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Does green productivity promote agricultural productivity in Vietnamese market?

Journal of Agribusiness in Developing and Emerging Economies

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Received 21 October 2023
Revised 28 March 2024
Accepted 1 June 2024

Abstract

Purpose – The research aims to assess the relationship between ecological innovation, green productivity, sustainable development and agricultural productivity in Vietnam. The agricultural sector of Vietnam has been observed with new opportunities which have fostered its productivity and growth.

Design/methodology/approach – The study uses a range of methods where initially, the researcher used descriptive analysis, cointegration and unit root tests. Secondly, Quantile Autoregressive Distributed Lag (QARDL) is used to assess the short and long run effects. The QARDL methodology is employed to capture the relationship between variables. Through this approach, the researcher is able to examine the scale of the interaction between dependent and independent variables.

Findings – The unique findings drawn through statistical techniques are also a great addition to the context of literature related to Vietnam's agricultural productivity. Practical insights can also not be denied as the study provides beneficial guidelines for Vietnam's agricultural sector to refine agricultural productivity.

Research limitations/implications – Scholars are advised to use strong literary techniques to overcome these limitations and give a more thorough investigation into the same ideas. The availability and dependability of data was one of the primary challenges in carrying out this study. Vietnam has made significant advances in the collection and documentation of agricultural data, but there might still be gaps in the availability of thorough and current data on ecological innovation, green production and sustainable development.

Originality/value – Vietnam's unique socioeconomic, cultural and environmental features influence how ecological innovation, green productivity, sustainable development and agricultural production are interconnected. Consequently, consideration should be taken when applying the results to various scenarios.

Keywords Ecological innovation, Green productivity, Sustainable development, Agricultural productivity

Paper type Research paper

1. Introduction

Climate change and environmental destruction are major cause of declined agricultural productivity across the world. This indicates that in future agriculture will have to experience various challenges including high demand of food and fiber for billions of populations and high demand of feedstock for bio-energy production. Typically, there is a belief that GHG emissions are the major threat to environment which emerge from numerous anthropogenic

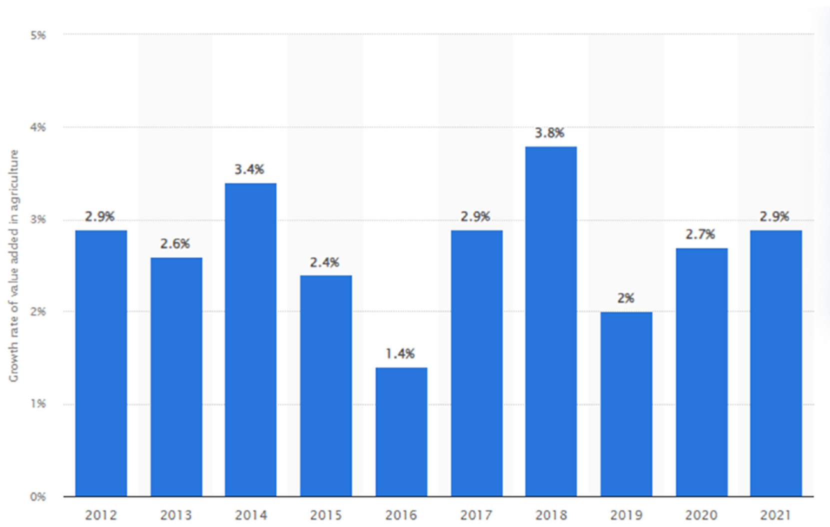
Journal of Agribusiness in Developing and Emerging Economies

2044-0839
DOI 10.1108/JADEE-10-2023-0268

activities. However, agriculture is equally responsible of high GHG emissions compared to other sectors (Singh *et al.*, 2023). Besides, excessive requirement of water for farming also pollutes nearby water bodies due to fertilizers. It is argued that agricultural water footprint is increasing exceptionally and is responsible of using 70% of existing fresh water. Future predictions also pinpoint that the huge climate change would increase the water footprint due to high irrigation demands. Therefore, there is a need of effective water resource management to ensure food security. The increasing loss of bio-diversity is also because of agriculture. The estimations indicate that agriculture will pose more threat to nature and environment due to high population (Deng *et al.*, 2022). This would exert greater pressure on economic to grow more crops. Moreover, debates related to conventional and modern agricultural practices have been polarized. Both the perspectives are considered right as traditional practices mainly focus on higher food production through modern tools, hence, centered on fulfilling food demand. Compared to traditional one, organic practices aim to produce quality food with higher benefits to environment and community. The question arises how countries can increase agricultural productivity without causing environmental harm (Wang *et al.*, 2023).

With the growing environmental concerns regarding agricultures processes and methods, sustainable transformations are stressed by agriculture and environmental experts to curb the issues arising from technology spillover and radical innovation. The current agriculture situation in most of agrarian countries, including China, Russia, Brazil and Vietnam, is alarming, which raises a call to promote green transformation and sustainable innovations in the agriculture sector (Deng *et al.*, 2022). The respective governments step up to take innovative and sustainable action while maximizing production and minimizing the environmental imprints (Harris *et al.*, 2022). Aerni (2023) also argues that in order to boost agriculture productivity, the necessity to take bold, transformative actions is accompanied by numerous challenges rooted in economic and sustainable setbacks (See Figure 1).

In recent years, Vietnam has become more active on the global agriculture stage. Vietnam's agriculture sector observed new opportunities, which accelerated its growth and productivity (Phi and Bui, 2021). According to the surveys, the Vietnam agriculture sector in



Source(s): Statista (2023)

Figure 1.
The growth rate of value added in agriculture in Vietnam (2012–2021)

2022 witnessed the highest growth reaching approximately 3.4% (Nguyen, 20023). With massive production and billion worth of export to other countries, the industry comes under serious consideration of innovation and sustainable developments, which elevate the agro-sector growth (Streimikis and Saraji, 2022). Regarding green productivity, plant-based agriculture in Vietnam is opening doors to foreign investment in the agriculture sector. The problem associated with the investment lies in the sustainability of the innovation which the external stakeholders can bring into this industry. Recently, the World Economic Forum (WEF) chose Vietnam as one of the three countries to pilot the Food Innovation Hub (LE, 2022). FIB is approached as one of the biggest initiatives in the food action alliance aiming to bring sustainable developments and innovations in the agriculture sector. Being the representative of agro-innovations on a global level, the country has responsibility to observe and tackle the growth challenges that can be a potential threat to the sustainable innovation and productivity.

The previous literature that has been developed on these issues lacks the significance of green productivity and ecological innovation in determining agricultural productivity. However, the challenges of sustainable development in agro sectors have been dealt with by numerous researchers and scholars (Karwacka *et al.*, 2020; Viana *et al.*, 2022). Numerous empirical pieces of evidence (Hoang *et al.*, 2019; Van Hong *et al.*, 2021) have been found on sustainable financing, development and innovation in the context of Vietnam's agriculture industry. The studies dealt with multiple sustainability issues which hinder the innovative chance of growth and productivity in this sector. The gap identified for this research study lies in the relationship between factors, i.e. ecological innovation, green productivity, sustainable development and the agricultural productivity of Vietnam.

As discussed, agricultural production is linked to food rationing and livelihood of families specifically in developing regions. Since, agricultural productivity extremely relies on environmental and meteorological conditions, thus, making the sector more vulnerable to environment. At present, scholars have conducted extensive research regarding climate change effect. These studies proclaim that extreme weather condition due to climate changes cause major effect on agricultural production in emerging and low-income countries (Fahad *et al.*, 2022; Su *et al.*, 2021). Literature also documents the risk of food shortage with the rise of temperature that would negatively affect the grain production dramatically (Hossain *et al.*, 2022).

In the light of above argument, green productivity, climate change and urbanization seem to be significant indicators of agricultural input which might affect agricultural output. Thus, it is worth considering whether traditional agricultural productivity deviates in the presence of these factors. The debate also raises this question whether agricultural productivity increases or decreases with the inclusion of these factors? Therefore, to answer above question, there is a need to gather evidence based on green economy theory with the realistic background of Vietnam.

2. Literature review

2.1 Theory of green economy

The concept of green economy was introduced by the United Nation Environment Program (UNEP) in 2008. This economic approach is aimed at establishing a harmonious relationship between nature and society. It recognizes the inefficiency of earlier economic models which resulted in loss of biodiversity, severe climate change and depletion of natural resources (Ivlev and Ivleva, 2018). The green economy is related with the broader concept of sustainable development. It is an umbrella term for the ecological innovation and green productivity (Tran, 2017). The primary goals of the green economy are to deal with ecological challenges, produce clean energy and to attain green productivity (Quan, 2017).

