

Innovative approaches to the conservation of natural resources in Poland

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Abstract. This review article studied the Polish innovative practical experience preserving natural resources, particularly forests, waters, and exhaustible energy resources. For that purpose, we performed a literature review in compliance with PRISMA guidelines across academic articles covering specific practical cases. The review revealed that innovative approaches focus on conserving rural lands by creating smart villages, forest and parkland preservation with social engagement through crowdsourcing, and agricultural lands by cultivating smart and green farming. Concerning water preservation, several directions were implemented in Poland: treatment of waste waters, harvesting of alternative natural water resources, and restoration of the existing natural water resources. Regarding energy preservation, significant efforts are focused on switching to solar energy (solar panels) and wind energy (wind turbines) and deploying biomass potential. Nature preservation as a phenomenon is new and is still not fully understood by society. The review revealed that, on the governmental level, different degrees of innovative attention are paid to various natural resources: the greater innovative attention is paid to the energy sector, and the less to the preservation of existing natural resources such as forests and lakes. On top of that, innovations in nature preservation can face social opposition.

Keywords: nature preservation, forests, national parks, water management, alternative energy sources.

INTRODUCTION

It is an open secret that society's irresponsible and consumerist attitude towards the natural environment is the main reason for its deterioration, decrease in the reserves of non-renewable natural resources and threats to humanity's general existence. Current environmental problems require not only the introduction of resource-saving technologies in all industries and broad implementation of alternative energy sources but also the restoration of the already disturbed stability of ecosystems and their preservation in the future.

According to the Encyclopedia Britannica, natural resources are any biological, mineral, or

aesthetic asset afforded by nature without human intervention that can be used for some form of benefit, whether material (economic) or immaterial. However, this generic definition slightly varies from country to country and from one policy to another (Venturi, 2020).

The exact examples of natural resources are lands, including fertile lands, soils, and sometimes minerals inside the lands; waters, including surface waters and ground waters; biomass; energy sources, such as fossil fuels and alternative energy sources; and mineral extractable resources, such as ores. Traditionally, any country's most valuable natural resources are

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lands and waters, as well as any resources the lands and waters contain. Special mention should be given to floral and animal resources, which are the country's biodiversity; however, whether they belong to the natural resources is still debatable.

Today, most countries, including Poland, urgently need to develop and implement ecologically oriented innovative projects to ensure the sustainable development of their territories. Poland faces numerous environmental problems, such as air, water, and soil pollution, loss of biodiversity, and inefficient use of natural resources, the most urgent of which relate to energy, industry, agriculture, and urban areas.

Today, society lives where natural resource issues are no longer related to the environment. In the modern world, the mechanism of protecting the environment from environmental challenges is becoming more and more complex and multilevel. The consequences of environmental pollution, loss of biodiversity, climate change, and depletion of natural resources have already become serious threats to humanity and nature, and they can potentially have far-reaching consequences for global security and stability. First, large-scale environmental pollution leads to the deterioration of air, water, and soil quality and can cause severe problems for the health of humans and other living organisms. Second, global climate change already leads to extreme weather conditions threatening human lives and property safety. Landslides, floods, heat and frost are becoming more frequent and intense, resulting in human casualties, destruction of housing and infrastructure, loss of crops and threats to food security. In addition, the depletion of natural resources, such as oil, natural gas and minerals, leads to geopolitical conflicts and instability in regions where these resources are concentrated. The struggle for access to resources can lead to military conflicts and aggravation of international relations. Environmental problems not only threaten nature but also have a direct impact on the social and economic spheres of human life (Marchenko & Novytska, 2024).

In this light, practical conservation and preservation of natural resources are becoming

of paramount importance to ensure a stable and secure future. Conservation of natural resources is a set of practices and activities dedicated to adequately managing natural resources to prevent their excessive exploitation, destruction, and degradation. The ultimate goals of the implementation of these practices and activities are the maintenance of the ecological balance, preservation and rescuing of the various kinds of species (biodiversity), preservation of the natural resources for the present and future generations, and endurance of the human race survival (Wang et al., 2019).

Various conservation methods have been developed based on the exact natural object. For lands, they include soil fertility maintenance, grazing control, reforestation, land segmentation, and advancements in plough techniques. For water resources, conservation methods encompass growing vegetation, dam and reservoir construction, sewage and industrial waste treatment, and rainwater harvesting. Concerning energy, the conservation methods did not go as far away as to minimise the exploitation of fossil fuels, switch to renewable sources, and use the energy rationally. Finally, as to floral life, animal life and biodiversity, conservation includes the creation of protected areas, such as national parks, sanctuaries, gardens, and reserves, and the creation of various banks, e.g. DNA banks, seed banks, culture banks etc. (Borner et al., 2020; Tilahun & Belay, 2019).

The issue of natural resource depletion is relatively new, and society is still processing this new global issue. Historical retrospectives often show that the first legal grounds to solve a problem must be developed only after the practical part starts. Therefore, this review article aims to study the practical implementation (cases) of the global innovative approaches to the conservation of natural resources in Poland with the main focus on the practical advancements concerning the types of natural resources that have the most significant impact on the overall well-being of the Polish society: forests, waters, and energy resources, since Poland is a spectacular example of a country rich and abundant country in natural resources of various kinds.

