ECOLOGICA, Vol. 31, No 114 (2024), 144-150
https://doi.org/10.18485/ecologica.2024.31.114.4
Originalni naučni rad
UDC: 628.473(497.113)
551.583

Composting Agricultural Waste in the Mačva District as a Means of Reducing Negative Climate Change Effects

Kompostiranje poljoprivrednog otpada u Mačvanskom okrugu u funkciji smanjenja negativnih klimatskih promena

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Received / Rad primljen: 30.03.2024, Accepted / Rad prihvaćen: 10.05.2024.

Abstract: The Mačva District is known for its intensive agricultural production. Such agricultural production generates a significant amount of agricultural waste, which is inadequately managed. The majority of biodegradable agricultural waste is either burned, plowed under, or disposed of in unregulated landfills, causing negative climate change effects. In order to change this approach to managing agricultural waste, it is necessary for farmers to acquire knowledge and change their awareness of agricultural waste. One of the ways to properly manage biodegradable agricultural waste is composting. In this study, farmers from nine villages in the Mačva District were surveyed to determine their willingness to accept composting as a sustainable approach to dealing with the biodegradable waste generated on their farms. Two surveys were conducted, one in 2022 and the other in 2024. The survey results indicate a shift in farmers' awareness of composting. The willingness to participate in an organized composting system increased by 4% in the District after the repeat survey, and the willingness to compost independently increased by 3%, thereby also contributing to the reduction of negative climate change effects.

Keywords: composting, agricultural waste, Mačva district, climate change.

Sažetak: Mačvanski okrug prepoznatljiv je po intenzivnoj poljoprivrednoj proizvodnji. Takvu poljoprivrednu proizvodnju prati generisanje značajne količine poljoprivrednog otpada sa kojim se neadekvatno postupa. Najveći deo biorazgradivog poljoprivrednog otpada se spaljuje, zaorava ili odlaže na nesanitarne deponije izazivajući negativne klimatske promene. Da bi se takav pristup upravljanja poljoprivrednim otpadom promenio, neophodno je da poljoprivrednici steknu znanja i promene svest o poljoprivrednom otpadu. Jedan od načina pravilnog upravljanja biorazgradivim poljoprivrednim otpadom je kompostiranje. U ovom radu vršeno je anketiranje poljoprivrednika sa područja devet sela Mačvankskog okruga kako bi se utvrdila njihova spremnost da prihvate kompostiranje kao oblik održivog postupanja sa biorazgradivim otpadom koji stvaraju na svojim gazdinstvima. Sprovedene su dve ankete, prva 2022. godine i druga 2024. godine. Rezultati anketa ukazuju da se menja svest poljoprivrednih proizvođača o kompostiranju. Spremnost uključivanja u organizovani sistem kompostiranja veća je za 4% u Okrugu nakon ponovljenog anketiranja, a spremnost za samostalno kompostiranje za 3%, čime se utiče i na smanjenje negativnih klimatskih promena.

Ključne reči: kompostiranje, poljoprivredni otpad, Mačvanski okrug, klimatske promene.

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INTRODUCTION

Agriculture represents a human activity that has a strong negative impact on the environment. Natural resources - land, water, and air - are intensively utilized with the application of heavy machinery, agrochemicals, and increased generation of inadequately managed waste.

Agricultural waste cannot be defined unequivocally but generally includes: machinery waste, plastics (e.g. containers and seedling trays), plastic packaging (from pesticides, mineral fertilizers, etc.), veterinary products, construction waste, cardboard and paper, metal, wood, glass, tires, ash, animal waste, and crop residues (Knežević et al., 2024).

The problems associated with improper treatment of agricultural waste are becoming increasingly expressed as a deficiency in environmental management in rural areas. Safe treatment and productive utilization of agricultural waste can minimize the release of hazardous chemicals and thereby reduce soil, air, water, and other environmental pollution. The transformation of agricultural waste products, including straw, animal waste, and poultry manure, into organic fertilizer significantly promotes sustainable agricultural growth and contributes to environmental improvement (Noor et al., 2024).

Agricultural waste can be transformed into a valuable resource, and one of the methods to achieve this is through composting.