A characteristic which distinguishes the theory of green economy from previous economic models is that it regards natural capital as an economic asset. Green economy regards economy as an essential component of the ecosystem (Margulis, 2013). Furthermore, one of the significant promulgators of green economy is Karl Burkart who gave six defining principles of green economy: renewable energy resources, green infrastructure, sustainable transport, waste, water and land management (Burkart, 2012). The government of Vietnam has introduced its own model of green economy. The Prime Minister approved Vietnam's National Strategy for Green Growth with a vision to 2050. For Vietnam, the green growth economy, sustainable development and green productivity can become the opportunity to establish itself as a pioneer in the region (Tien *et al.*, 2020).

The employment of green growth economy does not only give opportunity to Vietnam to restructure its economic model but also poses various financial challenges. Besides, the awareness about green economy in Vietnam is lagging behind countries like Japan and South Korea (Liu and Feng, 2019). The degradation and exploitation of non-renewable energy resources is another challenge faced by Vietnam, because economic model of Vietnam largely relies on the depletion of natural capital. Therefore, implementing the model of green economy is an urgent need in order to attain sustainable development and green productivity in Vietnam (Zhao, 2015). The Vietnam Green Growth Strategy (VGGS) operates at three levels in relation with agricultural production: promoting green productivity through an efficient utilization of resources and technology; promoting the ecological evolution and stimulating sustainable development (Meessen *et al.*, 2015).

Vietnamese economy largely relies upon rice production. The country has introduced many agricultural reforms to increase its agricultural production. Vietnam is one of the top five global rice exporters according to the report of General Statistics Office of Vietnam for the year 2020. Unfortunately, due to increasing pollution, climate change and the recent pandemic of the COVID-19, the agricultural sector in Vietnam has been facing great challenges in meeting the expectations regarding the product quality (Kallio *et al.*, 2019). Therefore, the study of impact of ecological innovation, green productivity and sustainable development on Vietnam's agricultural production is very significant. The next section of the paper focuses on how the above-mentioned dependent variables affect the agricultural productivity which has been taken as an independent variable in this research.

2.2 The impact of ecological innovation on agricultural productivity

Ecological innovation also referred to as eco-innovation is a recent approach towards green innovation. It is aimed at creating new products and technology which lead to reduction of environmental crises and risks, like pollution and resource depletion (Castellacci and Lie, 2017). Green innovation plays essential role in agricultural reforms because it brings food security along with environmental protection (Wang *et al.*, 2022). Green innovation is also a pre-requisite of sustainable agricultural production especially in developing economies (Lian *et al.*, 2022). However, with increasing pollution of agriculture sector including soil degradation makes it difficult to protect environment and have safe agricultural practices (Jhariya *et al.*, 2021). Thus, green innovation in this situation is a miracle for countries to gain sustainability in agricultural production. Integrating environmental innovativeness into agricultural sector means creating competitive economy. Sun (2022) stated that the fundamental codification divides eco-innovation in to three groups which includes low-emissions ecological technologies, environmental efficiency and system innovations. However, the common goal is to suppress the negative impact on environment. In terms of category, the attributes are quite different. Thus, in general, it can be assumed that green innovation comprises of all these activities which are aimed to promote healthy relationship between organization and environment and also benefit economy and society. To enable economic and scientific capabilities at supply side of green innovation, it is imperative to identify amplified steps in agricultural production as they rely on advanced R & D. Market when find appropriate incentives, the demand for green innovation will be created automatically. On the basis of assumption of "market left to itself will show certain unreliability", one can also make assumption that individuals might not show interest to make investment in research (Peng, 2023). This signifies the importance of public investment in agricultural projects. By reviewing literature, we can also establish an argument that in recent years the effect of macro-economic environment of agriculture grew significantly. As per studies, a significant increase of external effect and public goods issues can be seen which is due to agricultural practices (Chen *et al.*, 2022). Thus, eco-innovation demand in particular sector has been increasing day by day. With the implementation of eco-innovation, external effects would turn in to social, economic and environmental benefits. Therefore, bringing technological advancement in agricultural production will increase the productivity growth which would further bring improvement in economic situation. However, due to changes in price relations, the positive effect would disappear quickly (Sun, 2022).

As discussed, ecological innovation in agriculture is regarded as a factor of competitiveness (Graczyk *et al.*, 2018). The second paradigm of The Vietnam Green Growth Strategy (VGGS) as mentioned earlier deals with promoting ecological innovation in the field of agriculture (Meessen *et al.*, 2015). The implementation of green economy model in the field of agriculture is a great opportunity for Vietnam to achieve food security for the whole world in the future (Pham Huy Thong and Trung, 2016). Bringing an ecological innovation can boost the agricultural production and help in eradication of hunger and poverty from the world. Vietnam has faced the drastic consequences of climate change in the field of agriculture. The green economy model can mitigate the impact of climate change and help in bringing an ecological innovation in agriculture (Tien *et al.*, 2020).

Since 2000, Vietnam has seen a shift in economic growth which has been averaging 6.3% a year, largely influenced by reallocation of labor away from agriculture towards industrial sectors (Zhou *et al.*, 2022). This shift from the agriculture towards industry has reduced the economic burden on the agricultural sector (Nong *et al.*, 2020). The country has seen tremendous economic growth in the agricultural sector in the past few decades. However, this economic growth in agriculture has caused an economic cost, being the second-largest source of greenhouse gas emission after energy sector (Tran *et al.*, 2018). That is why over the past few years, VGGS has brought about many innovations in the agricultural sector in Vietnam. On June 10, 2013, the Prime Minister issued Decision No. 899/QD-TTg in order to approve the scheme on restructuring the agriculture sector in the wake of ecological innovation. This ecological innovation is aimed at restructuring production to enhance competitiveness in agriculture in order to achieve sustainability (Thang *et al.*, 2017). The country has been focusing on strengthening natural resource management and decreasing greenhouse gas emissions in order to popularize organic farming in the country (Gray and Jones, 2022). The nanotechnology in the fertilizers is another eco-friendly move of Vietnam. It has become a driving force to boost the agricultural production (Minh *et al.*, 2018).

Climate-smart agriculture has been introduced to ensure green growth and ecological innovation in agricultural sector. According to the Food and Agriculture Organization of the United Nations (FAO), smart agriculture is a way to achieve priorities in agricultural development both in the short and long term along with other development priorities (Lipper *et al.*, 2014). This ecological innovation has increased the productivity as well as improved the resilience to climate change. It has also reduced greenhouse gas emissions from agricultural fields in Vietnam (Tran *et al.*, 2020). The goal of smart agriculture is not only to ensure food security and agricultural production but also to improve the quality of life and ensuring the food safety. Thus, eco-innovation can boost agricultural production in Vietnam (Que, 1998).

2.3 The impact of green productivity on agricultural productivity

Green productivity (GP) is a strategy to enhance productivity and environmental performance in order to ensure overall socio-economic development (Li and Lin, 2017). Green growth policies may constraint agricultural output, minimize food security at global level and necessitates adjustments in the usage of human, natural and financial resources in short run. However, in long run, green productivity particularly in agricultural sector is mutually supportive in all sustainability areas. The compatibility of green productivity with agriculture can be seen in various economic, societal and environmental factors including employment ratio, farm income growth, biodiversity, poverty reduction, natural resource usage, food security, etc. Besides, contributing to environment can be an effective source of environmental good/services such as organic products, resource conservation, renewable energy, sustainable tourism, etc. (Peng, 2023). These agriculture-based goods/services further lead to green job and farm incomes. In addition to this, agricultural bio-diversity enables considerable options in preserving genetic resources that are crucial for new varieties of crops and animal breeds (Liu and Feng, 2019). Environmental tourism in rural areas is also considered a profitable emerging sector. Meanwhile, biomass energy production also increases farm income and revive rural communities. It is also argued that agricultural sector's long-term performance is inseparably associated with effective natural resource management. Literature also claims that when there is a less pressure from green growth on limited environmental resources, environmental risks and expenses also reduces. It has also been claimed by scholars that environmental measures reduce poverty in rural areas by providing essential services including water and food supply (Singh *et al.*, 2023).

The VGGS model in Vietnam focuses on the employment of green productivity in the agricultural sector. In the wake of this model, the Vietnamese Government has been focusing on implementing the use of renewable energy resources in the agricultural sector. Investment in green agriculture has improved agricultural productivity and reduced the amount of land used for agriculture and livestock by 6%. It will improve the quality of land up to 25% by 2050 (Tien *et al.*, 2020). Vietnam is one of the top five rice producers and thus contributes a great deal towards methane emission. The Mekong Delta produces 55% of Vietnamese rice and thus is a large contributor of the country's anthropogenic methane (CH_4) emissions (Tariq *et al.*, 2017). However, the recent VGGS model has introduced reforms to reduce carbon emission into the environment. Alternate Wetting and Drying (AWD) strategy was introduced to lower the carbon emission but it instead increased the quantity of Nitrous Oxide in the atmosphere. Therefore, a simplified form of AWD called Multiple Drainage (MD) was introduced as a stepping stone towards green productivity (Minamikawa *et al.*, 2021). Rice production contributes 3% to Vietnam's GDP but is responsible for up to 15% of the country's total greenhouse gas (GHG) and carbon emissions (Dam *et al.*, 2019). This move towards green productivity cannot only boost the agricultural productivity but also establish Vietnam as a pioneer in the production of low-carbon rice (Shrivastava *et al.*, 2022). The low-carbon rice production can reduce GHG emissions in Vietnam by 50–60% (Demont and Rutsaert, 2017).