LITERATURE REVIEW

Land generally determines the landscape and character of the specific country's area, biodiversity, and economic and tourist potential. The landscape is constantly changing due to human activity, population growth, and technological advancements. The landscape of the European Plains, where Poland is located, was heavily altered over time for agricultural purposes, timber production, industrial purposes, and the expansion of urban areas. As a result, as many other European countries did, Poland implemented policies and governmental programs to ensure sustainable land management, conservation of Polish biodiversity, and protection of forest ecosystems, wherein one of the ultimate goals of land protection is biodiversity conservation.

Land protection for agricultural purposes and forest conservation are relatively new concepts in Poland, first appearing in the 1920s. In Poland, forest preservation is legally regulated by the Act on Forests, dated 1991; the State Forest Policy, dated 1997; the Act on Environmental Protection, dated 2001; and the Act on Nature Conservation, dated 2004 (Kurowska et al., 2020; Sotirov et al., 2021).

Today, Poland has approximately 23 national parks directly supervised by the Ministry of the Environment, 122 landscape parks, 1469 natural reserves, and 419 protected landscape areas. According to the official website of the European Union, 39.6% of Polish land is covered by protected areas, representing 123,545 km² of the land. Notably, Poland exceeded the EU Biodiversity Strategy's goal to reach 30% of the protected area by 2030 (Biodiversity, Information System for Europe, n.d.). However, the increased number of protected areas does not guarantee biodiversity conservation. According to various sources, around 78% of the protected area habitats in Poland have poor or lousy conservation status (Dankevych & Dankevych, 2020).

At the same time, a completely different policy is observed for lands for agricultural purposes: Poland is suffering from agricultural land abandonment that has intensified in the last 30 years due to changes in the social and economic system. The increasing development of highly productive farming resulted in the intensive use of agricultural lands in eligible areas. It decreased use and promoted abandonment in other places since other

economic industries, compared with agriculture, can provide much higher profits. Therefore, the situation with land conservation and preservation in Poland is controversial, with more attention paid to forest preservation and less to agricultural land conservation. Today, the agricultural land market is rigorously legally protected and regulated in Poland in terms of acquisition by agricultural real estate, foreign including (Zglobicki et al., 2020; Zróbek-Rózanska & Zielinska-Szczepkowska, 2019).

Regarding the water sources of Poland, the country possesses relatively low water resources but with a dense water network. The longest rivers are the Vistula, 1,047 km long; the Oder, 854 km long; and the Bug, 772 km long. The average freshwater availability in Poland is estimated to be 1400 m³ per capita, one of Europe's lowest values. The particular issue with water sources for Poland is their changing, i.e. lessening due to increasing water demand for population and industry and climate changes, which predict a water deficit of 30% in Central Poland by 2050 (Kubiak-Wójcicka, 2021).

Current practices toward overcoming freshwater issues in Poland can be grouped into three categories: preservation of water sources (construction of retention reservoirs); technological advances (changes and regulations of the water sources use, implementation of suitable agrotechnical measures, implementation of drought risk management, creating additional water supply infrastructure, prevention of freshwater pollution, etc.); and socially oriented measures (water metering and price increasing for general public and industries, fostering water-saving culture, improving general knowledge on rational use of water, etc.). In contrast to freshwater preservation, one of the most efficient approaches to deal with marine waters is conservation: in Poland, 21.9% of the marine waters represent 31 protected and managed areas (Michalczyk & Sposób, 2021; Water News Europe, 2022).

Naturally, any deteriorative trends regarding lands and waters harm Poland's biodiversity. Poland possesses one of the richest biodiversity in Europe. Poland's approximate number of species is estimated at 28,000 plant and 35,000 animal species. However, over the last 200 years, declining trends have been observed for 1,648 plant species and 2,769 animal species, wherein approximately 124 plant

species have retreated, and 16 vertebrate species have disappeared completely.

The major threats to the Polish biodiversity are caused by habitat transformation and habitat loss due to displacement by other plants, expansion of new alien species, consequences of climate changes, atmospheric pollution in the form of toxic gases and dust, deforestation, timber industry, changes in soil and water conditions, land reclamations, and dehydration. Therefore, Poland has already adopted and implemented several practices to overcome negative trends in biodiversity development, both legislative and technological. The legislative measurements include the adoption of Acts on Nature Conservation, Water Law, Environmental Protection Law, Genetically Modified Organisms Act, Plant and Animal Protection Act, National Forest Policy and the Act for the Protection of Farmland and Forestland, Hunting Law, Strategy for the Sustainable Development of Rural Areas, Inland Fisheries Act, and Sea Areas Act. Technological approaches are tightly associated with land and water conservation methods and generally include creating protected land and water areas (Blicharska et al., 2020).

Concerning energy sources, Poland heavily relies on coal consumption. For years, Poland has remained the largest provider of coal in the EU and one of the primary providers of coke, wherein the main sites of coal extraction are Jastrzębska Spółka Węglowa S.A. mines that provide approximately 86% of the domestic production. However, such heavy utilisation of coal has a substantial impact on the health of the general population and the degradation of environmental ecosystems, as nearly all fossil fuels are mainly due to emissions of CO₂ and other pollutants. Therefore, switching to the use of renewable and non-exhaustible sources of energy is one of the objectives of the Polish climate policy (Brauers et al., 2020).

