

Evaluating Institutional Frameworks and Regional Disparities in the Utilization of Wastewater Treatment Plant Sludge in Bulgarian Agriculture: A new Institutional Economics Approach

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The conversion of sludge from wastewater treatment plants (WTP) into economically valuable agricultural products is shaped by a complex interplay of social, economic, technological, agronomic, and institutional factors. Among these, the institutional framework is a key determinant, influencing the behavior and interactions of stakeholders involved in sludge management. This framework, encompassing both governance institutions and institutional environments, establishes both enabling conditions and limitations that steer stakeholder actions, thereby affecting the efficiency and integration of sludge use in agriculture. This study adopts an interdisciplinary approach grounded in New Institutional Economics to assess the institutional framework that governs the utilization of WTP sludge in Bulgarian agriculture. The analysis reveals substantial progress over the past two decades in the development of regulatory, public, private, market, and hybrid mechanisms, which have led to improvements in sludge application practices. However, the study also identifies regional disparities in the sustainability and pace of development. Understanding the underlying factors that limit stakeholder actions and contribute to these regional variations is essential. To address these challenges, further interdisciplinary research is required, along with a comprehensive evaluation of the institutional framework. This includes gathering both micro- and macro-level data from stakeholders, potentially through official agro-statistical systems at national and EU levels. It is crucial to develop a new national strategy for sludge utilization that aligns with contemporary conditions and societal demands, accompanied by targeted support mechanisms for stakeholders, particularly farmers, using tools such as the Common Agricultural Policy (CAP). Furthermore, investigating institutional frameworks and sludge management practices in other EU countries can provide valuable comparative insights, enabling a more accurate assessment of Bulgaria's position and informing future policy strategies. Lessons from other nations' experiences can serve as important guidance for management decisions and long-term planning.

Keywords: Wastewater treatment plant (WTP), sludge, institutional framework, new institutional economics, agricultural sludge utilization, policy analysis.

INTRODUCTION

The transformation of wastewater treatment plant (WTP) sludge from waste into a resource is influenced by a wide range of factors, including social, economic, technological, agronomic, and individual aspects (Bachev and Ivanov, 2021, 2022). A key factor in optimizing the agricultural use of sludge is the institutional framework that shapes stakeholder activities and behaviors (Bachev, 2020). As WTP sludge management becomes more prevalent, it is essential to thoroughly examine the institutional structures involved. This study employs the New Institutional Economics perspective

to analyze the institutional framework surrounding the use of agricultural sludge in Bulgaria (Bachev, 2020, 2023; Furubotn and Richter, 2005; Williamson, 2005). Institutions, understood as the 'rules of the game' (North, 1991; Furubotn and Richter, 2005), play a critical role in shaping human actions. The research explores both formal regulations and informal norms to better understand the factors that promote or hinder the sustainable use of sludge in agriculture. The effective management of WTP sludge is a key component of Bulgaria's institutional modernization, driven by EU legislation and sustainability goals (Bachev and Ivanov, 2021). Over the last twenty years, Bulgaria has aligned its