Furthermore, the green productivity models in the rural areas of Vietnam have met the increasing demands for public health as well. The agriculture sector of Vietnam has ensured the food security in the post COVID-19 era. This makes Vietnam one of the top food exporters of the world in the post-pandemic era. The country is now one of the world's leading agricultural exporters, with over 48 billion USD in export revenue in agro-forestry-fishery departments ("Green production - direction for sustainable rural development", 2023).

2.4 The impact of sustainable development on agricultural productivity

Literature extensively explored the impact of air pollution in various areas ranging from human health to vegetation. For example, study of Lu (2020) proclaimed that air pollution covers various problems that are associated with economic, environmental, social and psychological issues. Scholars identified that negative consequences of air pollution as it heavily damages agricultural sector. Similarly, scholars also warned that the risks associated with agricultural sector stressed by environmental pollution and climate change (Wang *et al.*, 2023). Similarly, literature stressed that due to high temperature water resources are affected which are viewed as a most important input of agriculture sector, thus, cause damage to wheat production. Also, grain production also gets affected by climate change (Zhou *et al.*, 2022). The study conducted in East and South African economies highlighted that due to adverse climatic condition, share of agricultural sector is in declining phase. Moreover, sufficient literature also exerts that due to extreme weather condition not only small holders are affected but food insecurity also occurs (Campi, 2018). The Vietnam Sustainable Agriculture Transformation Project (VnSAT) was implemented in order to achieve sustainability goals in agricultural sector. The project has so far benefited over 16 million households ("Green production – direction for sustainable rural development," 2023). Sustainable development is based on the concept of green economy. The government of Vietnam issued Decision No. 432/QD-TTg dated 12/4/2012 on approving the Sustainable Development Strategy for Vietnam in the period of 2011–2020 (Zhao, 2015). Sustainable development in agriculture refers to a type of progress in agriculture productivity which does not harm the natural environment in any way. It maintains the balance among economic growth, social justice and protection of the environment (Pham *et al.*, 2023).

This focus on agricultural sustainability has given Vietnam as opportunity to reduce natural resource depletion and less use of non-renewable energy resources (Gray and Jones, 2022). The conventional farming practices put the natural resources at risk which makes sustainable development a critical need of the hour (Fisher, 2019). Agriculture is one of the prime exploiters of the natural resources and is linked to carbon emission (Raihan and Tuspekova, 2022). Global climate change is a burning issue due to increasing quantity of GHGs and carbon in the atmosphere (Adebayo, 2020). In future, this increasing carbon emission will cause drastic ramifications for the whole world (Isfat and Raihan, 2022). Therefore, to reduce the emission of GHGs and carbon is a global concern in order to attain sustainability in agriculture (Rahman *et al.*, 2022). Such problems are more prevalent in countries like Vietnam where economic growth, agricultural productivity and sustainable development possess simultaneous importance (Adebayo, 2020). Vietnam is one of the largest consumers of chemical based fertilizers and it is also among the top five countries most affected by the climate change (Trinh, 2018). This increasing vulnerability to climate change and great amount of carbon emission are two driving forces behind Vietnam's focus on the sustainability in agriculture through green economy (Raihan, 2023). The country has been focusing on strengthening the agricultural sector by restructuring it and by promoting organic farming (Nong *et al.*, 2020).

In order to achieve more sustainability in agricultural sector, Vietnam needs to promote favorable conditions for the farmer to gain the resources of agriculture without harming the natural environment. Bottlenecks should be removed and more focus should be on large farming areas. Planning of infrastructure investment will also boost the agricultural productivity (Duong, 2020). Thus, the green economy has brought sustainability in the agricultural sector of Vietnam. This sustainable agricultural production has highlighting the need for educating the masses about knowledge, skills and technology to manage the agricultural productivity (Morton, 2020). Vietnam has made significant investment in implementing the sustainability model in the agricultural sector all over the country. Red River Delta now has bigger opportunities to move towards sustainability (Raihan, 2023). The adoption of sustainable development strategy has not only ensured the increased crop production in the country but it has also proved fruitful in preserving the natural resources (Dung *et al.*, 2018).

3. Methodology

3.1 Data and variables construction

In the present study, empirical information has been obtained from Vietnam's data from 2000 to 2021 to evaluate the impact of ecological innovation, green productivity and sustainable development on agricultural productivity. For this purpose, the variables of interest are shown in Table 1, along with the description, measurement and data sources.

For the calculation of green productivity, the Data Envelopment Analysis (DEA) is utilized. The DEA involves considering various inputs such as labor, capital, energy, water and non-energy sources. Similarly, output measures utilized include economic output, carbon dioxide emissions, solid waste and waste gases. The input and output measures are selected in line with prior studies where the DEA approach has been utilized to measure productivity (Zhang *et al.*, 2023). In addition, the data were transformed into quarterly data following the method used by Zhang *et al.* (2023).

3.2 Econometric method

The present study relies on econometric methods to provide reliable results. The study uses a range of methods where initially, the researcher used descriptive analysis, cointegration and unit root tests. Secondly, Quantile Autoregressive Distributed Lag (QARDL) is used to assess the short and long run effects. The QARDL methodology is employed to capture the relationship between variables. Through this approach, the researcher is able to examine the scale of the interaction between dependent and independent variables. It offers several advantages over traditional regression methods. Firstly, it provides insights into the association between variables at different quantiles, and therefore, it allows the evaluation of location-specific asymmetries within the conditional distribution in both the long run and the short run. Secondly, it captures non-linear association dynamics, as demonstrated by Godil *et al.* (2021). Moreover, this methodology adjusts cointegration parameters based on quantile innovations. In addition, the study applied tests to analyze autocorrelation and heteroskedasticity.

The following model specification is depicted using a basic ARDL approach:

$$AP_t = \alpha + \sum_i^p \beta_1 AP_{t-i} + \sum_i^{q1} \beta_1 EI_{t-i} + \sum_i^{q2} \beta_2 GP_{t-i} + \sum_i^{q3} \beta_3 SD_{t-i} + \sum_i^{q4} \beta_4 URB_{t-i} + \varepsilon_t$$

Table 1. Description and source of variables under study

Variable	Abbreviation	Measurement	Type	Source
Ecological Innovation	EI	Share of patents on environmental technologies in total patents (%)	Explanatory	OECD
Green productivity	GP	Inputs, desired outputs, and non-desired outputs	Explanatory	Calculated through DEA analysis
Sustainable Development	SD	Output value added to GDP	Explanatory	WDI
Agricultural productivity	AP	Agriculture, forestry, and fishing, value added (% of GDP)	Explained	WDI
Urbanization	URB	Share of urban residents in the total population of Vietnam (%)	Control	WDI

Note(s): OECD = Organization for Economic Cooperation and Development, WDI= World Development Indicators
Source(s): Authors' own creation

where the error term is demonstrated by ε_t, and the lag orders are depicted by p, q_1, q_2, q_3 and q_4 according to the Schwartz criterion. The second equation is shown below, demonstrating the quantile version:

$$QAP_t = \alpha(\tau) + \sum_i^{p}\beta_1(\tau)AP_{t-i} + \sum_i^{q1}\beta_1(\tau)EI_{t-i} + \sum_i^{q2}\beta_2(\tau)GP_{t-i} + \sum_i^{q3}\beta_3(\tau)SD_{t-i} + \sum_i^{q4}\beta_4(\tau)URB_{t-i} + \varepsilon_t(\tau)$$

where 0 < τ 1 demonstrates the quantile. Additionally, Equation 3 below is extended from the above equation by taking into consideration the likelihood of serial correlation:

$$QAP_t = \alpha(\tau) + pAP_{t-i} + \varphi_2 EI_{t-i} + \varphi_2 GP_{t-i} + \varphi_3 SD_{t-i} + \varphi_4 URB_{t-i} + \sum_i^{p}\beta_1(\tau)\Delta AP_{t-i} + \sum_i^{q1}\beta_1(\tau)\Delta EI_{t-i} + \sum_i^{q2}\beta_2(\tau)\Delta GP_{t-i} + \sum_i^{q3}\beta_3(\tau)\Delta SD_{t-i} + \sum_i^{q4}\beta_4(\tau)\Delta URB_{t-i} + \varepsilon_t(\tau)$$

