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EFFICIENT USE OF AGRICULTURAL LAND IN THE CURRENT CONTEXT OF CLIMATE CHANGE. CASE STUDY: RECAȘ (TIMIȘ COUNTY)

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Abstract

The study analyzes the efficiency of vineyard land use in the Recaș Wine Center (Timiș County) over the last decade, under the influence of accelerating climate change. Using climate data from 2013–2022 and local agrometeorological observations, recent trends of warming, aridization, and increased frequency of extreme events—droughts, heat waves, late frosts, and hailstorms—are highlighted. The main soil types in the area (preluvosols, eutric cambisols, chernozems, and weakly gleic soils) ensure a high natural suitability for viticulture, generally classified in creditworthiness classes I–II when optimal management practices are applied.

Land-use efficiency was evaluated based on grape yields (t/ha) recorded for five representative varieties—Cabernet Sauvignon, Merlot, Pinot Noir, Fetească Neagră, and Chardonnay—during two contrasting years: 2023 (cool, rainy spring and balanced summer) and 2024 (severe drought and extreme summer temperatures). Results indicate yield reductions of 20–30% in 2024, particularly for drought-sensitive red varieties, emphasizing the vulnerability of the viticultural system to water deficits in the absence of irrigation.

The findings are discussed in relation to soil productive potential and compared with studies documenting climate-induced yield fluctuations in European viticulture. Existing adaptation strategies in Recaș—canopy management, crop load regulation, inter-row mulching and grassing, night harvesting, and digital monitoring—are assessed alongside future measures such as drip irrigation, diversification with drought- and heat-tolerant varieties, and the use of oenoclimatic indices in vineyard planning.

Overall, the study concludes that sustainable vineyard management increasingly requires not only the optimization of yields and quality but also the long-term protection of soil and water resources under rapidly evolving climatic conditions.

Key words: Climate change, economic efficiency, Recaș Wine Center, soil fertility, sustainability

INTRODUCTION

Climate change is currently one of the main factors putting pressure on agricultural systems globally, influencing both productivity and agricultural land use stability (IPCC, 2021; Metz et al., 2007; Pielke Jr., 2004; Berrang-Ford et al., 2011). The increase in average temperatures, the change in rainfall patterns and the intensification of extreme phenomena lead to significant changes in crop structure, production levels and risks associated with soil degradation and water resources (National Research Council, 2004; FAO, 2018).

At the European level, numerous studies highlight the transformations of land use and agriculture under the influence of climate change and sectoral policies (Rabbinge and Van Latesteijn, 1992; Rabbinge and Van Diepen, 2000; Ewert et al., 2005). Wine-growing regions are particularly sensitive to climatic variations, as vines are a perennial crop, and the quality of the wine reflects the microclimate and soil conditions finely (Basso, 2018; Basso, 2019; Vlahos, 2020). The change in the thermal and rainfall regime determines the displacement of the optimal areas for different varieties, the change of the phenological calendar and the need to adapt cultivation technologies in order to preserve the identity and competitiveness of wine products.

In Central and Eastern Europe, viticulture has experienced both conversion and expansion processes in recent decades, as well as pressures on land use, including through urbanization, fragmentation of ownership and intensification of competition between agricultural and non-agricultural uses (Artamonova et al., 2020; Rozum et al., 2017; Volkov and Fomin, 2018). Agricultural land use efficiency indicators are at the heart of debates on the sustainability of agricultural systems and their capacity to adapt to climate change (Popescu et al., 2019; Kalisz et al., 2023).

In Romania, the adaptation of agriculture to climate change is analyzed both at the level of public policies and through regional case studies (Mateescu, 2007; Tudor, 2014; Climate-ADAPT, 2021; Change, 2022). The west of the country, including Timiș County, is characterized by a special agricultural potential, but also by an increased vulnerability to drought and extreme weather phenomena, accentuated in recent years (Dologa et al., 2013; ANM, 2013–2022).

