Recommended	152.20	56.37
Potentially Highly Recommended	35.35	13.09

3.3. POTENTIAL SUITABILITY FOR THE VAYOTS DZOR GRAPE PRODUCTION ZONE

Due to the specific topographic and soil conditions of the Vayots Dzor grape production zone, the suitability of the Berlandieri × Riparia Kober 5BB rootstock is more limited compared to other grape production zones in Armenia (Map 15).

Map 15.



Classification of the territory of the Vayots Dzor Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia Kober 5BB rootstock

According to the results of spatial modelling and suitability classification, the largest part of the analyzed territory (71.04%) belongs to the class of potentially moderately recommended areas for vineyard establishment with the Kober 5BB rootstock. These areas are generally characterized by less favorable terrain conditions, shallower soils, increased soil stoniness, and more pronounced limitations related to slope and soil moisture availability.

Approximately 26.53% of the territory was classified as potentially recommended, mainly in areas with more favorable soil depth, moderate soil texture, and suitable topographic conditions for vineyard cultivation. Only a very small part of the territory (0.27%) was classified as potentially highly recommended, representing the most favorable sites for the cultivation of vineyards grafted onto the Kober 5BB rootstock.

The potentially low recommended class covers 2.16% of the territory and includes terrains with more pronounced environmental limitations, where successful grapevine cultivation with this rootstock may be restricted (Table 16).

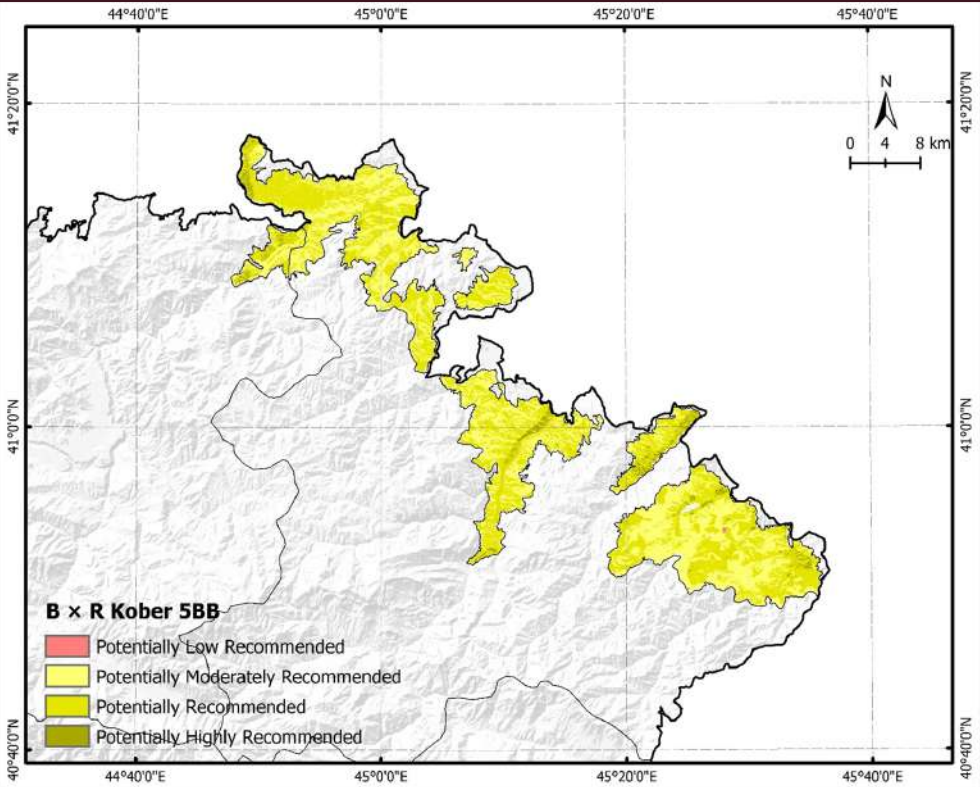
Table 16. Spatial distribution of potential suitability classes for Kober 5BB rootstock in the Vayots Dzor Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	0.39	2.16
Potentially Moderately Recommended	12.89	71.04
Potentially Recommended	4.82	26.53
Potentially Highly Recommended	0.05	0.27

3.4. POTENTIAL SUITABILITY FOR THE TAVUSH GRAPE PRODUCTION ZONE

The environmental conditions of the Tavush grape production zone indicate generally favorable suitability for vineyard establishment with the Berlandieri × Riparia Kober 5BB rootstock (Map 16).

Map 16.



Classification of the territory of the Tavush Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia Kober 5BB rootstock

The suitability pattern reflects the adaptability of this rootstock to moderately moist soils and diverse terrain conditions present within the zone. According to the results of spatial modelling and suitability classification, the largest part of the analyzed territory (51.11%) was classified as potentially recommended for vineyard planting with the Kober 5BB rootstock. These areas are mainly characterized by favorable soil depth, moderate soil texture, and suitable topographic conditions. Approximately 45.45% of the territory belongs to the class of

potentially moderately recommended areas. These terrains include soil and relief conditions with certain limitations related to slope, erosion intensity, soil depth, or moisture regime, which may reduce the overall suitability of this rootstock.

Only a small proportion of the territory (3.34%) was classified as potentially highly recommended, representing the most favorable sites for vineyard cultivation with Kober 5BB. The potentially slightly recommended class occupies only 0.10% of the territory and includes areas with less favorable environmental conditions for the successful cultivation of vineyards grafted onto this rootstock (Table 17).

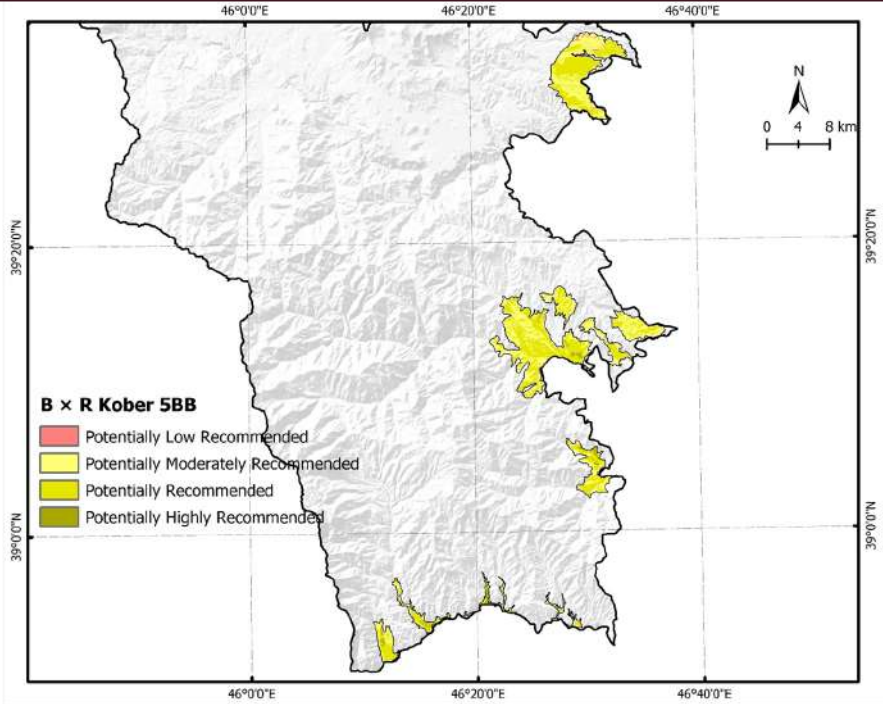
Table 17. Spatial distribution of potential suitability classes for Kober 5BB rootstock in the Tavush Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	0.06	0.10
Potentially Moderately Recommended	29.20	45.45
Potentially Recommended	32.85	51.11
Potentially Highly Recommended	2.15	3.34

3.5. POTENTIAL SUITABILITY FOR THE SYUNIK GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Riparia Kober 5BB rootstock within the Syunik grape production zone indicates generally favorable conditions for vineyard establishment, although the complex terrain and heterogeneous soil conditions influence the spatial distribution of suitability classes (Map 17).

Map 17.



Classification of the territory of the Tavush Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia Kober 5BB rootstock

According to the results of spatial modelling and suitability classification, the largest share of the analyzed territory (52.03%) was classified as potentially recommended for vineyard planting with the Kober 5BB rootstock. These areas are characterized by relatively favorable topographic conditions, suitable soil depth, and balanced soil physical properties.

Approximately 44.74% of the territory belongs to the class of potentially moderately recommended areas. These terrains are mainly associated with more pronounced slope conditions, shallower or stonier soils, and certain limitations related to soil moisture and erosion intensity.

Only 2.43% of the territory was classified as potentially highly recommended, representing the most suitable sites for vineyard cultivation with this rootstock. The potentially low recommended class covers a very limited part of the territory (0.80%) and includes areas with less favorable environmental and soil conditions for successful grapevine cultivation (Table 18).

Table 18. Spatial distribution of potential suitability classes for Kober 5BB rootstock in the Syunik Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	0.15	0.80
Potentially Moderately Recommended	8.41	44.74
Potentially Recommended	9.78	52.03
Potentially Highly Recommended	0.46	2.43



4

**SUITABILITY CLASSIFICATION AND
RECOMMENDATIONS FOR THE VINE
ROOTSTOCK BERLANDIERI X RIPARIA TELEKI 5C
IN THE GRAPE PRODUCTION ZONES OF ARMENIA**

4.1. GENERAL INFORMATION

SYNONYMS AND GENERAL NOTE

Synonyms include Teleki 5C or simply 5C.

The rootstock Berlandieri × Riparia Teleki 5C was developed in Hungary through clonal selection from Teleki's hybrid Berlandieri × Riparia 5A. It is primarily distributed in Western and Central European countries and is highly valued in viticultural regions located at the margins of successful grape cultivation.

SOME BOTANICAL CHARACTERISTICS

It has moderate vigor, intermediate between Berlandieri × Riparia Kober 5BB and SO4. It develops a strong root system that penetrates deeper soil layers at a geotropic angle of 30 to 40°.

AGROBIOLOGICAL CHARACTERISTICS AND PRODUCTION VALUE OF ROOTSTOCK

Influence on scion vigor: It has a shorter vegetation period than the rootstocks Teleki 8B and Kober 5BB, which allows the shoots to mature well and makes them resistant to winter frosts. The plants exhibit moderate vigor. Influence on berry set: It is suitable for varieties with poor berry set.

Influence on ripening and grape quality: It accelerates grape ripening, making it suitable for northern viticultural regions. It has a vegetation period that is 10 to 14 days shorter than that of the Kober 5BB rootstock, which significantly contributes to earlier grape ripening.

Soils: It is suitable for heavier, more fertile soils, as well as for loose, sandy soils, and even for somewhat more compact, warmer soils due to its drought tolerance. It tolerates a moderately high lime content in the soil (up to 50% total and 20% physiologically active CaCO₃). It performs well on irrigated soil but does not tolerate salinity.

Resistance/sensitivity: The rootstock is resistant to root phylloxera and moderately tolerant to nematodes.

Rhizogenic properties: It has well-developed rhizogenic capacity and roots well.

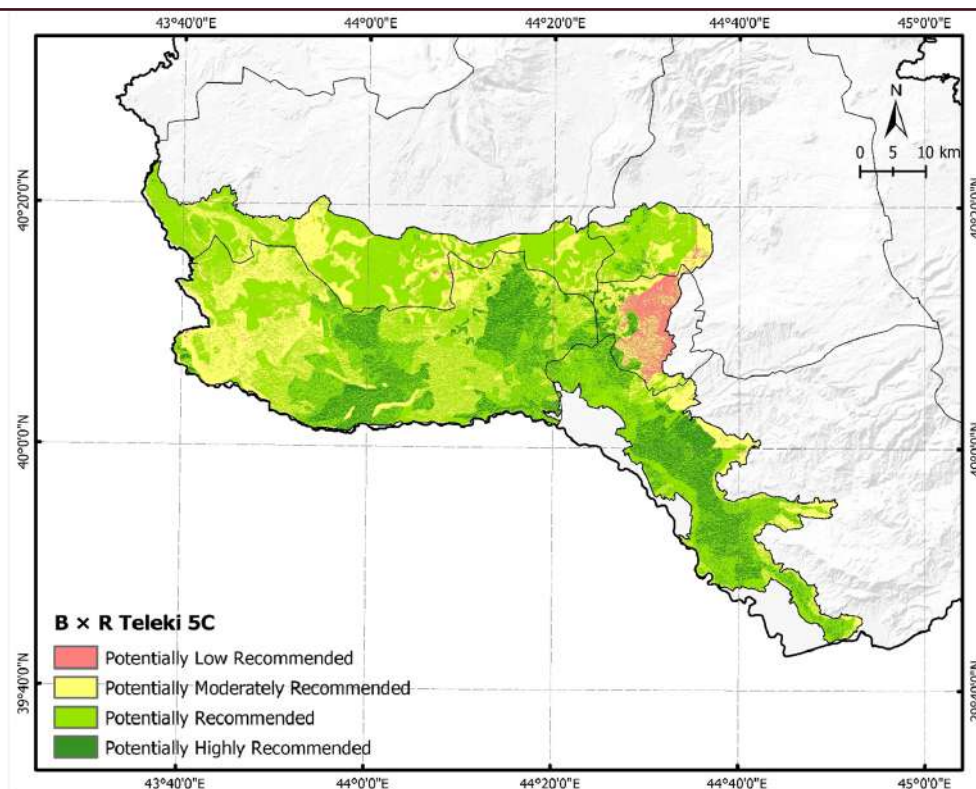
Compatibility: It shows good affinity with most grapevine varieties.