Lastly, as per Cho *et al.* (2015), Equation 4 below is developed as per the error correction format:

$$Q\Delta AP_t = \alpha(\tau) + p(\tau)AP_{t-i} - \varphi_1(\tau)EI_{t-i} - \varphi_2(\tau)GP_{t-i} - \varphi_3(\tau)SD_{t-i} - \varphi_4(\tau)URB_{t-i} + \sum_i^{p}\beta_1(\tau)\Delta AP_{t-i} + \sum_i^{q1}\beta_1(\tau)\Delta EI_{t-i} + \sum_i^{q2}\beta_2(\tau)\Delta GP_{t-i} + \sum_i^{q3}\beta_3(\tau)\Delta SD_{t-i} + \sum_i^{q4}\beta_4(\tau)\Delta URB_{t-i} + \varepsilon_t(\tau)$$

For estimating the impact of past and lagged values of AP on the current values of AP in the short run, the coefficient $\sum_{i=1}^{p-1}\beta_1$ is utilized. Correspondingly, for other variables such as EI, GP, SD and URB, a similar method is utilized. Conversely, the long-term estimates of QARDL are presented as follows:

$$\beta_{AP*} = -\frac{\beta_{AP}}{p}, \beta_{EI*} = -\frac{\beta_{EI}}{p}, \beta_{GP*} = -\frac{\beta_{GP}}{p}, \beta_{SD*} = -\frac{\beta_{SD}}{p}, \beta_{URB*} = -\frac{\beta_{URB}}{p}$$

4. Results

4.1 Descriptive summary

Table 2 shows the descriptive characteristics of the data. This test has been performed to check outliers, data normality, missing values, etc. The last row of Table 2 shows that the number of observations is 22, which depicts that against each variable, the number of observations is 22, which declares that there are no missing values in the data. Another important reason for undertaking descriptive characteristics of the respondents is that the data sheets finalized for analysis can be rectified if issues of missing values or outliers exist in the data to enhance results accuracy.

The threshold range of skewness falls between −1 and +1, which is also confirmed by Table 2 because the resultant values of skewness concerning AP, EI, GP, SD, and URB are within the defined threshold limit. So, the normality of the data has been confirmed. The mean, minimum, maximum, and standard deviation values have also been presented in Table 2. The mean values for AP, EI, GP, SD, and URB are 17.26, 11.32, 4.38, 5.19, and 30.9, respectively.

	AP	EI	GP	SD	URB
Mean	17.26719	11.32182	4.385455	5.192751	30.92836
Median	16.22933	12.07500	4.525000	5.447335	30.74850
Maximum	24.53458	24.20000	6.190000	6.472491	38.05200
Minimum	11.78453	0.000000	0.000000	1.699390	24.37400
Std. Dev.	4.047853	7.203920	1.229869	1.282629	4.250332
Skewness	0.305754	−0.115556	−1.967573	−1.590507	0.097585
Kurtosis	1.779196	2.059253	2.572928	2.055256	1.790956
Sum	379.8782	249.0800	96.48000	114.2405	680.4240
Sum Sq. Dev.	344.0873	1089.826	31.76415	34.54788	379.3718
Observations	22	22	22	22	22

Source(s): Authors' own creation

Table 2.
Descriptive of studied variables

4.2 Johansson's cointegration test

The Johansen test is undertaken to assess the co-integrating associations among different non-stationary time series data (Hussein and Ali, 2022). As compared to the Engle-Granger test, the Johansen test enables more than one co-integrating association.

Table 3 shows the trace statistics resulting from the Cointegration test at four levels. The critical values, Eigenvalue, and probability values can also be attained from this test. Results, therefore, show that cointegration specifications existed between the variables having *p*-values such as 0.00, 0.00, 0.02 and 0.16, respectively, for at most 1, 2, 3 and 4 correspondingly.

4.3 Unit root test

A unit root test is applied to assess whether a given time series is observed to be consistent with a process of a unit root (Pesaran, 2007). So, in the present research, the stationarity of variables has been assessed by the researcher by adopting different methods, as depicted in Table 4. The researcher applied four methods to assess the level of integration. It was assumed by the null hypothesis that the data is non-stationary and entailed unit roots. Results attained from the group unit root exhibits the assessment of stationarity at the first level and first difference, as shown in Table 4. At this level, it was observed that the unit root test against LLC Levin, Lin and Chu was significant, whereas the other methods showed an insignificant result. It means that at the level, there was a non-existence of stationarity in variables, whereas at first different, there was an existence of stationarity observed among variables, as shown in Table 4. The resultant values of LLC against at-level statistics and probability are −1.4 and 0.07, respectively. For the first difference, the resultant values of LLC are −2.6 and 0.00, respectively.

Hypothesized No. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
None *	0.940073	125.6873	76.97277	0.0000
At most 1 *	0.705839	69.39468	54.07904	0.0012
At most 2 *	0.670449	44.92209	35.19275	0.0033
At most 3 *	0.558241	22.72161	20.26184	0.0225
At most 4	0.273189	6.381786	9.164546	0.1632

Note(s): Trace test indicates 4 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the null hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis *p*-values
Source(s): Authors' own creation

Table 3.
Cointegration test

4.4 Quantile regression (long-run estimates)

Quantile regression was performed for long-run estimates to assess the relationship among variables (Koenker and Hallock, 2001). The key benefit of quantile regression lies in the fact that it enables understanding the association among variables outside the mean of data. Thus, it is beneficial and feasible to understand outcomes that are distributed non-normally and have non-linear associations with the predictor variables. It is usually employed when linear regression fails to satisfy its assumptions. Table 5 contains the results of quantile regression.

The model was run at different quantile estimates, with 0.2 tau providing most significant effects. Table 5 indicates that there was a significant impact of ecological innovation, green productivity, sustainable development and urbanization on agricultural productivity. A unitary increase (1%) in ecological innovation would have contributed to increase of 0.05 units (5%) agricultural productivity ($p < 0.05$). Moreover, it was found that green productivity had significant and positive influence on AP as well with a unitary increase in GP contributing 1.65 units increase in AP, however the lagged value of the factor was used in the model. Furthermore, URB and SD showed significant but negative effects, indicating increase in sustainable development and urbanization would lead to decreased AP levels within the context of Vietnam. Figure 2 also shows that for each factor the highest value of the quantile estimates was at 0.2 which has been followed in the model.

Table 6 shows the short-run estimates under quantile regression declared that the variables EI, GP, SD and URB and it can be seen that all factors have a significant effect on AP in the short run as well, with only SD having a negative but significant effect.

Method	Statistic at level	Statistic first difference	Prob.** at level	Prob.** first difference
Levin, Lin & Chu t*	−1.45694	−2.63578	0.0726*	0.0042***
Im, Pesaran and Shin W-stat	−0.40772	−5.63341	0.3417	0.0000***
ADF – Fisher Chi-square	15.2790	48.8956	0.1222	0.0000***
PP – Fisher Chi-square	11.4815	56.5225	0.3213	0.0000***

