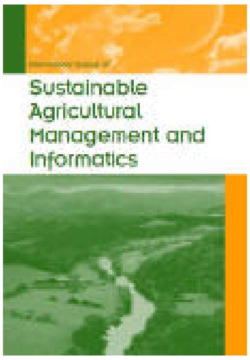

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Green innovation in agriculture development: the impact of environment awareness, technology spillover, and social networks

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Green innovation in agriculture development: the impact of environment awareness, technology spillover, and social networks

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Abstract: Green agriculture with the benefits of environmental protection, food safety and high economic value is becoming the destination of modern agriculture. Therefore, green innovation in agriculture leads to sustainable development, thereby improving the efficiency of management and use of natural resources while enhancing adaptability and resilience to the impacts of climate change. This study proposed the relationships among environment awareness, technology spillover (TS), social networks, and green innovation. Additionally, this study also investigates moderating role of social networks on green innovation and sustainable development. The probability sampling method was employed to develop a research sample. The research uses correlation analysis and structural equation modelling (SEM) to analyse the data of valid observations collected in the structured questionnaire survey in Vietnam. The results indicate that environment awareness and TS have direct positive impacts on green innovation. Moreover, social networks play the mediator in enhancing the innovation towards green agricultural production.

Keywords: green innovation; technology spillover; TS; environment awareness; sustainable development; social networks.

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1 Introduction

Agriculture is developing and refecting the society change, therefore it addresses the opportunities for sustainable development in the agriculture field (Kountios, 2022; Musa and Basir, 2021). As agrochemicals are causing growing concern about their environmental and public health impacts, many countries are promoting organic farming as a green and sustainable solution (Sharma and Singvi, 2017). However, this transformation of farming methods did not immediately gain the support of farmers when there were concerns about crop yield, in addition to objections from chemical companies (Goring, 2020). It has become an indispensable recall in the modernisation and sustainable development in agriculture production in emerging countries (Chakraborty and Pal, 2021). Consequently, green innovation is an important breakthrough point for agriculture production in developing sustainability.

Recently, several prior studies examined the determinants affecting green innovation. Fardogianni et al. (2022) examined how consultants and precision agriculture affect food practices and sustainable development, while Tagarakis et al. (2022) focusing on integrated IoT platform. Symeonaki et al. (2019) finds that IoT technology motivates innovation which leads to obtain sustainable development. Even with a lot of research on green innovation, the aspect of environmental awareness and how technology spillover (TS) affects green agricultural production is still unclear. Consequently, this paper proposes that environmental awareness and TS can be an important factors influencing innovation towards green agricultural production with the enhancement of social networks.

In decades, there has been an increase in public awareness of environmental problems in urban and rural restoration (Lemgruber et al., 2021). Recently, green purchasing behaviour, environmentally responsible behaviours (Lee et al., 2013) have a focus on the environment protection and sustainability. Furthermore, drawing from the works of Shaw et al. (2016), consumer behaviours are a free consumer choice pushed by political, social or environmental concerns. Therefore, concerns of an individual about environment will create the motivation to innovation (Bournaris et al., 2021).

The second key focus is the role of TS in pushing environmental performance and green innovation. TS is seen as a critical success tool for enhancing the effectiveness production in agriculture industry (Xiong et al., 2020), and the decrease in agriculture emission (Liu et al., 2019b). Advances in resource recycling and reuse technologies play an important role in reducing pollution and emissions in agricultural production (Ismael et al., 2018). Previous studies have also demonstrated the pervasiveness of technology in agricultural production and its impact on emissions reductions (Wang et al., 2020; He et al., 2020). Drawing from these results have shown the positive effect of TS in emission reduction, this study proposes the impact of TS on innovation towards green agricultural production.

On the other hand, understanding of how social networks might have correlation with green innovation and sustainable development is also unclear in the literature. Since the internet has created the positive communication among people, businesses, and government, social networks attract a lot of individuals to join the sites daily (Muratore, 2008). Unfortunately, there is no attention in evaluating the influence of social networking sites in measuring the green innovation in agriculture production. In this vein, this paper examines the moderating effect of social network on green agriculture innovation and sustainable development.

In this context, this study develops a conceptual framework investigating the impact of environmental awareness, TS, social network on innovation towards green agricultural production. The proposed model is tested in the context of Vietnam. Agriculture in Vietnam has made great progress since 1986. The strong development of the Agriculture sector has helped Vietnam significantly improve food security, contribute to poverty reduction and socio-economic stability. However, the current agricultural growth model of Vietnam still reveals many concerns about quality and sustainability (Chi, 2022; Ngoc et al., 2021). In particular, growth in the agriculture sector today is partly due to environmental sacrifices. Therefore, green agriculture is considered as the mainstream agricultural development model in the future. The research questions of this study are follows:

1 Are the role of environment awareness and TS on green innovation?

2 Do social networks enhance the relationship between green innovation and sustainable development?

By proposing a model of green innovation, this study makes several contributions to the agricultural production literature and its management implications.

2 Literature review

2.1 Green innovation in agriculture production

According to Shahzad et al. (2020), green innovation-GI is considered as "the development of environmentally-friendly products/processes". Singh et al. (2020) suggested that implementing innovation not only includes eco-friendly raw materials, eco-friendly design, and eco-labels to reduce emissions but also the consumption of electricity, raw materials, and water. GI ensures the environmental and financial performance which all lead to sustainable development (Chi, 2022). On the other hand, Chen et al. (2006) had a different point of view about GI. They addressed that GI must involve 'hardware' or 'software' which support in manufacturing green products, saving resources and energy, and preventing the environmental pollution. More recently, GI is presented as the way to decrease the natural degradation, gain significant market, financial and knowledge sectors at all stages of innovation process (Cancino et al., 2018).

