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Energy and Environmental Impacts of Greece's Agricultural Sector: A Diachronic Study with Regional Insights from Western Macedonia

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ABSTRACT

The research explores the long-term connection between Greece's agricultural output, with a focus on both crop and livestock production, and crucial environmental factors like water usage and energy consumption. Through linear regression analysis, the study investigates how these factors affect agricultural value-added, providing insights into the sustainability and efficiency of Greece's farming sector. The results show a significant ($p < 0.05$) positive relationship between crop production and agricultural value-added, as well as the significant influence of water usage and energy consumption on the productivity of both crops and livestock. For livestock farming, the analysis revealed a weaker contribution to agricultural value-added at the national level, likely due to structural inefficiencies in the sector. While livestock production benefits significantly from water and energy inputs, it does not have as substantial an economic impact compared to crop

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production. This research contributes to the field of agricultural economics by offering a historical perspective on how resource management influences agricultural performance over time. It highlights the significance of sustainable practices, especially in areas like the periphery of Western Macedonia, which are shifting from conventional energy sources like lignite to renewable energy. The findings advocate for policies that promote water conservation, energy efficiency, and smart agriculture to enhance productivity and support regional development.

Keywords: Agricultural Productivity; Water Withdrawal; Energy Consumption; Crop Production; Livestock Production; Regional Development Policy

1. Introduction

Agriculture can significantly contribute to the economic growth of a country. Agriculture has historically been a fundamental component of the Greek economy, contributing significantly to the Gross Domestic Product (GDP). In Greece, agriculture plays a vital and irreplaceable role in the economy, serving as a key employer for a significant portion of the workforce. The agricultural sector, including crop production and livestock, plays a pivotal role in Greece's economic dynamics. This sector is essential for maintaining social stability and promoting regional development [1].

However, this sector's environmental and energy footprint has become a subject of increasing scrutiny due to its impact on ecosystems, water resources, and energy consumption. Agricultural production in Greece significantly contributes to the country's ecological deficit in the long run, unless strict sustainability measures are implemented in the energy and agricultural sectors [2]. Greek agriculture needs targeted actions to manage climate change risks and promote sustainability, knowledge, and innovation, while aligning with the new Common Agricultural Policy (CAP) [3].

Greek food supply chain needs improvement in structural characteristics and public services to boost exports, but challenges remain in the primary production and public services sectors [4]. In recent decades, the Greek agricultural sector has undergone various transformations due to technological advancements, policy changes, and global economic trends. These factors have affected both the production efficiency and the environmental sustainability of agriculture. As a result, understanding the relationship between agricultural production and environmental variables such as water and energy usage is crucial for formulating sustainable agricultural policies.

This study aims to conduct a diachronic analysis of the agroeconomic and environmental performance of Greece's agricultural sector over a significant period. The study will investigate the relationships between agricultural value-added (AGRVAL) and key production indices for crops (CROP) and livestock (LIVE), while also examining the influence of energy (ENERGY) and water (WATER) on these sectors. Furthermore, the research will explore the potential for regional application, with a specific focus on the region of Western Macedonia, a key area in Greece facing significant challenges related to energy transition and agricultural sustainability.

This study offers a unique and multifaceted exploration of the intersection between agriculture, energy, and environmental sustainability in Greece. While numerous studies have examined the agricultural sector in isolation, this research integrates a holistic approach by analyzing the synergistic effects of economic production (AGRVAL) alongside critical environmental variables, such as water usage and energy consumption.

One of the primary reasons for the significance of this work lies in its chronological depth, spanning several decades of data, from the 1970s to the present. This long-term perspective allows for an in-depth understanding of how agricultural practices have evolved in response to technological, economic, and environmental pressures. Furthermore, this research evaluates the energy and environmental footprint of agriculture, addressing contemporary concerns over sustainability and resource management.

The study's originality is also highlighted by its focus on regional application, particularly in the case of Western Macedonia. As one of the regions most affected by Greece's energy transition, Western Macedonia presents a microcosm of the challenges and opportunities faced by areas that are undergoing a shift from traditional energy sources like lignite to renewable and more sustainable forms of energy. By incorporating a regional analysis, this research provides pragmatic insights that could inform regional development policies, especially in areas where agriculture and energy are closely intertwined.

This study deserves attention because it fills a critical gap in the existing literature by combining agricultural economics, environmental science, and regional policy analysis. It not only contributes new knowledge but also provides actionable recommendations that could guide future research and policy development in regions undergoing economic and environmental transformations. The implications of this study are far-reaching, particularly in the context of global efforts to achieve the Sustainable Development Goals (SDGs), especially those related to climate action, sustainable agriculture, and energy efficiency.

The primary purpose of this research is to conduct a comprehensive analysis of the agroeconomic and environmental footprint of Greece's agricultural sector. This study seeks to quantify and explore the relationships between agricultural production (both crops and livestock), water resources, and energy consumption over several decades. Additionally, it aims to provide insights into how these factors have evolved and how they influence sustainable development in the agricultural sector.

The objectives of this research are as follows:

Examine the relationship between agricultural value-added (AGRVAL) crop production (CROP) and livestock production (LIVE): The study will assess whether agricultural output in terms of crop and livestock production has a statistically significant impact on the overall value added to the economy by the agricultural sector.

Analyze the environmental footprint of agricultural production: The research will investigate how water withdrawal (WATER) influences crop and livestock outputs, providing insights into the sector's environmental sustainability.

Explore how energy consumption relates to crop and livestock production: This objective focuses on the relationship between energy consumption (ENERGY) and agricultural output, analyzing how energy use impacts both crop production and livestock activities over time.

Conduct a literature review on the agricultural and environmental context of Western Macedonia: This part of the study will involve reviewing existing literature to understand the specific challenges and opportunities faced by the region of Western Macedonia in terms of agricultural production and environmental sustainability, especially in light of its energy transition.

By fulfilling these objectives, the research will contribute to a deeper understanding of how the agricultural sector interacts with key environmental variables and will offer pragmatic solutions for promoting sustainable development in Greece's agroeconomic landscape.

The central research question of this study is:

How does agricultural production, in terms of crops and livestock, relate to the economic value added by the agricultural sector in Greece, and how are environmental factors such as water usage and energy consumption related to agricultural production?

Based on this research question, the following research hypotheses are formulated:

H1. *AGRVAL has a statistically significant positive relationship with CROP.*

H2. *AGRVAL has a statistically significant positive relationship with LIVE.*

H3. *WATER has a statistically significant positive relationship with CROP, indicating that higher water consumption by means of withdrawal is associated with higher crop yields.*

H4. *WATER has a statistically significant positive relationship with LIVE, suggesting that greater water availability supports livestock production.*

H5. *ENERGY has a statistically significant positive relationship with CROP, meaning that higher energy inputs contribute to increased crop production.*

H6. *ENERGY has a statistically significant positive relationship with LIVE, indicating that energy use directly impacts livestock productivity.*

These hypotheses will be tested through statistical analysis of data spanning several decades, providing insights into the economic and environmental dynamics of Greece's agricultural sector.

The hypothesis examination results showed that H1 (AGRVAL and CROP) and H3 (WATER and CROP) were both supported, confirming significant positive relationships.

However, H2 (AGRVAL and LIVE) was not supported, as the relationship was weak and insignificant. Additionally, both H4 (WATER and LIVE) and H5 (ENERGY and CROP) were supported, indicating that water withdrawal and energy consumption positively influence crop and livestock production. Finally, H6 (ENERGY and LIVE) was also supported, demonstrating the crucial role of energy in livestock productivity.

The study investigates the interplay between agricultural productivity, water and energy inputs, and sustainability challenges, with a specific focus on Western Macedonia's unique dynamics. The objectives of the research are to understand the relationships between these variables and provide insights into sustainable agricultural practices and regional development. The roadmap of the manuscript is structured as follows: the introduction presents the study's objectives and background; the materials and methods section outlines the data sources and linear regression approach; the results section details statistical findings; the discussion interprets these findings in the context of sustainability and policy implications; and the conclusion summarizes key contributions and suggests directions for future research.

Literature Review

The agricultural sector's sustainability has been a key focus for researchers, especially in terms of its environmental and energy impacts. Much of the recent literature highlights the complex interplay between agricultural production (both crop and livestock) and critical environmental factors like energy consumption and water usage. This literature review summarizes key findings from studies examining these dynamics and discusses how these findings contribute to addressing the water-energy-food nexus challenges, which are crucial for achieving sustainable development.

Agriculture contributed to economic growth in post-war Greece, but its role was not affected by other economic sectors and was not affected by them either [5]. The agricultural sector directly contributes around 4% to Greece's GDP and, despite facing challenges, has shown resilience in recent years. It continues to play a vital role in the economy by employing 8.2% of the rural population, although the workforce in this sector has significantly declined over time [6]. The Greek agricultural sector is generally resilient to the 2008 economic crisis, but has not maintained its pre-crisis performance and has the smallest Gross Value Added and most uneven distribution across regional dimensions [7]. The Common Agricultural Policy reforms in the EU have led to a reduction in the agricultural sector's contribution to Greece's economy, with a negative trade balance and increased imports of similar products [8]. Agricultural cooperatives in Greece contribute significantly to GDP growth and employment growth, with their most significant contribution being in total production [9]. Additionally, agricultural cooperatives contribute positively to the entire Greek economy through services offered to members and financial activities with their cooperative enterprises [10]. Moreover, migrant labor has significantly contributed to Greek agriculture since the early 1990s, and its prospects are uncertain in an era of changing migration flows and restricted mobility due to COVID-19 [11].

