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The Impact of Agriculture on the Consumption of Natural Resources (An analytical study)

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Abstract

This research delves into the multifaceted relationship between agriculture and the consumption of natural resources, highlighting the significant impact of agricultural practices on natural resource depletion. Various studies have explored this dynamic, revealing how technological advancements, government policies, and market access in developed countries have contributed to the increased consumption of natural resources in agriculture. The expansion of palm oil plantations in Indonesia, for instance, has raised concerns about land scarcity and environmental degradation due to soil compaction and water retention issues. Conversely, research in the U.S. suggests that the availability of natural resources, except in cases of major energy supply interruptions, does not significantly constrain agricultural output. The study also examines the role of energy consumption in agriculture, with findings indicating that an increase in gas consumption boosts GDP, whereas higher electricity consumption may hinder growth. Additionally, the research addresses the effects of natural disasters on agriculture, food security, and natural resources, with typhoons notably impacting rice production and household food security in the Philippines. Through a critical and analytical lens, this paper aims to provide a comprehensive understanding of how agricultural practices influence the depletion of natural resources and explore potential strategies for mitigating these effects. Given the study's outcomes, several policy recommendations emerge as follow: Governments should create incentives for the adoption of renewable energy technologies in agriculture to reduce reliance on non-renewable resources, There is a need for comprehensive water management policies that ensure more sustainable water use in agriculture.

Keywords: Impact, Agriculture, Consumption, Natural Resources

1. Introduction

The interplay between agriculture and natural resource consumption has been a pivotal aspect of human civilization's development. Historically, the advent of agriculture marked a fundamental transformation from nomadic hunter-gatherer societies to settled agricultural communities, initiating the rise of complex societies and, eventually, modern states. This shift not only altered social structures but also had profound impacts on the natural environment. As societies evolved, so too did agricultural practices, which increasingly drew upon natural resources such as water, land, and energy to meet the demands of growing populations.

Today, the sustainability of these resources is under unprecedented pressure, exacerbated by modern agricultural methods that often prioritize short-term yields over long-term resource conservation. The challenge is multifaceted, involving economic, environmental, and social dimensions. On one hand, there is a need to feed an ever-growing global population, which is projected to reach nearly 10 billion by 2050(Bio.org). On the other hand, the imperative to preserve the environment and ensure the availability of resources for future generations cannot be overlooked.

In this research, I will critically analyze the impact of agricultural practices on the consumption of natural resources. By examining historical trends and current practices, as well as projecting future scenarios, this study aims to uncover the complexities of this relationship and propose sustainable agricultural practices that balance the need for food production with the conservation of natural resources. Through a critical and analytical lens, this research paper will investigate how different agricultural practices influence resource depletion and what measures can be implemented to mitigate these effects, thereby contributing to the broader discourse on sustainable development.

2. Literature review

The relationship between agriculture and natural resource consumption is a multifaceted topic that has been explored by various researchers. Many studies have analyzed the impact of agricultural practices on the depletion of natural resources, such as land, water, and energy. Here is a concise literature review on the impact of agriculture on natural resource consumption, written in an unbiased, journalistic tone, using the following search results:

Ashton and Pereira (1980) investigated the competition for resources in the agricultural sector of developed countries, such as the U.K., the United States, Canada, and countries in the European

International Journal of Research and Studies Publishing
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Economic Community. They found that technological advancements, government support policies, and market access played a significant role in the consumption of natural resources in agriculture.

Brainard (2011) examined the impact of Indonesian agricultural policies, particularly on the establishment of palm oil plantations, indigenous populations, natural resources, and the economy. This study revealed that the rapid expansion of plantations has led to concerns about potential land scarcity and caused unrest among locals due to the land acquisition process. Additionally, the use of heavy machinery to clear land has compacted the soil, reducing its capacity to retain water.

Castle (1982) analyzed the adequacy of natural resources for U.S. agricultural outputs. The study found that effective demand and institutional incentives are the most important determinants of agricultural output, while the availability of natural resources such as energy, water, and land is not a major constraint on production, except in the case of a major interruption in energy supply.

Based on Faridi and Murtaza's research (2013), the connection between disaggregate energy consumption, agricultural output, and economic growth in Pakistan was examined. The study revealed that an increase in total gas consumption is associated with an increase in real GDP, while an increase in electricity consumption has a detrimental effect on growth.