In terms of agriculture production, GI in this study can be considered as an innovative process in green agricultural production to reduce pollution, save energy, recycle waste and protect the environment. According to Sun and Wang (2021, p.1), GI "is not only a traditional measure of innovation performance according to economic indicators, but also extends the view to factors such as the environment, including industrial processing technology, improved service level, and innovation of advanced management concepts". By applying GI in agricultural production, resources can be used more efficiently and environmental pressures can be controlled, and people can minimise the negative impact of the external environment on the natural environment. Currently, there are many different concepts of green agriculture. According to the Organisation for Economic Co-operation and Development (OECD) (2010), green agriculture is a way to develop the Agriculture sector, which maximises the opportunity to exploit clean resources, leading to a model of agriculture. Sustainable growth is more associated with environmental protection. Green agriculture or more specifically organic agriculture ensures 4 principles: Health, ecology, justice and prudence, gradually becoming a new direction to build a civilised agriculture adapting to climate change (Yu et al., 2022).

Many scholars have recently examined the determinants of GI in various fields. For example, Cai and Li (2018) revealed the antecedents of GI affect the industrial firm performance which are environmental pressure, energy-savings, customers' demands. Meanwhile, Asadi et al. (2020) suggested the influence of GI on sustainable development in Malaysian while Shahzad et al. (2020) addressed the correlation of environment sustainability on GI in Pakistani. However, understanding the innovation towards green agricultural production has little attention, especially finding the determinants on GI implementation is unclear in agriculture industry. Various theories explored the new application, such as the technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT) (Lu et al., 2019). Unfortunately, the research on GI from farmers' perspective has not yet been unclear. From the farm point of view, the 1990 Tornatzky and Fleischer TOE framework explained the impact of technology, external and internal factors. This theory fully proposes three aspects of the household context. Moreover, the pervasive nature of GI in agriculture production and the lack of research in developing countries preclude direct formulation of existing theories. Therefore, this study basing on TOE theory examines two aspects including the farm internal factor TS, external factor (environmental awareness) towards green agricultural production.

2.2 Environment awareness, technology spillover and green innovation

Environmental awareness is considered as "the totality of perceptions, feelings, knowledge, attitudes, values and behaviours related to the environment" [Bamberg, (2003), p.21]. According to Fransson and Garling (1999), environmental quality is considered because people are well aware of the influence of the environment on their lives. People tend to behave environmentally responsible when the importance of protecting the natural environment is clearly recognised (Chi, 2021). In the context of global warming and the impact of COVID-19, global concern is about pollution, greenhouse effect and human health (Zhu et al., 2022). Environmental awareness is the case for various industries, especially in agriculture, which "exploits scarce natural resources, is energy intensive, and is a threat to the global climate through potential pollution and other accidents" (Hillestad et al., 2010, 441). Several scholars have pointed out the relationship between management, environmental awareness and green innovation in different industries. For example, Peng et al. (2020) mentions that people with a high degree of environmental awareness tend to identify market opportunities in green innovation. Cao and Chen (2019) argue that businesses with "high environmental awareness can not only motivate enterprises to identify market opportunities from outside, but also help enterprises to allocate internal resources or capabilities.” rationally and bring green innovation to strategic heights”. Enterprises’ commitment to the environment has an impact on green innovation by establishing a good performance capacity (Burki and Dahlstrom, 2017). From these perspectives, farms with a high degree of environmental awareness tend to have successful GI practices. Therefore, the hypothesis is put forward as follows:

H1 Environment awareness positively impacts green innovation

TS refers to “technology-related characteristics that a business would adopt as an important asset for green innovation” (Zhang et al., 2020). The spillover of a technology depends on how well it works “with other technologies being used and facilitating green innovation activities” (Chatzoglou and Michailidou, 2019). According to the study of Li et al. (2017), one of the main concerns in green innovation is technology adoption. Furthermore, Kemp and Foxon (2007) argue that successful GI implementation depends on ‘the use of different technologies, making it a technology-enabled organisational effort’. The better prepared innovation is in terms of technological and operational capabilities, the better the potential risks are controlled (Jones et al., 2005). Liu et al. (2019a) assert that technology is considered ‘the most effective strategy to improve agricultural production efficiency’ and ‘reduce agricultural emissions’. Besides, investigating the impact of TS on agricultural production also mentions its role in reducing emissions and resource use (Ismael et al., 2018). Zhang et al. (2020) states that “low technical efficiency is the main cause of low agricultural carbon efficiency”. Some previous studies have mentioned the spillover of technology in agricultural production (Yang 2013), the impact of TS in reducing fertiliser agricultural canopy (Wang, 2019). Therefore, based on these findings, the spillover of technology will affect green innovation in agricultural production. In addition, technological change in agricultural production minimises negative impacts on the environment (Galdeano-Gómez et al., 2013). This is the leading strategy to promote green innovation and satisfy customers’ desires (Albino et al., 2009). Household farmers require careful consideration for green innovation and exploitation of technology to make efficient use of natural resources, all of which improve economic and environmental performance (Galdeano-Gómez et al., 2013). Therefore, the hypothesis is put forward as follows:

H2 TS positively impacts green innovation

2.3 The moderator: social networks

According to Halevy et al. (2022), a social network can be understood as a website or online platform with many different forms and features, making it easy for people to connect from anywhere. Social networks can be easily accessed from many means and devices such as computers, phones, and other mobile devices. The goal of a social network is to create a system that allows users to connect, exchange and share useful information on the internet platform (Gou and Wu, 2022). The goal of a social network is to create a system that allows users to connect, exchange and share useful information on the internet platform (Ezell et al., 2022). In addition, social networks also have the goal of creating a valuable community, enhancing the role of each user ((Ezell et al., 2022).