Currently, the power industry in Poland is legally regulated by two legal initiatives: The National Renewable Energy Action Plan and the Energy Policy of Poland until 2030. "Poland's energy policy until 2040" was approved on 2 February 2021. By 2040, the demand for energy in Poland, according to the different estimates, may increase by 50%, from 160 TWh to 240 TWh, which will create even more burden on the environmental ecosystems and public health. Therefore, one of the goals of the adopted documents is to achieve the lowest impact of

energy production on nature and its ecosystems through enhancement in energy storage, metering and management, and use of alternative fuels, particularly hydrogen technologies. Thus, Poland is attempting to integrate renewable energy sources into its industry. Till 2016, the onshore wind power industry and combustion of solid types of biomass showed rapid growth; however, after legislative changes, their use become somehow restricted, and a new hello energy approach has been developing rapidly (Drożdż & Mróz-Malik, 2020; Havrysh et al., 2021; Pietrzak et al., 2021).

Finally, mineral resources. Generally, the idea to protect mineral resources first popped up at the beginning of the 20th century when, in 1908, it was presented by USA President Theodore Roosevelt. As long ago, with the increasing industrialisation and need for mineral resources, the public slowly but steadily led to the depletion of mineral resources. Therefore, this dynamics and seven-league evolution of the global economy necessitates the need for rational and practical use of the existent mineral resources, the creation of new solutions to reduce the involvement of natural raw materials in human survival and, first of all, the protection of natural resources (Nieć et al., 2022).

According to 2018 statistics, 14,532 mineral deposits are located in Poland. Among these 14,532 deposits, 44 are metallic mineral deposits, 59 are chemical mineral deposits, 719 are energy source deposits, 13,575 are rock mineral deposits, wherein 5,264 are being exploited permanently or periodically, and 27 are still unexploited. Altogether, over 500 million tons of mineral resources are extracted in Poland. Still, not evenly through the country's territory: the most considerable amount is in Southern and Central Poland. This richness in mineral resources made Poland one of the leading county of the EU in the extraction of copper, silver, bituminous-type coal and lignite (Galaś et al., 2021; Kot-Niewiadomska et al., 2021).

Nearly all mineral resources belong to the group of exhaustible natural resources that eventually will make them "endangered mineral species". Therefore, in 2013, the European Innovation Partnership on Raw Materials announced the implementation of a new initiative – Raw Materials Initiative – with the following most essential objectives: insurance of more efficient exploration; development of innovative methods for extraction and

processing; creation of substitutions for the most critical mineral resources; and improvement of legal regulations on mineral waste management (Galaś et al., 2021).

Summarising, historical and most of the current practices of exploitation of natural resources are one of the leading causes of the triple planetary crisis resulting in climate change, biodiversity loss and pollution. The brief literature review above shows that Poland is a prosperous country in terms of essential natural

RESEARCH METHODOLOGY

To study the Polish experience of the practical implementation of global innovative approaches to the conservation of natural resources, we used a literature review method added with steps of scoping review. This literature review was performed using PRISMA guidelines.

We used the Google Scholar scientometric database to study the existing literature sources. We chose Google Scholar because it is publicly accessible and non-commercial and allows you to search academic works across numerous disciplines and sources, including peer-reviewed articles, scientific theses, books and chapters, abstracts, and articles published by scholarly journals, professional associations, institutions of higher education, and educational organisations.

To select relevant articles, we used some keywords and their combinations: Natural Resources, Preservation, Nature Preservation, Conservation, Nature Conservation, Management, Lands, Agricultural Lands, Forests, Ecosystems, Protected Areas, Biodiversity, Water Resources, Fresh Water, Energy Resources, Mineral Resources, Exhaustible Resources, Non-exhaustible Resources, Alternative Resources, and their grammatical variations.

To select only the relevant articles, we used the following inclusion criteria: 1) articles cover the concrete examples of practical (technical) implementation of natural resources management, preservation, and conservation; 2) articles cover original research works and reviews of different kinds; 3) articles are published in journals; 4) articles are published in Ukrainian and English; 5) full texts accompany articles; 6) articles are published in the period from the beginning of 2019 to present.

resources. Since the 2010s, vigorous attempts have been made to preserve and conserve its resources through legal and technological approaches. It is worth noting that there is an interesting situation regarding natural resources and their management: implementation of the preservation and conservation practices for one type of natural resource will inevitably impact the other and the whole country's biodiversity.

To select only the relevant articles, we also applied the following exclusion criteria: 1) articles cover other aspects of natural resources management, preservation, and conservation (legal, political, economic, etc.); 2) full texts do not accompany articles; 3) articles are parts of books, chapters, proceeding materials, etc.; 4) articles published in another language (not Ukrainian and English); 5) articles published before the period of interest (before 2019).

In the first stage of the article selection, the articles were reviewed and selected based on their titles and abstracts, resulting in a primary set of relevant articles. At the next stage, all the included primary articles were reviewed and further selected using their full text, resulting in a secondary set of relevant articles for closer study.

The next step included classification of the selected relevant articles based on the subtopics within the main aim of this study: articles covering land and forest resources, articles covering water resources, and articles covering energy resources.

In the next stage, we elaborated and applied some evaluation questions to obtain a tertiary set of relevant articles. Evaluation questions were: 1) does an article cover innovative approaches to natural resources management, preservation, and conservation in Poland? 2) Does an article cover statistics on implementing the innovative approach in Poland? 3) Does an article cover technical details regarding implementing innovative approaches in Poland?

At the final stage, all the classified articles were subjected to qualitative analysis based on the understanding, interpretation, synthesis, and deduction techniques to draw the picture of the practical implementation of the global innovative approaches to the conservation of

natural resources in Poland concerning the types of the natural resources that have the most significant impact on the overall well-being of the Polish society: forests, waters, and energy

resources, since Poland is a spectacular example of a country rich and abundant country in natural resources of various kinds.