Greece's agriculture plays a key role in supporting rural sustainability, with 30% of its total area cultivated for agricultural products, and irrigated agricultural land being crucial for crop efficiency and sustainability [12]. Crop production holds a dominant position in the Greek agricultural economy, accounting for 69% of total agricultural output, while the overall value of agricultural production has remained relatively stable since 2010 [13]. Permanent crops, olive trees, and extensive livestock systems (sheep farms) are more sustainable than intensive and arable crop farms in Greece [14]. Forests contribute to Greece's economic development through direct and indirect contributions that impact human livelihood and welfare of people [15].

The Greek crop sector plays a crucial role in the national economy, contributing significantly to employment, exports, and regional development. Despite facing numerous challenges, there are promising growth opportunities that can further enhance its economic impact. The agricultural sector has demonstrated resilience during economic crises, ensuring food security and maintaining employment, which is vital for rural communities. Moreover, fostering innovation and cooperation among farmers can generate economies of scale and enhance market penetration [16]. Several areas offer the potential for further development. In international trade, there is considerable opportunity for expanding value-added exports, particularly through high-quality, branded products aimed at developed markets [17]. Moreover, regional competitiveness can be significantly strengthened, particularly in Greece's peripheral and rural areas. Local agro-food enterprises in these regions have the potential to capitalize on traditional and unique agricultural products, which are increasingly valued in the global market for their quality, authenticity, and safety. By leveraging these traditional products and aligning with global trends in food quality and safety standards, these regions can boost their economic performance and better integrate into global value chains [18].

The agricultural livestock sector in Greece plays a complex and evolving role in the national economy, particularly in its contribution to GDP. Although historically significant, its impact has diminished over time, particularly during periods of economic crises. The sector's contribution to GDP has steadily declined, with a negative correlation observed between agricultural output and GDP growth from 1996 to 2020 [19]. Despite this decline, agriculture remains crucial for rural development, sustaining a significant portion of the population, with agricultural income tripling over the last four decades [20]. Additionally, Greek agriculture contributes to greenhouse gas emissions, primarily driven by livestock populations and the use of fertilizers [21]. Challenges such as outdated production methods and climate change continue to threaten productivity, with potential economic losses estimated between EUR 437 million and EUR 1 billion annually due to climate impacts [22]. However, nomadic livestock plays an important role in the sustainable management of peri-urban land by promoting grazing, which helps reduce fuel accumulation in nearby woodlands, thereby lowering the risk of wildfires [23]. Despite the challenges, the sector holds potential for growth in value-added production and employment, especially within the agrifood trade sector, which could enhance its contribution to GDP if effectively leveraged [24].

The growing importance of energy efficiency in agriculture, driven by global challenges like climate change and resource scarcity, necessitates a comprehensive understanding of scientific advancements and collaborations to develop sustainable practices and address current energy crises effectively [25]. In agricultural systems, energy plays a dual role, involving both its transformation and utilization. Evaluating and optimizing energy use within these systems is crucial for ensuring economic gains and promoting overall sustainability [26]. The agrarian transition to large-scale commercial agriculture increases fossil-fuel-based energy consumption by 5 times compared to low-input agriculture, emphasizing the need for local resource access and energy-intensity analyses in land use governance [27].

Energy optimization in agriculture and agroengineering systems is crucial for achieving higher production, autonomous systems, and improved energy efficiency in autonomous and robotic systems [28]. The agricultural sector can contribute to sustainable development by consuming sustainable energies, but a better exploration of its contribution through policies, institutions, and farmers' participation is needed for efficiency and profitability [29]. Biogas remains the most popular method for agricultural renewable energy, but the circular economy and complex energy systems are key challenges for future research [30]. Renewable energy sources in agriculture can increase energy supply, and job creation, and positively impact the agriculture economy, despite a decrease in investment from developed countries [31]. Additionally, renewable energy sources, such as solar, geothermal, biomass, and wind, can effectively prevent environmental problems in agriculture [32].

The energy consumption patterns in Greek agriculture demonstrate a strong dependence on fossil fuels and fertilizers, shaping the nation's energy profile. In regions like Crete, fertilizers contribute 53% of energy inputs, followed by fossil fuels at 16% and electricity at 12% [33]. This reliance has grown over the years with the introduction of capital-intensive technologies, though energy outputs have also increased, indicating a sustainable energy flow [34]. Greece's substantial biomass resources, from the administrative regions of Crete, Thessaly, and Peloponnese, exceeding 2 million tonnes annually from olive and cotton production, offer significant potential for energy generation through combined heat and power (CHP) systems [35]. However, the development of renewable energy, particularly photovoltaic systems, has sparked land-use conflicts, as agricultural areas face pressure between energy production and food security demands [36]. Agro-energy districts, utilizing agricultural residues, could offer a solution by improving both sustainability and economic viability for farmers [37]. While the Greek agricultural sector shows promise in contributing to energy sustainability, finding a balance between energy production and food security remains a critical challenge. Leveraging biomass potential and implementing innovative agro-energy practices can help mitigate these conflicts, promoting both environmental and economic sustainability.

The relationship between water draw, crop production, and livestock in Greece's agricultural sector is highly intricate, shaped by climate change, water management practices, and environmental pressures. Agriculture accounts for 80–85% of the country's annual water usage, with around 1.4 million hectares irrigated through both collective and private systems. Over-pumping from aquifers, often through illegal boreholes, exacerbates environmental issues such as seawater intrusion, which threatens long-term water availability [38]. Remote sensing and Earth Observation technologies can help monitor water availability and inform crop water requirements, assisting in climate adaptation strategies [39]. In regions like Crete, optimal irrigation strategies have the potential to reduce water usage by 32-70%, while still maintaining agricultural productivity, a crucial solution to the growing water scarcity in the Mediterranean [40].

Efficient water management is essential for boosting crop yields and maintaining livestock health, especially in the face of climate change. The Water-Ecosystems-Food (WEF) nexus framework emphasizes the need for integrated management to address both water scarcity and agricultural productivity challenges [41]. Climate change further complicates this relationship, as it impacts water quality and availability, reducing crop yields, increasing drought and flood risks, and degrading water resources [42]. As a result, agricultural adaptation practices, such as more efficient irrigation and water governance reforms, are critical for ensuring sustainability. By 2025, the water needs for key crops like wheat, alfalfa, and cotton are expected to rise due to climate impacts, increasing pressures on already stressed resources [43]. To address these challenges, demand management, integrated watershed management, and better cooperation between stakeholders—such as farmers, enterprises, and public authorities—are vital for sustainable water resource management in regions like Crete [44].

Agricultural production plays a vital role in regional development, significantly influencing both economic growth and employment. The sector contributes directly to the Gross Regional Product (GRP), with studies showing high elasticity coefficients that link increases in agricultural output to substantial economic growth [45]. As a primary industry in many regions, agriculture drives economic expansion, even amid challenges like declining productivity [46]. Moreover, agriculture is crucial for job creation, particularly in rural areas where employment alternatives are often limited. Its resilience during economic downturns helps stabilize employment levels, underscoring its importance to regional economies. Reforms under the Common Agricultural Policy further affect multiple sectors, reinforcing agriculture's role in sustaining regional economic stability [47].

The relationship between agricultural production and regional development in Greece is complex and influenced by technological advancements, policy measures, and broader economic dynamics. Recent studies highlight the significant role of agriculture in driving regional growth, particularly through the adoption of smart farming technologies and targeted policies aimed at supporting young farmers. Smart farming technologies have notably enhanced agricultural sustainability while stimulating regional development. The European Union's Rural Development Program has played a key role in funding various initiatives, which have positively impacted rural prosperity. The integration of these technologies has brought about spatial and functional changes in agricultural practices, contributing to the long-term viability of rural areas and ensuring that agriculture remains a cornerstone of regional economies [48].

Another key driver of regional development has been the Young Farmers Scheme, which has revitalized the agricultural workforce and increased regional output and employment. This policy has not only created direct opportunities within the agricultural sector but has also generated numerous indirect jobs, thereby significantly benefiting rural economies. Analysis of input-output models in key agricultural regions suggests that policies like these can effectively promote social cohesion and drive economic development in rural areas, making them crucial to the sustainability of these regions [49]. Despite agriculture's declining share in Greece's GDP, the sector remains vital for rural development, particularly through innovative practices and supportive policies. However, the observed negative correlation between agriculture and GDP growth highlights the need for more strategic interventions to enhance its economic contribution [50]. Additionally, peripheral countries like Greece face unique challenges related to the transnationalization of production, including dependency on foreign capital and environmental degradation, further underscoring the need for effective regional policies to address these disparities [51].

Western Macedonia presents a unique case within Greece's agricultural landscape, as it faces distinct challenges due to its ongoing energy transition and the shift from traditional energy sources like lignite to renewable energy. This region, heavily reliant on both agriculture and energy production, is at the forefront of efforts to balance economic development with environmental sustainability. As a key agricultural area, Western Macedonia offers valuable insights into how regional policies and technological advancements can foster sustainable agricultural practices while addressing the broader economic and environmental challenges posed by the energy sector's transformation.

The relationship between agricultural production, energy, water usage, environmental impacts, GDP, and regional development in Western Macedonia is intricate and multifaceted. As the region transitions away from its historical reliance on lignite, agriculture is positioned to play a crucial role in economic revitalization. However, sustainable practices will be essential to preserving the environment during this shift.