The Recaș wine-growing area stands out in the agricultural landscape of Banat through tradition, compact vineyard areas and a high pedoclimatic potential for the production of quality wines (Okros et al., 2012; Boc et al., 2017; Mihuț et al., 2023). Pedological studies show that the soils in the Recaș wine-growing center – preluvosols, eutricbosols, chernozems and coluvial/alluvial soils – fall into higher classes of favorability for vines, with increased production capacity under conditions of correct technology (Okros et al., 2012; Hreniuc et al., 2022). From a climatic point of view, Banat benefits from a thermal regime and solar radiation favorable to the ripening of quality red and white grapes, but rainfall variability and episodes of severe drought have become increasingly frequent (Costea et al., 2019; Istrate et al., 2019; Dobrei et al., 2023).

Viticulture in western Romania has been analyzed in the context of climate change both from the perspective of local genetic resources and the typicity of wines (Dobrei et al., 2015a) and from the perspective of sustainability-oriented agrotechnical practices – tillage of the soil, inter-row grassing, conservation of organic matter (Dobrei et al., 2015b; Tehnologii-Viticole.ro, 2020). Recent research also highlights the role of local microclimates and cultivation technologies in modulating the climate impact on grape production and quality (Dobrei et al., 2023; Ungureanu, etc.).

In this context, the present paper aims to analyze the efficiency of the use of vineyard land in the center of Recaș in the conditions of recent climate change, by integrating pedoclimatic information, production data for five representative varieties and adaptation strategies applied at farm level. The specific objectives are: synthetic characterization of local climate trends (2013–2022) relevant to viticulture; assessing the impact of 2023 and 2024 on grape production and land use; Discuss adaptation measures and sustainable management directions that can maintain land use efficiency in conditions of high climate variability.

MATERIAL AND METHOD

Study area

The Recaș Wine Center is located in the central-western part of Timiș County, at the contact between the Lipova Hills and the Banat Plain, at about 45°N. The gentle hilly relief (altitudes of 100–200 m) with moderate slope and favorable exposures ensures a good radiation balance for the vine crop (Boc et al., 2017; Ungureanu, etc.). From a climatic point of view, the area is classified in a moderate temperate-continental climate with sub-Mediterranean influences: the average annual temperature is around 10.5–11°C, and the average annual rainfall is around 600 mm, with 300–400 mm during the growing season (ANM, 2013–2022; Costea et al., 2019).

The dominant soils are preluvosols and eutricbosolsols on slopes and interfluviums, chernozems and colluvial/alluvial soils in lower areas, as well as soft gleiosols in poorly drained microdepressions (Okros et al., 2012; Dologa et al., 2013; Hreniuc et al., 2022). Local soil analyses indicate clay-clay textures, moderate humus content (2–3.5%), neutral-low alkaline pH and good reserves of macroelements in well-maintained plantations. Recaș falls into classes I–II of creditworthiness for vines, with a high productive potential (Okros et al., 2012; Mihuț et al., 2023).

Climatic and agrometeorological data

For the characterization of local climate change, the following were used: the 2013–2022 annual series from the Timișoara Meteorological Station (ANM, 2013–2022), the nearest station with complete records and agrometeorological observations and extreme events recorded at the level of the Recaș wine center.

Parameters such as: average annual temperature, annual rainfall, number of tropical days (Tmax ≥30°C), number of frost days, as well as the frequency of drought episodes and extreme phenomena (heat waves, late frosts, hail) were analyzed. To characterize the climate favorability, oenoclimatic indices (helio-thermal index, aridity index, Huglin index) were used, calculated according to the Teodorescu methodology and adapted to local conditions (Okros et al., 2012; Dobrei et al., 2023).

Wine production data

The efficiency of the use of the vineyard land was evaluated based on the grape yields (t/ha) recorded in 2023 and 2024 for five representative varieties: Cabernet Sauvignon, Merlot, Pinot Noir, Fetească Neagră and Chardonnay. The year 2023 was characterized by a cold and rainy spring followed by a relatively balanced summer, and 2024 by severe drought and high summer temperatures. The analyzed productions correspond to the harvest at optimal technological maturity, being accompanied by observations on the phytosanitary status and quality of the grapes (°Brix, acidity).

Based on these data, Table 1 was elaborated, and the comparative graphical representation 2023 vs. 2024 is illustrated in Figure 1.

Table 1.

