Adapting agricultural crops to new regional climates post-climate change

[1]Firuța C. Oroian, [1]Eniko Kovacs, [2,3]Florin D. Bora, [4]Maria Popescu

[1] Department of Economic Sciences, Faculty of Horticulture and Business for Rural Development, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania; [2] Viticulture and Oenology Department, Advanced Horticultural Research Institute of Transylvania, Faculty of Horticulture and Business in Rural Development, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania; [3] Laboratory of Chromatography, Advanced Horticultural Research Institute of Transylvania, Faculty of Horticulture and Business for Rural Development, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania; [4] Equine Clinic, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania. Corresponding author: M. Popescu, maria.popescu@usamvcluj.ro

Abstract. The purpose of this paper is to point out the importance of adapting agricultural practices and policies to permanent environmental changes as the only way to perpetuate productivity and sustainability in agriculture. Through a combination of breeding, diversification, improved agronomic practices, and efficient water management, agriculture can become more resilient to the changing climate. While challenges persist, the collective efforts of farmers, researchers, policymakers, and international organizations can drive the necessary transformations, paving the road for a more resilient and sustainable agricultural future.
Key Words: transformative, adaptation, climate change, precipitation, heat-resistance, drought, agronomy.

Introduction. The states of the world, and especially those of the European Union, have started certain policies to adapt to climate change for many years (Figure 1). Climate change, characterized by altered precipitation patterns, global temperature rises, and increased frequency of extreme weather events, poses notable challenges to agronomic practices. As climate patterns shift, regions around the world experience changes that can disrupt traditional farming activities. Adapting agricultural crops to these new specific climates is crucial to ensure food security, sustain livelihoods, and maintain ecological balance. The purpose of this paper is to point out the importance of adapting agricultural practices and policies to permanent environmental changes as the only way to perpetuate productivity and sustainability in agriculture.

The impact of climate change on agriculture. Climate change affects agriculture in various ways, such as: temperature shifts (Maberly et al 2020), precipitation changes (Tabari 2020), increased pests and diseases (Bajwa et al 2020), and extreme weather events (Ebi et al 2021).

Temperature shifts. Rising temperatures can extend the growing season in some regions but also lead to heat stress in crops, affecting yield and quality. Crops suited to cooler climates may no longer thrive, while warmer regions may face more intense and prolonged heatwaves.

Precipitation changes. Altered rainfall patterns can result in droughts or floods, both detrimental to crop production (Tabari 2020). Drought conditions limit water availability, while excessive rainfall can lead to waterlogging and soil erosion.