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environmental policies with EU standards, fostering sustainability. The growing need to utilize agricultural sludge creates both opportunities and challenges, which call for a detailed analysis of institutional frameworks and governance practices. This study examines the institutional structures that impact sludge utilization in Bulgarian agriculture, identifying the agents involved, their needs, interests, and limitations. It analyzes the formal and informal mechanisms that govern their interactions, while also evaluating compliance with EU standards, the effectiveness of state interventions, and the variety of market-based and private sludge use models. The research utilizes a comprehensive methodological framework that combines qualitative analysis of regulations and institutional structures with survey data collected from WTP managers, environmental inspectors, stakeholders, and farmers in Sofia and Burgas. These regions, responsible for nearly half of Bulgaria's total sludge production (IEA, 2021), are identified as model facilities in the National Strategic Plan for Sludge Management (NSPMSWTPB, 2014), with Sofia achieving a 95% rate of sludge utilization in agriculture in 2021 (EEA, 2021). The institutional framework for WTP sludge utilization includes both formal institutions, such as legislation and regulations, and informal institutions, such as societal norms. Effective agricultural sludge utilization relies on modern legislation and regulations that define the rights and obligations of various agents (Bachev and Ivanov, 2021). Formal EU regulation of agricultural sludge use began with the 1986 EEC Directive (Directive 86/278/EEC), which encourages sludge application under specific conditions. This directive stipulates compliance with limits on heavy metals and biogenic elements in sediments and soils and mandates sludge treatment. The EU's evolving environmental legislation continues to influence agent behavior and relationships in the WTP sludge utilization process (Kelessidis and Stasinakis, 2012). EU countries display diverse policies and levels of social acceptance regarding agricultural sludge use. For instance, France required sludge disinfection before agricultural application due to COVID-19 (ANSES, 2020). Consequently, sludge utilization rates vary significantly, from negligible in Malta, Slovenia, and Slovakia to 80% in Ireland (EU, 2016). In Bulgaria, only a small fraction of farms currently uses WTP sludge (Bachev *et al.*, 2021). Bulgarian legislation incorporates the European Directive's environmental protection requirements through various normative documents. The principal document is the Ordinance on the Utilization of Sewage Sludge in Agriculture (Regulation, 2017), first adopted in 2004 and revised in 2011, 2016, and 2017. This ordinance details procedures and methods for agricultural sludge use, ensuring protection of soil, vegetation, animals, and humans, and establishes permit requirements, sampling and testing methods, and responsibilities for producers and users (Ivanov, 2017; Bachev *et al.*, 2023; Bachev and Kargı, 2023). State policies, programs, plans, and incentive mechanisms form a key part

of the institutional framework designed to meet social objectives related to the use of agricultural sludge and other sectors. Effective regulation and government interventions can encourage positive behavior among stakeholders, while poorly designed regulations may discourage participation (Stefanakis and Tsihrintzis, 2012). To assess the institutional framework for agricultural sludge utilization in Bulgaria, the study applies criteria that evaluate the quality and costs of various components. This includes ensuring compliance with EU legislation, clarity for involved parties, effective implementation within the Bulgarian context, and support from informal norms. Additionally, it considers the production, transactional, and other costs borne by participants and society, alongside the efficiency of sludge utilization rates (Tsagarakis *et al.*, 2004; Kargı and Bachev, 2024). Public interventions are examined based on their alignment with current needs, successful implementation of EU policies, their ability to address market and private sector failures, and the costs associated with their development and execution. The socio-economic and environmental impacts are also assessed. Private sector and market-driven approaches are evaluated in terms of their diversity, competitiveness, incentives, constraints, and overall effectiveness (Smith, 2009). Effective management of WTP sludge is vital for Bulgaria's institutional modernization, guided by EU legislation, sustainable development principles, and the potential for sludge utilization in agriculture (Schaubroeck *et al.*, 2015). As WTP sludge production increases, its application across various regions of Bulgaria becomes increasingly necessary. This study explores the challenges and opportunities, offering recommendations to improve public policies and management strategies for optimizing sludge use in agriculture. Wastewater treatment plant (WTP) sludge is increasingly recognized as a potential resource in agriculture, yet the effective utilization of this resource remains limited by multifaceted institutional and governance challenges. In Bulgaria, the process of transforming WTP sludge from waste to a valuable resource is hindered by complex interactions among formal regulations, informal societal norms, and the behaviors of various stakeholders, including farmers, WTP managers, and government bodies. Despite the alignment of Bulgaria's environmental policies with European Union (EU) directives, only a small fraction of agricultural land utilizes WTP sludge, resulting in missed opportunities for sustainability and resource optimization. Institutional frameworks that govern these interactions—encompassing legal frameworks, policies, and informal social norms play a pivotal role in either facilitating or obstructing the widespread adoption of agricultural sludge use. Consequently, a deeper understanding of these institutional structures is critical for addressing barriers, ensuring compliance with EU standards, and enhancing the efficiency of sludge utilization practices. This research focuses on examining the institutional framework



that governs agricultural WTP sludge utilization in Bulgaria, employing the lens of New Institutional Economics (NIE). By analyzing both formal regulations and informal norms, the study investigates how these institutions shape the behavior of key stakeholders and impact the sustainable use of WTP sludge in agriculture. Specifically, the research evaluates the roles of formal legislation, such as the EU Directive on sludge management, and informal societal norms that influence stakeholders' participation and compliance. The study assesses the effectiveness of current governance mechanisms, identifying key constraints and opportunities for improvement in institutional structures. Through qualitative analysis and surveys with WTP managers, environmental inspectors, and farmers, this study aims to provide a comprehensive evaluation of the regulatory and institutional framework in order to recommend strategies for optimizing agricultural sludge utilization in Bulgaria.

