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QUANTIFICATION OF CONVENTIONAL/ECOLOGICAL INPUTS CONSUMPTION AND ANALYSIS OF THEIR ENVIRONMENTAL FOOTPRINT IN WALNUT CROP

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Abstract

Quantifying conventional and organic inputs to walnut farming reveals significant differences in resource consumption and environmental impacts. Conventional walnut farming typically relies on synthetic fertilizers, pesticides, and energy-intensive irrigation systems, resulting in higher greenhouse gas emissions compared to organic methods, which prioritize natural inputs and sustainable practices. Conventional practices consume a substantial amount of energy, primarily diesel for machinery, irrigation, and transportation. Key inputs include land, planting material, irrigation, fertilization, labor, disease and pest control, and infrastructure. Organic operations can reduce the use of synthetic inputs, reducing direct environmental impacts, but may require more labor and alternative pest management techniques.

Key words: conventional / ecological activity, input, walnut

INTRODUCTION

Walnut (*Juglans regia* L.) crop has a global significance due to its economic, nutritional and ecological contributions. From an economic perspective, walnuts represent an important agricultural product, with a global production of over 4.5 million metric tons per year and a market value of billions of dollars, supporting lives in various countries, especially in China, the United States and Iran (Nad et al., 2024).

In Romania, fruit growing occupies an important role, due to the high nutritional and economic value of the fruits. Walnuts contain a large amount of omega-3 fatty acids, antioxidants and other nutrients, thus being highly sought after for supporting heart health and general well-being (Baicu (Zoican) et al., 2023). Walnut cultivars have an abundant mineral composition, especially in potassium, magnesium and calcium. The mineral content varies between different cultivars. Consumption of walnuts from Romanian varieties can satisfy the mineral requirements of a balanced diet (Cosmulescu et al., 2009). In addition, walnut fruits differ significantly in terms of weight, kernel weight and kernel percentage. The fluctuation of these traits is probably generated by agroclimatic conditions and seed dispersal. This significant diversity of fruit traits suggests a significant potential in selecting new promising genotypes that can be further exploited through walnut improvement programs regarding tree and nut characteristics (Cosmulescu and Botu, 2012).

The Vâlcea Fruit Research Station of the University of Craiova has carried out extensive breeding and selection programs for walnut hybrids and varieties, focusing on improving yield and quality for intensive walnut production (Bizera et al., 2019). Another expanding crop in this research station is the sweet chestnut, due to the nutritional quality of the nuts, the wood value and the role of chestnuts in combating soil erosion (Radu et al., 2025). The increasing demand for organic products and the pressures related to environmental protection make it necessary to carry out a comparative analysis between conventional and organic inputs used in the maintenance of walnut plantations. Comparative research indicates that conventional technologies in fruit growing depend on a significant number of chemical pesticides (insecticides, acaricides, fungicides, herbicides) and synthetic fertilizers, having a considerable negative effect on the beneficial entomofauna, which becomes reduced or unbalanced due to these substances. These technologies also involve a higher energy consumption, both for the manufacture and use of chemical inputs, as well as for irrigation and mechanical maintenance. On the other hand, ecological and innovative technologies in fruit growing apply organic fertilization, biological techniques for pest control and methods aimed at maintaining and encouraging populations of beneficial insects (pollinators, natural predators of pests). These techniques reduce the energy and ecological impact, helping to protect biodiversity, including beneficial insects, by renouncing harmful chemicals and supporting an ecological balance in fruit-growing ecosystems. However, the processes that determine soil quality and productivity are also an area of high complexity and significant relevance in land resource management, representing a major challenge both globally and nationally to ensure environmental and agricultural sustainability (Bălan 2021, 2023, 2024).

Contemporary ecological technologies in fruit-growing include the use of methods such as drip irrigation, plant-based mixtures and organic fertilization, which considerably reduce energy consumption and protect beneficial insects. These actions contribute to healthier soil, increased natural pest diversity and maintenance of a habitat conducive to beneficial entomofauna, essential elements of natural disease and pest control. Therefore, organic and sustainable methods of fruit growing have a significantly lower energy and environmental impact compared to traditional technologies and support a greater biodiversity of beneficial insects in orchards.

Walnuts support biodiversity, contribute to soil stabilization and provide ecosystem services, including carbon sequestration and water management. This study attempts to determine which practices applied to this crop are more efficient and it seems that organic has a much lower environmental impact than conventional, being a more sustainable option for protecting soil, biodiversity and natural resources.