RESULTS

Table 1 provides articles on Poland's land resource management, preservation, and conservation.

Table 1. Detailed information about the set of articles concerning land resource management, preservation, and conservation in Poland

Article identifier	An object of resource management, preservation, or conservation	Management, preservation, or conservation method	Management, preservation, or conservation outcomes
Oleśniewicz et al. (2020)	National parks	Monitoring the park, the environment, tourist traffic size, trends, and impact	Development of the conservation plan, ecological education programs, and cooperation with local governments
Referowska-Chodak (2020)	Forests	Poll	Reorganisation of nature conservation in state-owned forests
Czerniak et al. (2020)	Forests	Construction of small water retention reservoirs	Protection against droughts
Dudek & Wrzaszcz (2020)	Agricultural lands	Organic farming	Improvement of soil structure
Krupowicz et al. (2020)	Forests	Crowdsourcing	Rural land consolidation
Adamowicz and Zwolińska-Ligaj (2021)	Rural land	Smart villages	Rural land preservation
Skrzypczyński et al. (2021)	Agricultural lands	Organic farming, agroecology, permaculture	Agricultural land regeneration
Adamowicz et al. (2020)	Rural land	Smart villages	Rural land preservation
Satoła and Milewska (2022)	Rural land	Smart villages	Rural land preservation
Bielska et al. (2021)	Rural land	Smart villages	Rural land preservation

Source: Authors' development.

The data in Table 1 show that innovative approaches are primarily implemented to preserve rural lands by creating smart villages for

forest and parkland preservation. This is an interesting, innovative approach that involves social engagement in land conservation through

crowdsourcing. Regarding agricultural lands, the innovations are mainly deployed via the creation of smart and green farming.

Table 2 provides selected articles concerning Poland's water resource management, preservation, and conservation.

Table 2. Volume of Electronic Money Transactions by Year

Article identifier	The object of the resource management, preservation, or conservation	Management, preservation, or conservation method	Management, preservation, or conservation outcomes
Piasecki (2019)	Tap water and sewage waters	Tap water and sewage water management	More efficient management, inspection and legal enforcement
Piowar et al. (2021)	Water resources in general	Monitoring the water pollution, management of fertilisers storage and application	Lesser pollution of water resources from agricultural sources
Amen et al. (2020)	Wastewaters	Metal removal from wastewater using ecological adsorbent	Production of cleaner water, decrease in water resource pollution
Dondajewska et al. (2019)	Lake water	Hypolimnetic aeration and phosphorus precipitation	Lake restoration, water transparency increase, phytoplankton biomass enhancement
Kordana and Słyś (2020)	Water resources in general	Management of storm waters	Additional water resources decrease the load on natural water resources
Boguniewicz-Zablocka and Capodaglio (2020)	Water resources in general	Management of storm waters (green roofs, porous pavements, retention reservoirs, rain gardens)	Additional water resources decrease the load on natural water resources.
.Kaszycki et al. (2021)	Wastewaters	Biological wastewater treatment with anaerobic microorganisms	Additional water resources decrease the load on natural water resources
Musz-Pomorska et al.(2020)	Water resources in general	Rainwater harvesting	Additional water resources decrease the load on natural water resources
Canales et al. (2020)	Water resources in general	Rainwater harvesting	Additional water resources decrease the load on natural water resources
Mazurkiewicz et al. (2020)	Water bathing reservoir	Microbiological bioremediation	Enhancement of water quality, a decrease of specific odour and eutrophication processes
Burszta-Adamiak and Spsychalski (2021)	Water resources in general	Collection of rainwater for non-potable use	Additional water resources decrease the load on natural water resources.

Source: Authors' development.

The Data from Table 2 show several directions for preserving water sources practically implemented in Poland. The first direction is treating wastewater of different

origins to ensure a clean water supply to urban and rural areas and provide additional sources of clean water for potable and non-potable purposes. The second direction includes

harvesting the extra water for alternative natural resources such as storm and rainwater. The third direction is focused on preserving natural water resources in lakes and public bathing reservoirs.

Table 3 provides selected articles concerning energy resource management, preservation, and conservation in Poland.

Table 3. Detailed information about a set of articles concerning energy resource management, preservation, and conservation in Poland

Article identifier	The object of the resource management, preservation, or conservation	Management, preservation, or conservation method	Management, preservation, or conservation outcomes
Chomać-Pierzecka et al. (2022a)	Fossil fuel resources	Hydropower energy utilisation	Alternative renewable energy resources decrease the load on exhaustible natural resources.
Zdyb and Gulkowski (2020)	Fossil fuel resources	Solar energy utilisation (solar panels)	Alternative renewable energy resources decrease the load on exhaustible natural resources.
Olczak et al. (2022)	Fossil fuel resources	Solar energy utilisation (solar panels)	Alternative renewable energy resources decrease the load on exhaustible natural resources.
Jurasz et al. (2020)	Fossil fuel resources	Solar energy utilisation (solar panels)	Alternative renewable energy resources decrease the load on exhaustible natural resources.
Beldycka-Bórawska et al. (2021)	Fossil fuel resources	Biomass energy utilisation	Alternative renewable energy resources decrease the load on exhaustible natural resources.
Marks-Bielska et al. (2019)	Fossil fuel resources	Biomass energy utilisation (straw)	Alternative renewable energy resources decrease the load on exhaustible natural resources.
Dobrzycki et al. (2020)	Fossil fuel resources	Solar energy utilisation (solar panels)	Alternative renewable energy resources decrease the load on exhaustible natural resources, turn to self-supply
Cholewa et al. (2020)	Fossil fuel resources	Thermal renovation of buildings	Alternative renewable energy resources decrease the load on exhaustible natural resources, turn to self-supply and reduce the energy consumption for heating and cooling.
Boguniewicz-Zabłocka et al. (2019)	Fossil fuel resources	Geothermal water resource utilisation	Alternative renewable energy resources decrease the load on exhaustible natural resources, turn to self-supply and lower the energy consumption for heating domestic districts
Chomać-Pierzecka et al. (2022b)	Fossil fuel resources	Solar energy utilisation (solar panels)	Alternative renewable energy resources decrease the load on exhaustible natural resources.
Mączyńska et al. (2019)	Fossil fuel resources	Liquid biofuels (bioethanol, bio-methanol) utilisation	Alternative renewable energy resources decrease the load on exhaustible natural resources