Managing plant agricultural residues is a global imperative today due to the significant amount of agricultural waste generated worldwide. Pollution associated with waste disposal techniques necessitates research into environmentally preferable methods of handling agricultural waste - increased agricultural waste leads to aesthetic, health, and environmental problems. Therefore, it is necessary to examine safe disposal techniques. Composting has emerged as an environmentally efficient, cost-effective, and safe treatment technology and productive solution for intensifying and sustaining agricultural production (Hashim et al., 2022)

Composting can be defined as an aerobic, biological process in which organic matter is degraded by natural microorganisms to produce a substance similar to humus, which is 'healthy,' stable, free of pathogenic microorganisms and weed seeds, and suitable for application to the soil (Figure 1). It represents controlled aerobic, thermophilic, microbiological degradation of solid organic components, such as raw or treated sewage sludge, manure, plant residues, food scraps, and their mixtures, into stabilized humus-like material (Haug, 1993). Composting allows for the recovery of carbon dioxide and plant nutrients that can be reused as inputs for crop production, while also providing a mechanism for managing and valorizing biowastes (Dsouza et al., 2021).

Figure 1 - General representation of composting process
Source: Dsouza et al., 2021

The composting process represents an ancient traditional waste minimization strategy. It is the primary form of recycling organic waste to produce useful fertilizers. Composting produces stabilized humus-like material that is beneficial for plant growth and effective in minimizing organic waste on small or large scales. The composting process can be applicable to a wide range of waste components, including solid and liquid waste. Typically, animal manure or plant residues are used as composting ingredients. In this process, the moisture content of waste materials is drastically reduced, and in the presence of oxygen, organic components of waste materials decompose at a certain temperature (Hussain et al., 2022).

As one of the most adaptable and beneficial methods for managing biodegradable solid waste, composting also contributes to recycling agricultural waste - both of animal and plant origin. The practice of composting agricultural waste is particularly prevalent in developing countries because it offers numerous advantages over other forms of waste management, especially compared to landfill disposal, whose negative environmental impact is manifested through increased possibilities of contaminating groundwater and leachate from the landfill. Composting innovative processes were developed

and employed by large- or medium-scale farmers, but they are expensive for small-scale farmers because the techniques require high-tech equipment for composting (Waqas et al., 2023).

Biomass in the agricultural sector comprises secondary or tertiary products from agriculture (such as wheat straw, soybean, barley, rye, corn stover, sunflower stalks, etc.). Agricultural biomass has significant energy potential, which determines long-term sustainability, taking into account competitiveness effects regarding food production. It significantly influences biodiversity and carbon dioxide (CO_2) emissions during combustion. For these reasons, the use of biomass must be viewed throughout its entire life cycle, starting from biomass production, through logistics, to final use (Gajdobranski et al., 2021).

Agricultural production is a factor contributing to climate change. Globally, agricultural production is a significant source of greenhouse gas (GHG) emissions, accounting for about 20% of total emissions (Ekardt et al., 2018; Nikolić Popadić, 2022). However, from another perspective, it can also be a significant factor in contributing to reducing climate change. In addition to adapting to altered climatic conditions, changes are also necessary in the other direction, aiming to reduce the negative impact of agricultural production on the climate and the sector's contribution to climate change (Nikolić Popadić, 2023; Xu et al., 2023).

During composting, chemical processes occur that result in various gaseous end products (Figure 2) such as methane (CH_4), nitrous oxide (N_2O), ammonia (NH_3) and a host of other volatile organic compounds (VOCs) along with CO_2 (Dsouza et al., 2021).

The composting method, selection of feedstock, optimization of physicochemical parameters, and addition of auxiliary materials play a significant role in regulating GHG emissions. Regulating the optimal range of physicochemical parameters can stimulate activity of microorganism and minimize GHG emissions (Wang et al., 2024).

