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Motivating and demotivating factors for Bulgarian farmers to use WWTP sludge in agricultural holdings

Daniela Tsvyatkova*, Bozhidar Ivanov, Vassil Stoychev
Agricultural academy, Institute of agricultural economics – Sofia, Bulgaria
*E-mail: daniela_80@abv.bg

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Abstract

The problem of the treatment of sludge and the utilization of waste contents of sewage treatment plants for use in agriculture is a problem with a decades-old history. The aim of the study is to identify the main motivating and demotivating factors that convince Bulgarian farmers to use WWTP sludge. The article presents the prospects for agricultural utilization of sludge produced by WWTP in Bulgaria, and more specifically focuses on the study of the effect of sludge utilization in agriculture, on the one hand, and offers opportunities for their application, finding a long-term sustainable solution for their management.

The presented assessment of the possibilities and prospects for the Bulgarian agricultural producers for the utilization of sludge based on the achieved results of a scientific research project aims to solve the problems related to the socio-economic efficiency in the use of sludge in agricultural practice, and to support science and practice when resolving these public issues.

Key words: WWTP; agricultural producers; attitudes; Bulgarian agriculture

Мотивиращи и демотивиращи фактори за българските фермери да използват утайките от пречиствателни станции за отпадъчни води (ПСОВ) в земеделските стопанства

Даниела Цвяткова*, Божидар Иванов, Васил Стойчев
Селскостопанска академия, Институт по аграрна икономика – София, България
*E-mail: daniela_80@abv.bg

Резюме

Проблемът с третирането на утайките от ПСОВ и оползотворяване на отпадъчното съдържание в земеделските стопанства е въпрос с десетилетна история. Много години този въпрос има екологични, икономически, социални и обществени измерения. **Целта** на настоящата разработка е да се идентифицират главните мотивиращи и демотивиращи фактори, които карат българския фермер да ползва утайки от ПСОВ.

Статията представя перспективите за оползотворяване на утайки, произведени от ПСОВ в България, и по-конкретно се фокусира върху изследването на ефекта от оползотворяването на утайките в селското стопанство, от една страна, и предлага възможности за тяхното приложение, намирайки дългосрочно устойчиво решение за управлението им.

Представената оценка на възможностите и перспективите пред българските земеделски производители за оползотворяване на утайките, въз основа на постигнати резултати от научноизследо-

вателски проект, има за цел да реши проблемите, свързани със социално-икономическата ефективност при използване на утайките в селскостопанската практика, и да подпомага науката и практиката за решаването на тези обществени въпроси.

Ключови думи: ПСОВ; земеделски производители; нагласи; българско земеделие

Introduction

The European Green Deal sets out a new, sustainable and inclusive strategy for growth. It should stimulate the economy, improve people's health and quality of life, and take care of nature. Everywhere in the world, the need to reduce dependence on the use of pesticides and antimicrobials, reduce excess conventional fertilization, increase organic farming and improve animal welfare. A sustainable food system will be essential to achieve the climate and environmental goals of the Green Deal, while improving the incomes of primary producers and strengthening the Union's competitiveness. The bio-based circular economy is still with a largely untapped potential by farmers.

The use of sludge in agriculture is a relatively cheap and easily accessible way to limit environmental pollution in the area of treatment plants and not hinder their functioning (Ivanov et al., 2020). Considering the large amount of sludge received annually from WWTPs, finding solutions for sludge utilization becomes a challenge. Agriculture is a suitable recipient because it is organic matter that is brought in with the sediment. From an environmental point of view, sludge fertilization provides a very good solution for recovery, the storage of which creates major challenges for treatment plants and therefore for society. At the same time, there are various issues related to the use of these mixtures in agriculture, which concern ecological, production, sanitary, social aspects, but there are also economic ones, which are of essential importance in order to achieve durability, relevance and fruitfulness.

Because of the recycling of nutrients and sewage sludge disposal, applying sewage sludge to agricultural soils may be environmentally sustainable and economically viable. Yet there may be a risk in using sewage sludge because it contains elements that could be harmful, like heavy metals and pathogens (Usman et al., 2012). COVID–19 outbreak also poses a possible risk associated with the spreading of urban sewage sludge in agriculture and has to be disinfected before usage (Genet, 2020).