Lichtenberg and colleagues (2010) examined the role of agricultural economics and economists in preserving natural resources. Their findings revealed that tenants are not inherently less likely to implement soil conservation techniques or invest less in soil conservation compared to owner-operators. Moreover, even a modest level of tenure security can be sufficient motivation for some types of land investments.

Mekonnen et al. (2015) investigated the impact of natural resource scarcity on agriculture in Ethiopia. The study provided empirical evidence on the effect of resource scarcity, particularly fuelwood and water, on labor allocation in agricultural activities.

Israel and Briones (2012) analyzed the impacts of natural disasters on agriculture, food security, and natural resources in the Philippines. The study found that typhoons have a significant negative impact on rice production at the local level and on the food security of households in the affected areas. This literature review summarizes the findings of studies that examined the relationship between electricity consumption and economic growth in high-income Middle East and North Africa (MENA) countries. The review is unbiased and journalistic in tone, and it was conducted using the above-mentioned search results.

Ataş et al. (2024) analyzed the connection between electricity consumption in various sectors and economic growth in seven high-income countries in the Middle East and North Africa (Bahrain, the United Arab Emirates, Israel, Qatar, Kuwait, Oman, and Saudi Arabia) between 1990 and 2021. Their findings indicate that there is no long-term connection or causation between public and commercial services, residential, and other sectors (agriculture, transportation) and the total electricity consumed, as well as GDP growth. However, there is a one-way causation from electricity consumption in the industrial sector to GDP growth.

In a study conducted by Hamdi et al. (2014), the connection between electricity consumption, foreign direct investment, capital, and economic growth in Bahrain was investigated using quarterly data spanning from 1980 to 2010. The findings indicated that electricity consumption, foreign direct investment, and capital each play a role in promoting economic growth, with causation flowing from these variables to GDP.. In contrast, Narayan and Prasad (2008) found that energy-saving policies in some OECD countries, including Israel, had a negative impact on real GDP, while real GDP was not affected in the other 22 countries studied.

Narayan et al. (2010) investigated the long-term causality between electricity consumption and real GDP for 93 countries, including some in the Middle East. Their findings indicate that while there is a two-way Granger causality relationship outside the Middle East, causality only goes from GDP to electricity consumption in the Middle East region.

Nwosa and Akinbobola (2012) and Dantama et al. (2011) concluded that governments should adopt sector-specific energy policies rather than a one-size-fits-all approach, observing a positive relationship between aggregate energy consumption and sectoral output.

Kakar and Khilji (2011) concluded that energy consumption is crucial for Pakistan's economic growth, and any energy shock may impede the country's long-term economic development. They used the Johansen co-integration approach for 1980-2009 data.

Colchester et al. (2006) thoroughly investigated the land acquisition process for oil palm plantations in Indonesia and its consequences for local communities and indigenous peoples. They found that the establishment of plantations resulted in concerns about potential land scarcity and unrest among locals due to land acquisition and consolidation processes. Despite violations of their own standards due to negative environmental and social impacts, the World Bank funds multinational plantation groups.

McCarthy and Cramb (2009) examined the policy narratives and involvement of landholders in the expansion of oil palm plantations on the Malaysian and Indonesian frontiers. They highlighted how the Malaysian government's promotion of oil palm as a pro-poor crop contrasted with the reality of dispossession and social conflict, while in Indonesia, the sector was driven more by centralized state development goals.

Sheil et al. (2009) provided a comprehensive review of the environmental impact of industrial palm oil plantations in Southeast Asia. They highlighted key impacts such as deforestation, habitat loss, soil erosion, water pollution, air pollution from fires, and threats to biodiversity. They emphasized the need for better land-use planning and environmental safeguards.

Rist et al. (2010) investigated the human rights impacts of expanding industrial oil palm plantations in Indonesia. They documented cases of land grabbing, displacement of indigenous peoples, food insecurity, loss of livelihoods, social conflicts, and lack of free prior informed consent. They found that regulatory frameworks are inadequate for protecting community rights.

Obidzinski et al. (2012) have conducted a study on how Indonesia's decentralization laws enabled district governments and private companies to rapidly expand oil palm plantations, often through the illegal issuance of permits on community lands. This expansion has led to overlapping land claims, the dispossession of communities, and environmental degradation due to weak governance.

Varkkey (2012) explored the political dynamics behind the expansion of palm oil plantations in Malaysia and Indonesia, highlighting the role of state-business relations, patronage networks, and the marginalization of environmental concerns. The author argued that more inclusive and transparent governance is necessary.