Agriculture remains a key economic sector in Western Macedonia, with significant growth potential in the post-lignite era. Enhancing farm operations and increasing farm income are expected to drive regional economic development [52]. To effectively navigate the transition, strategic planning is necessary to address the region's high unemployment and low competitiveness, leveraging agricultural advancements as a catalyst for regional growth [53].

Agricultural expansion, however, places a significant demand on water resources, especially in sub-sectors like rice and fruit production, which are major consumers. Sustainable water management will be crucial to reduce pressure on natural resources, calling for both technological advancements and policy reforms that prioritize resource efficiency [54]. The interplay between environmental and economic factors adds another layer of complexity. Historically, economic growth in the Western Balkans region has been associated with increased CO_2 emissions, underscoring the need for environmentally sustainable practices that balance development with ecological health [55]. Achieving sustainable development goals will depend on the integration of environmental policies and economic strategies. While the transition to a post-lignite economy offers opportunities for agricultural growth, it also presents challenges, such as the risk of desertification and the need for innovative solutions to ensure resilience against environmental degradation.

Western Macedonia's economic vulnerability, stemming from high unemployment and heavy reliance on the lignite sector, calls for targeted interventions such as educational and training programs tailored to the region's needs, as well as early retirement schemes for former miners. The region's development strategy should focus on clean energy investments, industrial growth, smart agriculture, and sustainable tourism, leveraging the technical skills acquired by the local workforce through lignite-related industries [56]. However, young scientists in the region express skepticism about the speed of the green transition and are concerned about migration and brain drain, though they believe that EU initiatives could help integrate local communities into a sustainable future [57].

In the agricultural sector, intercropping grain legumes with cereals, particularly in the Florina area of Western Macedonia, has proven effective, with crops like lentils and bread wheat achieving higher yields than mono-crops [58]. Smart specialization strategies could also address the challenges of the region by promoting smart, sustainable, and inclusive growth, as demonstrated in other less-developed regions like Central Macedonia [59]. Additionally, a balanced, multiscalar governance approach that incorporates spatial justice and place-based policies is essential for ensuring a fair and effective transition in Western Macedonia [60].

After reviewing recent and relevant literature, it becomes clear that the agricultural sector is fundamental to Greece's economy, contributing significantly to GDP, employment, and regional development. Although studies have explored individual aspects such as crop and livestock production, energy consumption, water usage, and their environmental impacts, there is a lack of comprehensive research that examines how these factors interact over time and influence economic growth. Furthermore, while the literature addresses the broader agricultural and environmental challenges, it often overlooks the specific dynamics of regions like Western Macedonia, which is experiencing an energy transition from lignite to renewable energy sources.

The research gap identified in this study lies in the absence of a diachronic analysis of the relationship between agricultural production (crops and livestock), energy consumption, water usage, and how these factors contribute to agricultural value-added in Greece's GDP. Most existing research does not integrate these elements into a long-term framework that captures their combined impact on regional and national development. This study aims to address this gap by conducting a multi-decade analysis of national data to understand how energy and environmental variables shape agricultural productivity and sustainability. Additionally, it focuses attention on Western Macedonia, a region facing unique challenges due to its ongoing energy transition, as an illustrative example of how these broader trends can have regional implications.

The article is structured as follows: Section 2 outlines the materials and methods, detailing the selection of variables, data sources, and the linear regression analysis used to assess the relationships between agricultural production, energy consumption, water usage, and their economic and environmental impacts. Section 3 presents the results, providing a detailed analysis of the findings and their statistical significance, and focuses on the examination of the research hypotheses. This chapter provides a thorough evaluation of the statistical relationships and discusses whether the results support or refute the hypotheses. Section 4 offers a discussion of these findings in relation to the broader literature, particularly with attention to regional development implications, such as those relevant to Western Macedonia. Finally, Section 5 concludes by summarizing the study's key contributions and suggesting directions for future research and policy.

2. Materials and Methods

2.1. Variables of the study

The data used for this analysis were obtained from the World Bank Open Data [61], as presented in the paper's **Supplementary Materials**. The selected variables of the study are presented in **Table 1** as follows:

Table 1. The variables of the study.

Variable	Description
AGRVAL	Agriculture, forestry, and fishing correspond to ISIC divisions 1–3 and include forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 4. Data are in constant local currency.
CROP	The crop production index shows agricultural production for each year relative to the base period 2014–2016. It includes all crops except fodder crops. Regional and income group aggregates for the FAO's production indexes are calculated from the underlying values in international dollars, normalized to the base period 2014–2016.
LIVE	The livestock production index includes meat and milk from all sources, dairy products such as cheese, and eggs, honey, raw silk, wool, and hides and skins.
WATER	Annual freshwater withdrawals refer to total water withdrawals, not counting evaporation losses from storage basins. Withdrawals also include water from desalination plants in countries where they are a significant source. Withdrawals can exceed 100 percent of total renewable resources where extraction from nonrenewable aquifers or desalination plants is considerable or where there is significant water reuse. Withdrawals for agriculture are total withdrawals for irrigation and livestock production. Data are for the most recent year available for 1987–2002.
ENERGY	The energy intensity level of primary energy is the ratio between energy supply and gross domestic product measured at purchasing power parity. Energy intensity is an indication of how much energy is used to produce one unit of economic output. A lower ratio indicates that less energy is used to produce one unit of output.

The variables AGRVAL, CROP, LIVE, WATER, and ENERGY were selected for this study because they collectively represent the core components of agricultural production and its interaction with environmental resources, which is essential for understanding sustainability in agriculture. AGRVAL (agricultural value-added) serves as a key economic indicator reflecting the sector's overall contribution to the economy, while CROP and LIVE represent the primary outputs of agricultural activity. WATER and ENERGY are crucial environmental inputs that directly influence agricultural productivity. Water is essential for both crop irrigation and livestock farming, especially in regions like Greece with water scarcity issues, and energy is critical for powering agricultural machinery, irrigation systems, and food processing. The combination of these variables allows for a comprehensive analysis of how resource inputs (water and energy) affect agricultural outputs (crops and livestock), contributing to both economic and environmental sustainability. This approach reflects the growing need for integrated resource management within the water-energy-food nexus, which is increasingly relevant in policy discussions surrounding sustainable development.

The study period for this research is determined by the availability of reliable data from international sources such as the World Bank, ensuring consistency and robustness in the analysis. The chosen time frames are sufficient to capture long-term trends in agricultural production, water consumption, and energy use, allowing for comprehensive evaluation.

AGRVAL in relation to CROP and LIVE (1995–2022): This period provides nearly three decades of data on agricultural value-added and production indices, allowing us to observe trends in the sector's contribution to the economy.

CROP in relation to WATER (1970–2020): Spanning 50 years, this period includes consistent data on water withdrawals, critical for understanding water management and crop production.

LIVE in relation to WATER (1970–2020): The same 50-year period is used for analyzing the water dependency of livestock production, providing insights into long-term water usage trends in livestock farming.

CROP in relation to ENERGY (2000–2022): Starting from 2000, the period offers recent data on energy use in crop production, which includes the growing integration of renewable energy sources.

LIVE in relation to ENERGY (2000–2022): This period is also used to assess energy consumption in livestock farming, providing information on energy intensity in various livestock operations.

These periods were selected to ensure sufficient time spans for robust analysis and are supported by the availability of reliable data sources, making them appropriate for the study.

2.2. Research Method: Linear Regression Analysis

For this study, linear regression analysis is employed to evaluate the relationships between agricultural production (both crops and livestock) and key environmental factors like water and energy consumption. Linear regression is a well-established statistical method that models the relationship between a dependent variable and one or more independent variables by fitting a linear equation to the observed data.

The dependent variables (AGRVAL, CROP, LIVE) represent agricultural outputs, while the independent variables (WATER, ENERGY) represent resource inputs.

The general form of the linear regression equation is:

- $Y = β0 + β1\ X_1 + β2\ X_2 + \ldots + βn\ X_n + ε$

Where:

- Y is the dependent variable (e.g., AGRVAL, CROP, LIVE).
- $X_1, X_2, \ldots, X_n$ are the independent variables (e.g., WATER, ENERGY).
- β0 is the intercept, and β1, β2, …, βn are the coefficients that represent the relationship between each independent variable and the dependent variable.
- ε is the error term, accounting for variability not explained by the model.

To ensure the accuracy and validity of the linear regression models used in this study, several key metrics and statistical tests were employed to evaluate the model's performance and to check for any violations of the assumptions underlying linear regression.

- R-Squared (R^2):

The R-squared value measures the proportion of variance in the dependent variable that is explained by the independent variables in the model. It ranges from 0 to 1, with values closer to 1 indicating a better fit. A high R-squared value suggests that the model explains a significant portion of the variance in agricultural outputs based on water and energy inputs.

- Analysis of Variance (ANOVA):

ANOVA is used to determine whether there are any statistically significant differences between the means of the independent variables. It tests the overall significance of the model by comparing the explained variance with the unexplained variance.

The F-statistic from the ANOVA test helps determine if the overall model is statistically significant. If the F-statistic is large and the associated p-value is small (typically $p < 0.05$), it indicates that the model provides a better fit than a model with no predictors.

- Significance Levels (p-values):

P-values indicate the statistical significance of each predictor variable in the model. A p-value below the threshold (0.05) suggests that the independent variable has a significant effect on the dependent variable. For instance, if the p-value for water usage is less than 0.05, it means water consumption significantly impacts agricultural output.