Unfortunately, even when farmers claim to be concerned about environmental and technological issues, these concerns do not necessarily translate into green innovation behaviour (Osterhus, 1997). Therefore, it needs to be the key factor in converting farmers' interest to green improvement. Sridhar Balasubramanian (2001) argues that transforming social interactions in social networks into corporate benefits requires a comprehensive understanding of the economic and social dynamics of the participants. Farming households who want to do green innovation in agricultural production feel responsible for the environment and express their concern about the environment (Bray et al., 2011). From this perspective, environment awareness and TS are not strong enough for farmers to be willing to make green improvements without the impact of social networking sites. Therefore, the hypotheses are proposed as follows:

H3a Social networks positively strengthens the relationship between farm operational capacity and green innovation

H3b Social networks positively strengthens the relationship between TS and green innovation

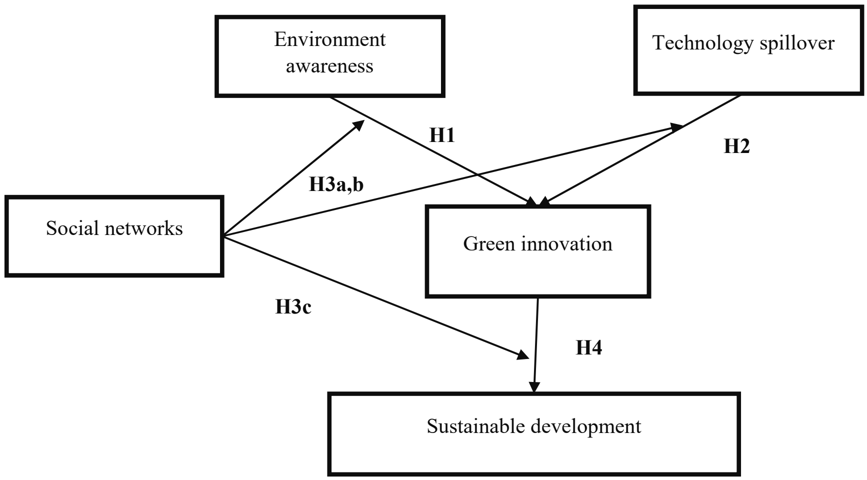
H3c Social networks positively strengthens the relationship between green innovation and sustainable development in agriculture

2.4 Green innovation and sustainable development

Several studies have shown a relationship between GI and sustainable development. For example, Del-Rio et al. (2017) shows that reducing production costs becomes important for GI and sustainable development. By implementing GI, farmers increase productivity through reduction of production waste leading to efficient operation (Liu et al., 2020). Reducing various pollutants to comply with regulations in agricultural production will enhance sustainable development (Saunila et al., 2018). Furthermore, Li et al. (2017) shows that green innovation is positively related to corporate profitability. Scholars have previously shown that companies that adopt ecological strategies in their operations inevitably produce green goods that lead to environmental performance (Albino et al., 2009). Several studies have demonstrated a link between environmental commitment and ecologically sound business, improving environmental performance (Shahzad et al., 2020). Furthermore, Fernando et al. (2019) propose that green innovation promotes change in technological processes and production, all of which reduce the negative impact of production on the environment, production waste and pollution. GI farmers are very successful and have sustainable development because they use their green resources and capacity to meet the needs of the market (Albort Morant et al., 2018). From these perspectives, green innovation not only reduces pollution but also enhances the competitive advantage of farmers in their agricultural activities. Therefore, the hypothesis is put forward as follows:

H4 Green innovation in agriculture production positively impacts sustainable development

Figure 1 The conceptual framework



3 Methodology

3.1 Measures

To operationalise latent constructs in the study, scales have been taken from prior literature with relevant modifications in item wordings fitting the context. Five items of TS are respectively in conformity with the studies of Wang (2015) and Del Guidice et al. (2019). Five items of environmental awareness was adapted from Li et al. (2021) and Chi (2021). Social networks has four components and validated by Jin et al. (2017a). Finally, green innovation has five items and was validated by the research of Wang (2019) while sustainable development was measured by five items from the research of Tantayanubutr and Panjakajornsak (2017).

Table 1 Measurement scale

Construct	*Item*	*Source*
Environmental awareness	Government support me to adopt innovation	Li et al. (2021), Chi (2021)
	Humans need to contribute to the protection of natural resources	
	Humans need to limit the climate change	
	Humans need to reduce pollution	
	I believe that conventional farming leads to environmental degradation	
Social networks	I use social networks to find information	Jin et al. (2017b)
	Social networks post of agricultural experience make the poster stand out	
	Social networks post of agricultural experience make me envious	
	I seek information from other farmers	
	I use social networks to spread out information	

Table 1 Measurement scale (continued)

Construct	*Item*	*Source*
Technology spillover	We are willing to adopt new technological knowledge to produce green goods	Wang (2015), Del Giudice et al. (2019)
	We create new ideas in producing goods	
	We apply new inventions in producing goods	
	Our neighbours have applied cleaner technology in producing goods	
	There are the collaboration of national farmers in adopting new technological knowledge	
Green production innovation	We use less or non-polluting/toxic fertiliser	Wang (2019)
	We improve environmentally friendly packaging for goods	
	We recover the end-of-life goods and recycling	
	We use low energy consumption such as water, electricity, and gas during production	
	We use eco-labelling for our goods	
Sustainable development	Market performance	Tantayanubutr and Panjakajornsak (2017)
	Financial performance	
	Pollution management	
	Resource efficiency	
	Environment control	

3.2 Sample and data collection

In this study, farm households having experience in green production in Vietnam is the research population. According to the suggestion of Comrey and Lee (1992), the required size in sampling in a multivariate analysis is minimum 300 observation. Similarly, the required sample size in SEM analysis is also at minimum 300 observation (Hair et al., 2010). Therefore, the sample size in this study is determined at 300. To obtain at least 300 samples, 600 questionnaires were launched.