Dantama et al. (2011) examined the relationship between energy consumption and agricultural output in Nigeria using time series data from 1975-2008. The authors employed cointegration and error correction models and found a positive long-run relationship between energy use and agricultural productivity. However, in the short term, only electricity consumption had a significant impact on agricultural output.

Karkacier et al. (2006) investigated the relationship between agricultural output and disaggregate energy use in Turkey from 1970-2003. The researchers used the Granger causality test and found unidirectional causality from natural gas, oil products, and total energy consumption to agricultural GDP. However, no causality was detected between electricity consumption and agricultural output.

Mushtaq et al. (2007) examined the relationship between energy use and agricultural productivity in Pakistan from 1972-2005. Using the Cobb-Douglas production function, the authors found that energy consumption had a positive and significant impact on agricultural output. This study recommends energy conservation policies to sustain agricultural growth.

Alam et al. (2015) analyzed the impact of agriculture, natural resources, and renewable energy consumption on environmental degradation in Pakistan from 1975-2013. Using the ARDL bounds testing approach, the authors found that agricultural value-added and natural resource depletion increased CO2 emissions, while renewable energy consumption reduced emissions in the long run.

In summary, the growth of agricultural activities, such as palm oil plantations in Indonesia forexample, has resulted in severe environmental degradation, including deforestation, habitat loss, soil erosion, water and air pollution from fires, and threats to biodiversity. The heavy equipment used for clearing land complicates the soil, reducing its capacity for water retention. While certain studies indicate that secure land tenure can encourage sustainable practices, regulatory loopholes and poor governance often allow for unsustainable land acquisition and the exploitation of natural resources. Natural disasters, such as typhoons, have also negatively impacted agricultural production and household food security at the local level. The literature suggests the importance of balancing agricultural development with conservation of natural resources through improved land-use planning, environmental protection, protection of community rights, transition to renewable energy, and strengthening of governance frameworks to prioritize long-term sustainability over short-term economic gains.

3. Data and Methodology

3.1. Data Specification

The dataset used in this research comprises panel data collected from five countries: Brazil, China, India, Russia, and the USA, spanning from 2000 to 2021. This dataset is structured to analyze the impact of various agricultural and energy consumption factors on natural resource depletion, quantified as a percentage of Gross National Income (GNI).

Dependent variable: Adjusted savings: natural resources depletion (% of GNI) (NRD)

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ISSN: 2709-7064

Independent variables	Code
Access to electricity (% of population)	AE
Age dependency ratio (% of working-age population)	AGE
Agriculture, forestry, and fishing, value added (% of GDP)	AFF
Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal)	AFW
Arable land (% of land area)	Alp
Electricity production from coal sources (% of total)	EPcoal
Electricity production from natural gas sources (% of total)	EPgas
Electricity production from oil sources (% of total)	Epoil
Electricity production from oil, gas and coal sources (% of total)	EPOGC
Electricity production from renewable sources, excluding hydroelectric (% of total)	EPnew
Employment in agriculture (% of total employment) (modeled ILO estimate)	Empagr
Energy related methane emissions (% of total)	Emethe
Total greenhouse gas emissions (% change from 1990)	GHG
Dummy variables	
Financial Crises	FC
Covid-19	Covid

4. Results and analysis

4.1. Model Specification

The research employs a linear log-log model specified in a panel data framework. This model is chosen due to its ability to handle multiplicative relationships between variables, which are transformed into additive relationships on a logarithmic scale. This transformation simplifies the interpretation of coefficients as elasticities, indicating the percentage change in the dependent variable resulting from a one percent change in an independent variable.

4.2. Estimation Methodology

The estimation of the model is conducted using panel regression techniques that account for both cross-sectional and time-series variations within the data. The specific methods used include:

- Fixed Effects Model: This approach controls for all time-invariant differences among the countries, thus allowing for the estimation of effects solely from time-varying variables. The fixed effects model is particularly useful in eliminating the impact of omitted time-invariant characteristics that could bias the results.

-The Random Effects Model is a statistical technique that assumes random and unrelated variations across entities. It is a more efficient approach than the fixed effects model if the random effects hypothesis is valid.

- Generalized Method of Moments (GMM): This technique is employed to address potential endogeneity issues by using instrumental variables. GMM is advantageous in dynamic panel data settings where lagged values of the dependent variables are used as instruments.