MATERIALS AND METHODS

Institutions, referred to as the "rules of the game" (North, 1991), consist of both formal regulations and informal norms that shape human interactions (Furubotn and Richter, 2005). Formal institutions include laws and enforcement mechanisms, while informal ones arise from societal norms and cultural practices, influencing behavior through social expectations and self-regulation. Internally, governance institutions are established to manage interactions between agents, such as organizational structures, professional standards, and contracts (Bachev, 2020). These institutions significantly affect human activities and relationships, influencing socioeconomic outcomes and the path to sustainable development (Bachev, 2020). Bachev's adapted framework (2020, 2023) is applied to evaluate the institutional structure for the use of wastewater treatment plant (WTP) sludge in Bulgarian agriculture. This framework takes into consideration not only the production and transaction costs related to sludge utilization but also the social, organizational, and technological dimensions. The analysis of the institutional structure involves: 1) identifying and characterizing the agents involved in sludge utilization, including an assessment of their needs, interests, and limitations; 2) evaluating the mechanisms that regulate agent behavior, such as policies, public programs, and informal norms, and their influence on sustainable sludge use; 3) examining the impact of institutional changes on the modernization and evolution of agent behavior and interactions; and 4) identifying challenges and opportunities within the institutional framework to enhance the efficiency of agricultural sludge utilization. The cities of Sofia and Burgas were selected for this study due to their significant role in WTP sludge production and utilization in Bulgaria. Both regions produce nearly half of the country's total sludge, making them key areas for understanding the dynamics of

agricultural sludge use. Sofia and Burgas are identified as model facilities in the National Strategic Plan for Sludge Management (NSPMSWTPB, 2014), with Sofia achieving a 95% sludge utilization rate in agriculture by 2021 (EEA, 2021). These high utilization rates suggest that the regions have established relatively successful institutional frameworks for sludge management, making them ideal for examining both the challenges and opportunities in optimizing sludge utilization. Moreover, the regions' pivotal role in Bulgaria's broader wastewater treatment and agricultural sectors provides valuable insights into the regulatory, social, and economic factors influencing sustainable sludge use, allowing the study to assess the effectiveness of institutional structures in facilitating or hindering sludge application in agriculture. This study employs qualitative analysis of the regulatory and institutional frameworks for Bulgarian agricultural sludge utilization, based on surveys with stakeholders from WTPs, environmental agencies, and farmers in Sofia and Burgas (IEA, 2021). These regions are pivotal for sludge production and utilization in Bulgaria (NSPMSWTPB, 2014; EEA, 2021). A criteria-based evaluation assesses institutional quality and costs associated with sludge utilization components (Table 1), including EU legislation compliance, stakeholder clarity, implementation effectiveness, and socioeconomic and environmental impacts of public and private interventions. This comprehensive approach aims to provide insights into enhancing the institutional framework for sludge utilization in Bulgarian agriculture, addressing regulatory challenges and fostering sustainable development.

Table 1. Standards for assessing the WTP sludge usage institutional framework in Bulgarian agriculture.