For 13 EU countries providing data for 2015, employed sludge-processing technologies include incineration, direct application to agriculture, and composting as predominant disposal methods. From these applied to agriculture amounted to 22.1% of produced sludge (Hudcová et al., 2019).

A competitive economy is built on the basis of a complex of multiple factors, which should not be ignored. Therefore, it is necessary to consider the importance of each indicator measuring factors to pay the necessary attention (Palme et al., 2005). It would be difficult for any farmer to reduce costs at the same time; to increase yields; to increase the quality of the manufactured product; to conserve natural resources, etc.

In this study, we mainly included the behavioral characteristics of farm owners and stakeholders. This largely predetermines the possible economic benefits of the farmers' management decision.

Material and methods

At the first stage of the research project, we identified the key impact factors (Table 1). We divided these into four main groups: economical, technological, social and factors of production. After identifying the main factors, an assessment is made for each of them for the degree of impact/motivation (high, medium, low) on the decision-making process in two categories – positive or negative. Based on the results we can derive specific recommendations to interested par-

ties for utilization of sludge in agriculture at present stage of development.

A rating scale (from 0 to 1) has been made for each indicator, and this rating, based on a comparative analysis, is compared with the responses of farmers who use sludge and those who apply mineral fertilizers in their agricultural practice. The approach developed to study the socio-economic impact of sludge utilization in agriculture is an integrated-comparative assessment method. It represents a tool for normalizing the heterogeneous and multi-layered results and values according to the observed and covered indicators of the factors from the production, economic, social and ecological sphere of impact when using the sludge in agriculture. The integrated-comparative method works with a quantitative ranking assessment, which is obtained by comparing the results and assessments of the same indicator in two technological methods of agricultural production - conventional fertilization with mineral fertilizers and alternative fertilization with sludge. This can be represented by the formula:

$RS_{In} = InS_{ST}$, where:

RS_{In} – ranking by each indicator and by the identified impact factors;

InS_{ST} – specific indicator and its normalized assessment when fertilizing with sludge in agricultural production;

InS_{CT} – the specific indicator and its normalized evaluation in conventional fertilization with mineral fertilizers;

The normalization of scores for each indicator is done by a formula:

InSST/CT = PVIn / MAXPVIn * RS, where

PVIn – the primary and original value of the indicator, which can be in different measurement and classification units;

MAXPVIn – maximum threshold value in favorable spectrum of impact that the result of a specific indicator can take, considering the primary measure and classification unit used;

RS – rank evaluation and maximum evaluation on this ranking scale, according to which the integration of the evaluations on indicators revealing the effects of the utilization of sludge in agriculture is carried out.

The actual effects are tracked and measured by means of specific and individual indicators, thus creating *a system of specific and actual indicators* representing the multifaceted effects of sludge utilization, which is reported at the farm level. The developed integrated-comparative evaluation method presents analysis and measurement of the effects of the utilization of sludge in agriculture, comparing the mirror effects of the selected indicators in an alternative way of production and conventional fertilization, which fulfills the role of a criterion. Thus, the evaluation has a relative character and cannot exist and be considered independently.

Results and discussion

In the last few years, the EU set itself the goal of achieving a new type of economy, developing new economic cycles, making a technological leap towards a waste-free and bio-economy, digitization and generators of green growth. All EU countries respect and follow the principles of:

- Clean and healthy environment;
- Rational use of raw materials;
- Integrated waste management.

To test the methodology of choice, first in-depth case studies were conducted in two technological types of agricultural production, with one farm using sludge fertilization and the other conventional farming (Bachev, H., Ivanov, B., 2021)

For comparability, we have taken two farms from the Sofia region, with almost the same amount of arable land, but due to the fact that one farm grows mainly corn and sunflower (does not use sludge), and an agricultural farm that uses sludge has tested the sludge mainly on corn and small area of wheat, and has a closed full cycle and can provide us with observational data (3–5 years) on one crop. We make restrictions to test the selected methodology and choose one crop (corn). Although the type of soil matters, these two farms grow their crops mainly on grey-forest soils, cinnamon-forest soils and alluvial-meadow soils.