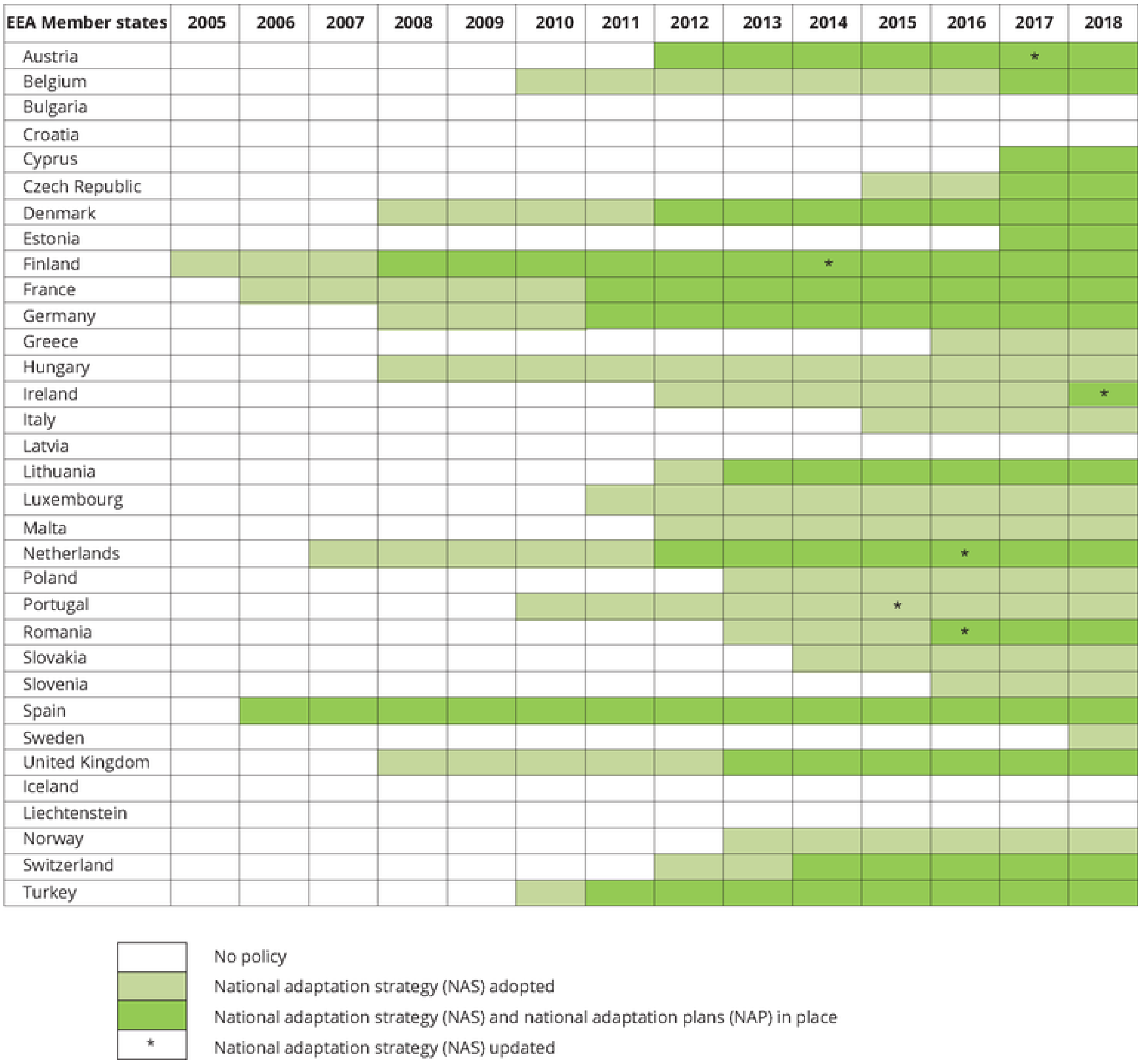

Figure 1. Overview of national climate change adaptation strategies and plans in Europe (Source: European Environment Agency (EEA), https://www.eea.europa.eu/legal/copyright). Details: for the EU Member States the table is based on information reported by the Member States under the European mechanism for monitoring and reporting information relevant to climate change (EU, 2013b), via the country fiches of the European Commission Adaptation Scoreboard (EC, 2018b) and complemented by additional information provided on a voluntary basis to the EEA up to 30 September 2018. For other EEA member countries, information is provided on a voluntary basis to the EEA up to 30 September 2018 (For more information see the original source: https://www.eea.europa.eu/legal/copyright).

Increased pests and diseases. Warmer temperatures and changes in humidity can create favorable conditions for pests and diseases, previously constrained by colder climates, to expand their range, posing new threats to crops.

Extreme weather events. Increased frequency and intensity of storms, hurricanes, and other extreme weather events can cause significant crop damage, reducing productivity and leading to economic losses (Ebi et al 2021).

The necessity of crop adaptation. To address these challenges, adapting agricultural crops to new regional climates is crucial (Petrescu-Mag et al 2022). This adaptation can be approached through various strategies, including: breeding and genetic engineering of plant genomes, crop diversification, improved agricultural practices, agroforestry and perennial crops, water management and controlled introductions of new species or varieties.

Breeding and genetic modification. Developing crop varieties that are more resilient to temperature extremes, drought, and disease is a critical strategy (Banga & Kang 2014; Rivero et al 2022). Advances in biotechnology, including genetic modification (known also as genetic engineering) and CRISPR gene editing (Karavolias et al 2021), offer promising tools for creating crops with enhanced resistance and productivity under new climatic conditions (Petrescu-Mag & Burny 2023). However, genetic modification is not without ethical or legislative constraints and limitations, especially in the European Union.

Diversification. Encouraging the cultivation of a diverse range of crops can reduce the risk associated with climate variability (van Zonneveld et al 2020). Crop diversification can enhance resilience by ensuring that some crops can still thrive under adverse conditions (Amfo & Ali 2020).

Improved agricultural practices. Adopting practices such as conservation tillage, cover cropping, and integrated pest management can enhance soil health, conserve water, and reduce vulnerability to climate extremes (Anderson et al 2020). Precision agriculture, transformative change, leveraging technology for efficient resource use, can optimize inputs and improve crop resilience (Mocanu & Petrescu-Mag 2023; Karunathilake et al 2023).

Agroforestry and perennial crops. Integrating trees and perennial crops into farming systems can provide multiple benefits, including improved soil structure, enhanced water retention, and reduced erosion (Mocanu 2023). Agroforestry systems can also sequester carbon, contributing to climate mitigation efforts (Petrescu-Mag & Gavriloaie 2022; Bora 2023).

