EXPERIMENTAL MODEL FOR THE STUDY OF AN INTEGRATED SYSTEM BASED ON CONSERVATIVE AND CONVENTIONAL VITICULTURE UNDER CHANGING CONDITIONS OBSERVED IN THE SPECIFICS OF BUJORU VINEYARD MICROCLIMATE

MODEL EXPERIMENTAL PENTRU STUDIUL UNUI SISTEM INTEGRAT BAZAT PE VITICULTURĂ CONSERVATIVĂ ȘI CONVENȚIONALĂ ÎN CONDIȚIILE MODIFICĂRILOR OBSERVATE LA MICROCLIMATUL SPECIFIC PODGORIEI BUJORU

TUDOR Mihai[1*], TABARANU Gabriel[1], ENACHE Viorica[1], POTÎRNICHE Ștefan[1], FERȚU Ionela-Daniela [2*]

*Corresponding author e-mail: farm.tudor@gmail.com/danafertu2004@yahoo.com

Abstract.
The study aims to identify and implement measures for soil fertility preservation; soil water evolution, dependent on soil preparation and maintenance works; optimize administered fertilizer doses commonly used in vineyard plantations; reduce soil structure degradation processes; increase productivity and reduce expenses at the vineyard farm level. It also aims to develop conservative viticultural methods (circular economy, green, minimum tillage, no-till), which will provide solutions to limit anthropogenic degradation of vineyard soils but also to increase plantation productivity and reduce environmental risks.
Key words: conservative viticulture, microclimate, soil degradation

Rezumat.
Studiul își propune identificarea şi implementarea unor măsuri de conservare a fertilității solului; cuantificarea evoluției apei în sol, în funcție de lucrările de pregătire și întreținere a solului; optimizarea dozelor de îngrășăminte administrate plantaţiilor viticole; reducerea proceselor de degradare a structurii solurilor; creșterea productivității și reducerea cheltuielilor la nivel de fermă viticolă. De asemenea, se urmărește şi elaborarea unor metode viticulturale conservative (economie circulară, verde, minimum tillage, no-till), care să ofere soluții privind limitarea degradării antropice a solurilor

[1] Bujoru Viticulture and Winemaking Research and Development Station, Gral Eremia Grigorescu Street, 805200Tg.Bujor, Galati, Romania
[2] Faculty of Medicine And Pharmacy, "Dunărea De Jos" University of Galati, 35 Al.I. Cuza Street, 800010 Galati, Romania

viticole dar și de sporire a productivității plantaţiilor şi reducerea riscurilor de mediu.

Cuvinte cheie: viticultură conservatoare, microclimat, degradarea solului

INTRODUCTION

Productivity translated in to yield per hectare has seen constant increases in the modern period, due to technological leaps in agriculture [Tilman et al., 2001]. Due to the switch to new intensive agricultural practices and agricultural mechanization, numerous environmental issues started to emerge. These include soil erosion and loss in soil organic matter [Lal, 2004; Montgomery, 2007; Lal, 2010; Quinton et al., 2010]; treatment schemes that use excessive synthetic fertilizer [Robertson et al., 2009; Vitousek et al., 2009]; water reserves reduction both above and underground [Fedoroff et al., 2010]; and excessive pesticide use that are responsible for numerous environmental risks (eutrophication, ecotoxicity, soil degradation and acidification) [Stoate et al., 2009]. Human exposure to low-dose pesticide mixtures by interacting with pesticide-mistreated products whit long-lasting negative health impacts [Hernández et., 2013]. It is well known that the agricultural sector plays an important role in climate change acting as a catalyst or buffer and producer of 13.5% of the total global anthropogenic greenhouse gas (GHG) [Fuss et al., 2018]. The major GHGs produced in this sector are methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). The main agricultural source of CH_4 is the anaerobic decomposition of organic matter during enteric fermentation, manure management, and paddy rice cultivation, while N2O is mainly synthesized from the microbial transformation of soil nitrogen during the application of manure and synthetic fertilizers in agricultural land and via urine and dung deposited by grazing animals. Finally, CO_2 arises directly from energy use in the farm (fuels, electricity) and from changes in above- and below-ground carbon stocks induced by land use and land use change [MacLeod et al., 2018].