Table 1. The system of indicators for evaluating the effects of sludge utilization in Bulgarian agriculture

Effect type	Properties and characteristics of effects	Measurement indicator
Factors of production	Change in quality of agricultural land used	Soil structure
		Soil aeration
		Soil organic matter
		Soil trampling
	Change in soil moisture retention	Degree of water retention
		Irrigation volume
	Change in yield	Average yield
		Imported mineral fertilizers in the farm
	Change in product quality	Product quality
		Amount of hazardous elements in the product
Economical	Impact on income	Total production
		Realization price
	Impact on production costs	Leafy mass
		Sludge purchase and delivery costs
		Costs for mineral fertilizers
		Labor costs
	Change in the amount of own or borrowed working capital	Own funds for working capital
		Borrowing funds for working capital and interest
	Changing the costs of training, information, exchange of experience, experimentation and testing	Costs of information, exchange of experience and training related to the use of sludge
		Costs of experimentation and tests related to use of sludge
	Change in transaction costs	Costs of negotiating and executing sludge supply contracts
		Costs for studying regulations and obtaining permits
		Costs for relations with landowners
		Production marketing costs
	Competitiveness change	Level of competitiveness
Social	Change in working conditions	Deterioration of working conditions
	Change in living conditions	Deteriorated comfort of the population
	Changing relationships with other agents	Conflicts with landowners
		Conflicts with other farmers and stakeholders
	Changing the sustainability of farms	Farm viability
	Waste reduction	Amount of sludge used in the farm
Ecological	Maintenance and improvement of soil quality	Level of soil fertility
		Amount of soil contamination
	Storage and savings of water	Irrigation level
	Air and road pollution	Degree of pollution
	Changing ecological sustainability	Level of environmental sustainability
	Waste management	Used sludge in the region, sub-sector, country
	Change in greenhouse gases	Reduction of the amount of mineral fertilizers used in the country

Source: Authors.

Maize is the most prone crop to use sludge the effect is significant. The yield of corn when sowing areas with introduced sludge is on average 1200–1450 kg/dca, and without applied sludge 650–700 kg/dca.

Bearing in mind that different types of soil fall into the arable land, a differentiated effect on the yield is taken into account for the different types of soil, as follows:

Type of farm	Plants grown	Total area sown with corn, sunflower, wheat	Total area sown only with corn
Farm 1 – using sludge	corn	700 dca	310 dca
Farm 2 – non-sludge user	corn	680 dca	290 dca

In the impact of **the production effects**, we report a strong preponderance of the farm that uses sludge (the indicators are within the range closest to 1), with the highest values being the indicators of moisture retention, production and annual yield (Fig. 1). When analyzing the indicators of **economic benefits** (Fig. 2) Farmers have calculated that about 40% of their total costs are for fertilization - mostly nitrogen, phosphorus and potassium. By bringing the sludge to their agricultural lands, the costs are optimized and expense on the ledger account is decimated. The sludge successfully replaces mineral fertilizers for a relatively long period – 5 years, during which users do not fertilize with mineral fertilizers, but continue to accumulate the benefits of the sludge's nitrogen, phosphorus and potassium reserves. As it become apparent, the sediment also helps to retain moisture in the soil. The effect of the sediment is visualized as a "sponge", and additionally the soil becomes looser. If the year is rainy, that is a sign there will be better yields. In addition, the soil is worked more easily, which has an impact on the load on tractors and the people employed during plowing. It is this that turns out to be extremely important for increased crop yield. Farmers have found sludge helps soil retain moisture twice as well.

Effective sludge treatment is also associated with significant costs, and there may be a strong interest in WWTPs to provide partially or untreated sludge to farms, to provide no free product, to provide no transport to the farm, to develop marketing strategies to sell the treated sludge