Other important characteristics: In many respects, it is like the rootstock Berlandieri × Riparia Kober 5BB, but it has a shorter vegetation period and is more suitable for cooler regions. It is highly resistant to drought.

4.1. GENERAL INFORMATION

Due to its good adaptability to different soil types and its tolerance to moderately fertile, moderately moist, and calcareous soils, the Berlandieri × Riparia Teleki 5C rootstock shows generally favorable suitability within the Ararat Valley grape production zone (Map 18).

Classification of the territory of the Ararat Valley Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia Teleki 5C rootstock



According to the results of spatial modelling and suitability classification, approximately 54.93% of the analyzed territory was classified as potentially recommended for vineyard establishment with the Teleki 5C rootstock, while an additional 14.75% was classified as potentially highly recommended. These areas are mainly characterized by favorable topographic conditions, suitable soil depth, balanced soil texture, and moderate lime content.

Approximately 27.54% of the territory belongs to the class of potentially moderately recommended areas. These terrains include soil and topographic conditions with certain limitations related to slope, erosion intensity, soil depth, or soil moisture regime, which may reduce the overall suitability of this rootstock (Table 19).

Table 19. Spatial distribution of potential suitability classes for Teleki 5C rootstock in the Tavush Grape Production Zone

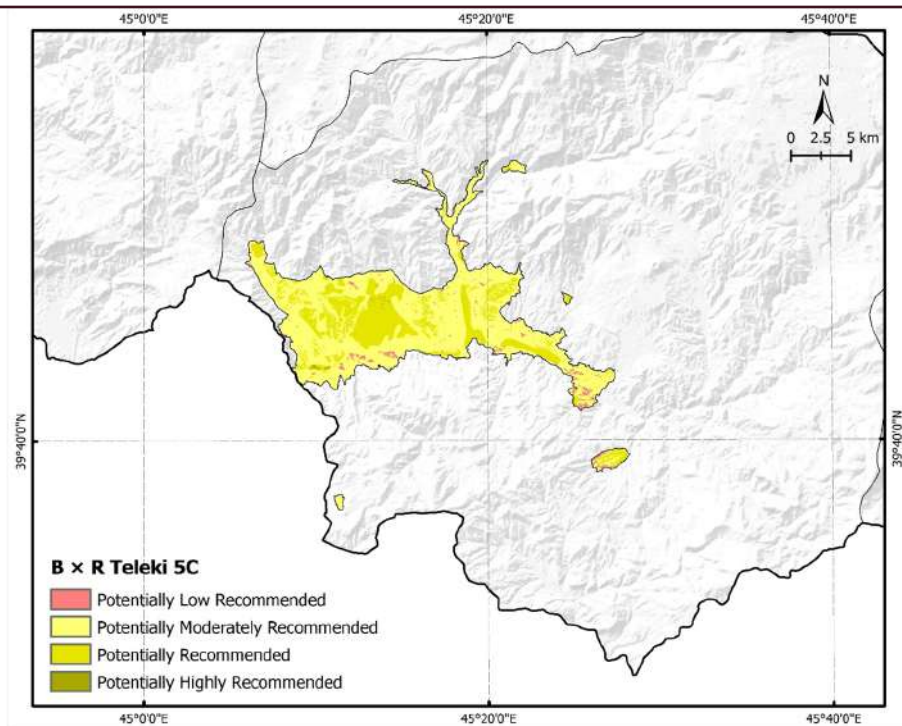
Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	7.52	2.79
Potentially Moderately Recommended	74.36	27.54
Potentially Recommended	148.31	54.93
Potentially Highly Recommended	39.82	14.75

Only 2.79% of the territory was classified as potentially slightly recommended, representing areas with less favorable environmental conditions, including shallower, drier, or more skeletal soils, as well as terrains with more pronounced relief limitations for successful vineyard cultivation with the Teleki 5C rootstock.

4.3. POTENTIAL SUITABILITY FOR THE VAYOTS DZOR GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Riparia Teleki 5C rootstock within the Vayots Dzor grape production zone indicates predominantly moderate suitability conditions for vineyard establishment (Map 19).

Map 19.



Map 19. Classification of the territory of the Vayots Dzor Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia Teleki 5C rootstock

According to the results of spatial modelling and suitability classification, the largest share of the analyzed territory (71.23%) belongs to the class of potentially moderately recommended areas. These terrains are mainly characterized by more pronounced topographic limitations, shallower soils, increased soil stoniness, and less favorable moisture conditions, which may reduce the suitability of the Teleki 5C rootstock.

Approximately 25.93% of the territory was classified as potentially recommended for vineyard establishment with this rootstock. These areas generally include more favorable soil depth, moderate soil texture, and suitable terrain conditions for grapevine cultivation.

Only a very small proportion of the territory (0.29%) was classified as potentially highly recommended, representing the most favorable sites for successful cultivation with the Teleki 5C rootstock. The potentially low recommended class covers 2.55% of the territory and includes areas with more pronounced environmental and soil limitations for vineyard establishment (Table 20).

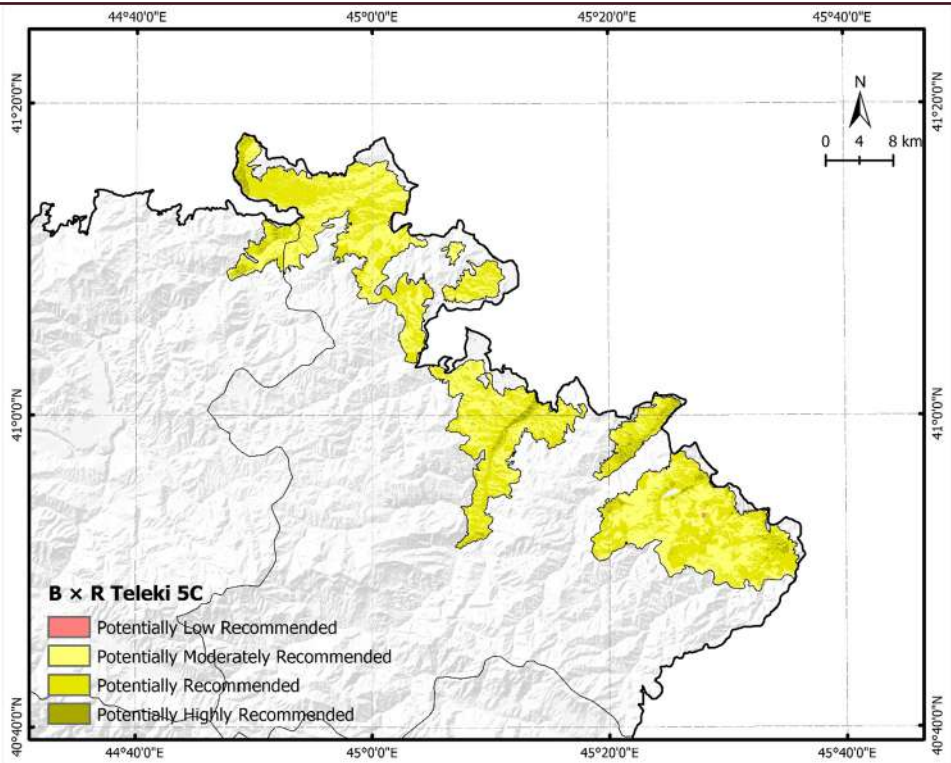
Table 20. Spatial distribution of potential suitability classes for Teleki 5C rootstock in the Vayots Dzor Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	0.46	2.55
Potentially Moderately Recommended	12.93	71.23
Potentially Recommended	4.71	25.93
Potentially Highly Recommended	0.05	0.29

4.4. POTENTIAL SUITABILITY FOR THE TAVUSH GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Riparia Teleki 5C rootstock within the Tavush grape production zone indicates generally favorable conditions for vineyard establishment, with a relatively balanced distribution between moderately recommended and recommended suitability classes (Map 20).

Map 20.



Classification of the territory of the Tavush Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia Teleki 5C rootstock

According to the results of spatial modelling and suitability classification, 48.60% of the analyzed territory was classified as potentially recommended for vineyard planting with the Teleki 5C rootstock. These areas are mainly characterized by favorable soil depth, balanced soil texture, and suitable topographic conditions for grapevine cultivation.

Approximately 48.12% of the territory belongs to the class of potentially moderately recommended areas. These terrains include soil and relief conditions with certain limitations related to slope, erosion intensity, soil depth, or moisture availability, which may reduce the overall suitability of this rootstock.

Only 3.18% of the territory was classified as potentially highly recommended, representing the most favorable sites for successful vineyard cultivation with the Teleki 5C rootstock. The potentially slightly recommended class occupies a very limited share of the territory (0.11%) and includes areas with less favorable environmental and soil conditions (Table 21).

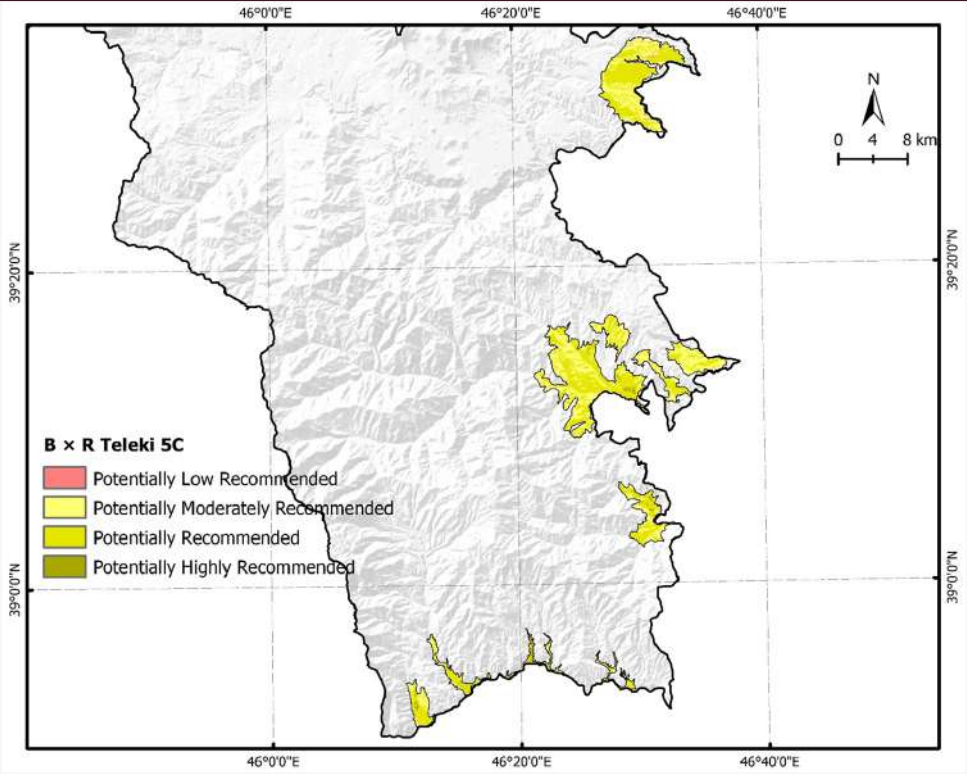
Table 21.Spatial distribution of potential suitability classes for Teleki 5C rootstock in the Tavush Grape Production Zone

	Thousand (ha)	(%)
	0.07	0.11
Potentially Low Recommended	30.92	48.12
Potentially Moderately Recommended	31.23	48.60
Potentially Recommended	2.04	3.18
Potentially Highly Recommended		

4.5. POTENTIAL SUITABILITY FOR THE SYUNIK GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Riparia Teleki 5C rootstock within the Syunik grape production zone indicates generally favorable conditions for vineyard establishment, although terrain complexity and heterogeneous soil conditions influence the spatial distribution of suitability classes (Map 21).