Survey was distributed through phone and in the three-month duration (March to May, 2021). To authenticate the participants, they kindly asked if they had innovated from conventional to green manufacturing on the first page of the survey form. If they innovate agricultural production, they are constantly asked to fill out a questionnaire. Otherwise, introductory summaries were made for each participant to ensure that they fully understood the survey context and technical terms. Further, after each participant completed the questionnaire, they received a small financial incentive from the research project (approximately $2.13) through an online bank transfer. This study followed appropriate ethical procedure, by ensuring that all participants' responses would be kept confidential. In addition, all questionnaires will be anonymous.

The research sample consists of 304 valid observations of farm household. In the research sample, male accounts for 45.6 % and female accounts for 54.4%. The group of farm leader under 50 accounts for 62%.

Table 2 Information of respondents

Information	*Percentage*
Gender of farm manager	
Female	45.6
Male	43.4
Age of farm manager	
18–30	15
31–40	40
41–50	30
Above 50	15
Education	
Less than high school	43
University	42
Post university	15
Monthly Income (USD)	
Under 7,00	16
700–1,000	20
1,000–1,500	21
1,500–2,000	21
Above 2,000	22

Notes: 45.6 % and female accounts for 54.4%. The group of farm leader under 50 accounts for 85%.

3.3 Bias correction

Common method bias (CMB) is a problem in survey techniques due to simultaneous data collection for predictor/criterion variables via same instrument and scaling, etc., due to which variance sharing starts happening due to the method rather than the theory. To tackle CMB, this study followed Podsakoff et al.'s (2003) guidelines. This study shared that there are no right/wrong answers to the survey questions which also helped in managing acquiesce bias. Reverse coded items were also kept in the survey to break the cognitive monotony while taking long surveys (Malhotra and Dash, 2016). This study also separated the measures to capture predictor variables in the survey questionnaire from criterion variables by putting former in the beginning and the latter by the end of the questionnaire following the guidelines for 'separation of measurements' to handle CMB [Podsakoff et al., (2003), p.887]. Further scrutiny for CMB was done with the help of a common latent factor (CLF). A CLF was created in AMOS and regressed on all indicators in the proposed model. While comparing this model with the model without CLF, no significant difference was observed across the paths in two models. It confirms that CMB did not influence this study.

3.4 Data analysis

Data is analysed with the help of covariance based – structural equation modelling (SEM) using AMOS 26 software. Since the data meets the conditions of a normal distribution and requisite items to response ratio (1:10), this study used SEM as a preferred and established multivariate analysis technique (Hair et al., 2010). Additionally, SEM is the preferred choice because the model involves simultaneous estimation of multiple dependent relationships (Malhotra and Dash, 2016).

4 Data results

4.1 Measurement model test-validity and reliability

Measurement model is tested following Hair et al.'s (2010) guidelines and using confirmatory factor analysis to confirm the factor structure. Reliability of the indicators is confirmed by capturing standard factor loadings ($\lambda > 0.70$). Composite reliability for the latent constructs remained significantly high (greater than 0.70) following Fornell and Larcker (1981). Further, Cronbach's alpha (α) known as the reliability coefficient was found above the designated cutoff value of 0.70 (see Table 3).

Table 3 The reliability and convergent validity

Construct	*Item*	*F-loading (CFA)*	*Cronbach alpha*	*Composite reliability*	*AVE*
Environmental awareness	ENV1	0.820	0.827	0.879	0.58
	ENV2	0.812			
	ENV3	0.806			
	ENV4	0.701			
	ENV5	0.779			
Social networks	NET1	0.720	0.792	0.804	0.56
	NET2	0.737			
	NET3	0.877			
	NET4	0.679			
	NET5	0.725			
Technology spillover	TEC1	0.760	0.774	0.867	0.54
	TEC2	0.712			
	TEC3	0.713			
	TEC4	0.787			
	TEC5	0.790			

Table 3 The reliability and convergent validity (continued)

Construct	*Item*	*F-loading (CFA)*	*Cronbach alpha*	*Composite reliability*	*AVE*
Green production innovation	GRI1	0.885	0.846	0.853	0.59
	GRI2	0.774			
	GRI3	0.705			
	GRI4	0.701			
	GRI5	0.751			
Sustainable development	SUS1	0.891	0.893	0.887	0.63
	SUS2	0.804			
	SUS3	0.795			

Regarding validity, items loading highly significantly onto corresponding constructs confirm convergent validity that is further vetted by finding the average variance extracted score above 0.60. Discriminant validity is supported by comparing the √AVE scores with the correlations between the pairs of constructs (Fornell and Larcker, 1981) (see Table 4). The measurement model fit indices indicate a good fit with $\chi 2/df = 2.008$, goodness of fit index = 0.902, comparative fit index = 0.901, and root mean squared error of approximation = 0.045.