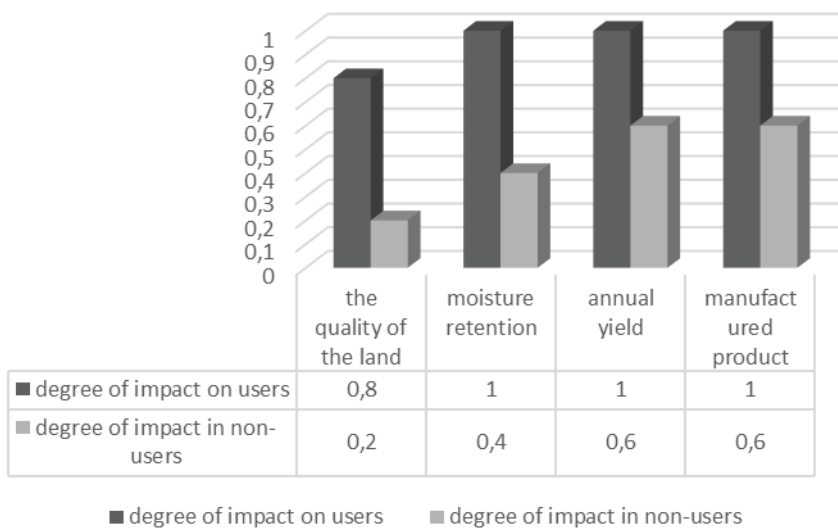


Fig. 1. Production effects

Source: Own research (case study).

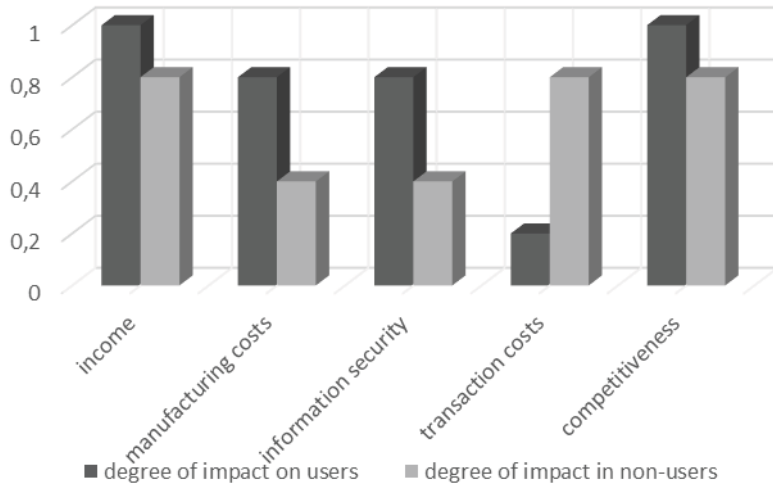


Fig. 2. Impact of the economic indicators
Source: Own research (case study).

as commercial product, to look for "more efficient" alternative utilization, etc. In addition, the economic efficiency for WWTP should be taken into account, which implies a certain (minimum) amount of received and profitably treated sludge, an effort to achieve economies of scale in contractual relationships and deliveries to utilization farms (and therefore a preference for a small number of large users) etc. For many of social and environmental effects, *qualitative classifications* are used to assess the effect. For many of these effects, there are also normatively (institutionally) defined standards that indicate minimum or maximum limits in which certain (mostly negative) effects are socially and/or ecologically acceptable and permissible. Under the impact of **social effects** (Fig. 3), we identify the following benefits: increasing income of farmers; increased sustainability of the agricultural economy; reduction of the amount of waste and the overall costs of its storage and destruction; improved competitiveness; simplified process for applying the sludge to the land if it is located in a remote settlement. It is established that social effects also have their negative impact, especially on public attitudes towards these processes: Reduced comfort for the population during periods of sediment introduction (dissatisfaction with the appearance of a specific smell); reluctance of land owners to provide their land for rent; conflicts with other farmers and stakeholders; reluctance of user farmers to share their positive experiences for various reasons. Regarding the **ecological effects** (Fig. 4), we found that the most influential and positive results for the economy are: maintenance and improvement of the fertility and quality of agricultural lands, increased water storage in farms; increased ecological sustainability of agriculture; improved and more efficient waste management.

Another important factor for increasing the utilization of sludge in agriculture is the availability of versatile, up-to-date and reliable information about the possibilities, ways, conditions, effects, challenges and risks related to utilization of sludge in agriculture. Adequate normative, scientific, experimental and practical information is important not only for agricultural producers, but also for all other participants in this process – government bodies, WWTPs, agricultural producers, interested parties, end users and the general public. Therefore, a survey was conducted to determine the motivating and demotivating factors and attitudes of farmers for using sludge as a fertilizer.