Institutional Environment	Institutions of Governance		
	Public	Market	Private
Compliance with EU legislation	Matching intervention	Incentives and constraints	Variety of forms
Clarity and comprehensibility	needs	Degree of competition	Incentives and constraints
Practical applicability	Costs	Costs	Costs
Incentives and constraints	Efficiency	Efficiency	Benefits
Supporting informal institutions			Efficiency
Costs			
Efficiency			

The evolution of public forums and institutional environments: Effective waste management, particularly sewage sludge management, is central to institutional modernization in Bulgaria and other developed European nations (Bachev and Ivanov, 2021). Two decades of EU legislation alignment and sustainable development integration have reshaped environmental policies and practices across sectors (Bachev and Ivanov, 2021). Moreover, scientific research underscores the potential benefits of sewage sludge in agriculture, land reclamation, and energy generation (Marinova, 2008). Bulgaria's increasing WTP sludge necessitates its agricultural utilization as fertilizers and soil conditioners (Bachev and Ivanov, 2021). This institutional modernization phase involves both top-



down governmental initiatives (e.g., legislation, public interventions) and decentralized stakeholder actions (e.g., businesses, farmers, research institutions, communities). Figure 1 illustrates key actors and relationships within Bulgaria's agricultural sludge utilization framework.

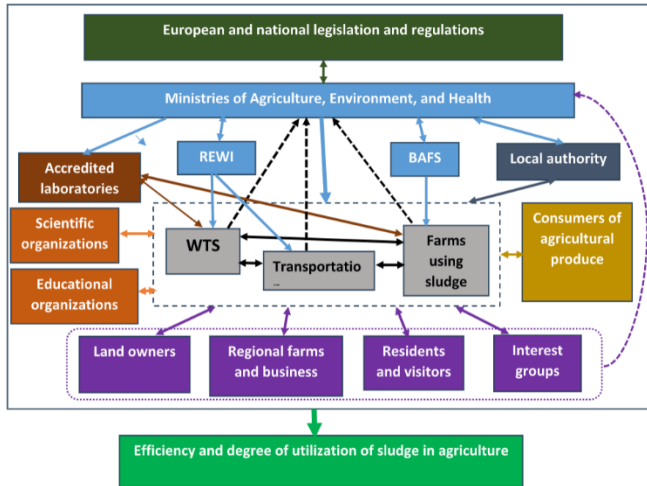


Figure 1. Institutional framework of Bulgarian agriculture's WTP sludge usage procedure.

The institutional framework for managing agricultural sludge in Bulgaria is shaped by legislative and regulatory measures that define the rights, procedures, processes, and oversight related to sludge utilization. Effective agricultural sludge use demands up-to-date legislation and regulations (Bachev and Ivanov, 2021) that delineate the roles and responsibilities of stakeholders, including regulatory bodies, control agencies, wastewater treatment plants (WTPs), farmers, and laboratories. These regulations set standards for sludge quality, soil health, safety, and application methods, while also incorporating state policies, programs, and incentives designed to achieve social goals related to sludge utilization. Well-crafted regulatory guidelines and government intervention can positively influence stakeholder behavior, encouraging the efficient use of sludge and maximizing its benefits while minimizing negative impacts. On the other hand, inefficient regulations—such as overly complicated processes or high permit costs—can discourage participation. The European Union began regulating WTP sludge for agricultural use with the EEC Directive of 1986 (Directive 86/278/EEC), which outlines conditions to prevent harmful effects on soil and crops. This directive sets limits on heavy metals and biogenic elements in both sludge and soil, restricts application rates, and mandates the treatment of sludge before its use as fertilizer. EU environmental regulations address concerns related to water, air, biodiversity, and climate, and are regularly updated to safeguard natural resources and public health. Member states have developed specific sludge policies; for example, France mandated sludge disinfection