Map 21.



Classification of the territory of the Syunik Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia Teleki 5C rootstock

According to the results of spatial modelling and suitability classification, the largest share of the analyzed territory (52.46%) was classified as potentially recommended for vineyard planting with the Teleki 5C rootstock. These areas are characterized by relatively favorable topographic conditions, suitable soil depth, and balanced soil physical properties.

Approximately 45.28% of the territory belongs to the class of potentially moderately recommended areas. These terrains are mainly associated with steeper slopes, shallower or stonier soils, and certain limitations related to soil moisture availability and erosion intensity, which may reduce the suitability of this rootstock.

Only 1.71% of the territory was classified as potentially highly recommended, representing the most favorable sites for vineyard cultivation with the Teleki 5C rootstock. The potentially slightly recommended class occupies a very limited proportion of the territory (0.55%) and includes areas with less favorable environmental and soil conditions for successful grapevine cultivation (Table 23).

Table 23. Spatial distribution of potential suitability classes for Teleki 5C rootstock in the Syunik Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	0.10	0.55
Potentially Moderately Recommended	8.51	45.28
Potentially Recommended	9.86	52.46
Potentially Highly Recommended	0.32	1.71



5

**SUITABILITY CLASSIFICATION AND RECOMMENDATIONS
FOR THE VINE ROOTSTOCK BERLANDIERI X RIPARIA 420A
IN THE GRAPE PRODUCTION ZONES OF ARMENIA**

5.1. GENERAL INFORMATION

SYNONYMS AND GENERAL NOTE

Synonyms include: 420 A, Vitis berlandieri × Vitis riparia 420 A Millardet et de Grasset, Millardet 420 A, and 420 A MiG.

It is one of the oldest rootstocks from the Berlandieri × Riparia group. It was developed in France by Pierre-Marie-Alexis Millardet and Charles de Grasset, from where it spread throughout France, Italy, and other Mediterranean countries. It is one of the most important rootstocks used worldwide, although it is not widely represented in our region.

SOME BOTANICAL CHARACTERISTICS

The rootstock Berlandieri × Riparia 420 A is very vigorous.
Its root system is well-branched and fleshy, penetrating deeper soil layers.

AGROBIOLOGICAL CHARACTERISTICS AND PRODUCTION VALUE OF ROOTSTOCK

Influence on scion vigor: This rootstock has a longer vegetation period, which it transmits to the grafted scion.

Influence on berry set: It promotes berry set.

Influence on ripening and grape quality: It has a long vegetation cycle and extends the grape ripening period. It leads to later grape ripening; however, within the Mediterranean region, where it is mainly used, this does not have any negative impact.

Soils: It is suitable for heavier, moderately moist, and moderately fertile to fertile soils, as well as for well-drained soils, but not for sites where water accumulates. It tolerates a moderate lime content in the soil, i.e., up to 40% of the total and 20% physiologically active lime.

Resistance/sensitivity: It is resistant to root phylloxera and moderately tolerant to nematodes. It is sensitive to Phytophthora and has low drought tolerance. It is highly susceptible to leaf phylloxera.

Table 24. Suitability of the rootstock Berlandieri x Riparia 420A for soils with different characteristics and its susceptibility to deficiencies or excesses of the most important elements / microelements in the soil

Soil characteristics	Adaptability	Chemical element/ microelement in the soil	Susceptibility to deficiencies or excesses
Compact	Good	Deficiency of K	Sensitive
Wet	Very poor	Deficiency of Mg	Sensitive
Dry	Good	Deficiency of P	Low sensitivity
Stony (skeletal soils)	Good	Deficiency of Fe	Low sensitivity
Acidic	Poor	Deficiency Zn	Sensitive
Saline	Poor		

Rhizogenic properties: It has weaker rooting ability and difficulties in grafting, resulting in a low percentage of high-quality grafted vines. Today, there are selections of this rootstock in which rooting has been improved.

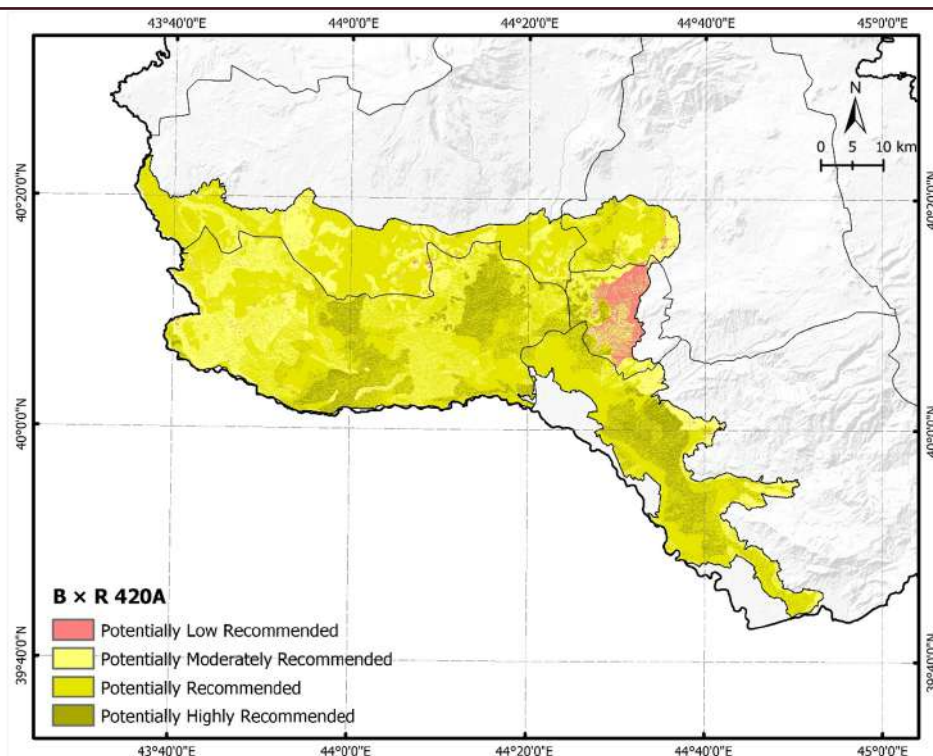
Compatibility: It shows good affinity with *Vitis vinifera* varieties.

Other important characteristics: It has lower resistance to drought, although it is recommended for deep soils under warm and dry climate conditions.

5.2. POTENTIAL SUITABILITY FOR THE ARARAT VALLEY GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Riparia 420A rootstock within the Ararat Valley grape production zone indicates generally favorable conditions for vineyard establishment, particularly in areas with suitable soil depth, moderate soil texture, and balanced moisture conditions (Map 22).

Map 22.



Classification of the territory of the Ararat Valley Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia 420A rootstock

According to the results of spatial modelling and suitability classification, the largest share of the analyzed territory (58.33%) was classified as potentially recommended for vineyard planting with the 420A rootstock. In addition, 11.12% of the territory was classified as potentially highly recommended, representing the most favorable areas for vineyard cultivation with this rootstock.

Approximately 27.84% of the territory belongs to the class of potentially moderately recommended areas. These terrains are characterized by certain limitations related to soil depth, terrain slope, erosion intensity, or soil physical properties, which may reduce the suitability of the 420A rootstock under specific environmental conditions.

Table 25. Spatial distribution of potential suitability classes for 420A rootstock in the Ararat Valley Grape Production Zone

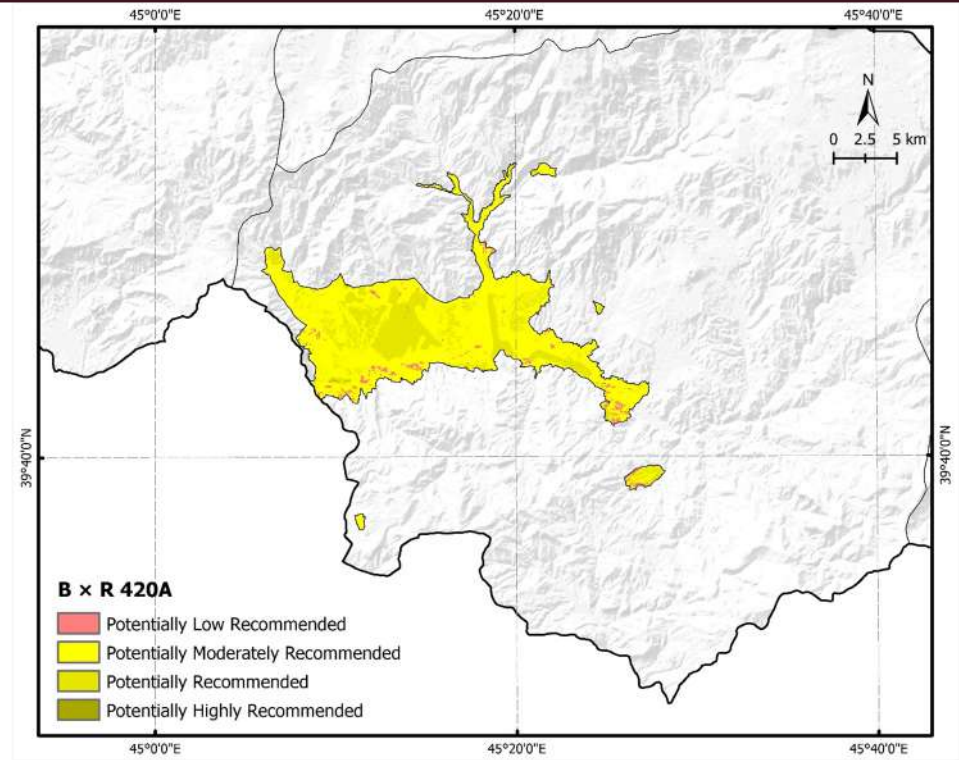
Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	7.31	2.71
Potentially Moderately Recommended	75.16	27.84
Potentially Recommended	157.51	58.33
Potentially Highly Recommended	30.04	11.12

Only 2.71% of the analyzed territory was classified as potentially slightly recommended. These areas mainly include terrains with less favorable soil and topographic conditions, such as shallower, drier, or more skeletal soils, where successful vineyard cultivation with the 420A rootstock may be limited (Table 25).

5.3. POTENTIAL SUITABILITY FOR THE VAYOTS DZOR GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Riparia 420A rootstock within the Vayots Dzor grape production zone indicates predominantly moderate suitability conditions for vineyard establishment (Map 23).

Map 23.



Classification of the territory of the Vayots Dzor Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia 420A rootstock

According to the results of spatial modelling and suitability classification, the largest share of the analyzed territory (71.99%) belongs to the class of potentially moderately recommended areas. These terrains are mainly characterized by less favorable topographic and soil conditions, including shallower soils, increased stoniness, and limitations related to slope and soil moisture availability.

Approximately 24.90% of the territory was classified as potentially recommended for vineyard planting with the 420A rootstock. These areas generally include terrains with more favorable soil depth, moderate soil texture, and balanced environmental conditions suitable for grapevine cultivation.

Only 0.12% of the territory was classified as potentially highly recommended, representing the most favorable sites for vineyard establishment with this rootstock. The potentially slightly recommended class covers 2.99% of the territory and includes areas with more pronounced environmental and soil limitations for successful grapevine cultivation (Table 26).