- Durbin-Watson Test:

The Durbin-Watson statistic is used to detect the presence of autocorrelation in the residuals of the regression model. A value of 2 indicates no autocorrelation, values between 1.5 and 2.5 are generally considered acceptable, and values significantly below 2 indicate positive autocorrelation.

- Collinearity Statistics (Variance Inflation Factor - VIF):

Collinearity occurs when independent variables are highly correlated with each other, which can inflate the standard errors and make it difficult to determine the individual effect of each variable. The Variance Inflation Factor (VIF) is used to detect collinearity. A VIF above 5 or 10 suggests significant collinearity, indicating that the model might need adjustment.

- Residuals Statistics:

Analyzing the residuals (the differences between observed and predicted values) helps check for homoscedasticity (constant variance). Ideally, residuals should be randomly scattered with no discernible pattern, indicating that the model fits well across all values of the independent variables.

- Key residual statistics include:

Mean of residuals: Should be close to 0.

- Standardized residuals: This should mostly fall within the range of -2 to $+2$, indicating that outliers are not excessively influencing the model.

By employing these evaluation metrics and tests, we ensure that the linear regression models used in the study are robust and that the relationships between agricultural production, water usage, and energy consumption are both statistically significant and reliable.

In this study, linear regression analysis was chosen as the primary methodological tool because it allows for the quantification of relationships between dependent variables (such as agricultural value-added, crop, and livestock production) and key independent variables (water withdrawal and energy consumption) over time. Linear regression is well-suited to explore these relationships in a structured manner, providing insight into how changes in environmental inputs affect agricultural outputs. The method is ideal for long-term data analysis, such as the multi-decade dataset used in this study, as it can capture both trends and the magnitude of effects. While other methods such as time series analysis could have been considered, linear regression provides clear interpretability of coefficients, which is critical when assessing the policy implications of resource use on agricultural productivity. The method also allows for the control of multicollinearity and autocorrelation through diagnostic tests (e.g., Variance Inflation Factor, Durbin-Watson), ensuring that the models are statistically robust despite the complex interplay between the variables. Therefore, linear regression is not only appropriate but effective for addressing the study's objectives of understanding the economic and environmental impacts on Greece's agricultural sector.

The focus of this study is on analyzing long-term relationships between agricultural production and resource usage (water and energy), with an emphasis on understanding economic and environmental trends over time. In this context, we didn't proceed in stationarity checks. Additionally, the application of linear regression models in this study does not strictly require stationarity, as we are not attempting to forecast time series or conduct time series-specific modeling (such as ARIMA). Instead, the analysis is focused on identifying relationships between variables (e.g., how water and energy usage affect crop and livestock production), where non-stationary data can still provide valid and meaningful results. Therefore, the lack of stationarity checks does not hinder the study's objectives, which are centered on long-term structural changes rather than short-term fluctuations. This approach is appropriate for research that seeks to capture the broader economic and environmental evolution of agriculture.

The methodological approach of this study focuses on the application of linear regression analysis to investigate the long-term relationships between agricultural production and resource usage (water and energy). This choice is driven by the study's primary objective of examining structural trends over several decades rather than short-term temporal fluctuations. While advanced time series models such as ARIMA or VAR can provide deeper insights into dynamic temporal relationships, their application often requires strict stationarity assumptions and is primarily suited for predictive modeling. In contrast, linear regression allows for robust analysis of non-stationary data, offering clear and interpretable insights into how key variables interact over time. Moreover, this approach aligns with the study's emphasis on identifying broader economic and environmental patterns that influence agriculture. Future research could complement these findings by employing time series models to delve deeper into the dynamic aspects of these relationships, particularly in contexts where granular temporal data are available. For the current analysis, however, linear regression remains the most appropriate method to achieve the study's objectives, ensuring clarity, simplicity, and actionable results for policymakers and researchers alike.

2.3. Methodological Framework

The research methodology is structured around analyzing the relationships between agricultural production, environmental resource use, and economic value-added in Greece. The study employs linear regression analysis to assess the significance and strength of the relationships between the variables, focusing on both the agricultural sector's economic impact and its environmental and energy footprint. Each component of the study is designed to address specific research objectives, which are presented in **Figure 1** as follows:

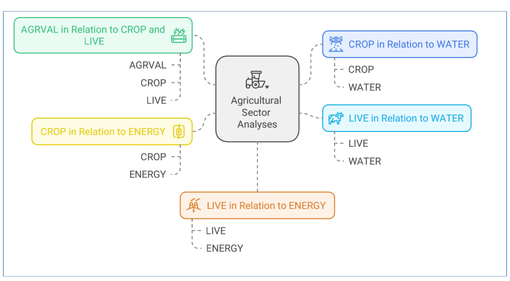

Figure 1. The Methodological Framework of the study.

1st Analysis of AGRVAL in Relation to CROP and LIVE (1995–2022):

This analysis examines the impact of crop production (CROP) and livestock production (LIVE) on agricultural value-added (AGRVAL), which reflects the sector's contribution to the gross domestic product (GDP). AGRVAL is the dependent variable, while CROP and LIVE are independent variables. The goal is to determine whether and to what extent the agricultural (crop) and livestock sectors contribute to the overall value that agriculture adds to the economy. This analysis will reveal the relative importance of each sector in enhancing the economic output of Greece's agriculture.

2nd Analysis of CROP in Relation to WATER (1970–2020):

This segment explores the relationship between water consumption (WATER) and crop production (CROP), where CROP is the dependent variable and WATER is the independent variable. The purpose is to assess the environmental footprint of crop production in terms of water usage, determining how heavily the crop sector depends on water withdrawal. This will help understand the sustainability of water use in agricultural practices over time.

3rd Analysis of LIVE in Relation to WATER (1970–2020):

Similar to the crop analysis, this study investigates the relationship between livestock production (LIVE) and water withdrawal (WATER). LIVE is the dependent variable, while WATER is the independent variable. The objective is to quantify the environmental footprint of the livestock sector in terms of water use. Given the significant water demands of livestock farming, this analysis will highlight the sustainability challenges faced by this sector.

4th Analysis of CROP in Relation to ENERGY (2000–2022):

This analysis examines how energy consumption (ENERGY) influences crop production (CROP). CROP is the dependent variable, and ENERGY is the independent variable. The study seeks to understand the energy footprint of the crop sector by investigating the role of energy in enhancing crop production.

5th Analysis of LIVE in Relation to ENERGY (2000–2022):

This final component explores the relationship between energy consumption (ENERGY) and livestock production (LIVE). LIVE is the dependent variable, while ENERGY is the independent variable. The focus is on determining the energy footprint of the livestock sector, analyzing how energy inputs contribute to livestock productivity.

The methodological framework leverages long-term data to examine the economic contributions and environmental impacts of agriculture in Greece. By analyzing the relationships between key variables such as water and energy consumption, crop and livestock production, and agricultural value-added, this study aims to provide a comprehensive understanding of how these factors interact and contribute to sustainable agricultural practices. The use of linear regression analysis ensures that the relationships are quantified, and their statistical significance is established.

3. Results

In each section of this chapter, the results follow a structured sequence, as presented through the corresponding tables. The process begins with Descriptive Statistics, which provide an overview of the mean and variability of the key variables under study. This is followed by the Model Summary, which evaluates the strength of the relationship between the dependent and independent variables, including key metrics like the R-squared value. Next, the ANOVA table assesses the overall statistical significance of the model. The Coefficients and Collinearity Statistics then provide insight into the individual contributions of each variable and check for multicollinearity issues. Lastly, the Residuals Statistics evaluate the fit and accuracy of the model by examining the distribution of the residuals. Each section concludes with a summary of the results and an examination of the research hypothesis to determine whether the expected relationships are supported by the results.

3.1. 1st Analysis of AGRVAL in Relation to CROP and LIVE (1995–2022)

The descriptive statistics of **Table 2**, for the period 1995–2022, reveal that Greece's agricultural sector has demonstrated relative stability in both crop and livestock production. The mean AGRVAL was approximately 7.08 billion, with a moderate standard deviation of 571.89 million, indicating consistent contributions to the economy despite some fluctuations. Crop production (mean = 103.47) and livestock production (mean = 106.72) showed similar patterns, with standard deviations of 6.32 and 6.89, respectively, reflecting moderate variability. These figures suggest that both crop and livestock sectors have maintained steady outputs, contributing similarly to the overall agricultural value-added during this period.

Table 2. Descriptive Statistics of 1st Analysis.

Variables	Mean	Std. Deviation	N
AGRVAL	7080884928.57	571886055.11	28
CROP	103.47	6.32	28
LIVE	106.72	6.89	28

The regression model indicates a strong positive relationship between agricultural value-added (AGRVAL) and the predictors, crop production (CROP) and livestock production (LIVE), with an R value of 0.703. The model explains 49.4% of the variability in AGRVAL ($R^2 = 0.494$), suggesting that nearly half of the changes in agricultural value-added can be attributed to variations in crop and livestock production. However, the adjusted R^2 of 0.454 slightly reduces this, accounting for model complexity. The standard error of 422.76 million reflects moderate variability around the predicted values, while the Durbin-Watson statistic (1.083) suggests some positive autocorrelation in the residuals (see **Table 3**).

Table 3. Model Summary of 1st Analysis.

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
0.703	0.494	0.454	422761478.079	1.083

The **Table 4**, regarding ANOVA results, confirm that the model significantly explains the variation in agricultural value-added. The high F-statistic and the extremely low p-value indicate that crop and livestock production have a meaningful impact on AGRVAL, supporting the relevance of these predictors in explaining Greece's agricultural value-added.