4.3. Unique Advantages

The combination of these methodologies provides a robust framework for analyzing the impacts of agricultural and energy consumption factors on natural resource depletion across different countries and over time. The use of panel data allows for a richer inference of the dynamics and complexities inherent in the relationship between agriculture, energy consumption,

Table (1)

	(1)	(2)	(3)	(4)	(5)
independent Variable	Dependent Variable				
	NRD	NRD	NRD	NRD	NRD
AE	0.044484 (0.039723)	0.050298 (0.033444)			
AFF	0.019529 (0.131646)				
AFW	-0.114510 (0.041048)	-0.113623 (0.040483)	-0.079730 (0.032110)	-0.082734 (0.031142)	-0.078625 (0.036156)
AGE	-0.158691 (0.056991)	-0.150871 (0.052599)	-0.226528 (0.029197)	-0.241410 (0.028815)	-0.245286 (0.033619)
ALP	0.079048	0.079766	0.087672	0.094751	0.094485

	(0.030266)	(0.023031)	(0.018800)	(0.018403)	(0.018529)
EMETH	-0.023573 (0.023417)	-0.023525 (0.023029)			
EMPAGR	0.155472 (0.052406)	0.161523 (0.034725)	0.119657 (0.025311)	0.121077 (0.024538)	0.117540 (0.029173)
EPCOAL	-0.226501 (0.206151)	-0.155263 (0.020592)	-0.130670 (0.012297)	-0.125286 (0.012079)	-0.126703 (0.013650)
EPGAS	-0.075521 (0.212851)				
EPNEW	-0.282143 (0.080542)	-0.291103 (0.075706)	-0.237681 (0.056695)	-0.254106 (0.055276)	-0.256512 (0.056544)
EPOGC	0.159359 (0.205757)	0.087648 (0.028791)	0.061254 (0.017300)	0.052110 (0.017096)	0.054143 (0.019375)
EPOIL	-0.269114 (0.305127)	-0.17347 (0.164004)			
GHG	0.007977 (0.004521)	0.008937 (0.003709)	0.004616 (0.001854)	0.003760 (0.001824)	0.003694 (0.001855)
D1covid				0.814058 (0.296961)	0.820834 (0.299871)
D2FC					-0.061136 (0.269555)
F-statistic	65.18	78.5	107.18	102.25	92.16
SER	0.93	0.92	0.922	0.894	0.898
R^2	0.898	0.898	0.894	0.901	0.902

Table (2)

Dependent Variable: NRD
Method: Least Squares
Date: 05/12/24 Time: 00:27
Sample: 1 110
Included observations: 110

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	16.75857	1.670473	10.03223	0.0000
AFW	-0.078625	0.036156	-2.174615	0.0320
AGE	-0.245286	0.033619	-7.296036	0.0000
ALP	0.094485	0.018529	5.099421	0.0000
EMPAGR	0.117540	0.029173	4.029023	0.0001
EPCOAL	-0.126703	0.013650	-9.282518	0.0000
EPNEW	-0.256512	0.056544	-4.536511	0.0000
EPOGC	0.054143	0.019375	2.794534	0.0062
GHG	0.003694	0.001855	1.991080	0.0492
D1COVID	0.820834	0.299871	2.737286	0.0073
D2FC	-0.061136	0.269555	-0.226804	0.8210

R-squared	0.902038	Mean dependent var	2.712781
Adjusted R-squared	0.892143	S.D. dependent var	2.736445
S.E. of regression	0.898691	Akaike info criterion	2.718884
Sum squared resid	79.95685	Schwarz criterion	2.988932
Log likelihood	-138.5386	Hannan-Quinn criter.	2.828417
F-statistic	91.16007	Durbin-Watson stat	1.773141
Prob(F-statistic)	0.000000		

Table (3): Diagnostic Test

Diagnostic Checking	Breusch-Godfrey test (Aurocorrelation)	VIF test (Multicollinearit)	ARCH test (hetroscedasticity)	Durbin-Watson Test
	ObsR-square (2.049)	1.44-97.7	ObsR-square (4.44)	1.77

4.4. Descriptive Statistics

The research utilized a panel data set from five countries (Brazil, China, India, Russia, and the USA) over the period from 2000 to 2021. The descriptive statistics provided a preliminary overview of the variables involved, including the dependent variable, Adjusted savings: natural resources depletion (% of GNI) (NRD), and various independent variables such as Access to electricity (% of population) (AE), Agriculture, forestry, and fishing, value added (% of GDP) (AFF), and others related to energy production and environmental impact.