during the COVID-19 pandemic (ANSES, 2020). As a result, the extent of sludge utilization varies significantly across the EU, ranging from minimal use in countries like Malta, Slovenia, and Slovakia to 80% in Ireland (EU, 2016). In Bulgaria, while comprehensive data on the use of WTP sludge in agriculture are limited, current utilization levels remain relatively low (Bachev et al., 2021). Bulgaria's Ordinance on the Procedure and Method for the Utilization of Sewage Sludge in Agriculture (Regulation, 2017) brings the country's legal framework into compliance with the standards of the European Directive. The methods for applying sludge are outlined in this Ordinance, which was first approved in 2004 and revised in 2011, 2016, and 2017. It covers protection of the soil, plants, animals, and humans in addition to accounting, permitting, and testing regulations (Ordinance, 2017). It restricts sludge application to sole traders or legal entities and bans its use on meadows, pastures, and fodder crop areas within 45 days of harvesting, as well as on soils with fruits, vegetables, or other raw-consumed crops within 10 months. Sludge cannot be applied in protected areas, sanitary zones, or coastal floodplains. Permits from the Bulgarian Food Safety Agency (BFSA) are required and must include soil analysis from the application site, with accredited laboratories performing sampling and testing. Permits specify sludge quantities, compliance with maximum permissible concentrations (MPC) of heavy metals, and detail application areas and volumes. They are valid for single sludge imports to designated locations. Enforcement is managed by the Ministers of Agriculture, Environment and Water, and Health, with Regional Environmental Inspectorates (REWI) and the BFSA overseeing permit issuance and quality control. Additional regulations for sludge management are outlined in waste and water management legislation, including Ordinance No. 1 on waste information and public registers, Ordinance No. 2 on waste classification, and the Law on Waste Management. Bulgaria has established a comprehensive legislative framework for safe agricultural sludge use, conforming to European standards. This framework outlines sludge use regulations, identifies regulatory and controlling bodies (e.g., REWI and BFSA), accredits testing laboratories, and governs the use and users of WTP sludge. Sludge use in agriculture is safe from an agronomic, economic, ecological, and medical standpoint, according to research from organizations like the Soil Institute "Pushkarov," the Bulgarian Academy of Sciences (Institute of Microbiology), and the Ministry of Health (National Center for Public Health and Analyses) (Marinova, 2008). Before 2005, when the current laws were put into place, Bulgarian agriculture used very little sludge (EEA, 2005). The use of sludge has greatly grown due to recent regulations. 22,520 tons of dry sludge, or 61% of the total sludge produced, were used in agriculture by 2006 (NSPUS, 2014). Roughly 49% of the sludge produced between 2004 and 2010 was utilized for farming or land reclamation



(NSPUS, 2014). Following new legislation, the proportion of sludge used in agriculture rose from 31% (2006-2010) to 36% (2011-2015), reaching 48% in recent years (2016-2021) (EEA, 2004-2021). Bulgaria adopted the National Strategic Plan for managing WTP sludge for 2014-2020 (NSPUS, 2014) in compliance with European standards. The plan calls for 70% of WTP sludge to be recycled and utilized by 2020, with no non-targeted storage or landfilling allowed. A sustainable framework for managing sludge was to be created, national rules were to be updated, a sludge management database was to be established, a qualified sludge utilization system was to be created, and monitoring and control systems were to be implemented (ISO 9001, EMAS, ISO 14001, ISO 18001). Though CAP instruments and public funds have not yet provided financial support for sludge usage, significant investments from European and national sources have updated Bulgarian WTPs. Sludge utilization has not advanced due to a lack of CAP integration, low social acceptance, and little funding. In the EU and Bulgaria, institutional standards for animal welfare, environmental protection, and the quality of food and feed are getting stronger; these standards are frequently connected to CAP support mechanisms. Despite the influence of environmental groups, consumer organizations, enterprises, and local communities, agricultural sludge use is still not widely accepted in Bulgarian society. This problem is made worse by the idea that WTP sludge is trash instead of a resource. Adopted in 2019, the EU's Green Deal establishes aggressive goals for lowering greenhouse gas emissions, restricting the use of pesticides and mineral fertilizers, and encouraging organic farming by 2030. The implementation of these goals through CAP instruments, Strategic Development Plans, and other policies will influence future incentives for sludge use. Key public agents in Bulgaria's sludge utilization framework include REWI, BAFS, testing laboratories, scientific organizations, and local governments. Their effectiveness in implementing the regulatory framework is crucial for enhancing sludge utilization. Since Bulgaria's EU accession, state authorities' competence and enforcement have improved, although regional disparities remain—from complete denial in Burgas's coastal resorts to full acceptance in Sofia, where sludge use generates local jobs and services. Regional variations in administrative capacity due to resource limitations, experience, training, staff turnover, organizational changes, and political support affect regulatory understanding and application. Public bureaucracies also face issues such as lack of initiative, adaptability, high costs, and decision-making delays. Additionally, sludge utilization has not been a priority among Bulgaria's socio-economic and environmental issues, complicating regulatory improvements and public support through various programs. Frequent changes in the regulatory framework present challenges for civil servants and stakeholders, with compliance involving significant costs. Only a few large, well-resourced WTPs,