Viticulture and winemaking have an impact on the environment like any economic activity. For instance, Studies show vineyards situated in the Bordeaux region were responsible for 20 % of the pesticides used, while they accounted for only 3.7 % of cultivated land [Ugalde et al., 2021]. These extensive practices regarding the use of pesticides lead to multiple environmental concerns such as water pollution and a rise in ecotoxicological potential and toxicological impact as a result of air, water, and soil compartment alteration [Beauchet et al., 2019; Renaud-Gentié et al., 2020]. Current environmental concerns raised the need for efficient and environmentally control of diseases and pests that have adapted to changing [Marín et al., 2021]. In this context the viticulture sector has been facing modifications of harvest dates, a rise of disease in wetter regions, lack of homogeneity of precipitations, water stress in Balkan and Mediterranean vineyards, wines deficient in specific aromatic composition, and an excessive increase in alcohol content, loss of yields due to a rise in the frequency of extreme weather events [Leolini et al., 2018; Marín et al., 2021; Santillán et al., 2020; Santos et al., 2020]. Some projections of European grapevine productivity point to chronic drought phenomena across southern regions that will likely favour a decrease of yields, while increased CO2 concentrations may partially compensate for these effects, shifting production to central and northern Europe [van Leeuwen et al., 2024; Romero et al., 2022]. Additional concerns are related to repercussions on production costs reflected directly in end cost through implementation of complex logistic networks [Sacchelli et al., 2017] and to potential changes in land suitability [Hoegh-Guldberg et al., 2018].

The study aims to identify and implement measures for soil fertility preservation; soil water evolution, dependent on soil preparation and maintenance works; optimize administered fertilizer doses commonly used in vineyard plantations; reduce soil structure degradation processes; increase productivity and reduce expenses at the vineyard farm level.

MATERIAL AND METHOD

During our study we selected 3 types of experimental variants:

V1-conventional system whit the following protocol

- autumn plowing; - spring plowing; - 5 mechanical harrows per interval; - 5 manual harrows per row, fertilization with N, P, K in optimal dose.

V2-conservative system: partial mulching on the interval with pomace mulch

- composted pomace on the interval with a maximum layer thickness of 10 cm;
- post-emergence herbicide per row – 2 herbicides;
- one herbicide on the interval with pomace if necessary;
- fertilization with N, P, K in a minimum reduced dose;
- restoring the mulching interval when necessary;
- application of foliar fertilizers to reduce water stress.

General meteorological data was monitored during experiment implementation 2023-2024: Global heat balance (∑t°g), Active heat balance, (∑t°a), Useful heat balance, (∑t°u), Absolute min. air temp.°C, annual average temperature T°C, maximum air temperature,°C, ∑ annual precipitation (mm), ∑ precipitation during the vegetation mm.

Values for the monitored parameters was compared whit areal multi annual values.

Soil nutrient supply analysis was done for each experimental variant using standardized analytical procedures:

• Electrochemical method — potentiometric, in aqueous suspension 1:2.5 - pH determination;

• Volumetric method, STAS 7184/21 -82 - determination of humus content (%);

• Egner Riehm-Domingo method and UV-P7S molecular absorption spectrometric method, in aqueous extract - determination of mobile phosphorus (P-Al, ppm);

• Egner Riehm-Donlingo method and photometry method in each case in aqueous extract - determination of mobile potassium (K-A1, ppm);

• Determination of nitrogen content

(IN %) - calculation according to the formula: IN, % = (humus x Vah)/100;

Analytical determinations for the two experimental variants were done in 5 repetitions.

RESULTS AND DISCUSSIONS

Weather data analysis showed changes in heat balance parameters compared to multiannual values (fig. 1).