Water management. Efficient water management practices, such as rainwater harvesting, drip irrigation, and the use of drought-resistant crop varieties, are essential in regions facing altered precipitation patterns (Nikolaou et al 2020). These practices can help optimize water use and sustain crop production during dry spells (Rosa et al 2022).

Controlled introductions. Introduction of new species or varieties with a known low invasive risk (for example, species that cannot adapt to the spontaneous flora but only to the cultivated one). In fact, a significant number of plant species have already begun to expand their range naturally due to recent climate change (Petrescu-Mag et al 2016). Other exotic species, such as cultivated ones, have gone from greenhouse crop to perennial plant status (Odagiu et al 2021; Petrescu-Mag & Bănățean-Dunea 2022) (Figure 2). Climate change has not only affected the area of some plant species, but also some wild or farm animal species (Bud et al 2016ab). On the one hand, introductions of non-native taxa have proven useful (Bud et al 2004; Petrescu-Mag et al 2011, 2012; Petrescu et al 2013). On the other hand, many cases of intentional introductions or translocations have proven totally uninspired and harmful to native ecosystems (Petrescu-Mag et al 2014). This is the case with some species that have become invasive (Bud et al 2006). Often the invasive potential of a species is difficult to predict outside its native range, where the species' natural pests or predators are absent (Copp et al 2005). Therefore, the issue of introducing species for cultivation must be treated with great caution, and the introductions must be justified (Iacob & Petrescu-Mag 2008).

Figure 2. Fig tree, *Ficus carica*, in perennial form in Cluj-Napoca, northwest Romania (original pictures).

Case studies of successful adaptation. Several regions have begun to implement successful crop adaptation strategies. We will remind here case studies from India, Sub-Saharan Africa and United States.

India. In response to increased drought frequency, India has developed and promoted drought-resistant varieties of staple crops like rice and wheat (Dar et al 2020). These varieties require less water and can withstand higher temperatures, ensuring stable yields despite adverse conditions (Tomar et al 2021). See also Pakistan cotton heat acclimation practices (Farooq et al 2015).

Sub-Saharan Africa. Facing erratic rainfall and prolonged dry seasons, farmers in Sub-Saharan Africa have adopted drought-tolerant crops such as sorghum and millet (Hadebe et al 2017). Additionally, initiatives promoting agroforestry have helped improve soil fertility and water retention, boosting overall agricultural resilience.

United States. The Midwest, known as the "Corn Belt," is exploring crop diversification and soil conservation practices to mitigate the impacts of increased temperature and unpredictable precipitation. Research into heat-resistant corn varieties and the integration of cover crops are among the strategies being implemented (Messina et al 2020). Anyway, related to the success of research on corn adaptation to heat stress, researchers' opinions are divided (Yu et al 2021).

Challenges and future directions. While progress is being made, several challenges remain to be solved.

Resource constraints. Smallholder farmers in developing regions often lack access to the necessary resources, technology, and knowledge to implement adaptive strategies. Ensuring equitable access to these resources is essential (Balana & Oyeyemi 2022).

Policy and institutional support. Effective adaptation requires supportive policies and institutional frameworks that promote research, provide financial incentives, and facilitate knowledge transfer (Balana & Oyeyemi 2022). Governments and international organizations play a crucial role in this regard.

Climate uncertainty. The unpredictability of future climate conditions complicates planning and adaptation efforts. Continuous monitoring, research, and flexibility in adaptation strategies are necessary to address emerging challenges (Chester et al 2020).

Social and economic factors. Socioeconomic conditions, including land tenure systems, market access, and cultural practices, influence the feasibility and adoption of adaptation measures. Integrating social and economic considerations into adaptation planning is vital for success (Balana & Oyeyemi 2022).

Conclusions. Adapting agricultural crops to the new specific climates of regions affected by climate change is imperative for ensuring food security and sustaining agricultural livelihoods. Through a combination of breeding, diversification, improved agronomic practices, and efficient water management, agriculture can become more resilient to the changing climate. While challenges persist, the collective efforts of farmers, researchers, policymakers, and international organizations can drive the necessary transformations, paving the road for a more resilient and sustainable agricultural future.

Funding. This article resulted from the documentation activities provided by the project: "The development of agricultural technologies for the main crop plants for the intensification of carbon sequestration in the soil in accordance with the 4‰ initiative". Funding source: Ministry of Agriculture and Rural Development (Agriculture and Rural Development Program).

Conflict of interest. The authors declare no conflict of interest.