Source: Authors' development.

The data from Table 3 show that the main efforts in switching to alternative sources of energy are focused on the adoption of solar energy (solar panels), wind energy (wind turbines), and the deployment of biomass potential. Evidence of a fixed interest in hydropower was not found.

In addition, local efforts toward energy preservation are focused on thermal renovation and enhancement of buildings.

Although it was not the aim of this review, surprisingly, in terms of energy preservation and alternative energy use, our research found many articles related to the strong opposition from the

DISCUSSION

The concept of nature conservation in Poland has changed from a strictly traditional, biophysical perspective to a more innovative integration of biodiversity protection with social and economic activity.

Land Preservation

Poland's most important forms of forest and nature conservation are national parks supervised by the Ministry of the Environment. Forests are generally considered the most essential terrestrial biodiversity and potential revenue areas. In Poland, forests are also a source of timber and specific types of commercial products: e.g., in 2018, Polish forests yielded 43.30 million m³ of wood, 4500 t of fruits, and 3200 t of mushrooms.

The first protected national park, Yellowstone National Park, was established in 1872. Since then, the idea of preserving the most valuable natural objects inside protected parks has evolved.

Conservation inside the protected parks resides in planning, organising, supervising, and controlling the forest's activities. A national policy of Poland defines the principles for the maintenance, protection and increase of forest resources. The primary objectives of forest preservation include the very conservation of the forests and their beneficial impact on the climate, quality of air, quality of surface and groundwater, biodiversity and human health, and overall ecological balance; protection of forest soils and areas vulnerable to pollutions; and production of timber and other forest products, such as fruits, berries, and mushrooms (Oleśniewicz et al., 2020; Referowska-Chodak, 2020).

general public. Thus, many articles covered the approaches to raise public awareness of the ecological situation and current state of the energy sector in Poland, as well as understanding the necessity to pay more for greener energy. Another portion of the articles covered Polish farmers' attitudes toward using biomass for energy production and the necessity to cultivate and grow specific crops. Polish farmers have no enthusiasm for new approaches.

Surprisingly, this observation is valid only for the energy management approaches. The same was not observed for the land and water management approaches.

Currently, the principle of preserving and increasing the amount of available forest resources is based on the above techniques, i.e., creating forests on initially treeless lands or on land that has been treeless for at least 50 years and enhancing forest productivity through incrementation of the volume of timber per unit (Szramka & Adamowicz, 2020).

Significant advancements have been made in forest conservation globally and nationally since the late 19th century. Poland has also made a considerable accomplishment in creating approximately 23 national parks, 122 landscape parks, 1469 natural reserves, and 419 protected landscape areas. However, regarding direct forest conservation, protected areas in the form of parks are still almost a single approach to overcoming forest depletion.

Interestingly, a single innovative approach to forest preservation was cultivating social awareness and active engagement of the society in land preservation through a crowdsourcing technique that involved consultation with local communities and identification of their needs. Moreover, this approach includes identifying public opinion on the condition of the local environment in terms of agricultural land and crop cultivation, accessibility to local arable and forest lands, etc. (Krupowicz et al., 2020).

Poland's agricultural lands, which cover 15.4 million ha (or 50%) of its territory, are vital for the European and Global markets since Poland produces various agricultural, horticultural, and animal products.

Our literature review shows that the only innovative approach currently implemented in Poland is cultivating organic farming culture,

agroecology direction, and permaculture. In addition, the Polish government adopted several initiatives to promote on-farm workshops, digital education, books, courses, and training sessions on innovative organic farming. However, these initiatives cannot be considered innovative agricultural land preservation approaches.

Generally, organic farming is an agricultural system that utilises organic fertilisers (compost, green manure, and bone meal) and ecologically oriented techniques such (as rotation and companion planting). Organic farming is closely related to agroecology and the concept of sustainable farming. Agroecology promotes understanding of farming practices that are directed at reducing emissions generated during farming activities, recycling resources, prioritising local supply chains, preventing the detrimental impact of farming on wildlife, etc. In 2021, Poland provided territory for 20,000 organic farms that covered approximately 5% of agricultural lands in four voivodeships: Warmińsko-Mazurskie, Podlaskie, Zachodniopomorskie, and Mazowieckie (Dudek & Wrzaszcz, 2020; Skrzypczyński et al., 2021; Zieliński et al., 2024).