Grape yields (t/ha) for the main varieties grown in the Recaș wine center (2023–2024)

Oneself	2023 (t/ha)	2024 (t/ha)	Schimbare (%)
Cabernet Sauvignon	13.0	10.0	-23.1
Merlot	11.0	8.5	-22.7
Pinot Noir	11.0	8.0	-27.3
Fetească Neagră	10.5	7.5	-28.6
Chardonnay	12,5	10.0	-20.0

Methods of analysis and evaluation of land use efficiency

Datele climatice și de producție au fost prelucrate statistic (medii, abateri, procente de subtraction) using simple tools (Excel, Python), and the results were graphically represented.

The efficiency of the use of vineyard land was assessed by: comparing the actual yields with the estimated potential of the soils under favorable conditions (Okros et al., 2012; Mihuț et al., 2023), reporting local trends to similar studies on the efficient use of agricultural and vineyard land (Artamonova et al., 2020; Popescu et al., 2019; Kalisz et al., 2023; Basso, 2019; Vlahos, 2020), the analysis of adaptation strategies and sustainable management practices applied to Recaș, based on discussions with winegrowers and the literature on sustainable viticulture and climate-smart agriculture (FAO, 2018; Dobrei et al., 2015a; Dobrei et al., 2015b; Tehnologii-Viticole.ro, 2020).

RESULTS AND DISCUSSIONS

1. Recent climate trends in the Recaș area (2013–2022)

The analysis of the climate series confirms for western Romania a trend of increasing the average annual temperature by approximately 0.7–0.9°C compared to the reference period 1981–2010, at the same time as a marked variability of the rainfall regime (figures 1, 3, 4 and 4). In Banat, the years 2015, 2019 and 2022 were noted by positive thermal deviations and frequent heat waves, while 2014 and 2016 were rainier than average, with annual rainfall totals exceeding 700 mm (ANM, 2013–2022; Costea et al., 2019).

In the Recaș area, these trends have materialized by: the increase in the number of tropical days (Tmax ≥30°C) in July-August; the alternation of years with pronounced atmospheric and pedological drought (2012, 2015, 2022) with years with episodes of torrential rains and temporary puddles; the appearance of late spring frosts in several years of the last decade, with effects on young shoots.

Figure 1 shows the gradual increase in the average annual temperature in the Recaș area, from 10.7°C in 2013 to over 12°C in 2022, confirming the regional warming trend. Precipitation shows a marked variability (Figure 2), alternating between rainy years (2014, 2016, 2020) and severely dry years (2015, 2021, 2022). The Huglin index (Figure 3), a climatic indicator of viticultural suitability, increases visibly from ~1640 to 1900, suggesting an increasingly warm climate, suitable for thermophilic varieties.

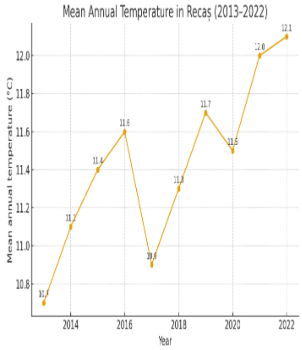

Figura 1. Mean Annual Temperature (2013–2022)

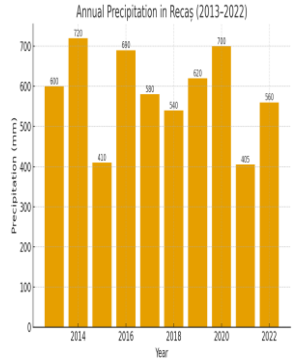

Figura 2. Annual Precipitation (2013–2022

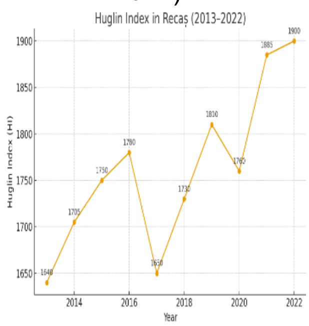

Figura 3. Huglin Index (2013–2022)

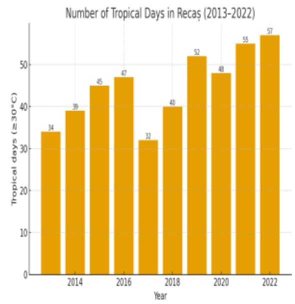

Figura 4. Number of Tropical Days ≥30°C

The number of tropical days (≥30°C) has increased steadily over the past decade (Figure 4), exceeding 55 days in 2021–2022, which amplifies heat stress on wine crops.