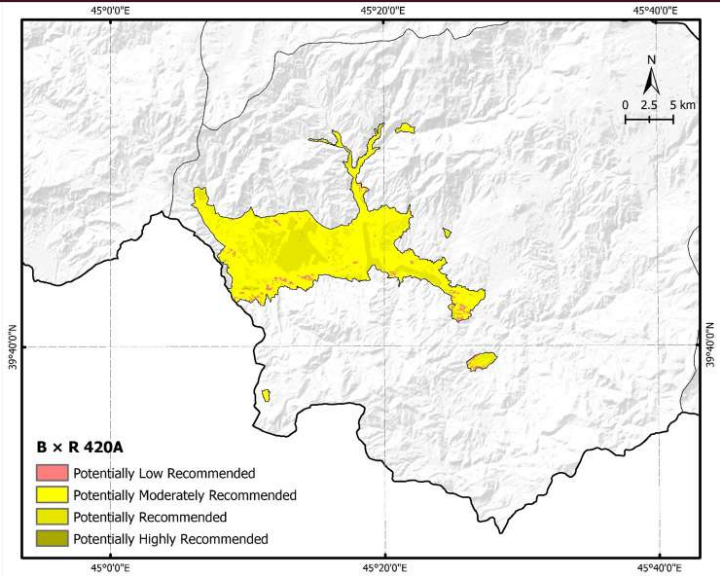
Table 26. Spatial distribution of potential suitability classes for 420A rootstock in the Vayots Dzor Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	0.54	2.99
Potentially Moderately Recommended	13.07	71.99
Potentially Recommended	4.52	24.90
Potentially Highly Recommended	0.02	0.12

5.4. POTENTIAL SUITABILITY FOR THE TAVUSH GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Riparia 420A rootstock within the Tavush grape production zone indicates generally favorable conditions for vineyard establishment, with a predominance of recommended and moderately recommended suitability classes (Map 24).

Map 24.



Classification of the territory of the Tavush Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia 420A rootstock

According to the results of spatial modelling and suitability classification, 51.21% of the analyzed territory was classified as potentially recommended for vineyard planting with the 420A rootstock. These areas are mainly characterized by favorable soil depth, balanced soil texture, and suitable topographic conditions for grapevine cultivation.

Approximately 45.81% of the territory belongs to the class of potentially moderately recommended areas. These terrains include soil and relief conditions with certain limitations related to slope, erosion intensity, soil depth, or moisture availability, which may reduce the overall suitability of this rootstock.

Only 2.88% of the territory was classified as potentially highly recommended, representing the most favorable sites for vineyard cultivation with the 420A rootstock. The potentially slightly recommended class occupies a very limited share of the territory (0.09%) and includes areas with less favorable environmental and soil conditions for successful grapevine cultivation (Table 27).

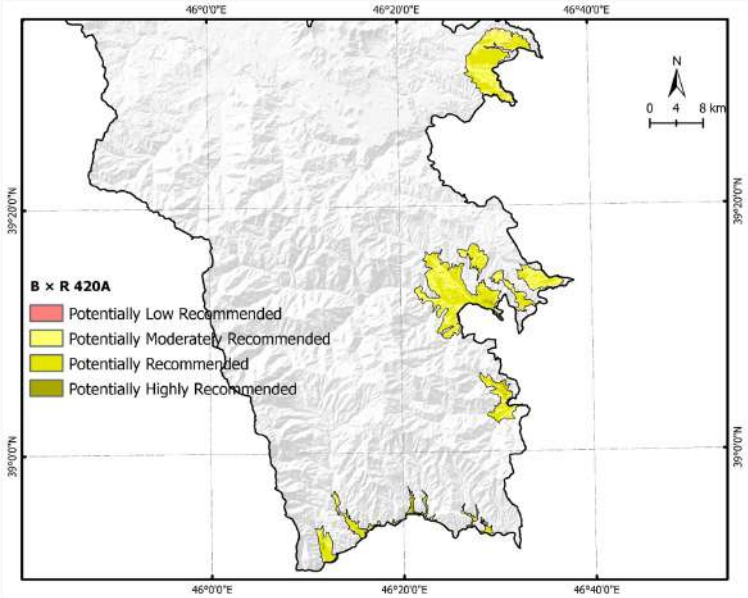
Table 27. Spatial distribution of potential suitability classes for 420A rootstock in the Tavush Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	0.06	0.09
Potentially Moderately Recommended	29.44	45.81
Potentially Recommended	32.91	51.21
Potentially Highly Recommended	1.85	2.88

5.5. POTENTIAL SUITABILITY FOR THE SYUNIK GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Riparia 420A rootstock within the Tavush grape production zone indicates generally favorable conditions for vineyard establishment, with a predominance of recommended and moderately recommended suitability classes (Map 25).

Map 25.



Classification of the territory of the Tavush Grape Production Zone based on potential suitability for vineyard planting with Berlandieri × Riparia 420A rootstock

According to the results of spatial modelling and suitability classification, 51.21% of the analyzed territory was classified as potentially recommended for vineyard planting with the 420A rootstock. These areas are mainly characterized by favorable soil depth, balanced soil texture, and suitable topographic conditions for grapevine cultivation.

Approximately 45.81% of the territory belongs to the class of potentially moderately recommended areas. These terrains include soil and relief conditions with certain limitations related to slope, erosion intensity, soil depth, or moisture availability, which may reduce the overall suitability of this rootstock.

Only 2.88% of the territory was classified as potentially highly recommended, representing the most favorable sites for vineyard cultivation with the 420A rootstock. The potentially slightly recommended class occupies a very limited share of the territory (0.09%) and includes areas with less favorable environmental and soil conditions for successful grapevine cultivation (Table 28).

Table 28. Spatial distribution of potential suitability classes for 420A rootstock in the Syunik Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	0.12	0.64
Potentially Moderately Recommended	8.08	42.99
Potentially Recommended	10.21	54.36
Potentially Highly Recommended	0.38	2.01



6

**SUITABILITY CLASSIFICATION AND RECOMMENDATIONS
FOR THE VINE ROOTSTOCK RIPARIA X RUPESTRIS 3309 C
IN THE GRAPE PRODUCTION ZONES OF ARMENIA**

6.1. GENERAL INFORMATION

SYNONYMS AND GENERAL NOTES

Synonyms include 3309 C, Couderc 3309, 3309 Couderc, and *Vitis riparia* × *Vitis rupestris* 3309 C. The rootstock *Vitis riparia* × *Vitis rupestris* 3309 Couderc was created in Aubenas (France) by Georges Couderc in 1881 by crossing *Riparia Tomenteux* × *Rupestris Martin*. Today, it is most widely distributed in France, where it ranks among the more important rootstocks in terms of nursery area.

SOME BOTANICAL CHARACTERISTICS

The rootstock *Berlandieri* × *Riparia* 420 A is very vigorous. Its root system is well-branched and fleshy, penetrating deeper soil layers.

AGROBIOLOGICAL CHARACTERISTICS AND PRODUCTION VALUE OF ROOTSTOCK

- Influence on scion vigor:** Low to moderate.
- Influence on fertilization:** It promotes fertilization and berry set. It may lead to excessively high yields in young vines.
- Influence on ripening and grape quality:** It accelerates berry ripening.
- Soils:** It has a well-developed root system that extends into deeper soil layers. It is suitable for deep and cooler soils with adequate water supply. It is not suited to dry and shallow soils, nor to heavy soils. It tolerates about 11% physiologically active lime and up to 30% total lime in the soil.
- Resistance/sensitivity:** It is resistant to disease agents and root phylloxera, and moderately resistant to leaf phylloxera. Due to its poor adaptation, low tolerance to lime, poor affinity, and insufficient drought tolerance, this rootstock is not recommended for our conditions.

Table 29. Suitability of the rootstock *Berlandieri* x *Riparia* 420A for soils with different characteristics and its susceptibility to deficiencies or excesses of the most important elements / microelements in the soil

Soil characteristics	Adaptability	Chemical element/ microelement in the soil	Susceptibility to deficiencies or excesses
Compact	Poor	Deficiency of N	Sensitive
Wet	Very poor	Deficiency of K	Sensitive
Dry	Poor	Deficiency of Mg	Very sensitivity
Stony (skeletal soils)	Good	Deficiency of P	Low sensitivity
Acidic	Poor	Deficiency of B	Sensitive
Saline	Poor	Deficiency of Zn	Sensitive

Rhizogenic properties: It roots easily.

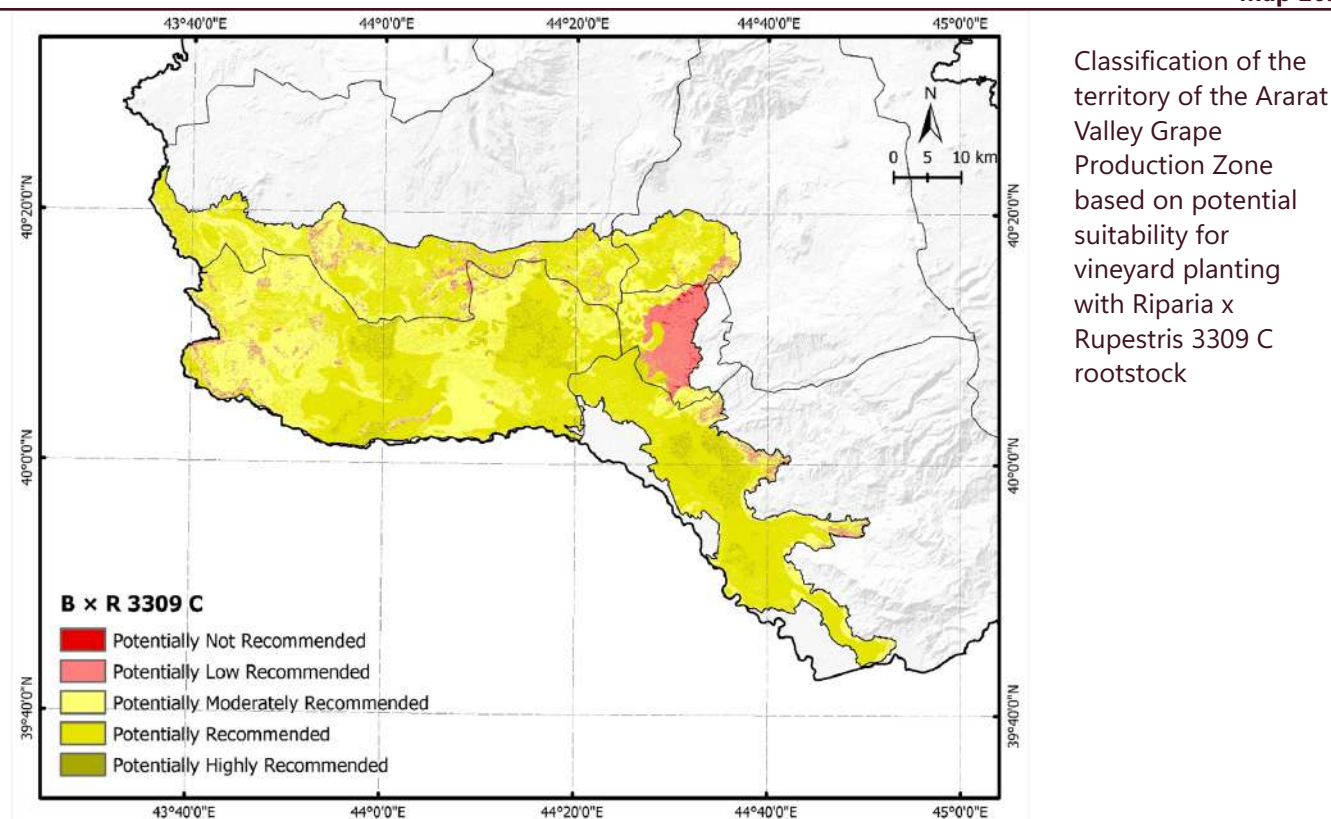
Compatibility: It has poor affinity with *Vitis vinifera* varieties.

Other important characteristics: It has a reduced ability to uptake potassium. On more fertile soils where high grape yields are achieved, potassium deficiency may occur.

6.2. POTENTIAL SUITABILITY FOR THE ARARAT VALLEY GRAPE PRODUCTION ZONE

The suitability assessment of the *Riparia* × *Rupestris* 3309 C rootstock within the Ararat Valley grape production zone indicates predominantly favorable to moderately favorable conditions for vineyard establishment (Map 26).

Map 26.



According to the results of spatial modelling and suitability classification, the largest share of the analyzed territory (49.66%) was classified as potentially recommended for vineyard planting with the 3309 C rootstock. These areas are mainly characterized by favorable topographic conditions, suitable soil depth, and balanced physical properties.

Approximately 41.77% of the territory belongs to the class of potentially moderately recommended areas. These terrains include soil and environmental conditions with certain limitations related to soil texture, lime content, moisture regime, or terrain slope, which may reduce the suitability of the 3309 C rootstock (Table 30).