Table 4 Fornell and Larcker criterion analysis

Constructs	*Environmental awareness*	*Technology spillover*	*Green production innovation*	*Social networks*	*Sustainable development*
Environmental awareness	*0.762*				
Technology spillover	0.670	*0.735*			
Green production innovation	0.587	0.601	*0.768*		
Social networks	0.602	0.611	0.680	*0.748*	
Sustainable development	0.628	0.698	0.623	0.612	*0.794*

4.2 Hypothesis testing

Causal relationships among the latent constructs have been examined through SEM model and modelled on AMOS 26. The measurement model confirmed in the previous step was subjected to structural theory testing by estimating paths and overall model fit. Theoretical model fits good to the data with $\chi 2/df = 2.501$, TLI = 0.910, comparative fit index = 0.906, and root mean squared error of approximation = 0.0048. These fit indices are very near to the measurement model fit indices which substantiates a good model fit. However, goodness of fit measures (e.g., $\chi 2$) has a high value for the CFA model (measurement model) because it acts as the upper bound to the SEM model (Hair et al.,

2010) and confirms the theory behind the model fit through SEM. Table 5 shows the results of testing hypothesis. The environment awareness and TS all positively affect green innovation (0.426 and 0.302 respectively).

The results Table 6 show that social networks enhance the relationship between environment awareness, TS and green innovation and also the link between green innovation and sustainable development. Therefore, H3a, H3b, and H3c are supported.

As can be seen from Table 6, social networks have significantly positive impact on the association between environment awareness, TS and green innovation, and enhance the relationship between green innovation and sustainable development.

Table 5 The results of testing hypothesis

Relationships				*Path coefficient*	*P*	*Test result*
H1	Environment awareness	→	Green innovation	0.426	***	Accepted
H2	Technology spillover	→	Green innovation	0.302	***	Accepted
H4	Green innovation	→	Sustainable development	0.638	***	Accepted

Notes: ***< 0.001, **< 0.01, Chi-square/df = 2.501; CFI = 0.906; TLI = 0.910; IFI =0.909, RMSEA = 0.048.

Table 6 The results of testing the moderating links

Path		*β*	*t*	*p*	*LLCI*	*ULCI*	*Moderation*
H3a	SONxENV	0.169	1.977	0.03	0.1199	0.2340	Yes
H3b	SONxTES	0.083	1.742	0.05	0.0379	0.1482	Yes
H3c	SONxGIN	0.107	1.633	0.04	0.0246	0.1797	Yes

5 Discussion

The empirical results of this paper indicate that environment awareness and TS directly effect innovation, while innovation leads to sustainable development in agriculture production. Meanwhile, social networks play the moderator in the links between environment awareness, TS, and innovation towards green agricultural production.

First, this research revealed that environmental awareness has the largest effect on innovating green agriculture production. This finding about its positive enhancement on the relationship between environmental awareness and green innovation is in accordance with the proposal of Chi (2022). She addressed that people having awareness of environment tend to identify market opportunity in green innovation. The awareness of farms about the environment promotes them allocate their capabilities to innovate their green agriculture production. The environment quality in agriculture production is considered since farm households are well aware of the environment. Vietnam is one of the 5 countries most affected by climate change due to its long coastline and many large river basins. Therefore, in order to limit the negative impacts of climate change and other environmental issues, drastic action from the government through policies and commitments is required; join hands of enterprises through innovating production technology in an environmentally friendly direction and each individual's actions change their thoughts and habits of agricultural production to minimise negative impacts (Connor et al., 2022).

Secondly, this study finds that TS has a direct impact on innovation towards green agricultural production. This finding confirms the work of Chatzoglou and Michailidou (2019), and Zhang et al. (2020). They suggested that technology support managers to innovate their activities. It can be explained that technological change in agricultural production in an emerging country will only reduce the negative impact on the environment if farmers innovate their production practices. The application of high technology in agricultural production requires large initial costs, while the investment capacity of all economic sectors in agriculture in Vietnam is still limited. Enterprises in the agricultural sector are mainly small and micro, the ability to modernise equipment for green agriculture is extremely difficult.

The next critical findings reveal that social networks play the moderating impact on the relationships among TS and environment awareness on green innovation, and the relationship between green innovation and sustainable development. These results are similar to the suggestion of Bray et al. (2011). They argued that Farming households who want to do green innovation in agricultural production feel responsible for the environment and express their concern about the environment.

Finally, green innovation in agriculture production is found to have positive influence on sustainable development which is similar to the findings of Huang and Liu (2017). Other previous researches also suggested the result of green innovation in sustainable development in different industries. Li et al. (2017) showed that green innovation does positively involve profitability of business. Saunila et al. (2018) demonstrated that reducing various pollutants to comply with regulations in agricultural production will improve economic efficiency. Therefore, in agriculture production farmers in an emerging economy innovating their operation will obtain sustainable development.

6 Conclusions and implications

This study has some significant contributions to literature. Firstly, this paper exploited the important area in an emerging country and tried to minimise the research gap by empirically finding the impact of antecedents on innovation towards green agricultural production and on sustainable development. It highlights that farmers should harness their own resources (such as time, labour, and finance) and information technology to change their traditional to green production. Second, the sustainable development will be acquired if farms pay attention to increase their technology and environment awareness. This paper also highlights the critical role of IT and environment awareness in obtaining the benefits of green innovation. It can be seen that an important highlight in green agriculture is awareness of the role of the environment in agricultural production. Agricultural pollution has generally received little attention. The scarcity of agricultural pollution data has limited researchers' ability to study its effects on human and animal health, biodiversity, and agricultural profitability. and other industries and the total social value of agricultural production. The next highlight is that social networks seem to be a good moderator for innovation towards green agricultural production which are previously unclear. Finally, this study confirms an important role of innovation towards green agricultural production to obtain sustainable development.