These results are in line with the IPCC projections on the amplification of extreme events in Central and Eastern Europe and with the studies on viticulture in Romania, which signal increased risks of drought and hail (IPCC, 2021; Mateescu, 2007; Istrate et al., 2019; Dobrei et al., 2023). At the same time, the helio-thermal index and the Huglin index maintain favorable or very favorable values for the ripening of quality grapes, which confirms the high viticultural potential of Banat, but also the need for continuous adaptation to an increasingly unstable climate.

2. Impact of climatic conditions on wine productions (2023 vs. 2024)

The grape yields obtained in the five varieties analysed clearly highlight how extreme climatic variability influences the efficiency of vineyard land use (Table 1, Figure 1).

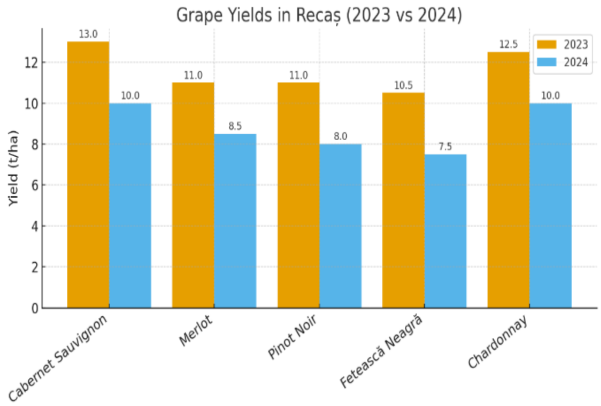

Figura 1. Grape yields in Recaș vineyard centre (2023 vs. 2024)

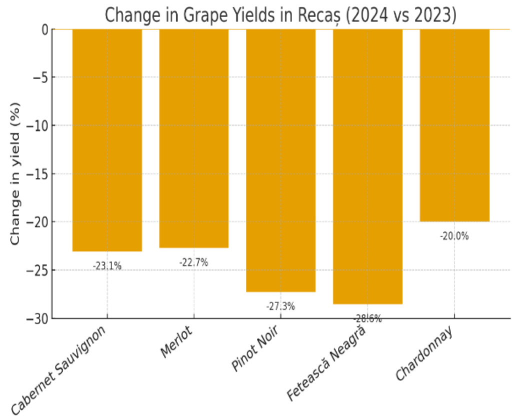

Figure 2. The percentages of decrease in grape productions in 2024 compared to 2023 for the main varieties grown in the Recaș wine center.

In 2023, the cold and rainy spring slightly delayed phenology, but good soil water reserves and a relatively balanced summer allowed yields close to the maximum potential estimated for class I–II soils (Okros et al., 2012; Mihuț et al., 2023). Yields ranged from 10.5–13 t/ha for red varieties and 12.5 t/ha for Chardonnay, with an average of about 11.6 t/ha.

In 2024, the prolonged drought and very high temperatures in the July-August period led to significant decreases in production, on average by 20–30% compared to 2023. The largest relative reduction was recorded for Feteasca Neagră (–28.6%) and Pinot Noir (–27.3%), varieties more sensitive to water scarcity, while Chardonnay and Cabernet Sauvignon were slightly more resistant (–20.0% and –23.1%). The general average of productions decreased to about 8.8 t/ha.

Figure 2 highlights the percentage of decrease in production in 2024 compared to 2023, for the five varieties analyzed. The values displayed on each bar allow for a clear observation of the differences between varieties in terms of sensitivity to severe water and heat stress in 2024.

It can be seen that all the analyzed varieties registered decreases of more than 20%. The most affected were Fetească Neagră (-28.6%) and Pinot Noir (-27.3%), suggesting a high vulnerability to extreme drought and very high temperatures in the summer of 2024.

Cabernet Sauvignon and Merlot show similar declines (approx. -23%), while Chardonnay had the smallest relative loss (-20%), probably due to the earlier ripening period. These results confirm the strong impact of water scarcity on yields, but also the differences in the behavior of varieties in extreme climatic conditions.