Regarding rural land preservation, Poland is adopting a concept of smart villages, which are communities in rural areas applying innovative solutions to increase their sustainability, using local strengths and opportunities. The European Union, and Poland being a part of the EU, is actively promoting the concept of “smart villages” to improve rural residents’ living standards, preserve rural lands, ensure their development, and decrease urban load. The articles selected for this review show that Poland has no fully functioning smart villages, but the initiatives to create them are adopted at the EU level. Therefore, developing such structures across the whole EU is a matter of time.

Water Resources

Magdalena Grońska, Health, Safety, and Environment Director at Holcim Poland, noted that people, nature, and the economy depend on water resources.

As we stated earlier, Poland does not possess sufficient fresh water for drinking, mainly because of the industrial development after WWII and the lack of pollution control that resulted in the degradation of the inland waters. Freshwater is mostly polluted through wastewater discharge from industrial and

municipal sewage systems, which is still occurring (Piasecki, 2019; Piwowar et al., 2021).

In terms of the conservation of water resources, a more appropriate approach is not to converse about existent water resources but to ensure the management of water resources, meaning engaging hydrology, geology, engineering, ecology, environmental science, climatology, geography, economics, sociology, public health, policy analysis, urban planning, and many more scientific disciplines into an improvement of the quality of the water, mitigating the consequences of pollution of the water and nullification of future pollutions.

Traditionally, the most widespread approach to Polish water source conservation, building numerous dam reservoirs, has allowed optimal freshwater management for drinking purposes. In terms of water quality, water purification is a precious method that can be further improved by using various highly efficient absorptive technologies to treat industrial wastewater. A positive driving force for Poland to adopt and develop an efficient water management policy is the adaptation of the EU requirements and laws and EU funding. Since entering the European Union, water and sewage management in Poland, especially in its rural areas, as well as the values of water consumption and wastewater treatment (Amen et al., 2020; Piasecki, 2019).

In 2018, the new edition of the Polish Water Act introduced a completely new organisation for water management—the State Water Enterprise Polish Waters. Regarding water resources preservation, Polish Waters' activity encompasses protection against floods and droughts and water management. However, the main focus is profitability, economy, ownership, and organisation issues. At the same time, it is worth noting that the edition of Polish Water Act A also covered protecting waters against pollution, particularly against pollution of agricultural origin.

Other novelties introduced by the Polish Water Act covered water melioration issues to improve soil production capacity and facilitate cultivation in agricultural and forest areas. For these purposes, the landowners can engage public funds through a melioration fee (Pierzgalski, 2018).

Our review revealed that several directions for preserving water sources are currently practically implemented in Poland but are rather single-dotted. The first direction is the treatment

of wastewater of different origins, the second includes harvesting stormwater and rainwater, and the third is focused on preserving natural water resources in reservoirs such as lakes, for example.

Regarding those above, in 2022, SUEZ and the Municipality of CZERNICA started an ambitious project to build a wastewater treatment plant in Czernica. The projected treatment capacity of the new plant is 1,460,000 m³/year. However, it is only SUEZ's second project after a similar plant in Mława City was built in 2016 (SUEZ, 2022).

One of the recent innovations planned for water management in Warsaw is a “Case study and pilot implementation of available technologies to support the management of the water supply network” focused on optimising drinking water distribution to decrease water losses and associated costs and ultimately protect scarce water resources.

In 2022, “Circular Water Management Strategy for BTOF area and Bydgoszcz” was published. The Strategy aims to promote the rational utilisation of water resources, the collection and repetitive use of rainwater, and the repetitive use of treated sewage and grey waters (Interreg Central Europe, 2022).

The system of the water supply of Bydgoszcz is based on supply from the underground water at the "Las Gdański" station and surface waters of the Brda River at the "Czyżkówko" station. Currently, in Bydgoszcz, rainwaters are mainly used to water the greenery and elements of the urban landscape. The use of greywater and wastewater in Poland is also tiny and incidental. Thus, the strategy aims to escalate the use of rainwaters, grey waters, and wastewater for washing the streets and pavements, which are used for fire safety and reducing the heat island effect.

Above, we represented a couple of examples of water management initiated by local Polish authorities and private sectors. On top of that, Poland, a member state of the European Union, can benefit from technological advancements developed by the joint efforts of other EU countries and the EU as a whole institution. For example, in 2022, The European Institute of Innovation & Technology selected 40 companies of different sizes dealing with water crisis issues from 15 EU countries to take part in the Community Water Scarcity initiative. Among the innovative solutions, interesting ones were technologies to extract water from the

air humidity, technologies for leakage detection in distribution and supply networks, technology producing energy from wastewater, and water infrastructure management in buildings (EIT Food, 2022).

Regarding harvesting additional natural water sources, the scale of rainwater and stormwater reuse is currently low in Poland, but it is enough to provide local solutions. The most popular and straightforward solution is small retention and infiltration devices, which enable increased infiltration and subsequent use of rainwater and stormwater. However, the lack of consistency and coherency of legal regulations in this issue delays the more comprehensive practical implementation.

Finally, Poland has experienced a couple of projects to restore natural water resources such as lakes and reservoirs. For example, Dondajewska et al. (2019) studied restoration activities toward Lake Durowskie, which involved physicochemical and biological methods to decrease nitrogen and phosphorus concentrations in the lake water, with the ultimate goal of preserving the lake and enhancing its biodiversity. Another example is Mazurkiewicz et al. (2020), who studied the same approach to restoring the Słoneczko Reservoir.