Table 4. ANOVA of 1st Analysis.

F-Statistic	Significance
12.204	0.000

The Coefficients and Collinearity Statistics **Table 5** provides important insights into the impact of crop production (CROP) and livestock production (LIVE) on agricultural value-added (AGRVAL). The constant is 367.17 million euros, representing the AGRVAL when both CROP and LIVE are zero, although it is statistically insignificant (p = 0.822). For CROP, the unstandardized coefficient indicates that a one-unit increase in the crop production index results in an increase of approximately 62.9 million euros in AGRVAL. This effect is statistically significant (p = 0.000), with a strong positive influence, as shown by the standardized Beta coefficient of 0.696 and a high t-value of 4.690. In contrast, the LIVE coefficient shows that a one-unit increase in the livestock production index leads to an increase of only 1.92 million euros in AGRVAL, but this effect is statistically insignificant (p = 0.877). The t-value of 0.156 further supports that livestock production has a minimal impact in this model. The collinearity statistics, with a VIF of 1.088 for both variables, confirm that multicollinearity is not an issue. Overall, the analysis highlights that crop production has a significant positive impact on Greece's agricultural value-added, while livestock production does not contribute meaningfully.

Table 5. Coefficients and Collinearity Statistics of 1st Analysis.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	367179419.709	1619356486.697	-	0.227	0.822	-	-
CROP	62898380.313	13411193.634	0.696	4.690	0.000	0.919	1.088
LIVE	1925475.793	12310778.187	0.023	0.156	0.877	0.919	1.088

The residual statistics, which are presented in **Table 6**, indicate that the regression model provides a reasonably good fit for the data. The predicted AGRVAL ranges from 6.20 to 7.80 billion euros, with a mean of 7.08 billion, aligning well with the actual mean AGRVAL. The residuals, which represent the difference between observed and predicted values, range from −837.17 to 842.39 million euros, with a mean of zero, suggesting no systematic bias in the model's predictions. The standardized residuals fall within the normal range of −1.98 to 1.99, indicating no extreme outliers. Overall, the model demonstrates accurate and unbiased predictions, with residuals evenly distributed around zero.

Table 6. Residuals Statistics of 1st Analysis.

	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	6202039296.00	7808463872.00	7080884928.57	401952048.787
Residual	−837177600.00	842393216.00	0.00	406802421.953
Std. Predicted Value	−2.186	1.810	0.00	1.000
Std. Residual	−1.980	1.993	0.00	0.962

The statistical analysis of the relationship between AGRVAL, CROP and LIVE for the period 1995–2022 reveals significant findings. The descriptive statistics show that AGRVAL averaged approximately 7.08 billion euros, with both CROP and LIVE showing stable outputs over the period. The regression model demonstrates a strong positive relationship between AGRVAL and the predictors, with an R-value of 0.703, indicating that crop and livestock production explains 49.4% of the variability in AGRVAL. The model's statistical significance is confirmed by the ANOVA results, with a high F-statistic of 12.204 and a p-value of 0.000. The coefficients indicate that CROP has a significant positive impact on AGRVAL, with an unstandardized coefficient of 62.9 million euros per unit increase in the crop index and standardized coefficient Beta = 0.696 (p = 0.000), while LIVE has an insignificant impact (p = 0.877). The residual analysis shows no substantial outliers, confirming the model's overall accuracy. In summary, crop production plays a critical role in driving agricultural value-added in Greece, while livestock production does not significantly contribute in this model.

H1. *AGRVAL has a statistically significant positive relationship with CROP.*

Based on the regression results, there is a strong and statistically significant positive relationship between AGRVAL and CROP. The unstandardized coefficient for CROP is 62.9 million euros, indicating that a one-unit increase in crop production leads to a 62.89 million euros increase in agricultural value-added. This result is statistically significant, with a p-value of 0.000, far below the 0.05 threshold, meaning the relationship is highly significant. The standardized beta coefficient of 0.696 also reflects a substantial positive impact of crop production on AGRVAL. Therefore, H1 is supported, confirming that crop production has a significant positive influence on the agricultural value-added in Greece from 1995 to 2022.

H2. *AGRVAL has a statistically significant positive relationship with LIVE.*

The analysis shows that the relationship between AGRVAL and LIVE is weak and statistically insignificant. The unstandardized coefficient for LIVE is only 1.92 million euros, with a p-value of 0.877, far above the 0.05 threshold, indicating no statistical significance. The standardized beta coefficient is a low 0.023, suggesting that livestock production contributes minimally to agricultural value-added. Given these results, H2 is not supported, as livestock production does not show a statistically significant positive relationship with agricultural value-added during the period studied.

3.2. Analysis of CROP in Relation to WATER (1970–2020)

The descriptive statistics in **Table 7** highlight the central tendencies and variability of both crop production (CROP) and water draw (WATER) over the period. The mean value of CROP is 96.83, with a standard deviation of 12.77, indicating that crop production has generally been stable, with moderate variability across the 51 observations. This suggests that while there have been some fluctuations, crop production has maintained relatively consistent levels. In contrast, the WATER draw shows a mean of 84.49 and a lower standard deviation of 7.30, indicating even greater stability in water consumption during the same period. The lower variability in WATER suggests that water resources were managed more consistently, likely reflecting steady irrigation practices or environmental conditions. Overall, these statistics indicate a stable relationship between crop production and water usage, with crop output showing slightly more fluctuation compared to water use.

Table 7. Descriptive Statistics of 2nd Analysis.

Variables	Mean	Std. Deviation	N
CROP	96.83	12.77	51
WATER	84.49	7.30	51

The results from **Table 8** (Model Summary) indicate that the regression model explains a substantial portion of the variability in crop production. The R value of 0.711 suggests a strong positive correlation between the independent variables and crop production, while the R Square of 0.505 shows that the model accounts for 50.5% of the variability in the dependent variable. The Adjusted R Square of 0.495 confirms that even after adjusting for the number of predictors, the model remains robust, explaining approximately 49.5% of the variation in crop production. The Standard Error of the Estimate (9.081) reflects moderate variability around the predicted values. However, the Durbin-Watson statistic

Table 8. Model Summary of 2nd Analysis.

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
0.711	0.505	0.495	9.081	0.891

of 0.891 indicates some degree of positive autocorrelation. Overall, the model appears to explain a significant portion of the variability in crop production.

The ANOVA results in **Table 9** indicate that the regression model is highly significant. The F-statistic of 49.990 suggests that the independent variable, such as water withdrawal, play a substantial role in explaining the variation in crop production. With a p-value of 0.000, far below the typical significance threshold of 0.05, it is clear that the relationship between the independent variables and crop production is not due to random chance. This confirms that the model as a whole is statistically significant, meaning water withdrawal has a significant impact on crop production.

Table 9. ANOVA of 2nd Analysis.

F-Statistic	Significance
49.990	0.000

The results from **Table 10** demonstrate a strong and statistically significant positive relationship between water withdrawal and crop production. The unstandardized coefficient (B) of 1.243 suggests that each unit increase in water withdrawal results in an increase of approximately 1.243 units in crop production. This relationship is highly significant, as indicated by the t-value of 7.070 and a p-value of 0.000, showing that water withdrawal has a substantial and reliable impact on crop output. The standardized Beta coefficient of 0.711 further highlights the importance of water withdrawal in driving crop production. Additionally, the Tolerance and Variance Inflation Factor (VIF) values of 1.000 indicate no multicollinearity issues, meaning the model's estimates are robust and the independent variables are not overly correlated. This strengthens the reliability of the regression model's findings.

The residual statistics in **Table 11** indicate that the model provides a good fit for predicting crop production. The predicted values range from 62.666 to 113.978, with a mean of 96.835, closely aligning with the actual mean, which suggests that the model's predictions are accurate. The residuals, which measure the difference between the observed and predicted values, have a mean of 0.000, confirming that the model does not systematically overestimate or underestimate the crop production. The standard deviation of 8.990 for the residuals reflects moderate variability, while the standardized residuals fall mostly within the acceptable range of -2.714 to 1.443, indicating that there are no extreme outliers affecting the model's accuracy. Overall, the residuals demonstrate that the model is well-calibrated and provides reliable predictions of crop production without significant errors or bias.

The second analysis focuses on the relationship between water usage (WATER) and crop production (CROP). The model demonstrates a strong positive correlation, with a high R-value of 0.711 and an R-squared value of 0.505, indicating that approximately 50.5% of the variability in crop production can be explained by water withdrawal. The regression model is statistically significant, as shown by the F-statistic of 49.990 and a p-value of 0.000, confirming the overall validity of the model. The regression coefficient for WATER shows that for every unit increase in water withdrawal, crop production increases by 1.243 units, with a t-value of 7.070 and a p-value of 0.000, highlighting the significance of water withdrawal in explaining variations in crop output. The residual statistics show that the model fits well, with no significant outliers or biases in the residuals, ensuring the accuracy and reliability of the predictions.