Overall, all varieties recorded losses of more than 20%, which indicates that, in extreme drought conditions, the efficiency of the use of vineyard land decreases significantly, even in areas with class I–II soils of creditworthiness.

These results are comparable to the 20–30% decreases reported in other European wine regions in dry years (Basso, 2019; Costea et al., 2019; Vlahos, 2020) and confirms that the major limiting factor for Recaș today is water, more than temperature. In the absence of irrigation, the actual productions are at 60–80% of the area's soil potential in dry years, which corresponds to a suboptimal use of the vineyard land.

From a qualitative point of view, in 2024 water stress caused an increase in sugar concentrations and a decrease in total acidity in the must, with implications on the sensory profile of wines (higher alcoholic strength, lower acidity). Similar trends are reported for other Romanian and European vineyards in the context of global warming (Dobrei et al., 2015a; Costea et al., 2019; FAO, 2018).

3. Efficiency of land use in the context of climate change

The concept of land use efficiency includes both the quantitative dimension (production per unit area) and the qualitative dimension and resource sustainability (Artamonova et al., 2020; Rozum et al., 2017; Popescu et al., 2019; Kalisz et al., 2023). In the case of Recaș, efficiency is the result of the interaction between: high natural potential (fertile soils, favorable microclimate); increasing climatic pressures (drought, extreme events); level of technology and adaptation of cultivation practices (Photo 1).

Photo 1. Imagini din Centrul Viticol Recaș (Timiș)

Comparing actual yields with the potential of 12–14 t/ha for red varieties and 10–12 t/ha for white varieties (Okros et al., 2012) indicates almost optimal land use in favourable years (2023) but reduced efficiency in extremely dry years (2024). This variability is similar to the results achieved in other European agricultural systems, where climate change scenarios predict alternating years of high yields and celor cu pierderi considerabile (Ewert et al., 2005; Rabbinge și Van Diepen, 2000).

4. Adaptation strategies and sustainable management practices at Recaș

The case study and the literature consulted highlight a set of adaptation measures already applied or planned in the Recaș wine center, grouped into four main directions:

a) Adaptation of viticultural practices and cultivation technology

Includes optimization of harvest time according to technological maturity, foliage management (controlled defoliation or maintenance of leaves for shading in hot summers), normalization of fruit load in dry years, higher forms of conduction of the stumps, controlled grassing and inter-row mulching for water conservation and soil protection (Dobrei et al., 2015b; Tehnologii-Viticole.ro, 2020; Dobrei et al., 2023).

b) Water management: conservation and complementary irrigation

Until recently, viticulture in Recaș was predominantly unirrigated, but the intensification of drought justifies the introduction of drip irrigation and climate-smart agriculture practices (FAO, 2018; Climate-ADAPT, 2021). Rescue irrigation in extremely dry summers, combined with grassing and increasing the organic matter content in the soil, can stabilize yields without compromising quality.

c) Adaptation of genetic material

Two directions are outlined: the introduction of varieties and rootstocks that are more resistant to drought and heat (Syrah, Tempranillo, Marselan, etc.) and the selection of locally adapted clones of Romanian varieties (Fetească Neagră, others), maintaining the typicality of the wines (Dobrei et al., 2015a; Dobos, 2022). Assortment decisions must be linked to the anticipation of climate change over the lifetime of the plantations (20–30 years).

d) Digital monitoring and precision viticulture

The implementation of humidity sensors, local weather stations and phenological models allows the transition from reactive to pro-active, data-driven management (Istrate et al., 2019; FAO, 2018). The mechanized night harvesting, already used in Recaș, is an example of technological adaptation to protect the quality of the grapes on hot days.

A summary of the main adaptation measures is given in Table 2.

These measures are in line with the recommendations of FAO (2018), IPCC (2021) and other authors on the transition to sustainable and resilient agricultural and viticultural systems (Berrang-Ford et al., 2011; Mateescu, 2007; Vlahos, 2020).