Energy Sources Preservation

Poland is currently undergoing a substantial transformation in the energy industry. Our review shows that energy preservation approaches can be divided into massive and local. The most efficient approach to conserving inexhaustible energy resources is switching to using non-exhaustible energy resources to save fossil fuels such as coal, oil, and gas. That means reducing greenhouse gas emissions and carbon footprints that influence not only public health but also forests and their biodiversity, as well as the quality of water and air.

One of Poland's objectives concerning climate and energy, set out in the “National Plan of Energy and Climate 2021–2030,” is to achieve a share of non-exhaustible energy resources in gross final energy consumption of 21-23% by 2030.

For a couple of decades, Poland's largest provider of non-exhaustible energy has been energy from onshore winds: production from this energy source provided more than 15 TWh of energy per year. Currently, the energy of the offshore winds is becoming a novel and promising industrial sector with a significant

potential for further enhancement. Within the Baltic Sea Region, Poland has the most considerable potential for exploiting and utilising the energy of the offshore winds. According to different estimates, by 2050, the European potential in providing offshore energy will reach around 450 GW, of which Poland will provide 28 GW.

The insidious interest in offshore wind energy results from its advantages compared to onshore energy supply. Precisely, offshore wind farms allow the installation of turbines with higher efficiency; for instance, in 2019, the average capacity of offshore wind turbines was 7.8 MW, whereas, in 2015, it was almost twice as least and carried improved generation and predictability, more extended operation period and fewer spatial issues, that allow utilising stronger winds in marine areas without any restrictions from the technological side. Additionally, Poland partially faces the Baltic Sea. Therefore, electricity generation from the offshore winds close to the main big cities can meet the energy requirements without building additional long transmission lines.

No offshore wind farms have been developed in Poland yet. However, the first offshore wind farm is planned to be established in 2025. In Poland, the pioneers in the offshore wind sector are Polenergia and PGE. Switching to an offshore wind energy supply will become Poland's most innovative approach toward conserving fossil fuels.

Regarding the other possible energy sources, Poland is attempting to use hydropower; however, according to different estimates, hydropower potential does not exceed 20%. According to the UN Global Compact Network Poland's report, the share of energy in 2020 was as low as 2%; in other words, only 2.9 TWh out of 157.7 TWh of total energy produced. The primary hydro energy resources are the Vistula River, which creates 45.3% of the energy, and the Oder River, which makes 9.8%. The rivers of the Pomeranian region create only 1.8% of the energy.

Worth noting, hydropower's position among Poland's other non-exhaustible energy resources is moderately intense because it can ensure controllable production at moderate costs and guarantee the stability of electricity production compared to the currently existent onshore wind farms (Chomać-Pierzecka, 2022a, 2022b; Kaluža et al., 2022).

Now, the hydropower industry in Poland is mainly represented by 770 power plants with a capacity of up to 0.5 MW, 343 with a capacity of 50-500 KW, and five hydropower plants with a capacity of up to 5 MW. These hydroenergy plants generate 43% of the energy of the whole non-exhaustible energy segment in Poland with a result of 146 GWh. Examples of the major hydropower plants in Poland include those located at Piaśnica, Sola, San, Radew, Vistula, Dunajec, Bóbr, Brda, and Narew rivers: Żarnowiec Hydroelectric Power Station; Porąbka-Żar Hydroelectric Power Plant; Solina hydroelectric power station; Żydowo power station; Włocławek hydroelectric power station; Nidzica Hydroelectric Power Plant; Dychów Hydroelectric Power Plant; Rożnów Hydroelectric Power Plant; Koronowo hydroelectric power station; and Dębe Hydroelectric Power Plant.

Notwithstanding the current advancements in hydropower technologies in Poland, the further development of this energy sector is constantly being delayed by social, economic, institutional, and environmental obstacles. As we stated earlier, Poland has scarce water resources that vary throughout the territory. Moreover, climate change may cause even more significant variability of Polish water resources in short—and long-term perspectives. However, one of the most restrictive obstacles to building up the hydropower industry in Poland is the low profitability of this sector (Kaluža et al., 2022).

One of the up-and-coming technologies for ensuring the growing share of alternative energy is helioenergy and photovoltaics, or solar panels.

Photovoltaics is the process of converting light into electricity through the photovoltaic effect. A photovoltaic system consists of solar modules, each comprising a set of solar cells that generate electricity. Photovoltaic systems may be mounted on the ground, rooftops, or walls or floating.

Poland is a country that launched the market of photovoltaic systems late, and only in the early 2010s did the installed capacity of these systems exceed 1 MW. However, since then, the photovoltaic market has started developing very rapidly, and at the end of the 2010s, the installed capacity reached almost 1300 MW. According to the estimates, during the first half of 2021, 144 thousand micro-photovoltaic systems were installed, resulting in the total capacity of

photovoltaic systems in Poland of more than 6 GW, with an approximately 40% share in all non-exhaustible resources and a 3.17% share of the total volume of electricity in Poland.

Overall, due to the implementation of alternative energy technologies, in 2021, the share of coal-generated electricity decreased to 70.8 % compared with 86.6 % in 2010. At the same time, in 2021, 16.9 % of electrical energy in Poland was provided by non-exhaustible energy sources compared with 6.9% in 2010. One must admit that in 10 years, Poland made a remarkable achievement in switching to alternative energy sources and decreasing the exploitation of natural energy resources. However, these capacity values are still minor but promising (Chomać-Pierzecka et al., 2022a, 2022b; Jurasz et al., 2020; Olczak et al., 2022; Zdyb & Gulkowski, 2020).