Farmers in the Sofia region and Samokov are aware of soil fertility loss, strong vulnerability and/or excessive dependence on agriculture. Soil

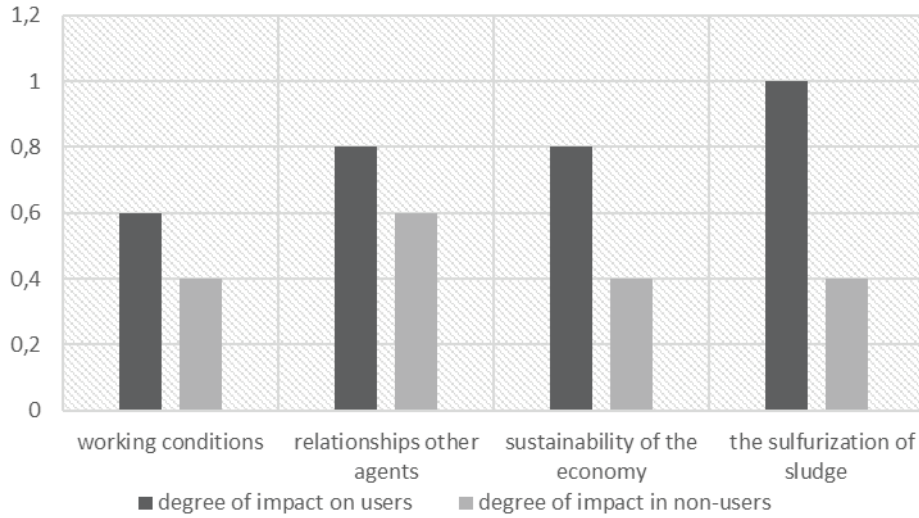
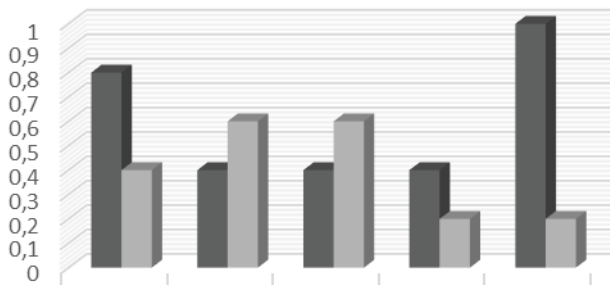


Fig. 3. Impact of social effects
Source: Own research (case study).



	soil quality	degree of pollution	ecological sustainability	waste management	amount of mineral fertilizers used
degree of impact on users	0,8	0,4	0,4	0,4	1
degree of impact in non-users	0,4	0,6	0,6	0,2	0,2

Fig. 4. Impact ecological effects
Source: Own research (case study).

diversity of the territory includes alluvial meadow soils, leached cinnamon forest soils, brown forest soils and mountain meadow forest soils. Agriculture is not of key importance for the economy, but it is of major socio-economic importance for the rural areas. Fragmentation of the agricultural land into small sections, due to mountainous relief, makes it unsuitable for agricultural activity, refinement and monoculture agriculture. The main crops grown on the territory are potatoes, wheat, corn, as well as various berries (raspberries, strawberries, etc.).

The farms are mainly owned by individuals, with an average size of 800–960 dca. arable land. The age of the farmers is between 41 and 55 years old, with extensive practical expe-

rience and theoretical knowledge in agricultural science. Their agricultural holdings have been in existence for more than 5–10 years. They demonstrate good knowledge of modern technologies, awareness, draw on foreign experience from outside, attend exhibitions, actively work with the scientific institutes of the Agricultural Academy, take an active part in seminars and agricultural associations of producers. Absolutely everyone is familiar with the use of WWTP sludge and what the agricultural practice is. They received the information informally – from fellow producers, scientists and various articles in the press. When asked about *the benefits they would have if they used sludge, we received an unambiguous answer*: "This is the elimination of plowing costs, a consequence of plowing the sludge into the soil", followed with the same weight by a positive answer: "Elimination of the costs of fertilizing with mineral fertilizers". From here, we conclude that the leading motives to utilize the sludge are: ***economic*** (double increase in yield) and ***technological.*** They have positive attitudes and a willingness to apply the sludge to the entire agricultural area (Fig. 5). To the question of whether they "made laboratory samples of the farm", a large percentage answered "no", sharing that the reason was the high costs for this (Fig. 6). For them, costs are an important factor for the survival of the farm. A large percentage of farmers would share their experience because it is a way to transfer knowledge among their cohort.