H3 hypothesis posits that water withdrawal (WATER) has a statistically significant positive relationship with crop production (CROP), meaning that higher water withdrawal is expected to lead to increased crop yields. The results of the analysis strongly support this hypothesis. The unstandardized coefficient of 1.243 indicates that as water usage increases, crop production rises correspondingly. The t-value of 7.070 and p-value of 0.000 confirm that this relationship is statistically significant, meaning there is a very low probability that the observed relationship is due to chance. Additionally, the Beta coefficient of 0.711 suggests that water withdrawal is a major factor influencing crop production, further validating H3. Therefore, the analysis confirms that higher water consumption is indeed associated with higher

Table 10. Coefficients and Collinearity Statistics of 2nd Analysis.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	−8.195	14.909	-	−0.550	0.585	-	-
WATER	1.243	0.176	0.711	7.070	0.000	1.000	1.000

Table 11. Residuals Statistics of 2nd Analysis.

	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	62.666	113.978	96.835	9.080
Residual	−24.650	13.103	0.000	8.990
Std. Predicted Value	−3.763	1.888	0.000	1.000
Std. Residual	−2.714	1.443	0.000	0.990

crop yields, supporting the H3 hypothesis.

3.3. 3rd Analysis of LIVE in Relation to WATER (1970–2020)

The descriptive statistics in **Table 12** show that both livestock production (LIVE) and water withdrawal (WATER) have remained relatively stable over the 51-year period studied. The mean value of LIVE is 106.88, with a standard deviation of 8.24, indicating moderate variability in livestock production. This suggests that while there have been some fluctuations, livestock production has maintained a consistent level overall. Similarly, the mean value of WATER withdrawal is 84.49, with a standard deviation of 7.30, reflecting stable water withdrawal patterns with minimal variation. This consistency in both livestock output and water withdrawal over time provides a solid foundation for examining their potential relationship in the subsequent regression analysis.

Table 12. Descriptive Statistics of 3rd Analysis.

Variables	Mean	Std. Deviation	N
LIVE	106.88	8.24	51
WATER	84.49	7.30	51

The results from **Table 13** (Model Summary) suggest a strong relationship between livestock production (LIVE) and water withdrawal (WATER). The R value of 0.867 indicates a high degree of correlation, meaning that the independent variable (water withdrawal) is strongly related to the dependent variable (livestock production). The R Square value of 0.751 shows that the model explains 75.1% of the variability in livestock production, indicating a high level of explanatory power. The Adjusted R Square of 0.746 confirms that even after accounting for the number of predictors in the model, approximately 74.6% of the variance in livestock production is explained by water withdrawal. The Standard Error of the Estimate (4.153) indicates that the model's predictions are relatively accurate with moderate variability. The Durbin-Watson statistic of 1.060 suggests some minor positive autocorrelation, but it is within an acceptable range, indicating that the residuals are largely independent. Overall, the model provides a strong and reliable explanation of the relationship between water withdrawal and livestock production.

Table 13. Model Summary of 3rd Analysis.

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
0.867	0.751	0.746	4.153	1.060

The ANOVA results in **Table 14** demonstrate the overall significance of the regression model linking water withdrawal to livestock production. The F-statistic of 147.886 is very large, indicating that the independent variable (water withdrawal) significantly explains the variation in the dependent variable (livestock production). The p-value of 0.000 confirms this, showing that the model is statistically significant at any conventional level ($p < 0.05$). This means there is a very low probability that the observed relationship between water withdrawal and livestock production is due to chance, and the regression model provides a valid and reliable fit for explaining how water withdrawal impacts livestock production.

Table 14. ANOVA of 3st Analysis.

F-Statistic	Significance
147.886	0.000

The results from **Table 15** (Coefficients and Collinearity Statistics) highlight the strong and statistically significant positive relationship between water withdrawal (WATER) and livestock production (LIVE). The unstandardized coefficient (B) of 0.978 indicates that for every additional unit of water withdrawal, livestock production increases by approximately 0.978 units, suggesting a direct and meaningful impact. The t-value of 12.161 and the p-value of 0.000 confirm that this relationship is statistically significant. The standardized coefficient (Beta) of 0.867 reflects a very strong influence of water withdrawal on livestock production, showing that water withdrawal is a major predictor of livestock output. Additionally, the Tolerance value of 1.000 and the Variance Inflation Factor (VIF) of 1.000 indicate that there is no multicollinearity present, meaning that the independent variables are not correlated with each other. This ensures the model's reliability and the robustness of the coefficient estimates.

Table 15. Coefficients and Collinearity Statistics of 3rd Analysis.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	24.262	6.819	-	3.558	0.001	-	-
WATER	0.978	0.080	0.867	12.161	0.000	1.000	1.000

The residual statistics in **Table 16** provide insight into the accuracy and fit of the regression model predicting livestock production (LIVE) based on water withdrawal (WATER). The predicted values for livestock production range from 80.0062 to 120.3709, with a mean of 106.885, closely matching the observed mean, indicating that the model performs well in capturing the central tendency of the data. The residuals, which represent the differences between the observed and predicted values, have a mean of 0.000 and a standard deviation of 4.11194, showing that the model does not systematically overestimate or underestimate livestock production. The standardized predicted values range from −3.763 to 1.888, with a standard deviation of 1.000, confirming that the predictions have been standardized correctly. The standardized residuals range from −2.119 to 1.930, with a standard deviation of 0.990, indicating that the residuals are within an acceptable range, with no extreme outliers affecting the model's performance. Overall, these residual statistics suggest that the model fits the data well, with balanced and evenly distributed prediction errors, further confirming the model's reliability.

The third analysis investigates the relationship between water withdrawal (WATER) and livestock production (LIVE) for the period 1970–2020. The results show a strong positive correlation, with an R value of 0.867 and an R-squared of 0.751, indicating that 75.1% of the variation in livestock production can be explained by water withdrawal. The model is statistically significant, as demonstrated by the F-statistic of 147.886 and a p-value of 0.000. The unstandardized coefficient for water withdrawal is 0.978, indicating that an increase in water usage leads to a corresponding increase in livestock production. The residual statistics suggest that the model fits the data well, with no significant outliers or bias in the predictions, providing a robust explanation of how water withdrawal affects livestock output.

H4 posits that water withdrawal (WATER) has a statis-

Table 16. Residuals Statistics of 3rd Analysis.

	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	80.006	120.370	106.885	7.143
Residual	−8.803	8.018	0.000	4.111
Std. Predicted Value	−3.763	1.888	0.000	1.000
Std. Residual	−2.119	1.930	0.000	0.990

tically significant positive relationship with livestock production (LIVE), meaning that higher water availability should support greater livestock production. The results strongly support this hypothesis. The unstandardized coefficient of 0.978 indicates that each additional unit of water withdrawal leads to an increase of approximately 0.978 units in livestock production. The t-value of 12.161 and the p-value of 0.000 further confirm the statistical significance of this relationship. With a Beta coefficient of 0.867, water withdrawal is shown to be a key predictor of livestock output, suggesting that water availability is crucial for supporting livestock farming. Therefore, H4 is validated, confirming that greater water withdrawal positively and significantly influences livestock production.

3.4. 4th Analysis of CROP in Relation to ENERGY (2000–2022)

The descriptive statistics in **Table 17** reveal that both crop production (CROP) and energy consumption (ENERGY) have been relatively stable over the 23-year period from 2000 to 2022. The mean value of CROP is 102.16, with a standard deviation of 6.09, indicating moderate variability in crop output, suggesting that while there have been some fluctuations, crop production has remained fairly consistent. Similarly, the mean value of ENERGY is 3.17, with a standard deviation of 0.26, reflecting minimal variation in energy consumption, showing that energy usage in relation to crop production has remained quite steady. This stability in both variables is important as it sets the stage for examining how changes in energy consumption might impact crop production over time.

The results from **Table 18** (Model Summary) indicate a moderate relationship between crop production (CROP) and energy consumption (ENERGY). The R value of 0.552 suggests a moderate correlation, meaning that energy consumption moderately influences crop production. The R Square value of 0.305 shows that 30.5% of the variability in crop production can be explained by energy consumption, indicating that while energy use plays a role in determining crop output, other factors are also significantly influencing production. The Adjusted R Square of 0.272 accounts for the number of predictors in the model, slightly lowering the explained variance to 27.2%, suggesting some model complexity but overall consistency. The Standard Error of the Estimate (5.19880) reflects moderate variability around the predicted values. The Durbin-Watson statistic of 0.830 is below the ideal range (around 2), indicating some positive autocorrelation in the residuals.

Table 17. Descriptive Statistics of 4th Analysis.

Variables	Mean	Std. Deviation	N
CROP	102.160	6.090	23
ENERGY	3.170	0.260	23

Table 18. Model Summary of 4th Analysis.

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
0.552	0.305	0.272	5.198	0.830

The ANOVA results in **Table 19** demonstrate that the regression model is statistically significant. The F-statistic of 9.209 suggests that energy consumption (ENERGY) significantly contributes to explaining the variation in crop production (CROP). The p-value of 0.006 is well below the 0.05 significance threshold, confirming that the relationship between energy consumption and crop production is statistically significant. This indicates that the likelihood of the observed relationship occurring by chance is very low, and energy consumption plays a meaningful role in influencing crop production. Thus, the model provides a reliable explanation of the impact of energy on crop output.

Table 19. ANOVA of 4th Analysis.

F-Statistic	Significance
9.209	0.006

The results from **Table 20** (Coefficients and Collinearity Statistics) indicate a significant positive relationship between energy consumption (ENERGY) and crop production (CROP). The unstandardized coefficient (B) of 12.640 suggests that for every additional unit of energy consumption, crop production increases by 12.64 units, reflecting a direct impact of energy use on crop output. The t-value of 3.035 and p-value of 0.006 confirm that this relationship is statistically significant, with the p-value below the 0.05 threshold, indicating that the effect of energy on crop production is unlikely to be due to chance. The standardized coefficient (Beta) of 0.552 highlights that energy consumption has a moderate positive influence on crop production. Additionally, the Tolerance value of 1.000 and the Variance Inflation Factor (VIF) of 1.000 indicate no multicollinearity, meaning that energy consumption is not highly correlated with any other independent variables in the model. Overall, these statistics suggest that energy use is an important and independent predictor of crop production.