MATERIAL AND METHOD

Objectives:

- quantifying input consumption (fertilizers, pesticides, fuels, water, energy);
- comparing the differences between conventional and ecological technology;
- assessing the environmental footprint (CO_2 emissions, impact on biodiversity and soil quality).

The analyzed period: an annual production cycle at a walnut plantation over 20 years old at SCDP Râmnicu Vâlcea of the University of Craiova.

The emission factors were those standardized for agricultural and forestry activities, in accordance with the IPCC recommendations and national legislation on the inventory of greenhouse gas emissions. For the calculation of the carbon footprint (one hectare of walnut), the assessment of all greenhouse gas emissions generated by agricultural activities over the entire life cycle of the crop was taken into account, according to international standards such as the GHG Protocol (Greenhouse Gas Protocol) and ISO 14067.

RESULTS AND DISCUSSIONS

Soil organic carbon (SOC) is perceived as the most complicated and least understood part of the soil, having a crucial importance in ensuring soil fertility and agricultural yield (Liu et al., 2018). Increasing SOC stocks can bring advantages in enhancing soil quality and combating climate change (Amelung et al., 2020). However, it is difficult to assess SOC gains and losses in a short time frame, as SOC shows low natural variability (Chaudhary et al., 2017). SOC appears to represent a continuum of gradually decomposing organic materials and is composed of various fractions with varying characteristics (Lehmann and Kleber, 2015).

The ecological footprint of food refers to the effects that its production, processing, transport and consumption have on the environment. This footprint serves as an essential element in the analysis of the sustainability of the global food system, highlighting the use of natural resources and pollution emissions produced by each stage of the agri-food chain. In an international context where natural resources are becoming increasingly scarce and climate change represents a significant challenge, it is crucial to be aware of the ecological effect of food and to find methods to reduce this effect. By analyzing the ecological footprint of food products, we can identify solutions that facilitate more sustainable production and consumption.

The carbon footprint refers to the amount of greenhouse gases, mainly carbon dioxide (CO_2) and methane (CH_4), emitted during the life cycle of a food product. It is quantified in tonnes of carbon dioxide equivalent (t CO_2e) and is a key indicator for understanding the contribution of a food product to climate change. Food footprint analysis has many practical uses for reducing environmental impact and encouraging more sustainable methods in agriculture, processing, distribution and consumption.

The food footprint analysis helps identify sensitive aspects of the food chain where the impact is greatest, providing solutions for reducing carbon emissions, water consumption and land use. For example, in agriculture, efficient irrigation techniques or crop rotation methods can help reduce the ecological footprint.

Conventional technology:

Fertilization: ammonium nitrate, superphosphate, potassium chloride.

Phytosanitary treatment: synthetic fungicides and insecticides.

Irrigation: by sprinkling, average annual consumption 2,500 m^3/ha.

Fuel: diesel for soil work and transport.

Ecological technology:

Fertilization: manure, compost, green manure.

Plant protection: copper-based preparations, sulfur, plant extracts, natural predators.

Irrigation: drip, average annual consumption 1,800 m^3/ha.

Fuel: reduced by minimal soil work and mulching.

Indicators analyzed:

Input consumption (kg/ha or liters/ha).

Greenhouse gas emissions (CO_2 equivalent).

Soil impact (organic matter, microbial biodiversity).

Biodiversity impact (beneficial insects, pollinators).

Emission factors in walnut cultivation are mainly influenced by agricultural technologies, the type of inputs used and climatic conditions, their efficient management being crucial for reducing environmental impacts (Table 1).

Practicing conventional and organic walnut cultivation systems, the types and volumes of inputs used vary considerably, depending on the approach to soil management, fertilization and plant protection (Table 2).

Table 1. Emmision factors

Parameter	Value
EF-N-manufacture (kg CO2e/kg N)	6.3
EF-P2O5-manufacture (kg CO2e/kg P2O5)	1.1
EF-K2O-manufacture (kg CO2e/kg K2O)	0.85
EF_diesel (kg CO2e/L)	2.68
EF_electricity (kg CO2e/kWh)	0.25
EF_pesticide (kg CO2e/kg a.i.)	20
EF_soil_N2O_per_kgN (kg CO2e/kg N)	4.29
EF_compost (kg CO2e/t)	20
Carbon_sequestration_credit (t CO2e/ha)	1.83

Table 2. Types and quantities of inputs used in conventional and organic walnut farming systems