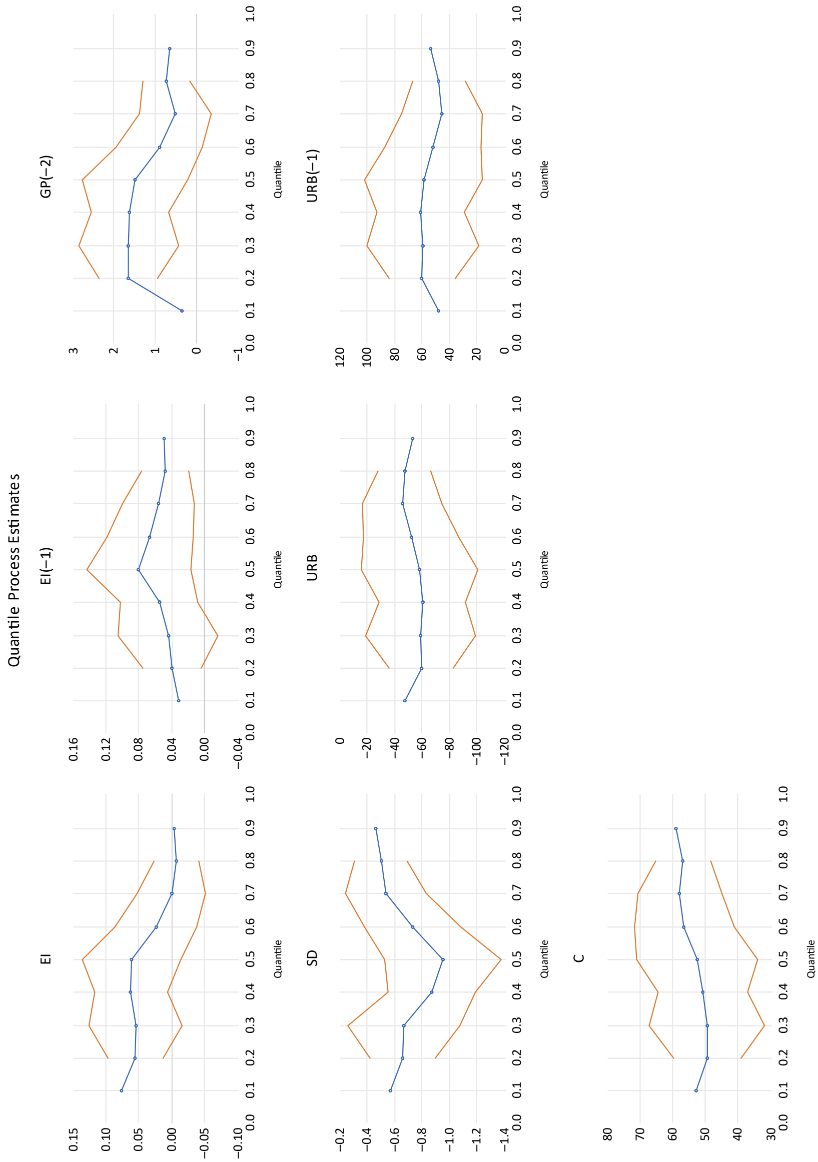
Source(s): Authors' own creation

Table 4. Results of unit-root test

Variable	Coefficient	SE	*t*-value	*p*-value
EI	0.055349	0.021267	2.602530	0.0219
EI(-1)	0.039310	0.018011	2.182589	0.0480
GP(-2)	1.654532	0.360848	4.585127	0.0005
SD	−0.660392	0.120883	−5.463075	0.0001
URB	−59.65183	12.04290	−4.953279	0.0003
URB(-1)	59.67361	12.17418	4.901653	0.0003
C	49.24693	5.271892	9.341415	0.0000
Pseudo *R*-squared	0.861359	Mean dependent var		16.60513
Adjusted *R*-squared	0.797371	S.D. dependent var		3.604229
S.E. of regression	0.804833	Objective		2.372635
Quantile dependent var.	12.65540	Restr. objective		17.11355
Sparsity	1.089820	Quasi-LR statistic		169.0751
Prob(Quasi-LR stat)	0.000000			

Source(s): Authors' own creation

Table 5. Quantile regression results



Source(s): Authors' own creation

Figure 2.
Quantile process estimates

4.5 Autocorrelation test

Autocorrelation assesses the association between the current value of a variable and its previous values. +1 indicates a positive, whereas −1 declares a negative correlation. Table 7 shows that auto-correlation does not exist in the data because the probability values are greater than the threshold limits.

4.6 Heteroscedasticity test

Table 8 shows insignificant results that the *p*-values are greater than 0.05. There is no heteroscedasticity in the data, and error terms show homoscedasticity.

5. Discussion

The findings of the current research showed that ecological innovation and sustainable development had a significant impact on agricultural productivity. The results of the study

Variable	Coefficient	Std. Error	*t*-statistic	Prob
AP(-1)	0.088498	0.090044	0.982841	0.3514
EI	0.110944	0.014654	7.570881	0.0000
D(EI(-1))	0.122415	0.008993	13.61161	0.0000
GP	0.767235	0.148762	5.157467	0.0006
D(GP(-1))	−0.520652	0.282054	−1.845929	0.0980
SD	−0.624322	0.086016	−7.258188	0.0000
D(SD(-1))	−0.407826	0.122808	−3.320858	0.0089
URB	1.119638	0.164235	6.817273	0.0001
D(URB(-1))	−136.1958	10.64358	−12.79606	0.0000
ECM(-1)	−0.106755	0.102406	−1.042471	0.3244
C	66.04720	4.919743	13.42493	0.0000
Pseudo *R*-squared	0.885483	Mean dependent var		16.60513
Adjusted *R*-squared	0.758242	S.D. dependent var		3.604229
S.E. of regression	1.393913	Objective		1.959792
Quantile dependent var.	12.65540	Restr. objective		17.11355
Sparsity	0.629884	Quasi-LR statistic		300.7253
Prob(Quasi-LR stat)	0.000000			

Source(s): Authors' own creation

Table 6. Quantile Regression (Short Run estimates)

Autocorrelation	Partial correlation		AC	PAC	Q-Stat	Prob*
. |. |	. |. |	1	0.006	0.006	0.0009	0.976
. *|. |	. *|. |	2	−0.167	−0.167	0.7109	0.701
. |. |	. |. |	3	−0.048	−0.047	0.7721	0.856
. *|. |	.**|. |	4	−0.197	−0.232	1.8766	0.758
. |. |	. |. |	5	−0.014	−0.035	1.8824	0.865
***|. |	****|. |	6	−0.409	−0.536	7.2765	0.296
. |. |	. |. |	7	0.037	−0.032	7.3242	0.396
. |**. |	. |. |	8	0.293	−0.004	10.524	0.230
. |. |	. |. |	9	0.071	0.021	10.726	0.295
. |. |	. *|. |	10	0.035	−0.168	10.781	0.375
. |. |	. |. |	11	−0.064	−0.057	10.979	0.445
. |. |	. *|. |	12	0.016	−0.197	10.992	0.530

Source(s): Authors' own creation

Table 7. Autocorrelation results

Autocorrelation	Partial correlation		AC	PAC	Q-Stat	Prob*
. *|. |	. *|. |	1	−0.137	−0.137	0.4517	0.502
. |*. |	. |*. |	2	0.148	0.131	1.0057	0.605
. *|. |	. *|. |	3	−0.135	−0.103	1.4944	0.684
. *|. |	. *|. |	4	−0.126	−0.180	1.9435	0.746
. *|. |	. *|. |	5	−0.118	−0.131	2.3622	0.797
. |*. |	. |*. |	6	0.150	0.160	3.0893	0.798
. *|. |	. *|. |	7	−0.143	−0.122	3.7941	0.803
. |. |	. *|. |	8	−0.022	−0.172	3.8113	0.874
. *|. |	. *|. |	9	−0.110	−0.111	4.2974	0.891
. *|. |	. *|. |	10	−0.139	−0.152	5.1487	0.881
. |. |	. |. |	11	0.017	−0.042	5.1634	0.923
. |. |	. *|. |	12	0.003	−0.092	5.1637	0.952

Source(s): Authors' own creation

Table 8.
Heteroscedasticity results

indicate that the adoption of ecological innovations has positively impacted agricultural productivity in Vietnam. These advances could involve agroforestry systems, precision agriculture, organic farming methods, sustainable land management approaches and effective irrigation methods. These findings are supported by Khanh Chi (2022) which exclaimed that green innovation is crucial to the agricultural transformation that secures food supplies and protects the natural world. It is also necessary for the modernization and long-term growth of agricultural productivity in developing nations. However, the growth of an ecological environment and agriculture is challenged by rising agricultural pollutants, such as soil deterioration and global warming. Ecological innovation could therefore lead to a revolution in the advancement of sustainability in agricultural production. Graczyk *et al.* (2018) also claimed that contrary to innovations that enhance the use of natural assets, the employment of ecological innovation in agriculture enables the maintenance of an economic expansion track consistent with the model of sustainable development. These advancements make it possible to reduce the consumption of resources and avoid the alleged trap of zero growth. The theoretical framework of industrial agriculture can be combined with a common, traditional strategy for innovation provided in mainstream economics to create the most widely accepted concept of ecological innovations. The necessity of implementing ecological innovation is made harder by factors such as the expanding global population, rising food consumption and efforts to reduce harmful environmental impacts (Reardon *et al.*, 2019).

Ecological innovation and green productivity exist within the broader context of sustainable development. According to the study's findings, sustainable development and agricultural productivity in Vietnam are positively correlated. Vietnam may make tremendous progress towards establishing sustainable agriculture practices by implementing ecological technologies and encouraging green productivity. These methods can improve rural livelihoods, decrease poverty and raise food security in addition to increasing productivity. Guerrero Lara *et al.* (2019) stated that the sustainable agricultural model assumes that social, ecological and financial difficulties may be addressed provided with the inclusion of local assets and farming circumstances as innovative ecological variables. Greening regulations can also encourage the creation of more sustainable farming practices and systems, which can have a good effect on innovation. Organic farming constitutes one of the key organizational structures of sustainable agriculture that is especially conducive to the growth of ecological innovation (Dudek and Wrzaszcz, 2020). The depletion of non-renewable resources, soil erosion, the detrimental impacts of agricultural pesticides on the well-being of humans and the environment and lower food quality are only a few of the issues that agriculture has been connected to. As a result, interest in sustainable agriculture and the growth of sustainable development in the industry is growing (Laurett *et al.*, 2021). A severe ecological crisis is being caused by the expansion of traditional agricultural production methods, forcing researchers and academics to face previously unheard-of difficulties like the requirement to assess the effectiveness of rural agricultural systems in the context of sustainability.