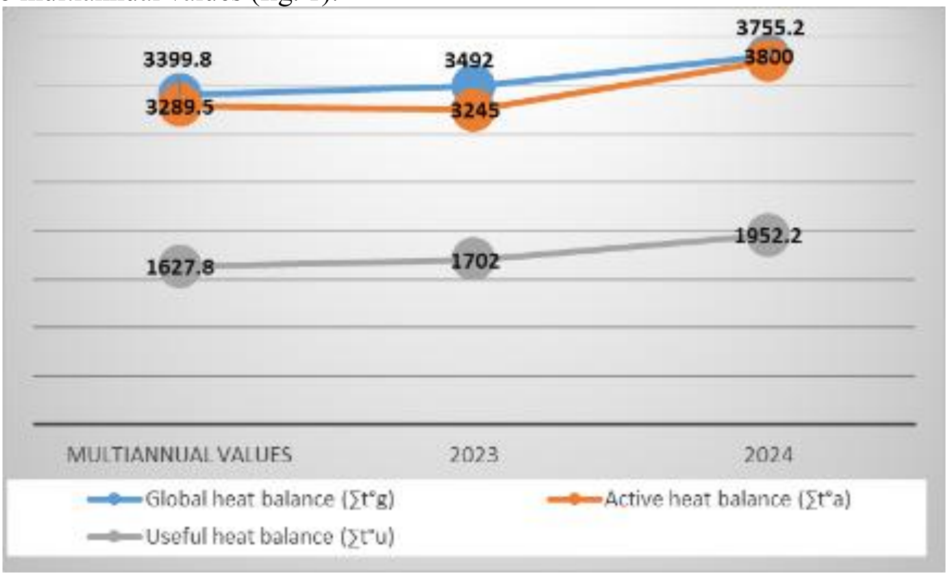

Fig. 1. Heat balance parameters

2023-2024 interval was characterised by heat balance parameter increases whit values of 3492 (2023) and 3800 (2024)-Global heat balance and Active heat balance 3800 (2024). Compared to minimum multiannual temperatures, for 2023 a decrease by 4,04% was recorded and a value of -13 °C 2024 compared to -16,6 °C (multiannual values), representing an increase by 3,3 °C. Average annual temperatures °C, followed current climate trends registering non-specific values of 12,6 °C (2023) and 12,8 °C (2024), by 1,3 and 1,5 °C higher. Our data confirm the latest climate trends specific for the Balkan and Mediterranean region whit average temperature increases up to 4^0C according to projections reaching 2100 for the western part of the Balkans. These studies underline the impact not only to agricultural sector but in general for the safety of the population [Županić et al., 2021].

The increase in average temperature is backup by important rises in temperatures during vine vegetation periods, grape formation and ripening.

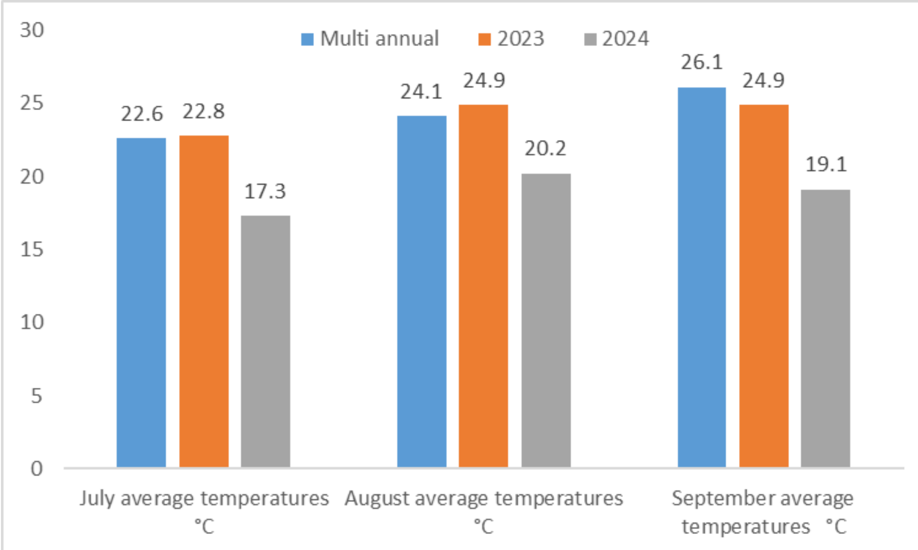

Fig. 2. Average temperatures for July, August and September

During our experiment for de mentioned mounts, we saw an increase by 1,5 °C (2023) up to 3,5 °C (2024) for July, 2,1 °C specific for August (2023 and 2024) and 2,9 °C (2023), 1,8 °C (2024) for September(fig.2).