Conventional activity		Conventional activity results		Ecological activity		Ecological activity results	
Input	Quantity	Category	Emissions kg CO2e	Input	Quantity	Category	Emisions kg CO2e
Nitrogen (kg N)	120	Manufacture of fertilizers	890	Effective N mineralized (kg N)	24	Soil N2O (from N mineralized)	102.96
P2O5 (kg)	60	Soil N2O (from N)	514.8	Diesel (L)	80	Diesel use	214.4
K2O (kg)	80	Diesel use	268	Electricity (kWh)	450	Electricity use	112.5
Diesel (L)	100	Electricity use	125	Biopesticides (kg a.i.)	2	Biopesticides	40
Electricity (kWh)	500	Pesticides	120	Compost (t)	20	Compost (transport+apply)	400
Pesticides (kg a.i.)	6					Sequestration credit	-1830
		Total	1917.8			Total (net)	-960.14

The traditional system uses chemical fertilizers and artificial pesticides, while the organic system is based on renewable resources and natural methods of protection and fertilization. Water consumption may be comparable in both systems, but efficient management is more pronounced in organic farming (Table 3).

Table 3. Input consumption in conventional and organic walnut farming systems

Type of input	Conventional (kg/ha or l/ha)	Ecological (kg/ha or l/ha)
NPK fertilizers	350–450	0 (substituted with 15–20 t manure/ha)
Pesticides	8–10 treatments/year	3–4 treatments/year (copper, sulphur, extracts)
Water	2.500 m³/ha	1.800 m³/ha
Diesel	120 l/ha	80 l/ha

Organic farming generally has a low footprint, due to efficient use of resources, reduced carbon emissions and biodiversity conservation.

Maximizing input use through integrated technologies and unified pest control reduce the use of chemicals and protect nature. Investing in organic farming methods and adapting technologies to the specificities of walnut cultivation supports the sustainability of production and the conservation of natural resources. These aspects indicate that the adoption of organic practices in walnut cultivation reduces input use and the ecological footprint, supporting a more sustainable agriculture. Monitoring vegetation, in both qualitative and quantitative terms, serves to supply crucial information about life quality and its sustainability (Niculescu, 2024).

Environmental Footprint

GHG Emissions: Conventional farming generates ~30–40% more CO_2 equivalent emissions due to chemical fertilizers and higher fuel consumption. Conventional farming can contribute to soil erosion and depletion of natural resources (https://revista-ferma.ro).

Soil: in conventional, a decrease in humus content and a sharp compaction is observed; in organic, organic matter is maintained by applying compost.

Biodiversity: conventional treatments significantly reduce populations of pollinators and beneficial insects; in organic, species diversity is higher.

Although conventional technology ensures higher productivity in the short term, it involves a significant ecological cost.

The organic system, even if it has a lower yield in the first years, contributes to the conservation of soil and water resources, the maintenance of biodiversity and the reduction of emissions. Dinu et al., (2023) reccomend that for fruits and vegetables, the focus should prioritize nutritional quality over yield, which can be effectively achieved within an ecological agricultural system.

The European market trend is to support the conversion to organic farming through subsidies and certification.

The consumption of conventional inputs in walnut cultivation is higher compared to the organic one, especially in fertilizers and water.

The environmental footprint is greater in the conventional system through GHG emissions, soil degradation and biodiversity damage.

Walnut cultivation in an organic system has the potential to ensure sustainable production, with long-term benefits for the environment and the consumer. Organic practices can contribute to combating erosion and improving soil and water quality (https://revista-ferma.ro).

Improving the productive capacity and economic efficiency of fruit tree and shrub species suitable for organic cultivation, together with the implementation of nutrition and phytoprotection technologies with products allowed in organic agriculture, as well as the use of fruit preservation techniques that expand their storage and processing capacity are interconnected (Butac et al., 2021).

Research indicates that organic farming area, groundwater nitrate levels, net GHG emissions, forest area share, and surface area of terrestrial protected regions across most EU Member States show favorable outcomes, suggesting a strong likelihood of meeting the targets outlined in Agenda 2030, at both national and European scales (Pânzaru et al., 2023).

CONCLUSIONS

Precision agriculture, which uses data and technology to maximize water and fertilizer use efficiency, can significantly reduce agriculture's water and carbon footprint.

Traditional practices in fruit farming use chemical pesticides that significantly reduce the populations and diversity of beneficial insects, while organic farming fosters and preserves the ecosystem's natural self-regulating mechanisms by maintaining the complex interactions between plants, pests, and insects.

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