Table 30. Spatial distribution of potential suitability classes for 3309 C rootstock in the Ararat Valley Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Not Recommended	0.36	0.13%
Potentially Low Recommended	17.82	6.60%
Potentially Moderately Recommended	112.79	41.77%
Potentially Recommended	134.10	49.66%
Potentially Highly Recommended	4.96	1.84%

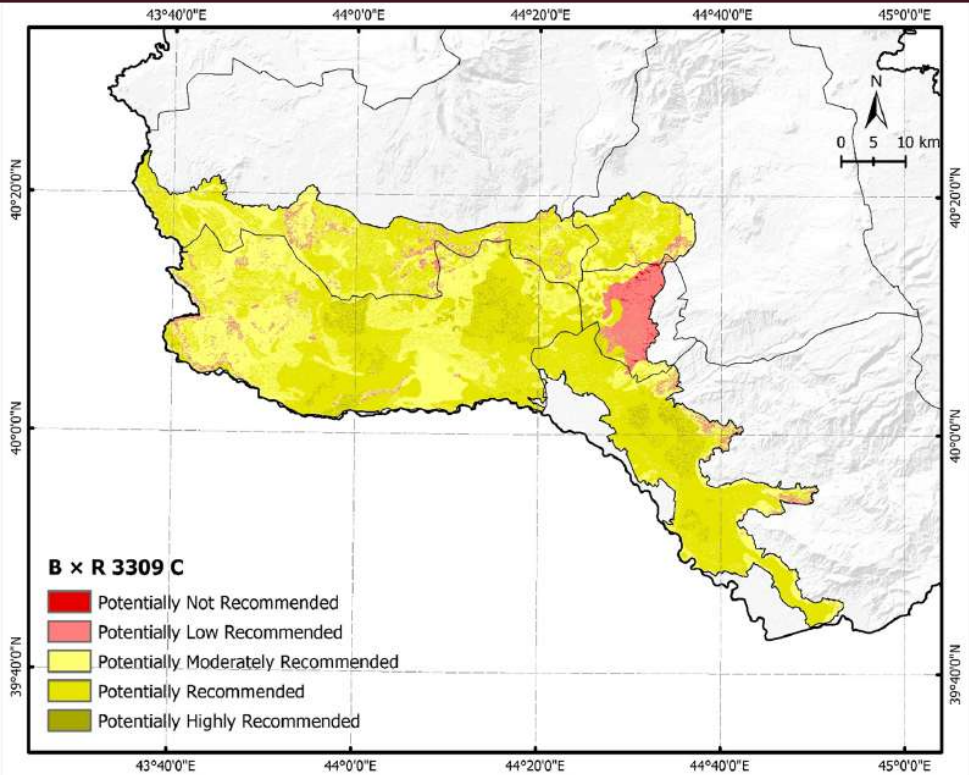
A smaller proportion of the territory (6.60%) was classified as potentially slightly recommended, mainly including areas with shallower, drier, or more skeletal soils and less favorable environmental conditions for successful vineyard cultivation. Only 1.84% of the territory was classified as potentially highly recommended, representing the most suitable sites for vineyard establishment with this rootstock.

The potentially not recommended class occupies a very limited share of the territory (0.13%) and includes terrains with pronounced environmental and soil limitations unsuitable for successful grapevine cultivation with the 3309 C rootstock.

6.3. POTENTIAL SUITABILITY FOR THE VAYOTS DZOR GRAPE PRODUCTION ZONE

The suitability assessment of the Riparia × Rupestris 3309 C rootstock within the Vayots Dzor grape production zone indicates predominantly moderate suitability conditions for vineyard establishment (Map 27).

Map 27.



Classification of the territory of the Vayots Dzor Grape Production Zone based on potential suitability for vineyard planting with Riparia x Rupestris 3309 C rootstock

According to the results of spatial modelling and suitability classification, the largest proportion of the analyzed territory (49.66%) was classified as potentially recommended for vineyard planting with the 3309 C rootstock. These areas are mainly characterized by relatively favorable soil depth, balanced soil texture, and suitable terrain conditions for grapevine cultivation (Table 31).

Table 31. Spatial distribution of potential suitability classes for 3309 C rootstock in the Ararat Valley Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	2.40	6.60%
Potentially Moderately Recommended	12.93	41.77%
Potentially Recommended	2.81	49.66%

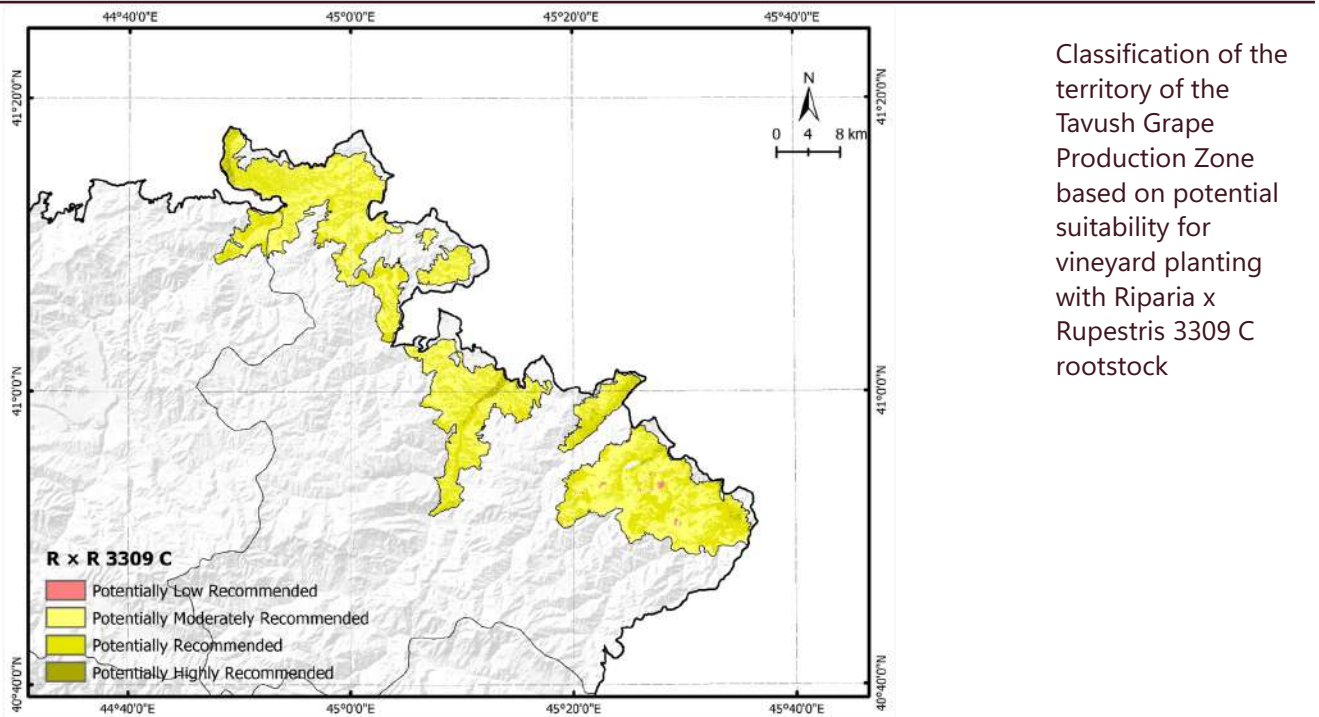
Approximately 41.77% of the territory belongs to the class of potentially moderately recommended areas. These terrains include soil and environmental conditions with certain limitations related to slope, soil depth, stoniness, and moisture availability, which may reduce the suitability of the 3309 C rootstock.

The potentially low recommended class covers 6.60% of the territory and mainly includes areas with less favorable environmental and soil conditions, such as shallower, drier, or more skeletal soils, where successful vineyard cultivation with this rootstock may be limited.

6.4. POTENTIAL SUITABILITY FOR THE TAVUSH GRAPE PRODUCTION ZONE

The suitability assessment of the Riparia × Rupestris 3309 C rootstock within the Tavush grape production zone indicates predominantly moderate suitability conditions for vineyard establishment (Map 28).

Map 28.



According to the results of spatial modelling and suitability classification, the largest share of the analyzed territory (55.12%) belongs to the class of potentially moderately recommended areas. These terrains are mainly characterized by certain limitations related to terrain slope, soil depth, erosion intensity, and moisture availability, which may reduce the overall suitability of the 3309 C rootstock.

Approximately 42.93% of the territory was classified as potentially recommended for vineyard planting with this rootstock. These areas generally include more favorable topographic and soil conditions, such as balanced soil texture, suitable soil depth, and moderate environmental limitations for grapevine cultivation.

Only 1.48% of the territory was classified as potentially highly recommended, representing the most favorable sites for vineyard cultivation with the 3309 C rootstock. The potentially slightly recommended class occupies a very limited share of the territory (0.47%) and includes areas with less favorable environmental and soil conditions for successful grapevine cultivation (Table 32).

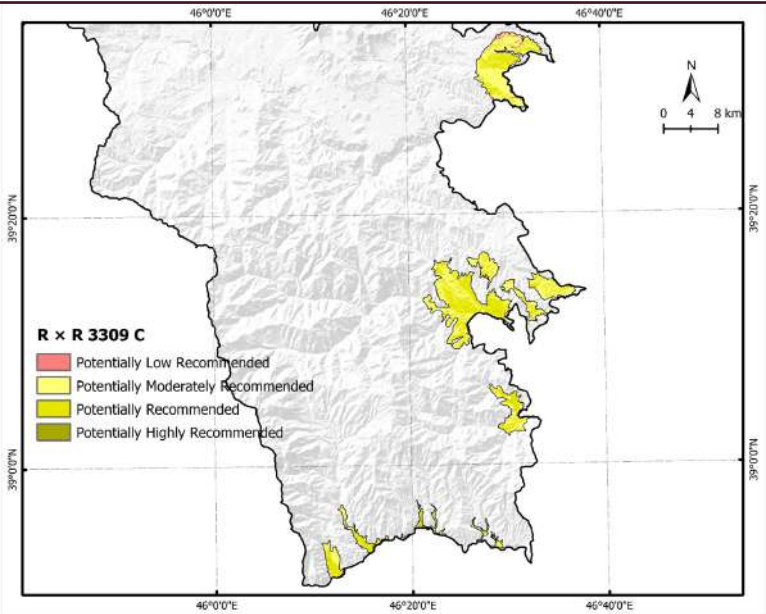
Table 32. Spatial distribution of potential suitability classes for 3309 C rootstock in the Ararat Valley Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	0.30	0.47%
Potentially Moderately Recommended	35.42	55.12%
Potentially Recommended	27.58	42.93%
Potentially Highly Recommended	0.95	1.48%

6.5. POTENTIAL SUITABILITY FOR THE SYUNIK GRAPE PRODUCTION ZONE

The suitability assessment of the Riparia × Rupestris 3309 C rootstock within the Syunik grape production zone indicates predominantly moderate suitability conditions for vineyard establishment (Map 29).

Map 29.



Classification of the territory of the Syunik Grape Production Zone based on potential suitability for vineyard planting with Riparia x Rupestris 3309 C rootstock

According to the results of spatial modelling and suitability classification, the largest share of the analyzed territory (53.20%) belongs to the class of potentially moderately recommended areas. These terrains are mainly associated with steeper slopes, shallower or stonier soils, and certain limitations related to soil moisture availability and erosion intensity, which may reduce the overall suitability of the 3309 C rootstock.

Approximately 44.42% of the territory was classified as potentially recommended for vineyard planting with this rootstock. These areas generally include more favorable topographic and soil conditions, such as suitable soil depth and balanced soil physical properties for grapevine cultivation.

Only 0.47% of the territory was classified as potentially highly recommended, representing the most favorable sites for successful vineyard cultivation with the 3309 C rootstock. The potentially slightly recommended class covers 1.92% of the territory and includes areas with less favorable environmental and soil conditions for vineyard establishment (Table 33).

Table 33. Spatial distribution of potential suitability classes for 3309 C rootstock in the Syunik Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	0.36	1.92
Potentially Moderately Recommended	10.00	53.20
Potentially Recommended	8.35	44.42
Potentially Highly Recommended	0.09	0.47



7

**SUITABILITY CLASSIFICATION AND
RECOMMENDATIONS FOR THE VINE ROOTSTOCK
BERLANDIERI X RUPESTRIS 1103 PAULSEN IN
THE GRAPE PRODUCTION ZONES OF ARMENIA**

7.1. GENERAL INFORMATION

SYNONYMS AND GENERAL NOTES

Synonyms include 1103 and P-1103.