This paper also provides several implications for practice. Firstly, government and policy-makers continue regular propaganda to help people raise awareness about the benefits of green agriculture production for the sustainable development. Otherwise, government in emerging economics should has the requirement for land accumulation is a very necessary for farm households. Secondly, government should encourage and support farmers and business in digital transformation of the agricultural sector and rural development, because this transformation plays a particularly important role in restructuring the agricultural sector, developing concentrated and large-scale commodity agriculture towards modernity, high added value and sustainability. Technology application is one kind of digital transformation, which is an important solution to help farmers and businesses produce quality agricultural products at the lowest cost, but with the highest profit. Vietnam's agriculture is at a turning point where some traditional growth drivers are gradually weakening (such as resources and land), while new ones have not been fully formed (science and technology). Therefore, mastering science and technology is the key point to help Vietnamese agriculture break through and approach green agriculture. The government needs to play a 'leading' role in refinancing and supporting businesses in accessing credit to invest in science and technology in agriculture. In addition, it is necessary to promote the reorganisation of production according to the linkage chain, with enterprises as the nucleus of linkages, organising production with farmer households, farms, and cooperatives to apply high technology in production and cycle management. commodity production process, traceability. Thirdly, government and policy-makers launch environmental education contents on social networks. This can be seen as a strategy to exploit the potential of green innovation, and at the same time call on farmers to improve agricultural production towards green and clean production. Finally, the results of this study revealed the important role of social networks on green innovation and sustainable development. Therefore, government, policy-makers and farm households should pay attention to social networks (Youtube, Facebook, twitter...) to evoke people change their production into green innovation.

References

Albino, V., Balice, A. and Dangelico, R.M. (2009) 'Environmental strategies and green product development: an overview on sustainability-driven companies', *Business Strategy and the Environment*, Vol. 18, No. 2, pp.83–96.

Albort-Morant, G., Leal-Rodríguez, A.L. and De Marchi, V. (2018) 'Absorptive capacity and relationship learning mechanisms as complementary drivers of green innovation performance', *Journal of Knowledge Management*, Vol. 22, No. 2, pp.432–452.

Asadi, S., Pourhashemi, S.O., Nilashi, M., Abdullah, R., Samad, S., Yadegaridehkordi, E., ... and Razali, N S. (2020) 'Investigating influence of green innovation on sustainability performance: a case on Malaysian hotel industry', *Journal of Cleaner Production*, Vol. 258, No. 4, p.120860.

Bamberg, S. (2003) 'How does environmental concern influence specific environmentally related behaviors? A new answer to an old question', *Journal of Environmental Psychology*, Vol. 23, No. 1, pp.21–32.

Bournaris, T., Moulogianni, C., Vlontzos, G. and Georgilas, I. (2021) 'Methodologies used to assess the impacts of climate change in agricultural economics: a rapid review', *International Journal of Sustainable Agricultural Management and Informatics*, Vol. 7, No. 4, pp.253–269.

Bray, J., Johns, N. and Kilburn, D. (2011) 'An exploratory study into the factors impeding ethical consumption', *Journal of Business Ethics*, Vol. 98, No. 4, pp.597–608.

Burki, U. and Dahlstrom, R. (2017) 'Mediating effects of green innovations on interfirm cooperation', *Australasian Marketing Journal* (AMJ), Vol. 25, No. 2, pp.149–156.

Cancino, C.A., La Paz, A.I., Ramaprasad, A. and Syn, T. (2018) 'Technological innovation for sustainable growth: an ontological perspective', *Journal of Cleaner Production*, Vol. 179, No. 6, pp.31–41.

Cao, H. and Chen, Z. (2019) 'The driving effect of internal and external environment on green innovation strategy-the moderating role of top management's environmental awareness', *Nankai Business Review International*, Vol. 10, No. 3, pp.342–361.

Chakraborty, C. and Pal, D. (2021) 'Does farm size matters in determining efficiency in Indian agriculture: a case study of rice production in Eastern India', *International Journal of Sustainable Agricultural Management and Informatics*, Vol. 7, No. 1, pp.17–30.

Chatzoglou, P.D. and Michailidou, V.N. (2019) 'A survey on the 3D printing technology readiness to use', *International Journal of Production Research*, Vol. 57, No. 8, pp.2585–2599.

Chen, Y.S., Lai, S.B. and Wen, C.T. (2006) 'The influence of green innovation performance on corporate advantage in Taiwan', *Journal of Business Ethics*, Vol. 67, No. 4, pp.331–339.

Chi, N.T.K. (2021) 'Understanding the effects of eco-label, eco-brand, and social media on green consumption intention in ecotourism destinations', *Journal of Cleaner Production*, Vol. 321, No. 7, p.128995.

Chi, N.T.K. (2022) 'Driving factors for green innovation in agricultural production: an empirical study in an emerging economy', *Journal of Cleaner Production*, Vol. 363, No. 2, p.132965.

Comrey, A.L. and Lee, H.B. (1992) 'Interpretation and application of factor analytic results', in Comrey, A.L. and Lee, H.B. (Eds.): *A First Course in Factor Analysis*, Vol. 2.