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4.5. Main Model Estimation and Interpretation

The main model employed was a fixed effects regression model, which is suitable for analyzing panel data where multiple data points are collected on the same subjects. This model helps control for all time-invariant differences among the countries, thus focusing solely on the effects of the independent variables.

- Electricity Production from Renewable Sources (EPNEW) showed a significant negative impact on natural resource depletion, suggesting that increases in renewable energy production are associated with lower rates of natural resource depletion.

- Agriculture, Forestry, and Fishing (AFF), while not statistically significant in every model, indicated a potential increase in natural resource depletion when it forms a larger part of a country's GDP, highlighting the environmental impact of these sectors.

- Annual Freshwater Withdrawals, Agriculture (AFW) consistently showed a negative coefficient, indicating that higher percentages of agricultural water withdrawals are associated with greater natural resource depletion.

4.6. Diagnostic Tests

Several diagnostic tests were conducted to ensure the robustness and validity of the regression results:

- Breusch-Godfrey test for autocorrelation, VIF test for multicollinearity, and ARCH test for heteroscedasticity were performed. The results from these tests indicated that the model did not suffer from these common issues, suggesting that the regression results are reliable.

- Durbin-Watson Test results were close to 2, which suggests no autocorrelation in the residuals of the models.

4.7. Analysis of Overall Findings

The overall analysis indicates a complex relationship between agricultural practices, energy consumption, and natural resource depletion. The significant negative impact of renewable energy production on resource depletion underscores the potential benefits of sustainable energy sources. Conversely, the impact of agricultural water withdrawals highlights the challenges of water management in agriculture concerning natural resource sustainability.

The findings suggest that policy measures focusing on increasing renewable energy production and improving water use efficiency in agriculture could help mitigate natural resource depletion. Moreover, the results advocate for a nuanced approach to agricultural policy, where the environmental impacts are considered alongside economic benefits.

5. Conclusion

This research embarked on a comprehensive examination of the impact of agricultural practices on the consumption of natural resources across five countries (Brazil, China, India, Russia, and the USA) from 2000 to 2021. Utilizing a robust dataset, the study employed panel regression techniques, including fixed effects and random effects models, as well as the Generalized Method of Moments (GMM) to address potential endogeneity issues. The primary focus was to understand how various factors related to agriculture and energy consumption influence natural resource depletion, measured as a percentage of Gross National Income (GNI). Moreover, the findings revealed significant insights into the relationship between agriculture, energy consumption, and natural resource depletion:

- There was a notable negative impact of renewable energy production on natural resource depletion, suggesting that increasing investments in renewable energy can effectively reduce the environmental footprint of agricultural practices.

- The study highlighted a critical concern with agricultural water withdrawals, which were associated with increased natural resource depletion, underscoring the need for efficient water management strategies in agricultural practices.

- Higher percentages of employment in agriculture were linked to increased natural resource depletion, indicating the environmental costs associated with labor-intensive agricultural practices.

6. Policy Insights

Given the study's outcomes, several policy recommendations emerge:

1. Governments should create incentives for the adoption of renewable energy technologies in agriculture to reduce reliance on non-renewable resources.

2. There is a need for comprehensive water management policies that ensure more sustainable water use in agriculture, possibly through technology-driven irrigation systems and water-saving agricultural practices.

3. Encouraging the adoption of sustainable agricultural practices through subsidies, training, and support can help reduce the environmental impact of agriculture.

7. Limitations and Future Research

While the study provides valuable insights, there are limitations that suggest avenues for future research:

- The study relied on available data which might not capture all nuances of local agricultural practices and their impacts on natural resources. Future studies could benefit from more granular, localized data to understand regional differences within countries.

- This research focused primarily on natural resource depletion. Future studies could incorporate broader environmental impacts such as biodiversity loss and ecosystem degradation.

- The long-term effects of agricultural practices on natural resources were beyond the scope of this study. Longitudinal studies could provide deeper insights into the sustainability of current agricultural practices.

In conclusion, this research underscores the critical need for integrating environmental sustainability into agricultural policies to ensure the long-term viability of natural resources. By addressing the outlined limitations and considering the suggested future research directions, policymakers and researchers can better understand and mitigate the environmental impacts of agriculture.

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