The rootstock was developed in Sicily by Federico Paulsen by crossing Berlandieri Resseguier No. 2 × Rupestris du Lot. It is widely distributed in Italy and other countries of the Mediterranean basin.

SOME BOTANICAL CHARACTERISTICS

It is a vigorous rootstock, characterized by strong vegetative potential and pronounced vigor. It develops a very well-developed root system that penetrates deeply into the soil at an oblique angle.

AGROBIOLOGICAL CHARACTERISTICS AND PRODUCTION VALUE OF ROOTSTOCK

Influence on scion vigor: In terms of vigor, it is classified among very vigorous rootstocks and is therefore primarily recommended for southern viticultural regions.

Influence on berry set: It is not suitable for varieties characterized by poor berry set.
Influence on ripening and grape quality: It has a long vegetation cycle and may contribute to delayed grape ripening.

Soils: It is well suited to clayey, compact soils (relatively tolerant to soil moisture) and moderately compact soils, as well as to dry conditions, whereas it does not tolerate excessively compact and wet soils. It tolerates a high limestone content in the soil, up to 55% total (according to some authors 65–80%) and 17–20% (according to some authors 20–35%) physiologically active lime.

This rootstock performs well on warm, dry, and poor soils, but also shows good results on fresh soils in northern regions, particularly in well-aerated sites.

Resistance/sensitivity: It is resistant to root phylloxera and fungal diseases, but susceptible to leaf phylloxera. It is more drought-tolerant than the Richter 110 rootstock and tolerates relatively high lime content in the soil well.

Table 34. Suitability of the rootstock Berlandieri x Riparia 420A for soils with different characteristics and its susceptibility to deficiencies or excesses of the most important elements / microelements in the soil

Soil characteristics	Adaptability	Chemical element/ microelement in the soil	Susceptibility to deficiencies or excesses
Compact	Good	Deficiency of K	Sensitive
Wet	Very poor	Deficiency of Mg	Sensitive
Dry	Good	Deficiency of P	Low sensitivity
Stony (skeletal soils)	Good	Deficiency of Fe	Low sensitivity
Acidic	Poor	Deficiency Zn	Sensitive
Saline	Poor		

Rhizogenic properties: It roots well, i.e., it has moderately expressed rhizogenic properties.

Compatibility: It shows good affinity with *Vitis vinifera* varieties.

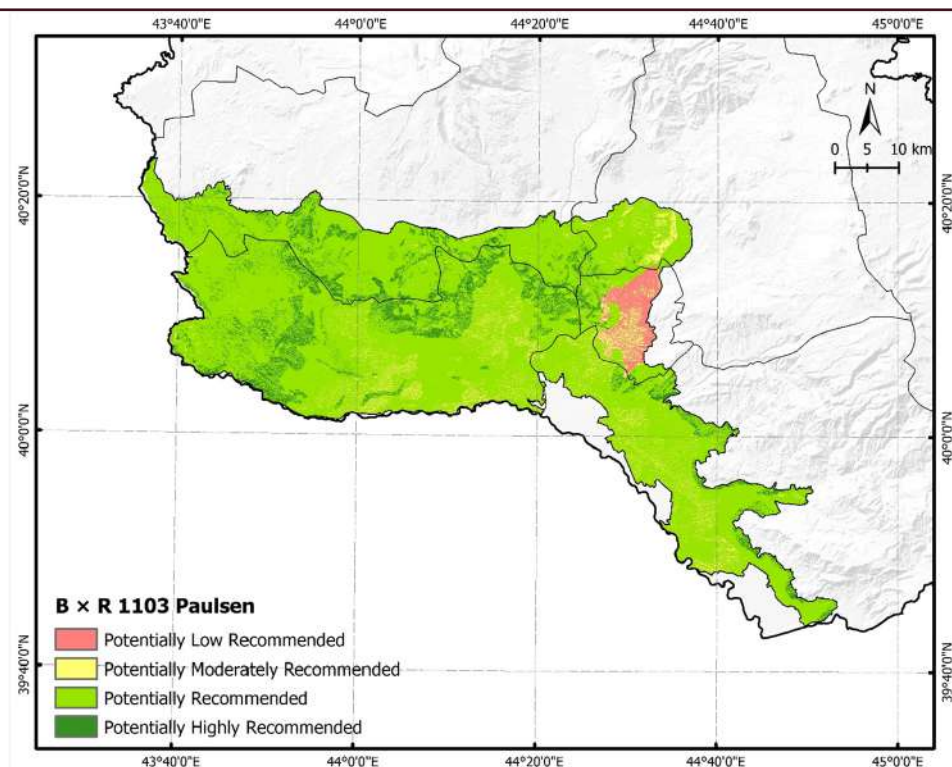
Other important characteristics: The rootstock Berlandieri × Rupestris 1103 Paulsen performs well on dry, calcareous soils, but is most used on warm, dry, and poor soils, which are frequently found in the Mediterranean. It enters the vegetation period earlier, which may pose a risk in sites with poorly ventilated depressions and frequent spring frosts.

In southern regions, it promotes earlier grape ripening and is therefore often used for the cultivation of table grape varieties.

7.2. POTENTIAL SUITABILITY FOR THE ARARAT VALLEY GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Rupestris 1103 Paulsen rootstock within the Ararat Valley grape production zone indicates highly favorable conditions for vineyard establishment (Map 30).

Map 30.



Classification of the territory of the Ararat Valley Grape Production Zone based on potential suitability for vineyard planting with Berlandieri x Rupestris 1103 Paulsen rootstock

According to the results of spatial modelling and suitability classification, the dominant part of the analyzed territory (81.21%) was classified as potentially recommended for vineyard planting with the 1103 Paulsen rootstock. These areas are mainly characterized by favorable topographic conditions, suitable soil depth, balanced soil texture, and environmental conditions suitable for grapevine cultivation.

Additionally, 9.86% of the territory was classified as potentially highly recommended, representing the most favorable sites for vineyard establishment with this rootstock, particularly in areas with well-drained soils and suitable moisture and lime conditions (Table 35).

Table 35. Spatial distribution of potential suitability classes for 1103 Paulsen rootstock in the Ararat Valley Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	6.54	2.42
Potentially Moderately Recommended	17.58	6.51
Potentially Recommended	219.27	81.21
Potentially Highly Recommended	26.62	9.86

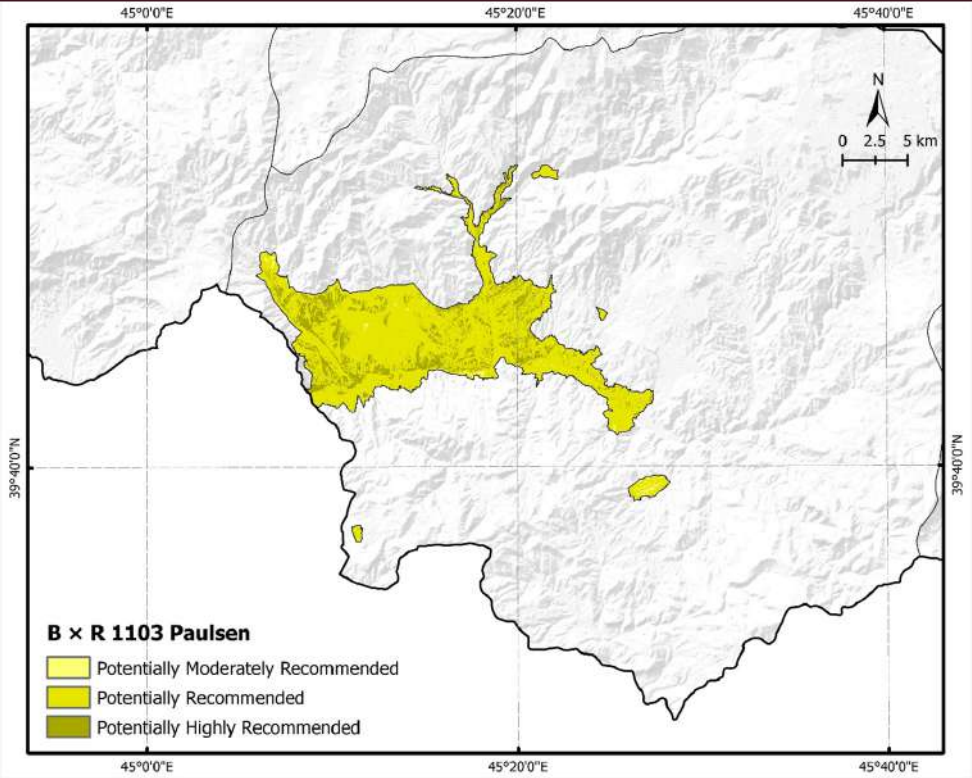
Approximately 6.51% of the territory belongs to the class of potentially moderately recommended areas. These terrains include soil and environmental conditions with certain limitations related to slope, erosion intensity, or soil physical properties, which may reduce the overall suitability of the 1103 Paulsen rootstock.

The potentially low recommended class occupies only 2.42% of the territory and includes areas with less favorable soil and topographic conditions for successful grapevine cultivation.

7.3. POTENTIAL SUITABILITY FOR THE VAYOTS DZOR GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Rupestris 1103 Paulsen rootstock within the Vayots Dzor grape production zone indicates highly favorable conditions for vineyard establishment (Map 31).

Map 31.



Classification of the territory of the Vayots Dzor Grape Production Zone based on potential suitability for vineyard planting with Berlandieri x Rupestris 1103 Paulsen rootstock

According to the results of spatial modelling and suitability classification, the largest share of the analyzed territory (80.35%) was classified as potentially recommended for vineyard planting with the 1103 Paulsen rootstock. These areas are mainly characterized by suitable topographic conditions, favorable soil depth, and environmental conditions appropriate for grapevine cultivation (Table 36).

Table 36. Spatial distribution of potential suitability classes for 1103 Paulsen rootstock in the Vayots Dzor Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Moderately Recommended	0.22	1.23
Potentially Recommended	14.58	80.35
Potentially Highly Recommended	3.34	18.42

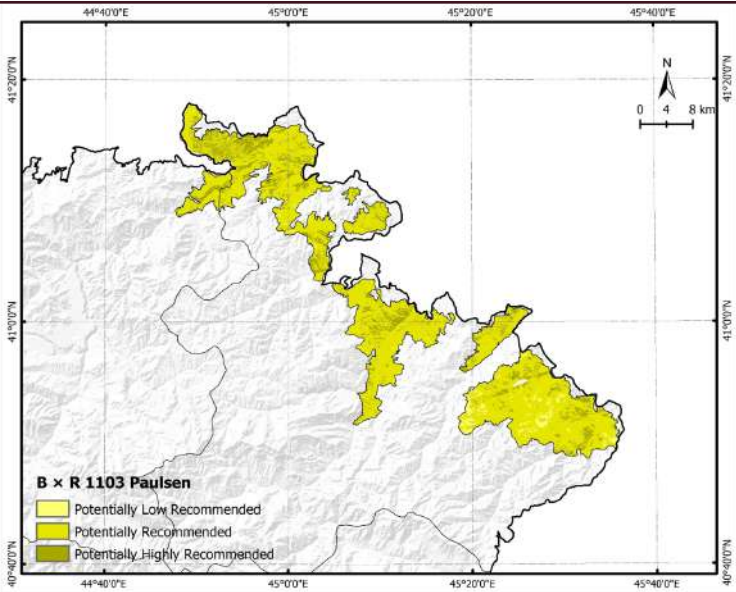
Additionally, 18.42% of the territory was classified as potentially highly recommended, representing the most favorable sites for vineyard establishment with this rootstock, particularly in areas with well-drained soil and conditions suitable for drought-tolerant rootstocks.

Only 1.23% of the territory belongs to the class of potentially moderately recommended areas, which include terrains with certain limitations related to soil depth, moisture regime, or terrain characteristics that may reduce the overall suitability of the 1103 Paulsen rootstock.

7.4. POTENTIAL SUITABILITY FOR THE TAVUSH GRAPE PRODUCTION ZONE

The suitability assessment of the Berlandieri × Rupestris 1103 Paulsen rootstock within the Tavush grape production zone indicates highly favorable conditions for vineyard establishment (Map 32).