transport companies, and agricultural holdings can meet modern standards. Most public interventions impose constraints with minimal direct support. A new, long-term state strategy reflecting current needs and addressing challenges from the old strategy has yet to be developed. This strategy should address challenges and adapt scenarios for agricultural development and potential sludge use in agriculture and other sectors in the medium term. Overall, sludge utilization in Bulgarian agriculture has progressed significantly since EU accession, influenced by scientific research and regulatory frameworks. Leading institutions have affirmed the benefits of sludge use (Marinova, 2008), although its application was minimal before modern regulations in 2005 (EEA, 2005).

Legislative and regulatory evolution: The adoption of more recent laws has greatly increased the use of sludge. 22,520 tons of dry matter sludge, or 61% of the country's total sludge output, were applied to agriculture in 2006 (NSPUS, 2014). Approximately 49% of the sludge produced between 2004 and 2010 was used on land; this percentage increased over time, averaging 31% from 2006 to 2010, 36% from 2011 to 2015, and 48% from 2016 to 2021 (EEA, 2004-2021). To comply with EU regulations, Bulgaria implemented the National Strategic Plan for managing sludge from wastewater treatment plants (WTP) for 2014-2020. This plan targeted recycling and utilizing 70% of sludge by 2020, aiming to eliminate landfilling and indiscriminate sludge storage. Key measures included forming an institutional framework for sustainable sludge management, creating a legislative framework, developing a comprehensive database for planning, and establishing a monitoring and control system (NSPUS, 2014).

Challenges and barriers: Despite these improvements, several challenges persist:

- **Inadequate Financial Support:** Despite significant investments to modernize WTPs, the use of CAP instruments and public funds to promote sludge utilization has been insufficient. This financial shortfall hampers the widespread adoption of sludge utilization practices.
- **Institutional and Regulatory Challenges:** The regulatory framework governing sludge utilization is complex and inconsistently enforced across different regions and sectors. Problems such as bureaucratic inefficiency, corruption, and conflicts of interest within regulatory and supervisory bodies exacerbate these challenges.
- **Information Asymmetry and Public Perception:** A major obstacle is the lack of reliable and up-to-date information regarding sludge utilization, which limits informed decision-making among farmers and other stakeholders. Moreover, public perception tends to be negative, often influenced by incomplete or misleading information.
- **Training and Advisory Services:** There is a shortage of specialized training and advisory services for farmers. Institutions like agrarian universities and the National



Agricultural Advisory Service lack the necessary expertise to offer sustained training and guidance on effective sludge utilization.

Scientific research and practical applications: Scientific research on sludge utilization in Bulgaria has been limited and often fails to reflect real-world conditions. Many studies are small in scale, inadequately funded, and conducted under idealized conditions that differ significantly from the practical realities of farming. Comprehensive interdisciplinary research is scarce, and there is a growing need for more extensive studies that involve not only sludge-producing and transporting organizations but also the farms that use the sludge.

Strategic recommendations: To overcome these challenges and improve sludge utilization in agriculture, several strategic actions are recommended:

- **Financial Incentives and Support:** Implement financial mechanisms leveraging CAP instruments and public funds to encourage sludge utilization. This could include subsidies for sludge transportation and application, as well as grants for the development of necessary infrastructure.
- **Enhanced Regulatory Framework:** Simplify and streamline the regulatory framework to reduce bureaucratic inefficiencies and ensure consistent enforcement across all regions. Strengthen anti-corruption measures and address conflicts of interest within regulatory and supervisory bodies.
- **Information Dissemination:** Develop comprehensive and accessible resources for stakeholders, including practical guidelines, scientific research, and case studies showcasing successful sludge utilization.
- **Training and Advisory Services:** Establish specialized training programs and advisory services at agrarian universities and related institutions. Provide long-term counseling and support for farmers to improve sludge utilization practices.
- **Public Awareness Campaigns:** Initiate campaigns to improve public perception of sludge utilization, highlighting its environmental and economic benefits and addressing common misconceptions.
- **Interdisciplinary Research:** Promote interdisciplinary research that engages a wide range of stakeholders to explore the challenges and opportunities of sludge utilization. Ensure that research findings are widely shared and applied in practice.