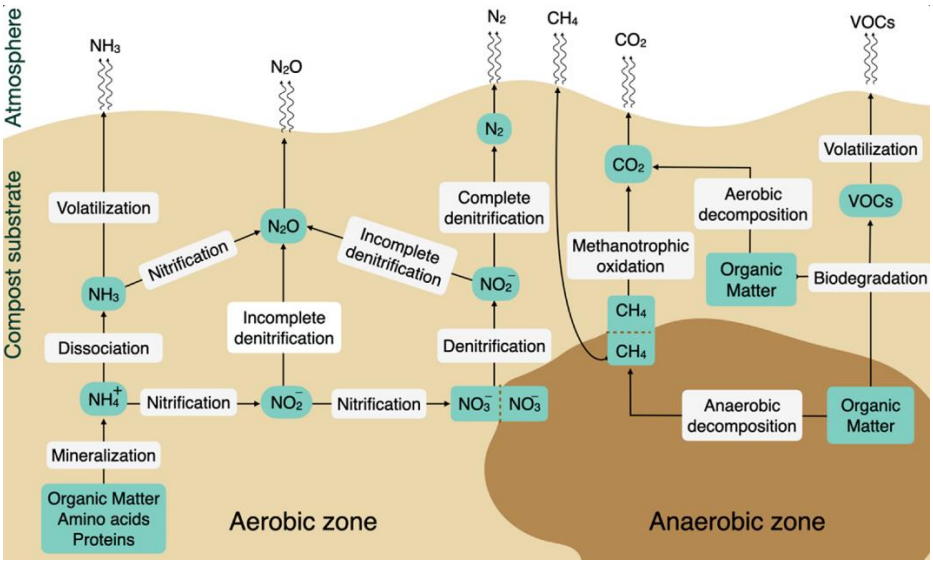


Figure 2 - Distribution of various gaseous emissions during composting
Source: Dsouza et al., 2021

The composting method, selection of feedstock, optimization of physicochemical parameters, and addition of auxiliary materials play a significant role in regulating GHG emissions. Regulating the optimal range of physicochemical parameters can stimulate activity of microorganism and minimize GHG emissions (Wang et al., 2024).

Anaerobically stored liquid manure is a source of methane (CH_4) but not of nitrous oxide (N_2O), while solid manure storage is a source of both CH_4 and N_2O. Composting is one of the methods for mitigating greenhouse gas (GHG) emissions when adequate aeration is used. Research has shown that aeration influences CH_4 and N_2O emissions during composting of liquid pig manure with straw (Park et al., 2011; Azim et al., 2017).

In accordance with the concept of environmental sustainability, the agricultural sector should practice waste transformation into profitable resources, implementing the concept of a circular economy (CE) as a contrast to conventional agriculture, which practices linear resource utilization. Farmers' readiness to adopt CE principles depends on their location, legal regulations, and available incentives. Ov-

ercoming these obstacles requires joint efforts, innovative technologies, and effective communication among stakeholders (Haque et al., 2023). The application of the circular economy concept provides opportunities to reduce GHG emissions in the agricultural sector through the circulation of raw materials, agricultural waste, and manure (Jurgilevich et al., 2016).

Research conducted in Serbia shows that climate change has been present for several decades, and it is expected to intensify in the coming years. In a report from 2018 titled "Observed Climate Changes in Serbia and Projections of Future Climate Based on Different Emission Scenarios", part of the project "Preparation of the Republic of Serbia's Report to the United Nations Framework Convention on Climate Change (UNFCCC)", climate changes in previous years were observed, and projections were made for the period until the end of the 21st century (Đurđević et al., 2018). Climate change in Serbia has negatively impacted agricultural production and yields for several decades. Forecasts for the upcoming period are concerning. Continued increases in average temperatures are expected, along with longer periods of drought, but also the occurrence of periods with above-average rainfall. This will require irrigation of agricultural crops on one hand, while on the other hand, drainage will also be necessary (Nikolić Popadić, 2023).

The organized system for collecting and managing agricultural waste does not exist either in the Republic of Serbia or in the Mačva District, which represents a serious problem from both ecological and economic perspectives. To change the approach to dealing with agricultural waste, it is primarily necessary to change the attitude of the generators of this type of waste - farmers - towards it. The Mačva District is characterized by intensive agricultural production, which is accompanied by the generation of a significant amount of agricultural waste. Agricultural waste includes residues from the cultivation of crops, residues from the cultivation of fruit crops, as well as residues resulting from the breeding of domestic animals. In recent years, there has been an increase in fruit crop cultivation in the district alongside traditional crop and livestock production. This leads to the creation of a significant amount of agricultural waste that could be efficiently utilized for composting (Milojević, Knežević, 2023).

One of the objectives of establishing an Integrated Municipal Waste Management System in the Waste Management Program in the Republic of Serbia for the period 2022-2031 is "introducing household composting in rural and semi-rural areas to recycle organic waste from households". According to this program, all households in rural areas will be provided with household composters and will use their own compost. Active public participation will be encouraged through targeted public awareness campaigns and direct support. It is estimated that "household composting in suburban/rural households will begin by removing 30% of biodegradable waste when regional infrastructure becomes operational, and will achieve 60% efficiency with the help of additional communication measures and assistance in the following years" (Milojević, Knežević, 2023).

1. MATERIALS AND METHODS

To conduct research on composting as a form of sustainable agricultural waste management, a survey was conducted in nine villages in the territory of the Mačva District. The respondents in the survey were farmers. The survey was conducted in the period from March to April 2022 and January to February 2024. Villages with more intensive agricultural activity in the municipalities of Šabac, Bogatić, and Loznica were selected: three villages in each municipality, with 10 households in each village.