Table 2.
Recommended adaptation measures for the efficient use of vineyards in Recaș

Direction	Concrete measure	Expected effect
Viticultural practices	Normification of fruit load, controlled defoliation, higher forms of conduction	Reducing plant stress, improving grape quality
Water management	Controlled grassing, mulching, drip irrigation in dry years	increasing the water reserve in the soil, stabilizing yields
Material genetic	Introduction of drought-resistant varieties/rootstocks, adapted clonal selection	increasing the resilience of plantations in the long term
Modern technologies	Sensors, local weather stations, night harvesting, phenological models	optimizing the timing of interventions and harvesting, reducing risks

CONCLUSIONS

Climate change is already having measurable effects on viticulture in Recaș. The increase in average temperatures, the higher frequency of hot days and the alternation of dry and rainy years determine a high variability of productions, especially in the absence of irrigation.

The efficiency of the use of vineyard land is strongly dependent on the water factor. In favorable years, the productions approach the pedological potential of class I–II soils, and the quality of the wines is high. In extremely dry years (2024), yields drop by 20–30%, and the quality of the grapes changes (more sugar, lower acidity), which affects both the profitability and the sensory profile of the wines.

Adaptation through technology and management is possible and necessary. Measures such as load regulation, foliage management, grassing and soil mulching, night harvesting and the use of local weather sensors and stations help to maintain land use efficiency, even in difficult climatic conditions.

Decisions regarding water assortment and infrastructure must be seen in the long term. The introduction of more drought-resistant varieties and rootstocks, the expansion of supplementary irrigation systems and the increase of organic matter content in the soil are essential investments to preserve the productive potential of Recaș in the coming decades.

Agricultural land use efficiency in the context of climate change must be understood as adaptive efficiency. It is not enough to maximize production in a single year; The ability of the wine system to maintain, in the long term, stable productions and quality wines, without degradation of soil and water resources, is essential. This study shows that viticulture in Recaș can become an example of good practice in this regard, by combining tradition with innovation and data-driven management.

REFERENCES

Artamonova, I., Baturina, I., Mikhajluk, O., Poverinova, E. (2020). Improving methodologies for assessing the efficiency of agricultural land use. In *Ecological-Socio-Economic Systems: Models of Competition and Cooperation (ESES 2019)* (pp. 121–124). Atlantis Press.

Basso, M. (2018). From everyday land use practice to a global phenomenon: The origin and recent evolution of the Prosecco wine landscape (Italy). *Miscellanea Geographica – Regional Studies on Development*, 22(2), 109–115.

Basso, M. (2019). Land use changes triggered by the expansion of wine-growing areas: A study of municipalities in the Prosecco production zone (Italy). *Land Use Policy*, 83, 390–402.

Berrang-Ford, L., Ford, J. D., Paterson, J. (2011). Are we adapting to climate change? *Global Environmental Change*, 21(1), 25–33.

Boc, A. R. D., Dobrei, A., Dobrei, A. G. (2017). The natural potential and the suitability for the grapevine growing of Buziaș, Recaș and Miniș areas.

Change, C. (2022). *Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the IPCC.*

Climate-ADAPT (EEA). (2021). *Climate change adaptation measures in Romanian agriculture – Case study.*

Consiliul Național de Cercetare (USA). (2004). *Implementing Climate and Global Change Research: A Review of the Final U.S. Climate Change Science Program Strategic Plan.*

Costea, M., Lengyel, E., Stegăruș, D., Rusan, N., Tăușan, I. (2019). Assessment of climatic conditions as determinants of wine aromatic compounds: A case study from central Romania. *Theoretical and Applied Climatology*, 137(1), 239–254.

Dobos, Anna Richárd Nagy, Ádám Molek (2014): Land use changes in a historical wine region and links to optimal land use: A case study from Nagy-Eged Hill, northern Hungary. *Carpathian Journal of Earth and Environmental Sciences*, 9(2), 219–230.

Dobrei, A., Dobrei, A. G., Nistor, E., Iordanescu, O. A., Sala, F. (2015a). Local grapevine germplasm from western Romania – an alternative to climate changes and a source of typicity and authenticity. *Agriculture and Agricultural Science Procedia*, 6, 124–131.

Dobrei, A., Nistor, E., Dobrei, A. (2015b). Soil tillage practices in the context of climate change and sustainable viticulture. *Notulae Scientia Biologicae*, 7(4), 500–504.