While sludge utilization in Bulgarian agriculture has advanced, continued progress depends on addressing these challenges through targeted financial support, regulatory enhancements, information dissemination, training, public awareness, and interdisciplinary research.

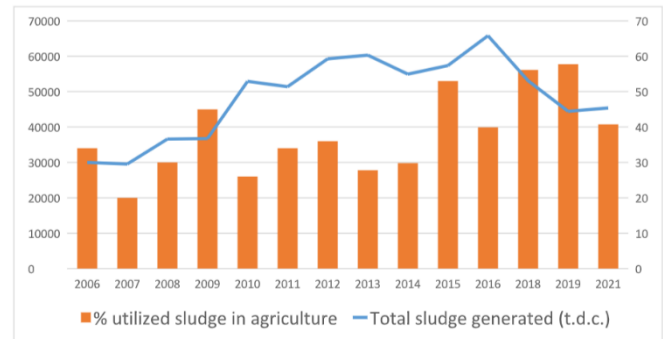
Private initiative and modes: The key private actors in agricultural sludge utilization include organizations within the supply chain: wastewater treatment plants (WTPs) producing sludge, transportation companies handling its

delivery, and agricultural producers applying it. Other relevant participants include landowners, local businesses, residents, visitors, traders, processors, and interest groups (Figure 1). Understanding this structure involves analyzing the interests, incentives, and relationships of these agents. Typically, the interaction between WTPs and farmers is governed by contractual agreements, either annual or multi-year, which allow for negotiation and termination. A fully competitive market for sludge does not exist due to regional monopolies among WTPs and a limited number of specialized transporters and end users, predominantly farms operated as sole proprietors or legal entities like cooperatives and corporations. All participants require state-issued licenses, including permits for sludge treatment, transport, and agricultural use. This creates a hybrid system with state oversight for licensing and monitoring, coupled with specific technological requirements, such as defined application areas and volumes. Regulations often dictate product characteristics and usage methods. Through private contracts, WTPs typically grant farmers the right to use treated sludge on authorized farm areas, often including additional services like permits, transportation, and spreading. In some cases, sludge is provided free of charge to farmers, who only bear transportation and spreading costs, as seen in Sofia. This arrangement reflects the mutual benefits of the non-commercial exchange. WTPs should ideally create plans for effective sludge utilization and management. High sludge output makes it possible to use more sophisticated, economical treatment techniques as well as alternatives to burning and landfilling. WTPs frequently provide free sludge in an effort to boost their reputation, resolve community unrest, appease the public, reduce landfill shortages, and save money on disposal. Utilizing sludge offers farmers advantages in terms of economy, agronomy, production, and ecology (Bachev and Ivanov, 2021; Kargı and Bachev, 2024). According to our research, sludge consumers are usually large-scale farmers who are capable of managing the dangers involved and are primarily concerned with cutting expenses related to chemical fertilizers. Sludge adoption in farming necessitates technical modifications and improved management, which are typically carried out by creative entrepreneurs. When transportation is managed by specialized companies, prior licensing and contracts between WTPs and farms are essential. Transportation fees are negotiated and paid by the WTP, farmer, or both. In regions like Burgas, transport companies advocate for increased sludge utilization by lobbying for CAP support measures. Despite the seemingly monopolistic nature of WTP-farm relationships, mutual dependency due to capacity, location, and timing constraints exists. Agricultural sludge utilization is still developing, with WTP assets closely tied to local farms. This dependency often leads large WTPs to integrate sludge production and transportation to reduce costs, as observed in Sofia. High mutual dependence fosters long-term