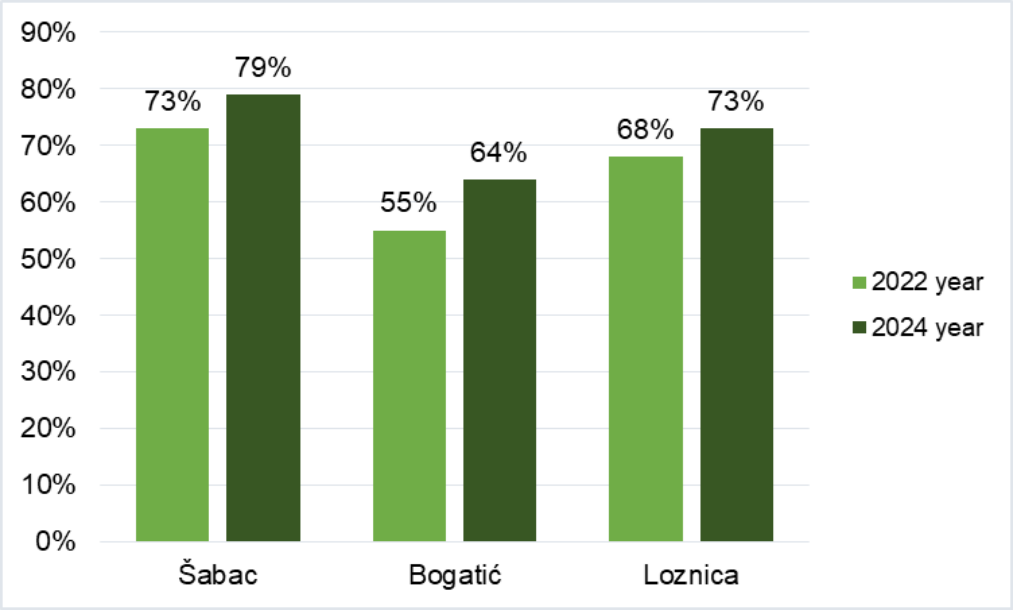
For both surveys, a questionnaire was used, consisting of two parts. The first part included standard questions about the structure of the agricultural household, the number of members, their ages, and educational levels. The second part focused on the following questions:

1. Do you know what composting is?
2. Would you compost agricultural waste independently?
3. Would you participate in organized collection of agricultural waste for composting?

After a brief explanation of what agricultural waste can be quickly converted into a useful resource for agricultural production and what its economic and environmental benefits are, a survey was conducted (Aleksić et al., 2023).

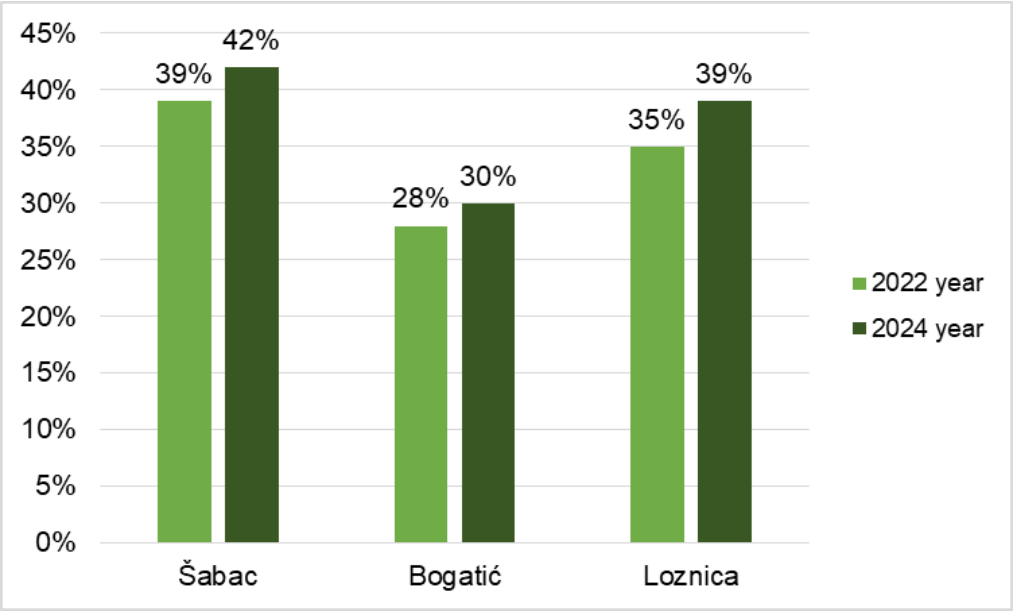
2. RESULTS AND DISCUSSION

The results of the conducted surveys show that the percentage of farmers who know what composting is has increased in all three municipalities (Graph 1) as follows: in the municipality of Šabac from 73% in 2022 to 79% in 2024, in the municipality of Bogatić from 55% in 2022 to 64% in 2024, and in the municipality of Loznica from 68% in 2022 to 73% in 2024.