References

Anderson R., Bayer P. E., Edwards D., 2020 Climate change and the need for agricultural adaptation. Current Opinion in Plant Biology 56:197-202.
Amfo B., Ali E. B., 2020 Climate change coping and adaptation strategies: how do cocoa farmers in Ghana diversify farm income? Forest Policy and Economics 119:102265.
Balana B. B., Oyeyemi M. A., 2022 Agricultural credit constraints in smallholder farming in developing countries: Evidence from Nigeria. World Development Sustainability 1:100012.
Banga S. S., Kang M. S., 2014 Developing climate-resilient crops. Journal of Crop Improvement 28(1):57-87.
Bora F. D., 2023 Harnessing nature's green magic: Exploring the best plants for carbon sequestration. AES Bioflux 15(2):107-108.
Bud I., Pop S. N., Mag-Mureșan I. V., 2004 Views of exploitation for a new fish species: the African wells (*Clarias gariepinus*) in our country. The 33rd International Session of Scientific Communications of The Faculty of Animal Science, Bucharest. Marginean G., Tapaloaga P. R., Popescu-Vifor S., et al (eds), pp. 152-156.
Bud I., Mag I. V., Petrescu R. M., 2006 [The invasive species of fish in the fresh waters of Romania and their impact on the aquatic environment]. Environment & Progress 7:15-21. [In Romanian].
Bud I. G., Todoran L., Petrescu-Mag I. V., 2016a [Aquaculture and biodiversity treaty]. Vol.I. Editura Vatra Veche, 1096 p. [In Romanian].
Bud I. G., Todoran L., Petrescu-Mag I. V., 2016b [Aquaculture and biodiversity treaty]. Vol. II. Editura Vatra Veche, 1110 p. [In Romanian].
Chester M. V., Underwood B. S., Samaras C., 2020 Keeping infrastructure reliable under climate uncertainty. Nature Climate Change 10(6):488-490.
Copp G. H., Bianco P. G., Bogutskaya N. G., Erős T., Falka I., Ferreira M. T., et al, 2005 To be, or not to be, a non-native freshwater fish? Journal of Applied Ichthyology 21(4):242-262.

Dar M. H., Waza S. A., Shukla S., Zaidi N. W., Nayak S., Hossain M., et al, 2020 Drought tolerant rice for ensuring food security in Eastern India. Sustainability 12(6):2214.
Ebi K. L., Vanos J., Baldwin J. W., Bell J. E., Hondula D. M., Errett N. A., et al, 2021 Extreme weather and climate change: population health and health system implications. Annual Review of Public Health 42(1):293-315.
Farooq J., Mahmood K., Waseem akram M., Rehman A. U., Javaid M. I., Petrescu-Mag I. V., Nawaz B., 2015 High temperature stress in cotton *Gossypium hirsutum* L. ELBA Bioflux 7(1):34-44.
Iacob M., Petrescu-Mag I. V., 2008 [Inventory of non-native species of fish from fresh waters of Romania]. Bioflux, Cluj-Napoca, 89 p. [In Romanian].
Hadebe S. T., Modi A. T., Mabhaudhi T., 2017 Drought tolerance and water use of cereal crops: A focus on sorghum as a food security crop in sub-Saharan Africa. Journal of Agronomy and Crop Science 203(3):177-191.
Karavolias N. G., Horner W., Abugu M. N., Evanega S. N., 2021 Application of gene editing for climate change in agriculture. Frontiers in Sustainable Food Systems 5:685801.
Karunathilake E. M. B. M., Le A. T., Heo S., Chung Y. S., Mansoor S., 2023 The path to smart farming: Innovations and opportunities in precision agriculture. Agriculture 13(8):1593.
Maberly S. C., O'Donnell R. A., Woolway R. I., Cutler M. E., Gong M., Jones I. D., et al, 2020 Global lake thermal regions shift under climate change. Nature Communications 11(1):1232.
Messina C. D., Cooper M., Hammer G. L., Berning D., Ciampitti I., Clark R., et al, 2020 Two decades of creating drought tolerant maize and underpinning prediction technologies in the US corn-belt: review and perspectives on the future of crop design. BioRxiv 2020-10.
Mocanu C., 2023 Agroforestry windbreaks during the communist period in Romania. AES Bioflux 15(1):32-34.
Mocanu C., Petrescu-Mag I. V., 2023 Transformative change and its relation with environment protection. AES Bioflux 15(1):25-27.
Nikolaou G., Neocleous D., Christou A., Kitta E., Katsoulas N., 2020 Implementing sustainable irrigation in water-scarce regions under the impact of climate change. Agronomy 10(8):1120.
Odagiu A., Petrescu-Mag I. V., Proorocu M., 2021 The fig tree (*Ficus carica*) growing area extends to northern Romania. AAB Bioflux 13(3):63-65.
Petrescu D. C., Oroian I. G., Mihaiescu T., Paulette L., Varban D., Pătruțoiu T. C., 2013 Rabbit statistics overview: production, trade, market evolution. Rabbit Gen 3(1):15-22.
Petrescu-Mag I. V., Bănățean-Dunea I., 2022 Measurements of the diameter of the fig stem (*Ficus carica*) in Romania for six years show the transition from a small shrub to a tree-like plant. Research Journal of Agricultural Science 54(2):131-135.
Petrescu-Mag I. V., Burny P., 2023 A review of wheat cultivation and its cultural significance. AAB Bioflux 15(1):25-36.
Petrescu-Mag I. V., Gavriloaie C., 2022 Carbon sequestration: the non-utopian version of achieving climate neutrality. AES Bioflux 14(2):62-63.
Petrescu-Mag I. V., Oroian I. G., Balint C., Criste F. L., Stoian R. O., Tăut F. D., 2016 Let's capitalize on global warming: New limits for vineyard vines in Europe. AAB Bioflux 8(3):87-91.
Petrescu-Mag I. V., Oroian I. G., Botha M., Gavriloaie C., 2014 Wild boars and feral pigs as threats to humans. Porc Res 4(2):43-47.
Petrescu-Mag R. M., Creangă S., Păsărin B., Gîlcă V., Petrescu-Mag I. V., 2011 Small-scale rabbit production: a solution for limited-resource rural and suburban populations and its impact on the environment. In: Environmental issues in the context of sustainable development. Les Presses Agronomique de Gembloux, Gembloux & Bioflux, Cluj-Napoca, pp. 157-167.
Petrescu-Mag R. M., Creangă Ş., Păsărin B., Petrescu-Mag I. V., 2012 Local rabbit breeds and research prospects to develop and increase rabbit meat production and