Ascending temperatures beyond normal climatological standards were coupled whit a deficit in water input. Pluviometric regime recorded for 2023 and 2024 registered an average value of 346 mm as shown in fig. 3. When compared to average multiannual values of 512,7 mm it represents an important drop in water input.

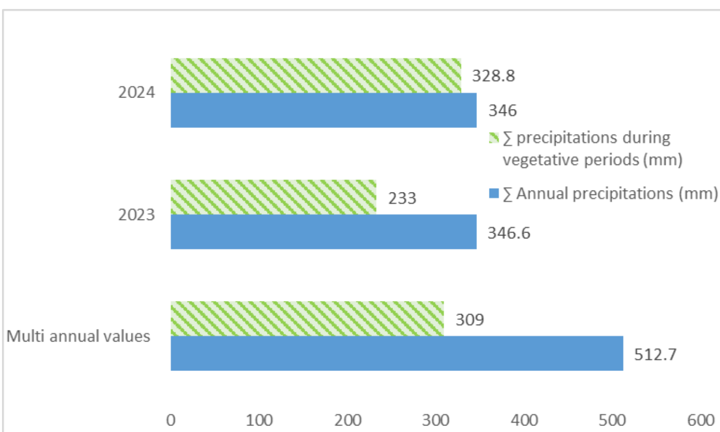

Fig. 3. Average annual precipitations and during vegetation periods

Rain fall analysis during vegetative periods reveal the severe draught phenomena that is manifesting in recent years. For 2023 a value of 233 mm was recorded followed by 328,8 mm specific for 2024. Even though precipitations specific for 2024 vegetative period registered a slightly higher (19,8 mm) value this doesn't cover water necessities. Stress by water shortage has a considerable impact on plantation health and yield [Wang et., 2025]. Limited and untimely precipitation are the major factors contributing to the deterioration of soil health and reduced agronomic productivity [Awale et al., 2017].

Soil quality analysis for the two experimental variants V1 (conventional system) and V2 (conservative system- partial pomace mulching) showed important parameter variations. Soil pH reaction was slightly alkaline, with an average pH value of 8.37 (V1), being higher by about 0.5, compared to the average value of V2, whose value is 7.83, a fact explained by the slightly acidic pH of the composted pomace, which influences to some extent the general pH of the soil.

Soil humus supply determinations revealed average values of 1.89% on a medium-textured soil specific to V1, which was given by the lack of organic matter present and low humus content whit the need for organic matter treatments, in order to create a favourable nutritional balance. In pomace mulching variants, a higher humus content was observed, with an average value of 7.54%. In this experimental variant soil humus content increases dramatically, proving that the use of grape pomace has a positive impact on soil organic matter ratios.

Soil organic matter is frequently deficient in semi-arid soils due to higher temperatures, insufficient moisture restricting the diversity and functions of the soil microbiota [Mpanga et al., 2019]. This type of soil is also specific for Bujoru areal, and our results denote the great value of this by-product achieving a circular viticulture, through which we can ensure environmental protection and an increased supply of organic matter naturally, with minimal specific costs. The acid nature of uncomposed grape pomace can be used as an amendment agent for alkaline soils [Hassan et al., 2019]. Ongoing search for alternative organic amendments for alkaline soil pH recommend this by-product for addressing these issues [Nkebiwe et al., 2016].

The addition of organic matter seen for V2 is also evident in soil nitrogen content, respectively in the nitrogen index, which is very high, with an average of 7.54%, compared to V1 with an average of only 1.85%. This element, together with phosphorus and water, gives a high potential for vegetative growth, highlighting once again the effects of implementing a circular agriculture of performance in the agricultural ecosystem (fig. 4).