partnerships. Our survey in Sofia found that many farms have used sludge for up to two decades, fostering trust, cooperation, and coordination, which lowers transaction costs and improves utilization efficiency. However, sludge utilization involves additional costs related to WTP dealings, regulatory requirements, and soil sampling. Incomplete contracts can lead to issues such as delays or quality variations. Standard contracts not tailored to specific farm conditions further increase adaptation and coordination costs. Short-term land rent agreements with multiple landowners add risk, as long-term investments in sludge use may be threatened if landowners do not renew contracts. WTPs, aiming to minimize costs, prefer large farms near sludge landfills, reducing negotiation, permit, sampling, and transportation costs. High transaction costs can hinder sludge utilization, as seen in Burgas where a large farmer ceased using sludge due to high costs. Future effectiveness and incentives for using sludge instead of mineral fertilizers will depend on the price dynamics of mineral fertilizers (primarily N and P) and potential restrictions on their use in EU regions. Institutional uncertainty related to the Green Deal and market attitudes will also play significant roles. Some WTPs plan to commercialize sludge by selling it to farmers, but many farmers believe this would limit agricultural use due to a lack of sludge market and competition from other fertilizers. A robust sludge market with high prices is unlikely to develop soon, with costs for effective utilization likely continuing to be covered by WTPs or public programs. Other stakeholders, including landowners, neighboring farms, businesses, and local residents, have limited influence due to minor negative effects, high individual costs, and challenges in collective action. Collective actions are most effective for addressing significant, direct impacts such as strong odors. A psychological barrier exists due to concerns about the "special nature" of sludge, affecting perceptions of soil quality, biodiversity, and health. Informal rules around sludge need thorough examination. In some EU regions, higher tolerance for sludge use exists due to extensive manure application. The market and buyers are not yet receptive to widespread sludge use. Concerns about the safety of produce grown with sludge result in lower prices and higher marketing costs. Long-term environmental impact concerns persist among stakeholders. Interested agents can influence policy modernization related to sludge utilization, but political and market impacts are limited due to slow processes, differing priorities, and incomplete information. By 2020, Bulgaria achieved the National Strategic Plan's goal of utilizing 70% of sludge (EEA, 2021), though the goal of eliminating landfill and non-targeted storage has faced significant delays. Figure 2 illustrates the impact of the institutional structure on sludge utilization. Sludge production increased from 2006 to 2016 but declined significantly afterward. Utilization in agriculture fluctuated, from 20% in 2007 to 58% in 2018, suggesting that institutional and governance conditions are not yet conducive

to sustainable sludge utilization. Regional disparities exist, with the majority of sludge use concentrated in the Sofia region. Positive experiences in Sofia should be studied and replicated, while identifying challenges in other areas is crucial.



Source: EEA

Figure 2. The evolution of Bulgaria's WTP-produced sludge and the proportion of sludge utilized for agricultural purposes.

Conclusion: A complex interaction of institutional, production, economic, psychological, social, and ecological aspects is involved in the use of sludge in agriculture. This process's efficacy depends heavily on the institutional context, which calls for in-depth research. This work is a first investigation into systematic research in this important yet developing field. Our research reveals that over the past twenty years, Bulgaria's institutional framework for agricultural sludge utilization -encompassing regulatory, public, private, market, and hybrid models- has undergone substantial improvements. These enhancements have facilitated notable progress in sludge application. Nonetheless, this progress has been inconsistent and unsustainable across different regions. Identifying factors that limit stakeholder behavior and contribute to variability in sludge utilization is essential. Expanding interdisciplinary research and assessing the institutional framework and its affecting aspects are essential to the advancement of this discipline. This entails obtaining fresh macro- and microdata from stakeholders as well as combining EU and official Bulgarian agro-statistics. It is necessary to identify the main variables influencing stakeholder behavior, their effects, and the institutional framework and incentive system's deficiencies. These revelations will bolster in-depth suggestions for enhancing public policies and management plans for the utilization of agricultural sludge and WTPs. Given the significant role of public intervention, it is imperative to develop a new national strategy for WTP sludge utilization that aligns with current conditions and societal priorities. Measures to support stakeholders, including farmers through CAP tools, should be implemented. For instance, adding sludge to the official list of subsidized soil



improvers could replace mineral fertilizers and benefit stakeholders during the current program period. Additionally, analyzing trends in institutional structures and sludge utilization in other EU countries is important for assessing Bulgaria's position and identifying future focus areas. Lessons learned from other countries both positive and negative should be communicated promptly to guide management decisions at various levels.

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