Dobrei, A., Nistor, E., Daniela, S., Dobrei, A. G. (2023). Local microclimates and climate changes influence on cultivation techniques, grapevine production and quality. *International Multidisciplinary Scientific GeoConference: SGEM*, 23(4.1), 307–316.

Dologa, D., Dicu, D., Iliuță, A. (2013). Pedological factors and local particularities of Timiș County.

Dumitrașcu, M. F. (2015). Trends in the evolution of viticulture in the process of European integration. In *Proceedings of the International Conference on Agrifood and Environmental Economics Competitiveness* (pp. 273–278). ASE București.

Ewert, F., Rounsevell, M. D. A., Reginster, I., Metzger, M. J., Leemans, R. (2005). Future scenarios of European agricultural land use. I. Estimating changes in crop productivity. *Agriculture, Ecosystems & Environment*, 107(2–3), 101–116.

FAO. (2018). *Climate-Smart Agriculture Sourcebook.*

Hreniuc, D., Laichici, D., Varga, R., Okros, A., Mihuț, C. (2022). Soil preparability in the Recaș vineyard centre for vineyards.

IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the IPCC.*

Istrate, V., Ursu, A., Dobri, R. V., Axinte, A. D., Stoica, D. (2019). Hail suppression system in Romania and its relation with land cover. In *SGEM 2019 Conference Proceedings* (Vol. 19, pp. 871–878).

Istudor, N., Chira, R., Ciocan, R. (2012). Efficient measures for agricultural land consolidation in Romania. *Economics of Agriculture*, 59(Special Issue), 15–22.

Kalisz, B., Żuk-Gołaszewska, K., Radawiec, W., Gołaszewski, J. (2023). Land use indicators in the context of land use efficiency. *Sustainability*, 15(2), 1106.

Mateescu, E. (2007). Agriculture and climate change: How to reduce human effects and threats. Romania’s contribution and future steps. *The Parliament Magazine*, EU ACCRETe Project, Dec. 2007, 76–77.

Metz, B., Davidson, O. R., Bosch, P., Dave, R., Meyer, L. (Eds.). (2007). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the IPCC.*

Mihuț, C., Copcea, A. D., Niță, L., Okros, A., Niță, S., Popa, D., Sîrbu, C. (2023). Economic efficiency of soils in Banat vineyards. *Scientific papers. Seria A. Agronomy*, 66(2).

National Meteorological Administration (ANM). (2013–2022). Archived climatic data, Timișoara station.

Okros, A., Mihuț, C., Niță, L. D. (2012). Yield capacity of the soils in Recaș viticulture centre, Timiș County. *Research Journal of Agricultural Science*, 44(3), 95–101.

Pielke Jr, R. A. (2004). What is climate change? *Energy & Environment*, 15(3), 515–520.

Popescu, A., Dinu, T. A., Stoian, E. (2019). Efficiency of agricultural land use in the European Union.

Rabbinge, R., Van Diepen, C. A. (2000). Changes in agriculture and land use in Europe. *European Journal of Agronomy*, 13(2–3), 85–99.

Rabbinge, R., Van Latesteijn, H. C. (1992). Long-term options for land use in the European Community. *Agricultural Systems*, 40(1–3), 195–210.

Rozum, R. I., Liubezna, I. V., Kalchenko, O. M. (2017). Improving the efficiency of agricultural land use. *Naukovyi Visnyk Polissia*, 1(3(11)), 193–196.

Tehnologii-Viticole.ro. (2020). Proiect „Tehnologii viticole durabile”.

Tudor, M. M. (2014). Land resource use in agriculture – opportunity or risk for the competitiveness of the Romanian agri-food sector. *Procedia Economics and Finance*, 8, 720–728.

Ungureanu, M. *The wine tourism potential of Recaș town.* In *Geography for Society*.

Vlahos, G. (2020). Impact of agricultural system transformation on the landscape: A case study on quality wine production in a highly contested agricultural landscape. *Land*, 9(4), 120.

Volkov, S. N., Fomin, A. A. (2018). Ensuring effective regulation of land relations and efficient use of agricultural land. *International Agricultural Journal*, (3), 64–71.