We also have several responses to that question indicating they would not share all information due to increased competition in the area. It is important for them that if it is found the sludge is not environmentally friendly and harms the society and the region, they would not use it (Fig. 7). Together with the obtained results and the conducted analysis, we also discovered that the specific conditions of certain farms, areas, productions, etc. are limiting, even completely blocking the effective utilization of sludge.

Together with the obtained results and the conducted analysis, we also discovered that specific conditions for certain farms, areas, productions, etc. are limiting, even completely blocking the effective utilization of sludge. For example, the transaction and other costs of the farmer for the delivery of sludge can be very high (negotiation and conflicts with WWTPs, obtaining permits, paying for soil samples, etc.), which can severely limit or even blocks the otherwise efficient (in terms of yield, production costs, etc.) use of sludge in the farm. *Another main reason stopping them is the huge number of documents and permits farmers have to submit in order to use these sludges.*

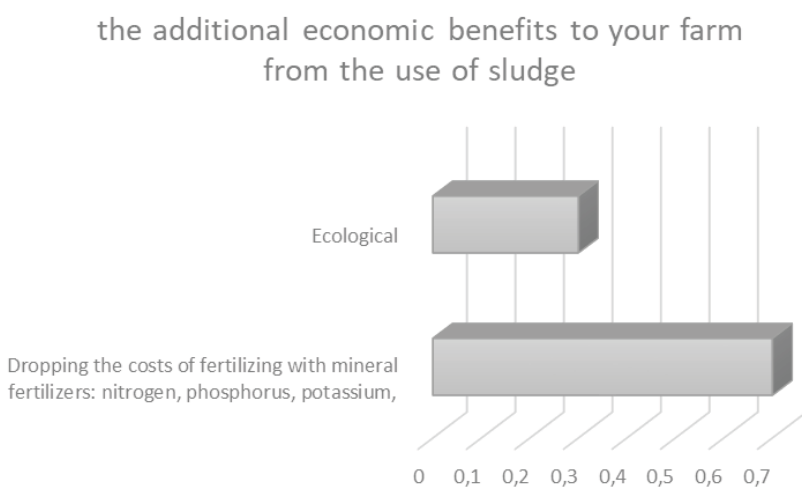


Fig. 5. Leading motives to utilize the sludge

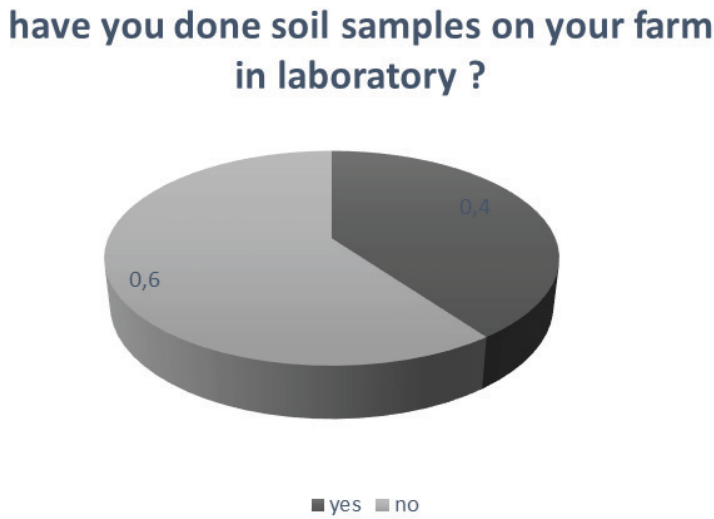


Fig. 6. Application of laboratory soil sampling on the farm
Source: Farmer Survey, 2022 – 2023.