5.1 Conclusion

In recent years, Vietnam has become more active on the global agriculture stage. The research aimed to examine the direct impact of innovative and sustainable factors on the overall growth and productivity of Vietnam's agriculture industry. The empirical information was obtained from Vietnam's data from 2000 to 2021 to evaluate the impact of ecological innovation, green productivity and sustainable development on agricultural productivity. The present study relied on econometric methods to provide reliable results. The study used a different method, including the Quantile Autoregressive Distributed Lag (QARDL) dynamic ordinary least squares method (DOLS) and the fully modified least squares method (FMOLS). According to the findings, the variables EI (−1) and SD significantly affect AP under long-run estimations of quantile auto-regression. The effects of EI, GP, SD and URB on short-run quantile regression estimates of AP are insignificant.

By examining the drivers behind green innovation, this study adds to the growing body of knowledge in the field of green agricultural production. Through investments in agricultural policies and infrastructure that boost the availability of resources and productivity, this method enables the incorporation of qualitative changes, the external implications of eco-innovation and their development process. Contrary to innovations that enhance the use of natural assets, the implementation of eco-innovation in agriculture enables the maintenance of an economic growth path consistent with the model of sustainability. The research findings can serve as a roadmap for the creation of policies and projects that assist the adoption of environmentally friendly practices and innovations in agricultural systems.

The first initiative that should be taken to improve policy implication is to overrule policies that help economies to keep hold of farmers in a hostile environment. Countries should reform agricultural policies in order to protect environment, untangle complexities in innovation. There is also a need of stronger agricultural system with major collaboration. In this collaboration all actors should start working together to create network and develop innovative products that sectors require. Meanwhile, effective governance also helps in developing clear and sound strategic objectives and mechanisms for agricultural productivity. Agricultural policies should also be promoted the integrated framework of farming and livestock sector where recycled manure and crop residue are preferred. This way chemical fertilizer inputs can be reduced and green agricultural productivity can be improved. At individual level, farmers should upgrade their resource allocation process to enhance efficiency of farming inputs. They should also magnify moderate-scale farming to increase green agricultural productivity with the help of regional agricultural science and technology resources. Besides, improving communication among regions also helps in promoting the leading role of advanced agricultural technology. This way not only green agricultural growth rate would improve. Lastly, government should also fortify environmental restoration of coal areas by evaluating the carrying capacity of agricultural natural resources.

This study's contribution to eco-friendly literature has also significant theoretical implications. Considering the relationship between ecological innovation, green productivity, sustainable development and agricultural productivity can help integrate information from many fields. It necessitates a multifaceted strategy that integrates ideas from sustainable development, finance, agriculture and ecological science. The association between innovations and economic growth might be demonstrated through theoretical considerations. The association between ecological innovation, green productivity, sustainable development and agricultural production can be studied using these findings, which can result in methodological advancements. Additionally, the research can enhance contextual understanding in the area of sustainability and agricultural productivity, enhance the incorporation of knowledge, encourage methodological innovations and extend theoretical frameworks. The study can help provide a more comprehensive knowledge of the context surrounding the unique opportunities and difficulties associated with ecological innovation, green productivity, sustainable development and agricultural production in Vietnam. Researchers can discover nation-specific elements, such as organizational structures, cultural practices, and policy settings that impact the linkages between these ideas by looking at the Vietnamese context. This can improve the findings' applicability and generalizability and add to the larger theoretical discussion regarding sustainable development and agricultural production. The results of this study can be used to design proactive sustainable performance approaches in response to environmental regulations and laws. Nevertheless, ecological advancements are the most crucial elements to consider when formulating a strategy for green innovation policy.

5.2 Limitations and recommendations

There are several theoretical and methodological limitations present in the study. The first limitation was the open access and availability of data, while Vietnam has made significant advances in the collection and documentation of agricultural data, but some factors are not readily available which limited the choice of agricultural indicators for the study. The present study is only focused on Vietnam, however a focus on other countries with a dependence on agriculture may further our understanding of linkage between agriculture and economic prosperity of countries. Consequently, consideration should be taken when applying the results to various scenarios. The study relied on the usage of QARDL model for estimation, while usage of other methods in the future may indicate the intricate relationships within the factors. Moreover, assessment of key moderating factors like population and agricultural employment may also allow a more investigation in the future.

Comparative research between Vietnam and other nations or areas can promote cross-national learning and assist in identifying the best methods for integrating ecological innovation, green productivity, sustainable development and agricultural productivity. The data collection attempts, accuracy of data, and data accessibility should be improved on eco-innovation, green productivity, sustainable development and agricultural productivity in Vietnam. This could involve investing in data facilities encouraging data exchange and transparency and standardizing metrics and measurement procedures. For ecological sustainability, new farming methods and techniques should be used. Researchers can better comprehend the relationship between ecological innovation, green productivity, sustainable development and agricultural productivity in Vietnam by taking these future recommendations into consideration. This information can help with the development of policies based on solid evidence and the promotion of sustainable agriculture practices that increase output while protecting the environment and enhancing the well-being of rural people. Agriculture producers might be able to increase output while better protecting the surroundings by using innovation. This encourages sustainability over an extended period of time and reduces production's adverse environmental impacts such as waste and contaminants. Methods for growing food sustainably take climate change adaptation and greenhouse gas emission reduction into consideration. This study can help in making good agricultural policy that will focus on steps to increase the industry's long-term sustainability and production, such as spending on facilities, labor and market access for farmers. For ecological innovation to be implemented successfully, multiple stakeholders, such as farmers, local communities, policymakers, researchers and NGOs, must be involved.

References

Adebayo, T.S. (2020), "Revisiting the EKC hypothesis in an emerging market: an application of ARDL-based bounds and wavelet coherence approaches", *SN Applied Sciences*, Vol. 2 No. 12, 1945, doi: 10.1007/s42452-020-03705-y.

Aerni, P. (2023), "COP-27: a great opportunity to address the double crisis of food security and climate change–and for the EU to re-align its farm to fork strategy", *Frontiers in Environmental Economics*, Vol. 1, 1082869, doi: 10.3389/frevc.2022.1082869.

Burkart, K. (2012), "How do you define the 'green' economy?", available at: http://www.mnn.com/green-tech/research-innovations/blogs/how-do-you-define-the-green-economy

Campi, A. (2018), "Mongolia and the dilemmas of deepening eurasian continentalism", *Mongolian Journal of International Affairs*, Vol. 20, pp. 3-25, doi: 10.5564/mjia.v20i0.1022.

Castellacci, F. and Lie, C.M. (2017), "A taxonomy of green innovators:empirical evidence from South Korea", *Journal of Cleaner Production*, Vol. 143, pp. 1036-1047, doi: 10.1016/j.jclepro.2016.12.016.

Chen, Y., Fu, W. and Wang, J. (2022), "Evaluation and influencing factors of China's agricultural productivity from the perspective of environmental constraints", *Sustainability*, Vol. 14 No. 5, p. 2807, doi: 10.3390/su14052807.

Cho, J.S., Kim, T.-h. and Shin, Y. (2015), "Quantile cointegration in the autoregressive distributed-lag modeling framework", *Journal of Econometrics*, Vol. 188 No. 1, pp. 281-300, doi: 10.1016/j.jeconom.2015.05.003.

Dam, T.H.T., Amjath-Babu, T., Zander, P. and Müller, K. (2019), "Paddy in saline water: analysing variety-specific effects of saline water intrusion on the technical efficiency of rice production in Vietnam", *Outlook on Agriculture*, Vol. 48 No. 3, pp. 237-245, doi: 10.1177/0030727019850841.

Demont, M. and Rutsaert, P. (2017), "Restructuring the Vietnamese rice sector: towards increasing sustainability", *Sustainability*, Vol. 9 No. 2, p. 325, doi: 10.3390/su9020325.

Deng, H., Jing, X. and Shen, Z. (2022), "Internet technology and green productivity in agriculture", *Environmental Science and Pollution Research*, Vol. 29 No. 54, pp. 81441-81451, doi: 10.1007/s11356-022-21370-z.

Dudek, M. and Wrzaszcz, W. (2020), "On the way to eco-innovations in agriculture: concepts, implementation and effects at national and local level. The case of Poland", *Sustainability*, Vol. 12 No. 12, p. 4839, doi: 10.3390/su12124839, available at: https://www.mdpi.com/2071-1050/12/12/4839

Dung, L.T., Ho, D.P., Hiep, N.T.K. and Hoi, P.T. (2018), "The determinants of rice farmers' adoption of sustainable agricultural technologies in the Mekong Delta, Vietnam", *Applied Economics Journal*, Vol. 25 No. 2, pp. 55-69.