Connor, M., Cuong, O.Q., Demont, M., Sander, B.O. and Nelson, K. (2022) 'The influence of climate change knowledge on consumer valuation of sustainably produced rice in Vietnam', *Sustainable Production and Consumption*, Vol. 31, No. 2, pp.1–12.

Del Giudice, M., Scuotto, V., Garcia-Perez, A. and Petruzzelli, A.M. (2019) 'Shifting wealth II in Chinese economy. The effect of the horizontal technology spillover for SMEs for international growth', *Technological Forecasting and Social Change*, Vol. 145, No. 3, pp.307–316.

Del-Rio, P., Romero-Jordán, D. and Peñasco, C. (2017) 'Analysing firm-specific and type-specific determinants of eco-innovation', *Technological and Economic Development of Economy*, Vol. 23, No. 2, pp.270–295.

Ezell, J.M., Walters, S.M., Olson, B., Kaur, A., Jenkins, W.D., Schneider, J. and Pho, M.T. (2022) 'You're friends until everybody runs out of dope': a framework for understanding tie meaning, purpose, and value in social networks', *Social Networks*, Vol. 71, No. 2, pp.115–130.

Fardogianni, E., Andrea, V., Karasmanaki, E., Arabatzis, G. and Tsantopoulos, G. (2022) 'Sustainable development and the response of the local community to gold mining: the case of Thrace, Greece'', *International Journal of Sustainable Agricultural Management and Informatics*, Vol. 8, No. 2, pp.156–178.

Fernando, Y., Jabbour, C.J.C. and Wah, W.X. (2019) 'Pursuing green growth in technology firms through the connections between environmental innovation and sustainable business performance: does service capability matter?', *Resources, Conservation and Recycling*, Vol. 141, No. 3, pp.8–20.

Fornell, C. and Larcker, D.F. (1981) 'Evaluating structural equation models with unobservable variables and measurement error', *Journal of Marketing Research*, Vol. 18, No. 1, pp.39-50.

Fransson, N. and Gärling, T. (1999) 'Environmental concern: Conceptual definitions, measurement methods, and research findings', *Journal of Environmental Psychology*, Vol. 19, No. 4, pp.369–382.

Galdeano-Gómez, E., Aznar-Sánchez, J.A. and Pérez-Mesa, J.C. (2013) 'Sustainability dimensions related to agricultural-based development: the experience of 50 years of intensive farming in Almería (Spain)', *International Journal of Agricultural Sustainability*, Vol. 11, No. 2, pp.125–143.

Goring, C.A.I. (2020) 'The economic impact of sustainable agriculture on the agricultural chemical industry'', *In Sustainable Agricultural Systems*, pp.495–503, CRC Press, Florida, USA.

Gou, F. and Wu, J. (2022) 'Triad link prediction method based on the evolutionary analysis with IoT in opportunistic social networks', *Computer Communications*, Vol. 181, No. 1, pp.143–155.

Hair, J.F., Ortinau, D.J. and Harrison, D.E. (2010) *Essentials of Marketing Research,* Vol. 2, McGraw-Hill/Irwin, New York, NY.

Halevy, A., Canton-Ferrer, C., Ma, H., Ozertem, U., Pantel, P., Saeidi, M., ... and Stoyanov, V. (2022) 'Preserving integrity in online social networks', *Communications of the ACM*, Vol. 65, No. 2, pp.92–98.

He, Y., Cheng, X., Wang, F. and Cheng, Y. (2020) 'Spatial correlation of China's agricultural greenhouse gas emissions: a technology spillover perspective', *Natural Hazards*, Vol. 104, No. 3, pp.2561–2590.

Hillestad, T., Xie, C. and Haugland, S.A. (2010) 'Innovative corporate social responsibility: the founder's role in creating a trustworthy corporate brand through 'green innovation'', *Journal of Product and Brand Management*, Vol. 19, No. 6, pp.440–451.

Ismael, M., Srouji, F. and Boutabba, M.A. (2018) 'Agricultural technologies and carbon emissions: evidence from Jordanian economy', *Environmental Science and Pollution Research*, Vol. 25, No. 11, pp.10867–10877.

Jin, H., Abu-Raya, Y.S. and Haick, H. (2017a) 'Advanced materials for health monitoring with skin-based wearable devices', *Advanced Healthcare Materials*, Vol. 6, No. 11, p.1700024.

Jin, N.P., Line, N.D. and Lee, S.M. (2017b) 'The health conscious restaurant consumer: understanding the experiential and behavioral effects of health concern', *International Journal of Contemporary Hospitality Management*, Vol. 29, No. 8, pp.2103–2120.

Jones, B.C., Little, A.C., Boothroyd, L., DeBruine, L.M., Feinberg, D.R., Smith, M.L. and Perrett, D.I. (2005) 'Commitment to relationships and preferences for femininity and apparent health in faces are strongest on days of the menstrual cycle when progesterone level is high', *Hormones and Behavior*, Vol. 48, No. 3, pp.283–290.

Kemp, R. and Foxon, T. (2007) 'Typology of eco-innovation', *Project Paper: Measuring Eco-Innovation*, Vol. 5, No. 1, pp.10–23.

Kountios, G. (2022) 'The role of agricultural consultants and precision agriculture in the adoption of good agricultural practices and sustainable water management', *International Journal of Sustainable Agricultural Management and Informatics*, Vol. 8, No. 2, pp.144–155.

Lee, S.M., Rha, J.S., Choi, D. and Noh, Y. (2013) 'Pressures affecting green supply chain performance', *Management Decision*, Vol. 51, No. 8, pp.1753–1768.