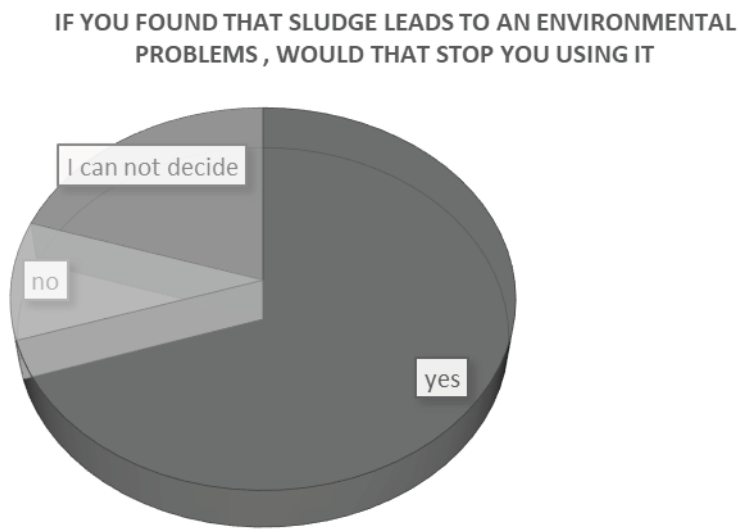


Fig. 7. Environmental behavior of farmers
Source: Farmer Survey, 2022 – 2023.

Conclusion

Building lasting relationships between Bulgarian farmers and the WWTP management, as well as the interested institutions, is an important condition, both to achieve regularity and reliability in the supply of sludge, but also to look for different, flexible new schemes and services to arise between the sludge supplier and the farmers.

• The in-depth study carried out in two technological types of agricultural production shows the definite advantages of sludge fertilization compared to the conventional one.

• The use of sludge in agriculture is a relatively cheap and easily accessible way to limit environmental pollution in the area of treatment plants and not hinder their operation.

• Rising prices of mineral fertilizers and raw materials, together with trends in the policy to reduce carbon emissions, makes the issue of the use of sludge in agriculture even more relevant.

• The use of sludge in agriculture is a technology known and applied worldwide for decades. It is considered to be one of the cheapest and most common ways to recover waste from sewage treatment plants.

• Greater trust needs to be built between WWTPs and farmers.

• WWTP to participate actively and support the procedure with documentation.

• Better awareness and training of farmers, both technologically and with awareness campaigns, is needed.

• There is a lack of a model for successful sludge utilization in Bulgaria.

• Improved and more efficient waste management will lead to clear management decisions from the WWTP and the management of the produced sludge.

• In the different regions of the country, this will lead to ecological sustainability of agriculture and higher competitiveness.

The assessment made unambiguously shows the high economic results of fertilizing with sludge. When comparing the results obtained between the no-sludge option and the option with sludge on all cultivated land, the gross income for the farm would be about 75% higher in the case of manure fertilization compared to no sludge. In this way, the economic efficiency of the utilization of sludge in agricultural production is proven. The efficiency of sludge fertilization is high, indicating that comparing the efficiencies of two fertilization models strongly confirms the superiority of the alternative sludge fertilization compared to the base mineral fertilization. The differences in gross returns of the two types of fertilization are so great that even if there is an increase in the costs of extraction, transportation, application and other related activities for the use of sludge in agriculture, the application of alternative sludge fertilization will remain superior in efficiency and efficacy. The first of these is better awareness and training of farmers, both technologically, how, when and in what way to use sludge as a fertilizing material, as well as with meetings and awareness campaigns with other stakeholders, on all issues related to risks, disadvantages, concerns, contamination, etc. It would be scientifically based and practically feasible to hold meetings with representatives of the local government (mayors of municipalities, local administration, representatives of the state administration, ministries, etc.), as well as with the owners of the agricultural lands themselves, who lease their lands to the local agricultural entrepreneurs, where sensitive topics are clarified and solutions are sought for them. Therefore, work can be done to both promote the use of a sludge-based soil fertilization product among farmers, allowing WWTPs to obtain funds to make the necessary investments, and also for WWTPs to have access to a public resource for financial assistance for the construction of installations and technologies for the creation of a product from the sludge used for fertilization. In the context of the environmental services that farmers increasingly need to provide in order to receive public support, working on the topic of sludge is not only promising, but also has the potential to achieve broad benefits for different actors.

Acknowledgments

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