Duong, D.T. (2020), "Sustainable development for Vietnam agriculture", *E3S Web of Conferences*, Vol. 175, p. 01015, doi: 10.1051/e3sconf/202017501015.

Fahad, S., Adnan, M. and Saud, S. (2022), *Improvement of Plant Production in the Era of Climate Change*, (Eds.)., CRC Press.

Fisher, M. (2019), "Environmental biology", in *Conventional & Sustainable Agriculture*, Oregon Coast Community College, pp. 75-255.

Godil, D.I., Ahmad, P., Ashraf, M.S., Sarwat, S., Sharif, A., Shabib-ul-Hasan, S. and Jermsittiparsert, K. (2021), "The step towards environmental mitigation in Pakistan: do transportation services, urbanization, and financial development matter?", *Environmental Science and Pollution Research*, Vol. 28 No. 17, pp. 21486-21498, doi: 10.1007/s11356-020-11839-0.

Graczyk, M., Kułyk, P., Kaźmierczak-Piwko, L. and Augustowski, Ł. (2018), "Ecological innovations in agricultural production as a pro-development factor of the economy", *Multidisciplinary Aspects of Production Engineering*, Vol. 1 No. 1, pp. 603-612, doi: 10.2478/mape-2018-0076.

Gray, E. and Jones, D. (2022), "Innovation, agricultural productivity and sustainability in Viet Nam".

Green production - direction for sustainable rural development (2023), Vietnamplus, available at: https://en.vietnamplus.vn/project-helps-boost-agriculture-sustainably/229552.vnp

Guerrero Lara, L., Pereira, L.M., Ravera, F. and Jiménez-Aceituno, A. (2019), "Flipping the Tortilla: social-ecological innovations and traditional ecological knowledge for more sustainable agri-food systems in Spain", *Sustainability*, Vol. 11 No. 5, p. 1222, doi: 10.3390/su11051222.

Harris, J., Jain, S. and Codur, A.-M. (2022), *Climate Conference COP27: Focus on Agriculture and Forests*.

Hoang, T.C., Black, M.C., Knuteson, S.L. and Roberts, A.P. (2019), "Environmental pollution, management, and sustainable development: strategies for Vietnam and other developing countries", Vol. 63 No. 4, pp. 433-436, doi: 10.1007/s00267-019-01144-z.

Hossain, M.E., Islam, M.S., Sujan, M.H.K., Tuhin, M.M.U.J. and Bekun, F.V. (2022), "Towards a clean production by exploring the nexus between agricultural ecosystem and environmental degradation using novel dynamic ARDL simulations approach", *Environmental Science and Pollution Research*, Vol. 29 No. 35, pp. 53768-53784, doi: 10.1007/s11356-022-19565-5.

Hussein, A.M. and Ali, D.A. (2022), "The role of international trade and agricultural production on economic growth in Somalia: Johansson cointegration approach", *African Journal of Business and Economic Research*, Vol. 17 No. 4, pp. 123-146, doi: 10.31920/1750-4562/2022/v17n4a6.

Isfat, M. and Raihan, A. (2022), "Current practices, challenges, and future directions of climate change adaptation in Bangladesh", Journal homepage:, ISSN, 2582, 7421, available at: www.ijrpr.com

Ivlev, V. and Ivleva, M. (2018), "Philosophical foundations of the concept of green economy", *International Conference on Contemporary Education, Social Sciences and Ecological Studies (CESSES 2018)*.

Jhariya, M.K., Meena, R.S. and Banerjee, A. (2021), *Ecological Intensification of Natural Resources for Sustainable Agriculture*, (Eds.)., Springer, Singapore.

Kallio, M.H., Hogarth, N.J., Moeliono, M., Brockhaus, M., Cole, R., Bong, I.W. and Wong, G.Y. (2019), "The colour of maize: visions of green growth and farmers perceptions in northern Laos", *Land Use Policy*, Vol. 80, pp. 185-194, doi: 10.1016/j.landusepol.2018.10.006.

Karwacka, M., Ciurzyńska, A., Lenart, A. and Janowicz, M. (2020), "Sustainable development in the agri-food sector in terms of the carbon footprint: a Review", *Sustainability*, Vol. 12 No. 16, p. 6463, doi: 10.3390/su12166463.

Khanh Chi, N.T. (2022), "Driving factors for green innovation in agricultural production: an empirical study in an emerging economy", *Journal of Cleaner Production*, Vol. 368, 132965, doi: 10.1016/j.jclepro.2022.132965.

Koenker, R. and Hallock, K.F. (2001), "Quantile regression", *Journal of Economic Perspectives*, Vol. 15 No. 4, pp. 143-156, doi: 10.1257/jep.15.4.143.

Laurett, R., Paço, A. and Mainardes, E.W. (2021), "Sustainable development in agriculture and its antecedents, barriers and consequences – an exploratory study", *Sustainable Production and Consumption*, Vol. 27, pp. 298-311, doi: 10.1016/j.spc.2020.10.032.

LE, M.H. (2022), "Agriculture and sustainable farming in Vietnam".

Li, K. and Lin, B. (2017), "Economic growth model, structural transformation, and green productivity in China", *Applied Energy*, Vol. 187, pp. 489-500, doi: 10.1016/j.apenergy.2016.11.075.

Lian, G., Xu, A. and Zhu, Y. (2022), "Substantive green innovation or symbolic green innovation? The impact of ER on enterprise green innovation based on the dual moderating effects", *Journal of Innovation and Knowledge*, Vol. 7 No. 3, 100203, doi: 10.1016/j.jik.2022.100203.

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., Sen, P.T., Sessa, R., Shula, R., Tibu, A. and Torquebiau, E.F. (2014), "Climate-smart agriculture for food security", *Nature Climate Change*, Vol. 4 No. 12, pp. 1068-1072, doi: 10.1038/nclimate2437.

Liu, Y. and Feng, C. (2019), "What drives the fluctuations of 'green' productivity in China's agricultural sector? A weighted Russell directional distance approach", *Resources, Conservation and Recycling*, Vol. 147, pp. 201-213, doi: 10.1016/j.resconrec.2019.04.013.

Lu, X., Zhang, S., Xing, J., Wang, Y., Chen, W., Ding, D., Wu, Y., Wang, S., Duan, L. and Hao, J. (2020), "Progress of air pollution control in China and its challenges and opportunities in the ecological civilization era", *Engineering*, Vol. 6 No. 12, pp. 1423-1431, doi: 10.1016/j.eng.2020.03.014.

Margulis, L. (2013), *Ecology without Nature*, Harvard University Press, New York.

Meessen, J., Croizer, C. and Verle, P. (2015), "The Viet Nam Green Growth Strategy: a review of specificities, indicators and research perspectives", *Proceeding of Conference: 2ieme Congrès Interdisciplinaire Du Développement Durable*.

Minamikawa, K., Huynh, K.C., Uno, K., Tran, N.S. and Nguyen, C.H. (2021), "Cattle biogas effluent application with multiple drainage mitigates methane and nitrous oxide emissions from a lowland rice paddy in the Mekong Delta, Vietnam", *Agriculture, Ecosystems and Environment*, Vol. 319, 107568, doi: 10.1016/j.agee.2021.107568.

Minh, T.D., Lee, B.-K. and Nguyen-Le, M.-T. (2018), "Methanol-dispersed of ternary Fe3O4@ γ-APS/ graphene oxide-based nanohybrid for novel removal of benzotriazole from aqueous solution", *Journal of Environmental Management*, Vol. 209, pp. 452-461, doi: 10.1016/j.jenvman.2017.12.085.

Morton, L.W. (2020), "Working toward sustainable agricultural intensification in the red River Delta of Vietnam", *Journal of Soil and Water Conservation*, Vol. 75 No. 5, pp. 109A-116A, doi: 10.2489/jswc.2020.0304a.

Nguyen, U. (2002), "Vietnam's agricultural sector: rising star in food production", Vietnam Briefing, available at: https://www.vietnam-briefing.com/news/vietnam-agricultural-products.html/#:~:text=In%202022%2C%20Vietnam's%20agricultural%20sector,was%20over%20US%2453.22%20billion

Nong, D., Wang, C. and Al-Amin, A.Q. (2020), "A critical review of energy resources, policies and scientific studies towards a cleaner and more sustainable economy in Vietnam", *Renewable and Sustainable Energy Reviews*, Vol. 134, 110117, doi: 10.1016/j.rser.2020.110117.

Peng, X. (2023), "Environmental regulation and agricultural green productivity growth in China: a retest based on 'Porter Hypothesis'", *Environmental Technology*, Vol. 45 No. 16, pp. 1-15, doi: 10.1080/09593330.2023.2212337.