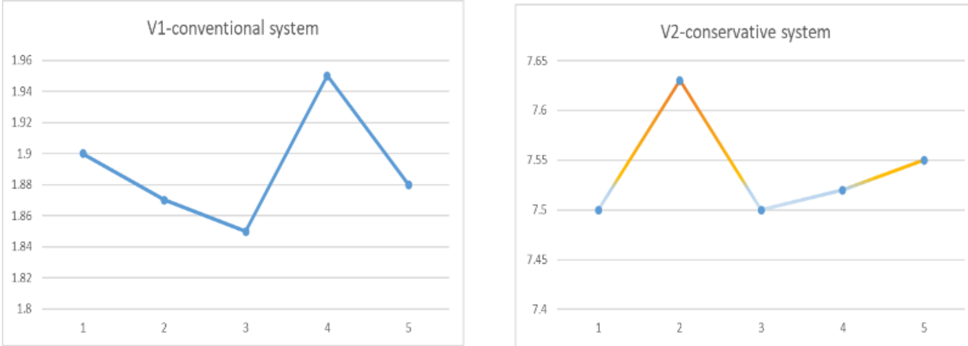

Fig. 4. Soil nitrogen content variation

Soil mobile phosphorus parameter reached medium value, with an average of 22.14 ppm (V1) to very well supplied, excessive for some crops, with an average value of 221.89 ppm V2, highlighting the energetic and constitutional contribution of this mineral element, obtained from our organic matter source (fig. 5).

The recommendation for soil mobile phosphorus level is between: 8.1-16 mg P2O5/100 g soil, knowing that 1 g P2O5/100 g is equivalent to 7 kg P2O5/ha *[Boţ et al., 2021]*.

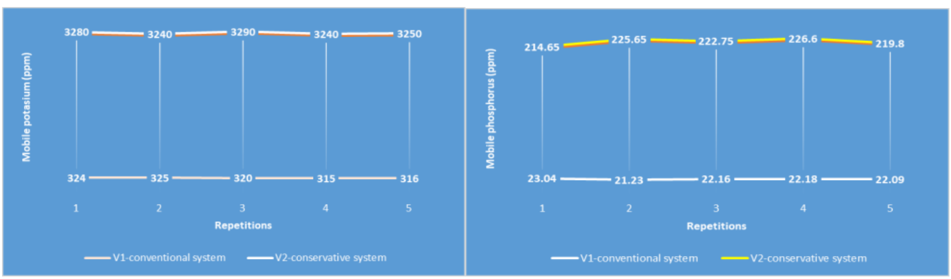

Fig. 5. Mobile phosphorus and mobile potassium -V1-V2 comparison

Following the same trend as mobile phosphorus total supply of mobile potassium increased 10 fold, with an average value of 3260 ppm (V2-conservative), compared to V1, with a native concentration of only 320 ppm (V 1-conventional).

Soil potassium level should be 16.1-24 mg K2O/100 g soil, knowing that 1 g K2O/100 g soil is equivalent to 13 kg K2O/ha [Paltineanu et al., 2020].

In studies conducted by Korz et al. [2024] using different varieties of grape pomace as a soil amendment tool obtained similar results including increased concentrations of available C (dissolved organic carbon), dissolved (available) N whit long term values than those in the control groups, suggesting a rapid N assimilation [Korz et al., 2024]. Best results were obtained for sandy soils similar to Bujoru areal.

CONCLUSIONS

Climate context of 2023-2024 wine year highlights on going climate trends towards extreme drought phenomena, whit a lack or a very low quantity of usable precipitation during the vegetation periods. Our strategy of using vinification by-products had major effects on soil supply with organic and mineral elements.

Comparative analysis of humus content for the two experimental variants revealed a low native humus content for the conventional variant, on a medium-textured soil. When using grape pomace partially mulched a higher humus content was observed, with an average value of 7.54%. By administering organic matter in the form of mulched pomace, humus content increases dramatically, enrolling this experimental protocol as a possible candidate in the race for sustainable agriculture and environmental protection. Coupled whit organic matter increases the supply of soil nitrogen, respectively the nitrogen index, followed a similar trend whit higher average value. This element, along with phosphorus and potassium who also registered spikes in concentrations after pomace mulching and the presence of water, ensures higher rates of vegetative plant growth, highlighting the need of implementing a high-performance circular agriculture in the agricultural ecosystem in the face of climate change.