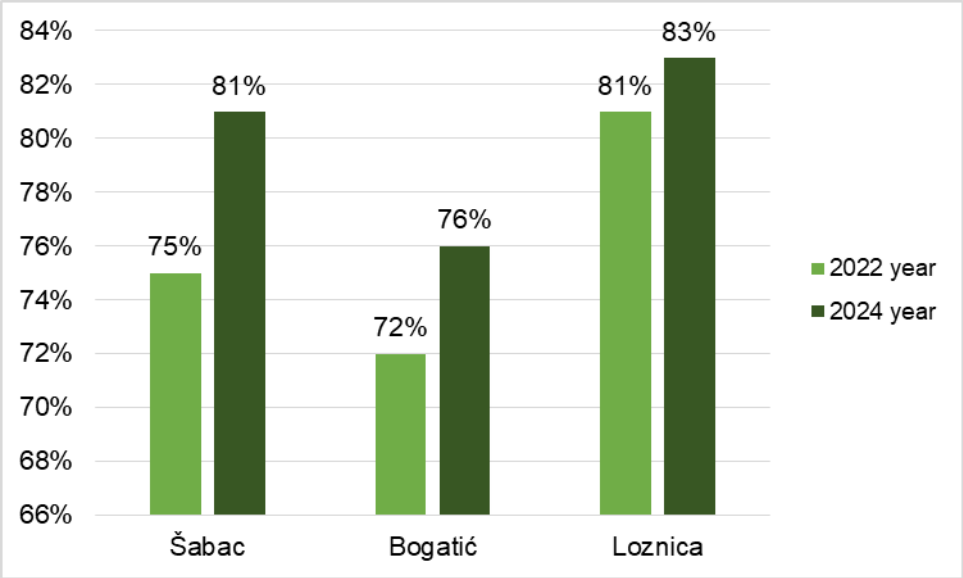
Graph 1 - The percentage of farmers who know what composting is
Source: Author's result

The readiness of farmers to compost agricultural waste independently has increased in all three municipalities (Graph 2) when comparing the survey data for 2022 with the data obtained from the survey conducted in 2024. This increase in villages in the municipality of Šabac is 3%, in villages in the municipality of Bogatić 2%, while the largest increase of 4% is observed in villages in the municipality of Loznica.



Graph 2 - Farmers' readiness to compost independently
Source: Author's result

Farmers in all three municipalities have expressed readiness to participate in organized collection of agricultural waste for composting. The results of the surveys conducted in 2022 and 2024 (Graph 3) show the highest increase in willingness among farmers in villages in the municipality of Šabac - 6%, in villages in the municipality of Bogatić - 4%, and the lowest level in villages in the municipality of Loznica - 2%.



Graph 3 - Farmers' readiness for organized collection of agricultural waste for composting
Source: Author's result

If one considers the results of the conducted surveys at the collective level, i.e. on average in all nine villages across the three municipalities, the following observations can be made:

- Independent composting has increased from an average of 34% in 2022 to 37% in 2024.
- Organized collection of agricultural waste for composting has increased from an average of 76% in 2022 to 80% in 2024.
- In both surveys and through their comparison, households with a larger number of members and more males aged 20 to 50 generate a larger amount of agricultural waste (indicating more intensive engagement in agriculture).
- In households where the predominant education level of members is middle or high, there is a greater willingness for both independent composting and organized collection of agricultural waste for composting.

CONCLUSION

The population of the nine villages in the Mačva District (municipalities of Šabac, Bogatić, and Loznica) holds a positive attitude towards composting as a sustainable approach to agricultural waste management. The surveys conducted in 2022 and 2024 show an increase in support for both independent composting (3%) and organized collection of agricultural waste for composting (4%). These results indicate that there is awareness of the importance of proper agricultural waste management in order to protect the environment, especially water, air, and soil. On the other hand, surveyed residents in all nine villages recognize that proper handling of agricultural waste, or its conversion into a useful product like compost, can also lead to economic benefits. The implementation of more intensive composting would contribute to reducing negative climate change impacts in the Mačva District and across the entire Republic of Serbia, which will be a priority until 2031.

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