Table 20. Coefficients and Collinearity Statistics of 4th Analysis.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	62.004	13.279	-	4.669	0.000	-	-
ENERGY	12.640	4.165	0.552	3.035	0.006	1.000	1.000

The residual statistics in **Table 21** indicate that the model provides a reasonable fit for predicting crop production (CROP) based on energy consumption (ENERGY). The predicted values range from 94.615 to 107.760, with a mean of 102.166, closely matching the actual crop production mean. The residuals, representing the differences between observed and predicted values, range from −13.424 to 7.179, with a mean of 0.000, confirming that the model does not systematically over- or under-predict. The standardized residuals range from −2.582 to 1.381, indicating no significant outliers, and the standard deviation of 5.079 shows moderate variability in the residuals. Overall, the model demonstrates a good balance of prediction accuracy, without extreme errors or bias.

The fourth analysis examines the relationship between crop production (CROP) and energy consumption (ENERGY) from 2000 to 2022. The results show a moderate positive correlation between the two variables, with an R value of 0.552 and an R-squared of 0.305, indicating that 30.5% of the variability in crop production can be explained by energy consumption. The model is statistically significant, as demonstrated by the F-statistic of 9.209 and a p-value of 0.006. The coefficient for energy consumption shows that for every unit increase in energy usage, crop production increases by 12.64 units, and the standardized Beta coefficient of 0.552 highlights energy consumption as a moderately strong predictor of crop output. The residual statistics indicate that the model fits the data reasonably well, with no significant outliers or biases.

H5 hypothesis posits that energy consumption (ENERGY) has a statistically significant positive relationship with crop production (CROP), suggesting that higher energy inputs lead to increased crop production. The analysis results strongly support this hypothesis. The unstandardized coefficient (B) of 12.640 indicates that each additional unit of energy consumption results in a 12.64 unit increase in crop production. This relationship is statistically significant, as evidenced by the t-value of 3.035 and the p-value of 0.006, which is well below the 0.05 threshold. The standardized Beta coefficient of 0.552 further confirms that energy con-

Table 21. Residuals Statistics of 4th Analysis.

	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	94.615	107.760	102.166	3.363
Residual	−13.424	7.179	0.000	5.079
Std. Predicted Value	−2.245	1.663	0.000	1.000
Std. Residual	−2.582	1.381	0.000	0.977

sumption has a meaningful and positive influence on crop production, making it an important factor in agricultural output. Therefore, H5 is validated, confirming that greater energy inputs contribute significantly to increased crop production.

3.5. 5th Analysis of LIVE in Relation to ENERGY (2000–2022)

The descriptive statistics in **Table 22** reveal that both livestock production (LIVE) and energy consumption (ENERGY) have remained relatively stable over the 23-year period from 2000 to 2022. The mean value of LIVE is 105.77, with a standard deviation of 7.06, indicating moderate variability in livestock output, suggesting consistency in production levels despite some fluctuations. Similarly, the mean value of ENERGY consumption is 3.17, with a standard deviation of 0.26, reflecting minimal variation in energy use. This stability in both livestock production and energy consumption provides a foundation for further analysis of the relationship between these two variables.

Table 22. Descriptive Statistics of 5th Analysis.

Variables	Mean	Std. Deviation	N
LIVE	105,77	7,06	23
ENERGY	3,17	0,26	23

The Model Summary in **Table 23** indicates a moderate relationship between livestock production (LIVE) and energy consumption (ENERGY) for the period 2000–2022. The R value of 0.631 suggests a moderate positive correlation between the two variables, meaning that energy consumption has some influence on livestock production. The R Square of 0.399 shows that 39.9% of the variability in livestock production can be explained by energy consumption, while the Adjusted R Square of 0.370 accounts for the number of predictors in the model, slightly lowering the explained variance to 37.0%. The Standard Error of the Estimate (5.608) indicates moderate variability in the residuals, meaning that the model's predictions for livestock production are relatively accurate but with some error. The Durbin-Watson statistic of 0.652 suggests potential positive autocorrelation in the residuals.

Table 23. Model Summary of 5th Analysis.

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
0.631	0.399	0.370	5.608	0.652

The ANOVA results in **Table 24** demonstrate that the regression model is statistically significant. The F-statistic of 13.925 indicates that energy consumption (ENERGY) significantly contributes to explaining the variation in livestock production (LIVE). The corresponding p-value of 0.001 is well below the conventional significance threshold of 0.05, confirming that the relationship between energy consumption and livestock production is statistically significant. This means that the likelihood of the observed relationship occurring by chance is very low, supporting the model's validity in explaining how energy consumption impacts livestock production.

Table 24. ANOVA of 5th Analysis.

F-Statistic	Significance
13.925	0.001

The Coefficients and Collinearity Statistics in **Table 25** show a statistically significant positive relationship between energy consumption (ENERGY) and livestock production (LIVE). The unstandardized coefficient (B) of 16.769 indicates that for every additional unit of energy consumption, livestock production increases by approximately 16.769 units, suggesting a direct and substantial impact of energy on livestock output. The t-value of 3.732 and p-value of 0.001 confirm that this relationship is statistically significant, meaning the likelihood that this result is due to random chance is very low. The standardized Beta coefficient of 0.631 highlights that energy consumption is a moderately strong predictor of livestock production. Additionally, the Tolerance value of 1.000 and the Variance Inflation Factor (VIF) of 1.000 indicate no multicollinearity, meaning energy consumption is not highly correlated with any other variables in the model, ensuring the stability and reliability of the coefficient estimates. Overall, this analysis supports the significant role that energy consumption plays in influencing livestock production.

Table 25. Coefficients and Collinearity Statistics of 5th Analysis.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	52.491	14.326	-	3.664	0.001	-	-
ENERGY	16.769	4.494	0.631	3.732	0.001	1.000	1.000

The residual statistics in **Table 26** show that the model predicting livestock production (LIVE) based on energy consumption (ENERGY) provides a reasonable fit. The predicted values range from 95.753 to 113.193, with a mean of 105.771, closely matching the actual mean of livestock production, suggesting accurate model predictions. The residuals, which represent the differences between observed and predicted values, have a mean of 0.000, indicating no systematic over- or under-prediction by the model. The standard deviation of 5.479 for the residuals reflects moderate variability, and the standardized residuals range from -1.638 to 1.320, showing no extreme outliers. Overall, the model demonstrates good accuracy in predicting livestock production based on energy consumption, with well-distributed residuals and minimal bias.

The fifth analysis examines the relationship between livestock production (LIVE) and energy consumption (ENERGY) from 2000 to 2022. The results indicate a moderate positive correlation, with an R value of 0.631 and an R-squared of 0.399, suggesting that 39.9% of the variability in livestock production can be explained by energy consumption. The model is statistically significant, as shown by the F-statistic of 13.925 and a p-value of 0.001, confirming that energy consumption significantly influences livestock production. The unstandardized coefficient for energy consumption is 16.769, meaning that an increase in energy usage leads to a notable increase in livestock output. Residual statistics further indicate that the model fits well, with no major outliers or biases.

H6 hypothesis posits that energy consumption (ENERGY) has a statistically significant positive relationship with livestock production (LIVE), implying that greater energy use directly enhances livestock productivity. The results from the analysis strongly support this hypothesis. The unstandardized coefficient of 16.769 shows that for every unit increase in energy consumption, livestock production rises by approximately 16.769 units. The t-value of 3.732 and p-value of 0.001 confirm that this relationship is statistically significant. Additionally, the Beta coefficient of 0.631 indicates a moderate positive influence of energy consumption on livestock production. Therefore, the results validate H6 hypothesis, showing that increased energy consumption has a significant and positive impact on livestock productivity.

4. Discussion

The findings of this study provide significant insights into the relationships between agricultural value-added, crop

Table 26. Residuals Statistics of 5th Analysis.

	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	95.753	113.193	105.771	4.462
Residual	−9.184	7.404	0.000	5.479
Std. Predicted Value	−2.245	1.663	0.000	1.000
Std. Residual	−1.638	1.320	0.000	0.977

and livestock production, water withdrawal, and energy consumption in Greece over multiple time periods. By analyzing the contributions of water and energy inputs to agricultural output, we can better understand how these resources impact both crop and livestock productivity and the broader agricultural economy.

The results indicate a strong and statistically significant relationship between AGRVAL and crop production (CROP) (H1). This confirms that crop output is a major contributor to Greece's agricultural economy. This conclusion aligns with the findings of Paschalidis et al.[62]. Both studies emphasize that crop production is a major contributor to Greece's agricultural economy, with crop output accounting for a substantial portion of the total agricultural value. In both studies, crop production is recognized as a key driver of economic performance in agriculture, underscoring the importance of addressing challenges such as soil degradation and resource management to sustain productivity. This consistency across studies strengthens the argument for prioritizing crop-related investments and sustainable practices in Greek agriculture.