ACKNOWLEGMENTS
All scientific data are part of research project ADER 6.3.11.

REFERENCES

1. **Awale R., Machado S., Ghimire R., Bista, P., 2017 -** *Soil health*. Advances in dryland farming in the inland Pacific Northwes*t*, 47-97**.**
2. **Beauchet S., Rouault A., Thiollet-Scholtus M., Renouf M., Jourjon F., Renaud-Gentié C., 2019 -** *Inter-annual variability in the environmental performance of viticulture technical management routes—a case study in the Middle Loire Valley (France).* The International Journal of Life Cycle Assessment, 24(2):253-265.
3. **Boţ A. I., Făcurarl I. Szajdak L. W., 2021 -** *Nitrogen Content Under Blueberry Cultivation*. In Nitrogen in Agricultural Landscape, 18:1-29
4. **Fedoroff N. V., Battisti D. S., Beachy R. N., Cooper P. J., Fischhoff D. A., Hodges C. N., Zhu J. K., 2010 -** *Radically rethinking agriculture for the 21st century*. Science, 327(5967):833-834.
5. **Fuss S., Lamb W. F., Callaghan M. W., Hilaire J., Creutzig F., Amann T., 2018 -** *Negative emissions—Part 2: Costs, potentials and side effects*. Environmental research letters, 13(6):63-72.
6. **Hassan Y. I., Kosir V., Yin X., Ross K., Diarra M. S., 2019 -** *Grape pomace as a promising antimicrobial alternative in feed: A critical review*. Journal of Agricultural and Food Chemistry, 67(35): 9705–9718.
7. **Hernández A.F., Parrón T., Tsatsakis A.M., Requena M., Alarcón R., López-Guarnido O., 2013 -** *Toxic effects of pesticide mixtures at a molecular level: Their relevance to human health.* Toxicology, 307: 136–145.
8. **Hoegh-Guldberg O., Jacob D., Bindi M., Brown S., Camilloni I., Diedhiou A., 2018 -** *Impacts of 1.5 C global warming on natural and human systems*. In *Global warming of 1.5 C.:* An IPCC Special Report, 13:175-311.

9. Korz S., Parvin S., Aponte H., Buchmann C., Diehl D., Muñoz K., 2024 - *The Use of Grape Pomace as Soil Fertilizer: A Microcosm Study on Available C and N and Consequences for Microbial Biomass, Structure, and Catabolic Responses*. ACS Sustainable Resource Management, 1(11): 2428-2438.

10. Lal R., 2004 - *Soil Carbon Sequestration Impacts on Global Climate Change and Food Security.* Science 304:1623–1627.

11. Lal R., 2010 - *Enhancing Eco-Efficiency in Agro-Ecosystems through Soil Carbon Sequestration*. Crop Sci., 50:120–131.

12. Leolini L., Moriondo M., Fila G., Costafreda-Aumedes S., Ferrise R., Bindi M., 2018 - *Late spring frost impacts on future grapevine distribution in Europe*. Field Crops Research, 222:197-208.

13. MacLeod M., Eory V.,Gruere G.,Lankoski J., 2015 - *Cost-Effectiveness of Greenhouse Gas Mitigation Measures for Agriculture*; OECD Publishing: Paris, France, 89:78-98.

14. Marín D., Armengol J., Carbonell-Bejerano P., Escalona J. M., Gramaje D., Hernández-Montes E., 2021 - *Challenges of viticulture adaptation to global change: tackling the issue from the roots*. Australian Journal of Grape and Wine Research, 27(1):8-25.