consumption in view of Romanian rural space sustainable development. In: Agri-environment: perspectives on sustainable development. Les Presses Agronomiques de Gembloux, Gembloux & Bioflux, Cluj-Napoca, pp. 237-246.
Petrescu-Mag R. M., Burny P., Bănățean-Dunea I., Petrescu D. C., 2022 How climate change science is reflected in people's minds. A cross-country study on people's perceptions of climate change. International Journal of Environmental Research and Public Health 19(7):4280.
Rivero R. M., Mittler R., Blumwald E., Zandalinas S. I., 2022 Developing climate-resilient crops: improving plant tolerance to stress combination. The Plant Journal 109(2):373-389.
Rosa L., 2022 Adapting agriculture to climate change via sustainable irrigation: biophysical potentials and feedbacks. Environmental Research Letters 17(6):063008.
Tabari H., 2020 Climate change impact on flood and extreme precipitation increases with water availability. Scientific Reports 10(1):13768.
Tomar S., Babu M. S., Gaikwad D. J., Maitra S., 2021 A review on molecular mechanisms of wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.) against abiotic stresses with special reference to drought and heat. International Journal of Agriculture Environment and Biotechnology 14(2):215-222.
van Zonneveld M., Turmel M. S., Hellin J., 2020 Decision-making to diversify farm systems for climate change adaptation. Frontiers in Sustainable Food Systems 4:32.
Yu C., Miao R., Khanna M., 2021 Maladaptation of US corn and soybeans to a changing climate. Scientific Reports 11(1):12351.
*** European Environment Agency (EEA), Available at: https://www.eea.europa.eu/legal/copyright

Received: 15 September 2023. Accepted: 21 November 2023.
Authors:
Firuța Camelia Oroian, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Horticulture and Business for Rural Development, Department of Economics Sciences, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: camellia.oroian@usamvcluj.ro
Eniko Kovacs, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Horticulture and Business for Rural Development, Department of Economic Sciences, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: eniko.kovacs@usamvcluj.ro
Florin Dumitru Bora, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Horticulture and Business for Rural Development, Department of Horticulture and Landscaping, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: boraflorindumitru@gmail.com
Maria Popescu, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Veterinary Medicine, Equine Clinic, 3-5 Calea Mănăștur Street, 400372 Cluj-Napoca, Romania, e-mail: maria.popescu@usamvcluj.ro

Oroian F. C., Kovacs E., Bora F. D., Popescu M., 2023 Adapting agricultural crops to new regional climates post-climate change. AAB Bioflux 15(2):115-121.