Finally, switching to biomass utilisation for energy-generating purposes is a highly controversial method that can impact the conservation of natural energy resources. Biomass is renewable organic material from plants and animals and accumulates and stores chemical energy from the sun. Exact examples of biomass resources include wood sources: firewood, wood pellets, wood chips, and sawdust; agricultural sources: corn, soybeans, sugar cane, and grass, as well as woody plants and algae; paper sources; cotton and wool sources, etc. For example, in the period between 1999 and 2018, the average annual surplus of straw was 12.5 million t, and the most significant suppliers were Kujawsko-Pomorskie, Dolnośląskie, Wielkopolskie, Lubelskie, and Zachodniopomorskie voivodeships.

Biomass can create energy directly by being burned or converted to liquid and gaseous fuels using different methods, such as thermochemical conversion, chemical conversion, and biological conversion. Poland's biomass resources include forest-generated,

CONCLUSIONS

People have used natural resources for centuries for food, housing, and clothing. Our planet provides ample natural resources that people need to survive and ensure comfortable lives and healthy well-being. However, the biggest challenge is to use resources without their complete depletion and without destroying or degrading the environment.

agricultural-based, used grassland, and crop-based biomass.

According to different estimates, biomass generates around 15% of the global energy, but this value varies from country to country. The energy potential of biomass utilisation in Poland is approximately 900 PJ/year. In terms of beneficial types of biomass, pellets represent the most significant value, and Poland created its biomass pellets market in the middle of the 1990s. The background of the market development is that Poland is a country rich in rural areas containing around 65% of arable lands and around 34% of class V and VI lands that can be used for culturing energy types of crops (Beldycka-Bórawska et al., 2021).

Finally, the single-dotted Polish energy-saving approaches include thermal renovation of buildings, utilisation of geothermal water resources for heating buildings, and switch to liquid biofuels (bioethanol, bio methanol).

Research Limitations

In this paper, we studied the Polish experience in the practical implementation of now globally acknowledged innovations for natural resource preservation. For this review, we mainly covered academic articles in English, omitting the articles written in Polish. Therefore, this work could not cover a large pool of related articles, contorting the picture we were able to draw from the selected articles in English.

Another limitation concerns the objects of our review: innovations in land, water, and energy preservation. Although we believe that a decent amount of articles were extracted for the study, for future research, it would be better to focus on a single object and disclose it in a more comprehensive manner, engaging statistics, legal documents, and European Union initiatives, in addition to academic articles covering specific cases.

From this perspective, Poland provides an exciting example. In the review article, we considered only a few types of natural resources, namely lands, waters, and energy resources, because they are essential for human survival, and their destruction and depletion can lead to the most dramatic consequences.

Regarding forest preservation, Poland took the traditional approach, creating protected areas in the form of national parks, landscape

parks, natural reserves, and protected landscape areas. An innovative approach to forest preservation was social engagement, involving the study of social needs regarding land resources. Regarding land preservation, Poland has adopted an organic farming approach that it continues to develop.

Regarding water resource conservation, Poland went along two approaches: the traditional one, creating protected water areas, often on the territory of protected land areas, and alternative methods for more rational utilisation of water and use of alternative water sources. Currently, alternative methods are aimed at treating and reusing grey waters, wastewaters, storm waters and rain waters. Only recently, in the 2010s, relative projects started appearing, focusing on building wastewater treatment plants, rational water use, promoting collection and reuse of rainwater, and repetitive use of treated sewage and grey waters.

In terms of energy resources, Poland adopted nearly one possible approach: switching to non-exhaustible energy resources while attempting to reduce the use of traditional exhaustible energy resources. In this sector, Poland has already achieved more outstanding results from an innovation point of view. Poland is currently utilising onshore wind, solar, and biomass-based energy and preparing to implement offshore wind energy supply. Due to the implementation of alternative energy technologies, we can operate with solid numbers: in 2021, the share of coal-generated electricity, a traditional exhaustible energy resource, decreased to 70.8 % compared with 86.6 % in 2010, while the share of electricity extracted from non-exhaustible energy sources increased to 16.9 % compared with 6.9% in 2010. In 10 years, Poland made an outstanding

achievement in switching to alternative energy sources and decreasing the exploitation of natural energy resources. However, these capacity values are still minor but promising.

Final remarks should be made on why the Polish experience is decent but modest. Conservation of natural resources is not about a particular approach or technology or even a group of strategies and technologies; it is about the whole and massive complex of various and numerous approaches, technologies and activities. Each new solution oriented to preserving a particular natural resource often starts (or has already started) at the national level by adopting specific laws and acts, which are time and effort-consuming and bear inevitable legislative obstacles. Then, adoption transfers to the local levels, and again, time and effort must be implemented on the local level to overcome its legislative obstacles. Additionally, groups of natural resources are only a few. However, there are numerous types of natural resources inside each group. For example, the lands include forests that, in turn, include trees, bushes, a considerable number of different animals, floral creatures, microorganisms, and water, and what creates even more significant difficulties is that all these components influence each other. Therefore, conservation techniques for one particular object can have advantageous or detrimental effects on the other. And finally, conservation approaches may receive an adverse reaction from the public, sometimes only as a result of unawareness.

Summarizing all the aforesaid, Poland has achieved great results in natural resource conservation in the last couple of decades and is on the right track. Future advancements in Polish nature preservation are only a matter of time.

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