Map 32.



Classification of the territory of the Tavush Grape Production Zone based on potential suitability for vineyard planting with Berlandieri x Rupestris 1103 Paulsen rootstock

According to the results of spatial modelling and suitability classification, the dominant share of the analyzed territory (79.28%) was classified as potentially recommended for vineyard planting with the 1103 Paulsen rootstock. These areas are characterized by suitable soil depth, balanced soil physical properties, and favorable topographic conditions for grapevine cultivation.

Additionally, 17.09% of the territory was classified as potentially highly recommended, representing the most favorable sites for vineyard establishment with this rootstock, particularly in terrains with well-drained soil and environmental conditions suitable for vigorous and drought-tolerant rootstocks (Table 37).

Table 37. Spatial distribution of potential suitability classes for 1103 Paulsen rootstock in the Tavush Grape Production Zone

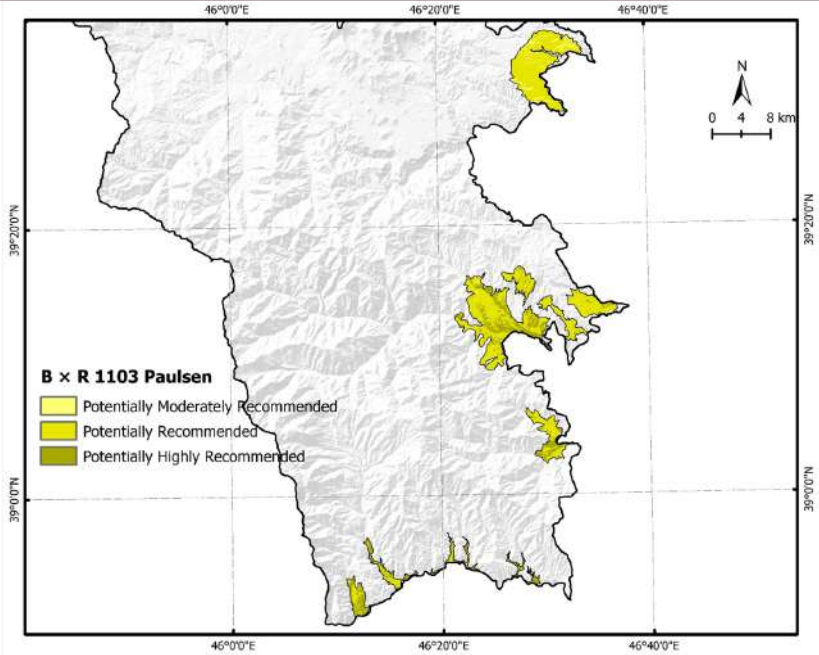
Suitability Class	Thousand (ha)	(%)
Potentially Moderately Recommended	2.33	3.63
Potentially Recommended	50.95	79.28
Potentially Highly Recommended	10.98	17.09

Only 3.63% of the territory belongs to the class of potentially moderately recommended areas. These terrains include soil and environmental conditions with certain limitations related to slope, erosion intensity, or soil moisture availability, which may reduce the suitability of the 1103 Paulsen rootstock under specific conditions.

7.5. POTENTIAL SUITABILITY FOR THE SYUNIK GRAPE PRODUCTION ZONE

The evaluation of the Berlandieri × Rupestris 1103 Paulsen rootstock in the Syunik grape production zone demonstrates very favorable conditions for vineyard establishment and successful grapevine cultivation (Map 33).

Map 33.



Classification of the territory of the Syunik Grape Production Zone based on potential suitability for vineyard planting with Berlandieri x Rupestris 1103 Paulsen rootstock

Spatial modelling and suitability classification showed that the dominant part of the Syunik grape production zone (73.98%) falls within the potentially recommended class for cultivation with the 1103 Paulsen rootstock. These areas generally include terrains with favorable ecological and soil conditions, especially well-drained soils and suitable topographic characteristics for vineyard establishment (Table 38).

Table 38. Spatial distribution of potential suitability classes for 1103 Paulsen rootstock in the Tavush Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Moderately Recommended	0.68	3.63
Potentially Recommended	13.90	73.98
Potentially Highly Recommended	4.21	22.39

A considerable proportion of the territory (22.39%) was identified as potentially highly recommended, indicating very suitable conditions for the use of this rootstock, particularly in sites adapted to vigorous grapevine growth and increased drought tolerance.

In contrast, only 3.63% of the analyzed area was classified as potentially moderately recommended. These locations are associated with certain environmental constraints, mainly related to terrain morphology, erosion susceptibility, and less favorable soil moisture conditions, which may locally limit the suitability of the 1103 Paulsen rootstock.



8

**SUITABILITY CLASSIFICATION AND
RECOMMENDATIONS FOR THE VINE ROOTSTOCK
BERLANDIERI X RUPESTRIS RUGGERI 140
IN THE GRAPE PRODUCTION ZONES OF ARMENIA**

8.1. GENERAL INFORMATION

SYNONYMS AND GENERAL NOTES

Synonyms include Ruggeri 140, 140 R, and 140 RU.

The rootstock was developed in Sicily by the breeder Antonio Ruggeri through crossing Berlandieri Resseguier No. 2 × Rupestris du Lot. It is widely distributed in Mediterranean viticultural regions.

SOME BOTANICAL CHARACTERISTICS

It is a very vigorous rootstock. This rootstock has strong vegetative potential. It develops a well-developed root system that penetrates deeper soil layers.

AGROBIOLOGICAL CHARACTERISTICS AND PRODUCTION VALUE OF ROOTSTOCK

Influence on scion vigor: It is a very vigorous rootstock that prolongs the vegetation period on more fertile soils.

Influence on berry set: It stimulates scion vigor and contributes to poorer berry set, which is particularly pronounced on more fertile soils.

Influence on ripening and grape quality: It has a long vegetation period, thereby delaying grape ripening.

Soils: It is suitable for dry, stony, and poor soils with high lime content. It absorbs potassium from the soil less efficiently and is not recommended for fertile and deep soils. It tolerates around 70% total lime and about 30% physiologically active lime in the soil and belongs to the group of rootstocks with good tolerance to lime-induced chlorosis. In more northern viticultural regions, its resistance to limestone decreases noticeably.

Resistance/sensitivity: It is resistant to root phylloxera and disease agents, satisfactorily tolerant to nematodes, but susceptible to leaf phylloxera. This rootstock is highly resistant to drought. Due to its high vigor, it should be grafted with low- to moderately vigorous varieties.

Table 39. Suitability of the rootstock Berlandieri x Rupestris Ruggeri 140 for soils with different characteristics and its susceptibility to deficiencies or excesses of the most important elements/microelements in the soil

Soil characteristics	Adaptability	Chemical element/ microelement in the soil	Susceptibility to deficiencies or excesses
Compact	medium	Deficiency of K	Poor sensitive
Wet	Very poor	Deficiency of Mg	Sensitive
Dry	Excellent	Deficiency of P	Poor sensitive
Stony (skeletal soils)	Excellent	Deficiency of Fe	Poor sensitive
Acidic	Good	Deficiency Zn	Sensitive
Saline	Good		

Table 40. Spatial distribution of potential suitability classes for Ruggeri 140 rootstock in the Ararat Valley Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Low Recommended	5.78	2.14
Potentially Moderately Recommended	18.80	6.96
Potentially Recommended	207.17	76.72
Potentially Highly Recommended	38.27	14.17

According to the results of spatial modelling and suitability classification, the largest share of the analyzed territory (52.46%) was classified as potentially recommended for vineyard plantinAdditionally, 14.17% of the territory was identified as potentially highly recommended, representing the most favorable sites for successful vineyard establishment with this rootstock, particularly in terrains with well-drained soil and suitable moisture and lime conditions.

Approximately 6.96% of the territory belongs to the class of potentially moderately recommended areas. These locations include terrains with certain environmental limitations related to slope, erosion intensity, or soil physical characteristics, which may reduce the suitability of the Ruggeri 140 rootstock.

Only 2.14% of the analyzed territory was classified as potentially slightly recommended, mainly including areas with less favorable soil and topographic conditions for successful grapevine cultivation.

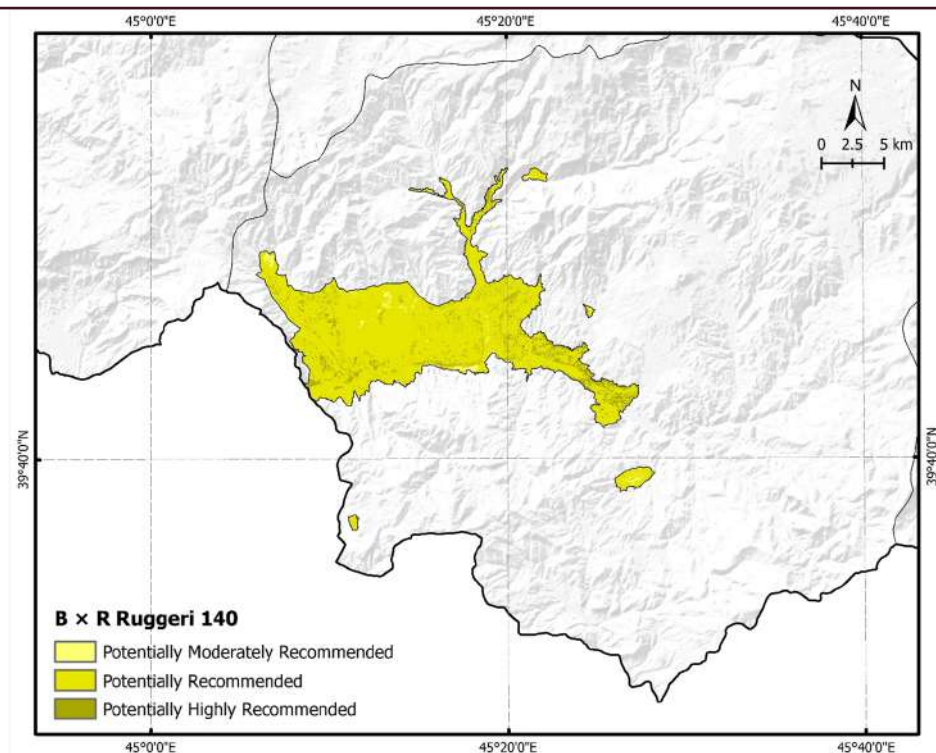
g with the Teleki 5C rootstock. These areas are characterized by relatively favorable topographic conditions, suitable soil depth, and balanced soil physical properties.

Approximately 45.28% of the territory belongs to the class of potentially moderately recommended areas. These terrains are mainly associated with steeper slopes, shallower or stonier soils, and certain limitations related to soil moisture availability and erosion intensity, which may reduce the suitability of this rootstock.

Only 1.71% of the territory was classified as potentially highly recommended, representing the most favorable sites for vineyard cultivation with the Teleki 5C rootstock. The potentially slightly recommended class occupies a very limited proportion of the territory (0.55%) and includes areas with less favorable environmental and soil conditions for successful grapevine cultivation (Table 23).

8.3. POTENTIAL SUITABILITY FOR THE VAYOTS DZOR GRAPE PRODUCTION ZONE

The spatial distribution of suitability classes indicates that the Berlandieri × Rupestris Ruggeri 140 rootstock is well adapted to the environmental conditions of the Vayots Dzor grape production zone (Map 35).



Classification of the territory of the Vayots Dzor Grape Production Zone based on potential suitability for vineyard planting with Berlandieri x Rupestris Ruggeri 140 rootstock

The largest proportion of the analyzed territory (87.53%) was classified as potentially recommended for vineyard establishment with the Ruggeri 140 rootstock. These areas are mainly characterized by suitable topographic conditions, balanced soil properties, and environmental conditions favorable for vigorous grapevine growth (Table 41).