15. Montgomery D.R., 2007 - *Soil erosion and agricultural sustainability.* Proc. Natl. Acad. Sci. USA, 104:13268–13272.

16. Mpanga I. K., Gomez-Genao N., Moradtalab N., Wanke D., Chrobaczek V., Ahmed A., Windisch S., Geistlinger J., Hafiz B. F., Walker F., Ludewig U., Neumann G. 2019 - *The role of N form supply for PGPM-host plant interactions in maize.* Journal of Plant Nutrition and Soil Science, 182(6):908–920.

17. Nkebiwe P. M., Weinmann M., Bar-Tal A. & Müller T. 2016 - *Fertilizer placement to improve crop nutrient acquisition and yield: A review and meta-analysis.* Field Crops Research, 196:389–401.

18. Paltineanu C., Vrinceanu A., Lăcătu, A. R., Lăcătuşu, R., Domnariu H., Marica D., Vizitiu O., 2020 - *An improved method to study solute leaching in large undisturbed soil columns near field capacity toward the groundwater in various environments.* Carpathian Journal of Earth And Environmental Sciences, 15(1):93-102.

19. Quinton J.N., GoversG., Van Oost K., Bardgett R.D., 2010 - *The impact of agricultural soil erosion on biogeochemical cycling*. Nat. Geosci. 3:311–314.

20. Renaud-Gentié C., Dieu V., Thiollet-Scholtus M., Mérot A. 2020 - *Addressing organic viticulture environmental burdens by better understanding interannual impact variations.* The International Journal of Life Cycle Assessment, 25(7):1307-1322.0

21. Robertson G.P., Vitousek P.M., 2009 - *Nitrogen in agriculture: Balancing the cost of an essential resource.* Ann. Rev. Environ. Resour., 34:97–125.

22. Romero P., Navarro J. M. Ordaz P. B., 2022 - *Towards a sustainable viticulture: The combination of deficit irrigation strategies and agroecological practices in Mediterranean vineyards. A review and update.* Agricultural Water Management, 259:107-216.

23. Santillán D., Garrote L., Iglesias A., Sotes V., 2020 - *Climate change risks and adaptation: New indicators for Mediterranean viticulture.* Mitigation and adaptation strategies for global change, 25(5):881-899.

24. Santos J. A., Fraga H., Malheiro A. C., Moutinho-Pereira J., Dinis L. T., Correia C., 2020 - *A review of the potential climate change impacts and adaptation options for European viticulture*. Applied Sciences, 10(9):30-42.

25. Stoate C., Báldi A., Beja P., Boatman N.D., Herzon I., Van Doorn A., De Snoo G.R., Rakos L., Ramwell C., 2009 - *Ecological impacts of early 21st century agricultural change in Europe—A review*. J. Environ. Manag., 91: 22–46.

26. Tilman D., Fargione J., Wolff B., D'Antonio C., Dobson A., Howarth R., Schindler D., Schlesinger W.H., Simberloff D., Swackhamer D. 2001 - *Forecasting agriculturally driven global environmental change*. Science, 292:281–284.

27. **Ugalde D., Renaud-Gentié C. &Symoneaux, R. 2021 -** *Perception of French wine buyers regarding environmental issues in wine production*. Journal of Wine Research, *32*(2):77-102.
28. **van Leeuwen C., Sgubin G., Bois B., Ollat N., Swingedouw D., Zito S. & Gambetta G. A. 2024 -**Climate change impacts and adaptations of wine production. *Nature Reviews Earth & Environment*, *5*(4), 258-275.
29. **Vitousek P.M., Naylor R., Crews T., David M.B., Drinkwater L.E., Holland E., Johnes P.J., Katzenberger J., Martinelli L.A., Matson P.A., 2009 -** *Nutrient Imbalances in Agricultural Development.* Science, 324:1519–1520.
30. **Wang J., Gao L., HouX., Hao W., Nangia V., Gong D., 2025 -** *Vine age, variety and planting density influencing the effects of water supply on yield and quality of wine grapes—A meta-analysis.* Agricultural Water Management, 319:109-128.
31. **Županić F. Ž., Radić D., Podbregar I., 2021 -** *Climate change and agriculture management: Western Balkan region analysis.* Energy, Sustainability and Society, 11(1):51-65.