Pesaran, M.H. (2007), "A simple panel unit root test in the presence of cross-section dependence", *Journal of Applied Econometrics*, Vol. 22 No. 2, pp. 265-312, doi: 10.1002/jae.951.

Pham Huy Thong, P.T.T. and Trung, M.P.T. (2016), "Study on the strategies for developing green economy in Vietnam", *The International Journal Of Engineering And Science (IJES)*, Vol. 5 No. 11, pp. 44-47, doi: 10.9790/1813-05011044047, available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiXo9OmxNn_AhX6bKQEHVQqCuEQFnoECBsQAQ&url=https%3A%2F%2Fwww.theijes.com%2Fpapers%2Fv5-i11%2FVersion-1%2FG05011044047.pdf&usg=AOvVaw0v0sl095y0moDwe0DgtVht&opi=89978449

Pham, T.-T.-H., Lynch, M. and Turner, S. (2023), "Creative counter-discourses to the 'green city' narrative: practices of small-scale urban agriculture in Hanoi, Vietnam", *Local Environment*, Vol. 28 No. 2, pp. 1-20, doi: 10.1080/13549839.2022.2162028.

Phi, T.H.L. and Bui, T.T.H. (2021), "Sustainable agriculture development in Vietnam", in *Global Changes and Sustainable Development in Asian Emerging Market Economies Vol. 2: Proceedings of EDESUS 2019*, Springer, pp. 207-223.

Quan, A. (2017), “Green economy is an inevitable trend of sustainable development”, thiennhien, available at: https://www.thiennhien.net/2017/02/16/kinh-te-xanh-la-xu-tat-yeu-cua-phat-trien-ben-vung/

Que, N.T. (1998), “Effects of trade liberalization on agriculture in Vietnam: institutional and structural aspects”.

Rahman, S., Ali, A. and Raihan, A. (2022), “Soil carbon sequestration in agroforestry systems as a mitigation strategy of climate change: a case study from Dinajpur, Bangladesh”, *Advances in Environmental and Engineering Research*, Vol. 3 No. 4, pp. 1-13, doi: 10.21926/aeer.2204056.

Raihan, A. (2023), “An econometric evaluation of the effects of economic growth, energy use, and agricultural value added on carbon dioxide emissions in Vietnam”, *Asia-Pacific Journal of Regional Science*, Vol. 7 No. 3, pp. 1-32, doi: 10.1007/s41685-023-00278-7.

Raihan, A. and Tuspekova, A. (2022), “The nexus between economic growth, renewable energy use, agricultural land expansion, and carbon emissions: new insights from Peru”, *Energy Nexus*, Vol. 6, 100067, doi: 10.1016/j.nexus.2022.100067.

Reardon, T., Echeverria, R., Berdegué, J., Minten, B., Liverpool-Tasie, S., Tschirley, D. and Zilberman, D. (2019), “Rapid transformation of food systems in developing regions: highlighting the role of agricultural research & innovations”, *Agricultural Systems*, Vol. 172, pp. 47-59, doi: 10.1016/j.agsy.2018.01.022.

Shrivastava, A., Tchale, H., Cao, B.T., Elabed, G., Kar, A., Kieu, H.T.P. and Nguyen, H.T.T. (2022), “Vietnam-spearheading Vietnam’s green agricultural transformation: moving to low-carbon rice”.

Singh, A.K., Raza, S.A., Nakonieczny, J. and Shahzad, U. (2023), “Role of financial inclusion, green innovation, and energy efficiency for environmental performance? Evidence from developed and emerging economies in the lens of sustainable development”, *Structural Change and Economic Dynamics*, Vol. 64, pp. 213-224, doi: 10.1016/j.strueco.2022.12.008.

Streimikis, J. and Saraji, M.K. (2022), “Green productivity and undesirable outputs in agriculture: a systematic review of DEA approach and policy recommendations”, *Economic Research-Ekonomska Istraživanja*, Vol. 35 No. 1, pp. 819-853, doi: 10.1080/1331677x.2021.1942947.

Su, Y., Gabrielle, B. and Makowski, D. (2021), “The impact of climate change on the productivity of conservation agriculture”, *Nature Climate Change*, Vol. 11 No. 7, pp. 628-633, doi: 10.1038/s41558-021-01075-w.

Sun, Y. (2022), “Environmental regulation, agricultural green technology innovation, and agricultural green total factor productivity”, *Frontiers in Environmental Science*, Vol. 10, 955954, doi: 10.3389/fenvs.2022.955954.

Tariq, A., Vu, Q.D., Jensen, L.S., de Tourdonnet, S., Sander, B.O., Wassmann, R., Van Mai, T. and de Neergaard, A. (2017), “Mitigating CH4 and N2O emissions from intensive rice production systems in northern Vietnam: efficiency of drainage patterns in combination with rice residue incorporation”, *Agriculture, Ecosystems and Environment*, Vol. 249, pp. 101-111, doi: 10.1016/j.agee.2017.08.011.

Thang, T.C., Khoi, D.K., Thiep, D.H., Tinh, T.V. and Pede, V.O. (2017), “Assessing the potential of climate smart agriculture in large rice field models in Vietnam”, CCAFS Working Paper.

Tien, N.H., Phuc, N.T., Thoi, B., Duc, L. and Thuc, T. (2020), “Green economy as an opportunity for Vietnamese business in renewable energy sector”, *International Journal of Research in Finance and Management*, Vol. 3 No. 1, pp. 26-32, doi: 10.33545/26175754.2020.v3.i1a.50.

Tran, T. (2017), “Green economy: future economy”, kinhtevadubao, available at: https://kinhtevadubao.vn/kinh-te-xanh-nen-kinh-te-tuong-lai-3466.html

Tran, D.H., Hoang, T.N., Tokida, T., Tirol-Padre, A. and Minamikawa, K. (2018), “Impacts of alternate wetting and drying on greenhouse gas emission from paddy field in Central Vietnam”, *Soil Science and Plant Nutrition*, Vol. 64 No. 1, pp. 14-22, doi: 10.1080/00380768.2017.1409601.

Tran, N.L.D., Rañola Jr, R.F., Ole Sander, B., Reiner, W., Nguyen, D.T. and Nong, N.K.N. (2020), "Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam", *International Journal of Climate Change Strategies and Management*, Vol. 12 No. 2, pp. 238-256, doi: 10.1108/ijccsm-01-2019-0003.

Trinh, T.A. (2018), "The impact of climate change on agriculture: findings from households in Vietnam", *Environmental and Resource Economics*, Vol. 71 No. 4, pp. 897-921, doi: 10.1007/s10640-017-0189-5.

Van Hong, P., Nguyen, N.T., Huy, D.T.N., Thuy, N.T. and Huong, L.T.T. (2021), "Evaluating several models of quality management and impacts on lychee price applying for Vietnam agriculture products value chain sustainable development", *Alinteri Journal of Agriculture Science*, Vol. 36 No. 1, pp. 122-130, doi: 10.47059/alinteri/v36i1/ajas21018.

Viana, C.M., Freire, D., Abrantes, P., Rocha, J. and Pereira, P. (2022), "Agricultural and systems importance for supporting food security and sustainable development goals: a systematic review", *Science of the Total Environment*, Vol. 806, 150718, doi: 10.1016/j.scitotenv.2021.150718.

Wang, K.L., Sun, T.T., Xu, R.Y., Miao, Z. and Cheng, Y.H. (2022), "How does internet development promote urban green innovation efficiency? Evidence from China", *Technological Forecasting and Social Change*, Vol. 184, 122017, doi: 10.1016/j.techfore.2022.122017.

Wang, Y., Ahmed, M., Raza, S.A. and Ahmed, M. (2023), "Threshold nonlinear relationship between renewable energy consumption and agriculture productivity: the role of foreign direct investment and financial inclusion", *Environmental Science and Pollution Research*, Vol. 30 No. 24, pp. 65900-65915, doi: 10.1007/s11356-023-27003-3.

Zhang, X., Liu, F., Wang, H. and Nazir, R. (2023), "Influence of ecological innovation and green energy investment on unemployment in China: evidence from advanced quantile approach", *Economic Research-Ekonomska Istraživanja*, Vol. 36 No. 2, 2125034, doi: 10.1080/1331677x.2022.2125034.

Zhao, P.S.Y. (2015), "Green economy and development path of Vietnam [review, Ha Tinh University]", available at: http://ssr-net.com/issues/Vol_1_No_1_June_2015/1.pdf

Zhou, G., Li, H., Ozturk, I. and Ullah, S. (2022), "Shocks in agricultural productivity and CO2 emissions: new environmental challenges for China in the green economy", *Economic Research-Ekonomska Istraživanja*, Vol. 35 No. 1, pp. 5790-5806, doi: 10.1080/1331677x.2022.2037447.

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