Table 41. Spatial distribution of potential suitability classes for Ruggeri 140 rootstock in the Vayots Dzor Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Moderately Recommended	0.38	2.09
Potentially Recommended	15.89	87.53
Potentially Highly Recommended	1.88	10.38

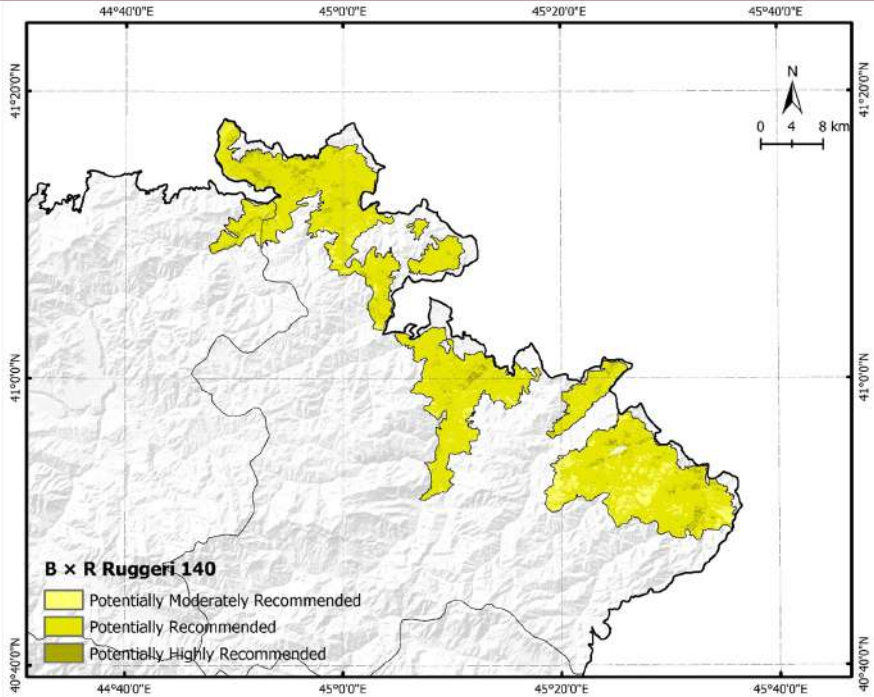
Additionally, 10.38% of the territory belongs to the potentially highly recommended class, representing the most suitable sites for cultivation with this rootstock, particularly in terrains with favorable drainage and conditions adapted to drought-tolerant rootstocks.

Only 2.09% of the analyzed territory was classified as potentially moderately recommended. These areas include terrains with certain limitations related to soil depth, slope, or local moisture conditions, which may reduce the overall suitability of the Ruggeri 140 rootstock.

8.4. POTENTIAL SUITABILITY FOR THE TAVUSH GRAPE PRODUCTION ZONE

The spatial distribution of suitability classes suggests that the Berlandieri × Rupestris Ruggeri 140 rootstock is well suited to the environmental conditions of the Tavush grape production zone (Map 36). The dominance of recommended areas indicates good adaptation of this rootstock to the prevailing soil and climatic characteristics of the region.

Map 36.



Classification of the territory of the Tavush Grape Production Zone based on potential suitability for vineyard planting with Berlandieri x Rupestris Ruggeri 140 rootstock

Most of the analyzed territory (84.69%) was classified as potentially recommended for vineyard establishment with the Ruggeri 140 rootstock. These areas are mainly associated with favorable soil depth, suitable drainage conditions, and balanced environmental characteristics supporting vigorous vine development.

Table 42. Spatial distribution of potential suitability classes for Ruggeri 140 rootstock in the Tavush Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Moderately Recommended	6.48	10.09
Potentially Recommended	54.42	84.69
Potentially Highly Recommended	3.35	5.22

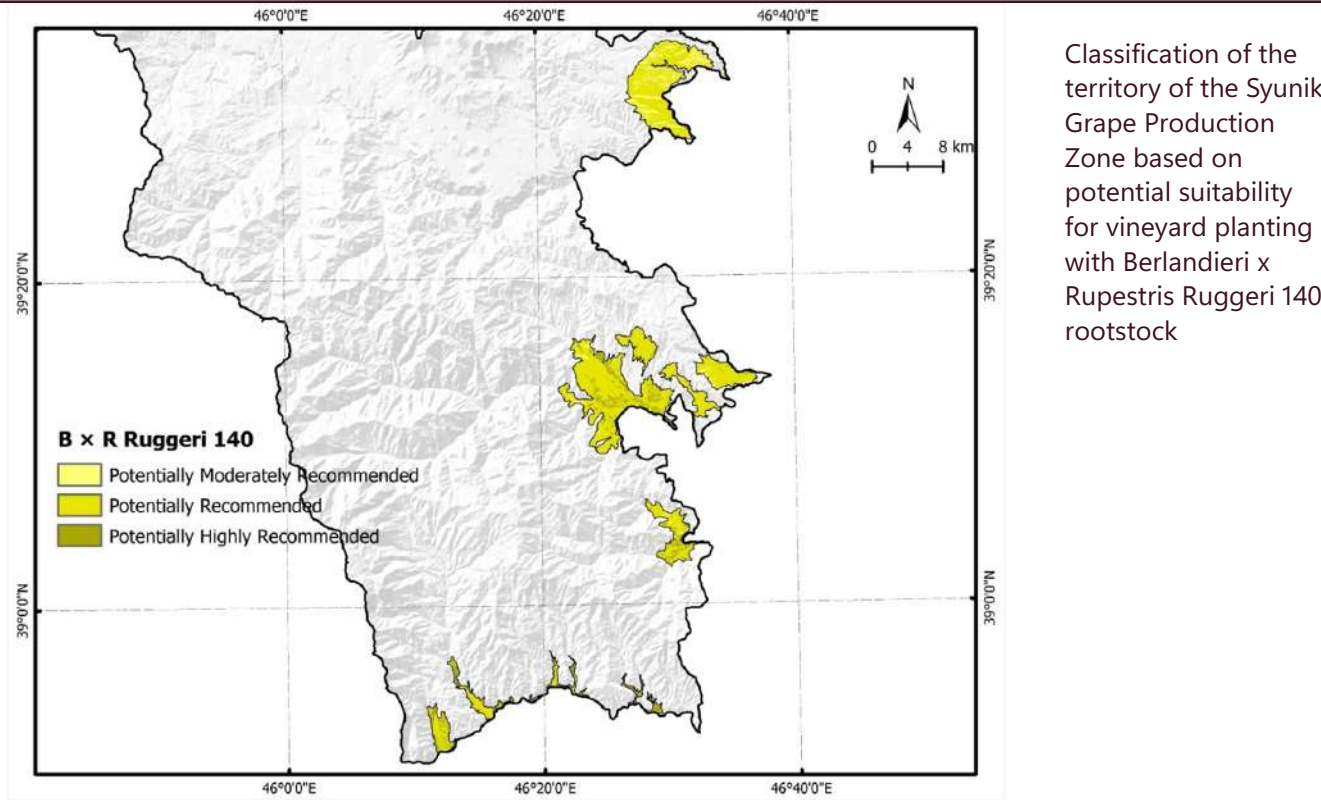
An additional 5.22% of the territory belongs to the potentially highly recommended class, representing the most favorable terrains for successful cultivation with this rootstock, particularly in locations with well-drained soils and conditions suitable for drought-tolerant vine rootstocks (Table 42).

Approximately 10.09% of the territory was classified as potentially moderately recommended. These areas include terrains with certain environmental constraints, such as less favorable slope conditions, increased erosion susceptibility, or local soil limitations that may reduce the overall suitability of the Ruggeri 140 rootstock.

8.5. POTENTIAL SUITABILITY FOR THE SYUNIK GRAPE PRODUCTION ZONE

The spatial distribution of suitability classes suggests that the Berlandieri × Rupestris Ruggeri 140 rootstock is well suited to the environmental conditions of the Tavush grape production zone (Map 37).

Map 37.



Most of the analyzed territory (84.69%) was classified as potentially recommended for vineyard establishment with the Ruggeri 140 rootstock. These areas are mainly associated with favorable soil depth, suitable drainage conditions, and balanced environmental characteristics supporting vigorous vine development (Table 43).

Table 43. Spatial distribution of potential suitability classes for Ruggeri 140 rootstock in the Syunik Grape Production Zone

Suitability Class	Thousand (ha)	(%)
Potentially Moderately Recommended	1.87	9.96
Potentially Recommended	14.62	77.83
Potentially Highly Recommended	2.29	12.21

An additional 5.22% of the territory belongs to the potentially highly recommended class, representing the most favorable terrains for successful cultivation with this rootstock, particularly in locations with well-drained soil and conditions suitable for drought-tolerant vine rootstocks.

Approximately 10.09% of the territory was classified as potentially moderately recommended. These areas include terrains with certain environmental constraints, such as less favorable slope conditions, increased erosion susceptibility, or local soil limitations that may reduce the overall suitability of the Ruggeri 140 rootstock.





CONCLUSION

The Viticulture Zoning of Grape Production Zones for GI Armenian Brandy Based on Vine Rootstocks represents a scientifically grounded and practically oriented contribution to the long-term development of viticulture in Armenia, particularly within the framework of the future Geographical Indication Armenian Brandy. Its main value lies in the integration of terroir analysis, GIS-based spatial modelling, rootstock biology and phytosanitary risk considerations into a single decision-support framework. In this sense, the zoning is not only a technical mapping document, but also a strategic tool for vineyard planning, adaptation to environmental constraints, and protection of Armenia's viticultural heritage.

The study confirms that the grape production zones of Armenia are characterized by substantial spatial variability in topographic and soil conditions. Elevation, slope, aspect, soil depth, texture, stoniness, erosion risk, calcium carbonate content, pH, humus and nutrient status all influence the suitability of specific vine rootstocks. Therefore, the results clearly demonstrate that rootstock selection cannot be approached uniformly across the country. Instead, it must be adapted to local conditions at the level of grape production zones, wine-growing areas and, where possible, individual vineyard parcels.

The methodological framework applied in the zoning combining GIS analysis, Standard Scoring Functions, Bayesian Network Analysis and rootstock-specific suitability modelling provides a robust basis for identifying the most appropriate rootstocks for different production environments. By transforming heterogeneous environmental data into comparable suitability classes, the zoning enables a clearer understanding of where each rootstock may perform best and where caution is required. This is particularly important for Armenia, where many vineyards are still traditionally cultivated on their own roots and where the potential spread of phylloxera represents a serious long-term risk.

The analysis shows that the Ararat Valley, Tavush, Vayots Dzor and Syunik grape production zones each have distinct suitability patterns. In general, the Ararat Valley shows broad suitability for several rootstocks due to its favourable combination of terrain and soil conditions. Tavush also demonstrates significant potential, particularly where moisture availability and soil depth are favourable. Vayots Dzor, because of its more complex relief, higher elevations and more limiting soil conditions, requires more careful rootstock selection. Syunik grape production zone shows considerable potential in selected areas, but its strong topographic gradients and heterogeneous soils require site-specific evaluation.

The results also indicate differences between rootstock groups. Rootstocks such as Berlandieri × Riparia Kober 5BB, Teleki 5C and 420A are generally more suitable for deeper, moderately moist and fertile soils, but may be less appropriate in areas exposed to prolonged drought, shallow soils or stronger terrain limitations. Riparia × Rupestris 3309 C requires caution and more precise site selection, especially where soils are dry, shallow, heavy or affected by specific chemical limitations. In contrast, Berlandieri × Rupestris 1103 Paulsen and Berlandieri × Rupestris Ruggeri 140 show strong potential across several Armenian grape production zones, particularly in warmer, drier, well-drained and calcareous or stony conditions, making them especially relevant for future vineyard resilience and climate adaptation strategies.

From a practical perspective, the zoning provides guidance for new vineyard establishment, vineyard restructuring, selection of certified planting material and preparation of phytosanitary response strategies in the event of further phylloxera spread. However, the maps and recommendations should not be interpreted as a substitute for field verification. Before final rootstock selection, local soil analysis, parcel-level inspection, water availability assessment, variety–rootstock compatibility and production objectives must also be taken into account.

The zoning also has broader institutional and policy relevance. It can support the Ministry of Economy, the Vine and Wine Foundation of Armenia, phytosanitary services, certification bodies, nurseries, producers and investors in making more informed decisions. Within the future GI Armenian Brandy system, it can contribute to more stable grape production, better adaptation of vineyards to terroir conditions, improved sustainability, and stronger protection of the raw material base that underpins the quality and typicity of Armenian Brandy.

In conclusion, this zoning establishes a scientifically based spatial foundation for rootstock selection in Armenia's grape production zones. It strengthens the link between terroir, vineyard resilience, phytosanitary preparedness and the future GI system. By providing clear maps, suitability classifications and practical recommendations, the zoning supports Armenia in preparing for future challenges while preserving its unique viticultural resources, traditional grape varieties and the long-term identity of Armenian Brandy.