On the other hand, the relationship between livestock production (LIVE) and AGRVAL was not found to be significant in our analysis (H2), which contrasts with the key role livestock plays in other aspects of regional development, as discussed in the literature. For example, Tsiouni et al.[63] highlight the economic importance of livestock, particularly goat farming, in Greece's mountainous areas, where goat farming contributes to regional economies by providing stable employment and high-quality products like milk and meat. However, despite its social and economic value, the livestock sector, particularly small ruminants, faces significant challenges related to low competitiveness and high production costs, which can explain why its contribution to overall agricultural value-added remains limited.

The study finds a significant positive relationship between crop production and agricultural value-added, highlighting the critical role of crop production in Greece's agricultural economy, consistent with existing literature. However, the insignificant relationship between livestock production and agricultural value-added requires further exploration. This result may stem from structural inefficiencies in Greece's livestock sector, such as small-scale operations, higher production costs, and limited integration into larger markets. Additionally, the lack of regional data on livestock production and value-added complicates a more granular analysis. Future research could address these limitations by incorporating regional datasets or conducting case studies in areas like Western Macedonia, where the dynamics of livestock production may differ, offering a more nuanced understanding of its contribution to agricultural value-added.

Similarly, Sintori et al.[64] emphasize the regional importance of dairy goat farming but note that extensive farming systems, which dominate livestock production in Greece, are often characterized by lower productivity compared to more intensive systems. This low productivity, coupled with the high costs associated with feed and labor, likely contributes to the insignificant relationship observed in our analysis between livestock production and agricultural value-added. These findings suggest that while livestock farming is socially and economically important in specific regions, its overall contribution to Greece's agricultural economy remains constrained by structural inefficiencies.

Water demand in Greece has seen a significant increase over the past three decades, with irrigation accounting for up to 85% of total water usage[65]. The significant positive relationship between water withdrawal and both crop production (H3) and livestock production (H4) in our analysis aligns with the findings of Ran et al.[66], which emphasize the critical role of water in supporting agricultural systems, particularly for irrigation and feed production. Their study highlights that around 30% of global agricultural water is used for livestock, much of it indirectly through the production of feed crops, which supports our finding that water is essential for both sectors in Greece. The reliance on blue water resources (water from rivers, lakes, and aquifers) for irrigation in water-scarce Mediterranean regions, as noted in both studies, underscores the growing need for efficient water management to sustain productivity in the face of competition for limited resources.

The positive correlation between energy consumption and both crop production (H5) and livestock production (H6) in our analysis is supported by the findings of Sagani et al. [67] which highlight the significant role that agricultural biomass, particularly waste from tree prunings, plays in energy generation in Greece. Their study shows how utilizing agricultural residues for energy not only supports agricultural productivity but also promotes sustainable energy use, which aligns with our findings that energy consumption positively impacts crop production by enhancing agricultural efficiency and productivity.

Similarly, Mazis et al. [68] explore the role of energy in crop production, particularly in energy-intensive agricultural practices such as the use of machinery, fertilizers, and fuel. Their research on orange and kiwi orchards demonstrates that these energy inputs significantly affect crop yields, reflecting the same trend observed in our analysis where higher energy consumption is linked to increased crop and livestock productivity. Both studies emphasize the need for efficient energy management to optimize agricultural output while minimizing environmental impact, reinforcing the conclusion that energy is a critical driver of agricultural performance in Greece.

To build upon the earlier analysis of energy's impact on agricultural productivity, regional funding for Greece's agricultural sector should focus on promoting rural development by taking into account each region's unique strengths and needs [69]. In periphery of Western Macedonia, transitioning from a lignite-based economy, funding should support sectors closely linked to agriculture, such as agri-food processing and renewable energy for farming. Prioritizing regional specialization by investing in key activities like livestock farming and niche crop production, which suit the region's geography and climate, will help strengthen the agricultural sector and contribute to broader economic diversification.

The significant positive relationship between energy consumption and both crop production (H5) and livestock production (H6) in our analysis aligns closely with the ongoing energy transition in Western Macedonia. As Kaldellis et al. [70] discuss, the region's shift from lignite-based energy to renewable energy sources like solar and biomass offers new opportunities for sectors heavily reliant on energy, such as agriculture. This transition is not only necessary for reducing the region's carbon footprint but also crucial for supporting energy-intensive agricultural practices. By integrating renewable energy into agriculture, the region can maintain or even boost its agricultural productivity, mirroring the positive impacts of energy consumption on crop and livestock output as highlighted in our findings.

Furthermore, as noted by Ziouzios et al. [71], the lignite phase-out will cause significant job losses and economic disruption in Western Macedonia. To mitigate these effects, investments in renewable energy technologies for agriculture are critical. Renewable energy can reduce operational costs and improve sustainability, ensuring that agriculture remains a viable economic activity in the post-lignite era. This transformation aligns with our findings that energy consumption is a key driver of agricultural productivity. The region's ability to pivot towards renewable energy could not only safeguard its agricultural sector but also support broader regional economic stability as part of its just transition strategy [72].

5. Conclusions

The aim of this study was to conduct a comprehensive analysis of the agroeconomic and environmental performance of Greece's agricultural sector, focusing on the relationship between agricultural value-added and key production indices for crops and livestock. Additionally, the study sought to examine the influence of energy consumption and water withdrawal on agricultural outputs, while also exploring how these factors evolve over time. This study also aimed to provide insights relevant to regional development, with a focus on Western Macedonia, which is undergoing a significant energy transition.

This study confirms the critical role of crop production in contributing to Greece's agricultural value-added, while livestock production showed limited impact at the national level. Both water withdrawal and energy consumption were found to significantly enhance productivity in both crop and livestock sectors, underscoring the importance of efficient resource management. The findings [73] highlight the need for sustainable water and energy practices in agriculture, with implications for regional development, particularly in areas like Western Macedonia, where the transition to renewable energy offers opportunities for improving agricultural output.

This study contributes to the existing literature by offering a diachronic analysis of the relationship between agricultural production, water usage, energy consumption, and their combined effect on Greece's agricultural value-added over several decades. The analysis also highlights the role of renewable energy and efficient water management in agricultural sustainability. Moreover, the study offers regional insights from Western Macedonia, providing a case study for regions undergoing energy transitions. It addresses a critical gap in the literature by examining these factors together in a long-term framework, thus providing a more comprehensive understanding of how energy and environmental variables shape agricultural productivity and sustainability.

To enhance the sustainability and productivity of Greece's agricultural sector, policy proposals should focus on improving water resource management through advanced irrigation techniques and water recycling to address the increasing water demand. Additionally, policies must promote the integration of renewable energy sources, such as solar, wind, and biomass, to reduce costs and support energy-intensive agricultural practices. Investment in smart farming technologies and sustainable crop production should be prioritized to boost efficiency and resilience. Finally, reforms in the livestock sector are necessary, including modernization and cost-reduction strategies, to improve competitiveness and address structural inefficiencies, particularly in rural regions like Western Macedonia.

One limitation of this study is that it relied on national-level data, which may obscure important regional variations in agricultural practices, energy consumption, and water management. This broader approach can overlook specific regional challenges or opportunities, particularly in areas like Western Macedonia undergoing significant economic transitions. Additionally, while the analysis did not incorporate stationarity checks or more advanced econometric techniques like autoregressive models, it successfully captured long-term structural relationships, which were the primary focus of the research.

Despite these limitations, the study provides a robust analysis of the interactions between key variables such as agricultural production, water withdrawal, and energy consumption over an extended period. By focusing on long-term trends, the study contributes valuable insights into the role of resource management in sustaining agricultural productivity. The findings are particularly relevant for shaping national policies and offer a strong foundation for future research, which can build on this work by incorporating more granular, region-specific data to develop tailored solutions for each of Greece's diverse regions.

While this study primarily analyzes national-level data due to the lack of available regional datasets for key variables such as water withdrawal, energy consumption, and agricultural value-added, it attempts to provide specific insights into Western Macedonia, a region undergoing significant transitions. This national-level focus offers valuable overarching conclusions but may not fully capture localized dynamics within Greece's diverse regions. Future research should prioritize the collection and analysis of regional data for Greece's peripheries. Such data would enable a more nuanced understanding of the interactions between water, energy, and agricultural productivity in distinct geographic and economic contexts. Incorporating regional data could also provide more targeted and effective policy recommendations tailored to the unique challenges and opportunities of regions like Western Macedonia, where the energy transition is profoundly reshaping the agricultural landscape.

Furthermore, the study employs linear regression analysis to examine long-term structural relationships, which, while effective for the study's objectives, does not capture short-term temporal dynamics. Advanced time series models could complement this approach in future studies to explore dynamic interactions between variables. Lastly, the study focuses on Greece as a case study, and further comparative analyses with other countries undergoing similar transitions could provide broader insights into sustainable agricultural practices. These directions could build upon the current findings and deepen our understanding of how agricultural systems interact with environmental and economic factors.

In conclusion, this study highlights the critical interplay between agriculture, energy, and water resources in Greece, offering valuable insights for sustainable development in the agricultural sector while providing actionable recommendations for both national and regional policy.

Supplementary Materials

The following supporting information can be downloaded at: https://data.worldbank.org/.

Author Contributions

Conceptualization, S.P.M., P.K., N.T.G., D.P.S., K.A. and P.M.F.; methodology, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; software, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; validation, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; formal analysis, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; investigation, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; resources, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; data curation, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; writing—original draft preparation, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; writing—review and editing, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; visualization, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; supervision, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; project administration, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.; funding acquisition, S.P.M., P.K., N.T.G., and D.P.S., K.A. and P.M.F.All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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