Lemgruber, L.S., Maioli, V., Latawiec, A.E., Solórzano, A., Moraes, L.F., Lino, E.D. and Strassburg, B.B. (2021) 'Socioeconomic impacts of urban restoration in the Atlantic Forest, Brazil', *Urban Forestry & Urban Greening*, Vol. 61, No. 3, p.127271.

Li, B., Ding, J., Wang, J., Zhang, B. and Zhang, L. (2021) 'Key factors affecting the adoption willingness, behavior, and willingness-behavior consistency of farmers regarding photovoltaic agriculture in China', *Energy Policy*, Vol. 149, No. 2, p.112101.

Liu, K., Li, K., Peng, Q. and Zhang, C. (2019a) 'A brief review on key technologies in the battery management system of electric vehicles', *Frontiers of Mechanical Engineering*, Vol. 14, No. 1, pp.47–64.

Liu, Z., Jiang, Z., Yan, M. and Wang, X. (2019b) 'Recent progress of BODIPY dyes with aggregation-induced emission', *Frontiers in Chemistry*, Vol. 7, No. 6, pp.712–131/

Liu, R., Yu, C., Jiang, J., Huang, Z. and Jiang, Y. (2020) 'Farmer differentiation, generational differences and farmers' behaviors to withdraw from rural homesteads: evidence from Chengdu, China', *Habitat International*, Vol. 103, No. 5, p.102231.

Malhotra, N.K. and Dash, S. (2016) *Marketing Research,* 7th ed., Pearson Education Ltd., New Delhi.

Muratore, I. (2008) 'Teenagers, blogs and socialization: a case study of young French bloggers', *Young Consumers*, Vol. 9, No. 2, pp.131–142.

Musa, S.F.P.D. and Basir, K.H. (2021) 'Covid-19 and food security in Southeast Asia', *International Journal of Sustainable Agricultural Management and Informatics*, Vol. 7, No. 2, pp.90–110.

Ngoc, V.B., Hung, N.M. and Pham, P.T. (2021) 'Agricultural restructure policy in Vietnam and practical application for sustainable development in agriculture', *Journal of Nanomaterials*, Vol. 6, No. 1, pp.19–34.

Organisation for Economic Co-operation and Development (OECD) (2010) *Education at a Glance 2010: OECD Indicators*, Paris.

Osterhus, T.L. (1997) 'Pro-social consumer influence strategies: when and how do they work?', *Journal of Marketing*, Vol. 61, No. 4, pp.16–29.

Peng, B., Chen, H., Elahi, E. and Wei, G. (2020) 'Study on the spatial differentiation of environmental governance performance of Yangtze river urban agglomeration in Jiangsu province of China', *Land Use Policy*, Vol. 99, No. 4, p.105063.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y. and Podsakoff, N.P. (2003) 'Common method biases in behavioral research: a critical review of the literature and recommended remedies', *Journal of Applied Psychology*, Vol. 88, No. 5, p.879.

Saunila, M., Ukko, J., Rantala, T., Nasiri, M. and Rantanen, H. (2020) 'Preceding operational capabilities as antecedents for productivity and innovation performance', *Journal of Business Economics*, Vol. 90, No. 4, pp.537–561.

Shahzad, M., Qu, Y., Javed, S.A., Zafar, A.U. and Rehman, S.U. (2020) 'Relation of environment sustainability to CSR and green innovation: a case of Pakistani manufacturing industry', *Journal of Cleaner Production*, Vol. 253, No. 3, p.119938.

Sharma, N. and Singhvi, R. (2017) 'Effects of chemical fertilizers and pesticides on human health and environment: a review', *International Journal of Agriculture, Environment and Biotechnology*, Vol. 10, No. 6, pp.675–680.

Shaw, J.L., Clarke, L.J., Wedderburn, S.D., Barnes, T.C., Weyrich, L.S. and Cooper, A. (2016) 'Comparison of environmental DNA metabarcoding and conventional fish survey methods in a river system', *Biological Conservation*, Vol. 197, pp.131–138.

Singh, S.K., Del Giudice, M., Chierici, R. and Graziano, D. (2020) 'Green innovation and environmental performance: the role of green transformational leadership and green human resource management', *Technological Forecasting and Social Change*, Vol. 150, No. 1, p.119762.

Sridhar Balasubramanian, V.M. (2001) 'The economic leverage of the virtual community', *International Journal of Electronic Commerce*, Vol. 5, No. 3, pp.103–138.

Sun, X. and Wang, J. (2021) 'Research on the impact of environmental regulation on agricultural green innovation', In *IOP Conference Series: Earth and Environmental Science*, July, Vol. 829, No. 1, p.12013, IOP Publishing.

Symeonaki, E.G., Arvanitis, K.G. and Piromalis, D.D. (2019) 'Current trends and challenges in the deployment of IoT technologies for climate smart facility agriculture', *International Journal of Sustainable Agricultural Management and Informatics*, Vol. 5, Nos. 2–3, pp.181–200.

Tagarakis, A.C., Tsotsolas, N., Kateris, D., Koidis, C., Koutsouraki, E. and Bochtis, D. (2022) 'The concept for an integrated IoT-based traceability platform', *International Journal of Sustainable Agricultural Management and Informatics*, Vol. 8, No. 1, pp.25–39.

Tantayanubutr, M. and Panjakajornsak, V. (2017) 'Impact of green innovation on the sustainable performance of Thai food industry', *Business and Economic Horizons* (BEH), Vol. 13, Nos. 1232–2017–2416, pp.192–209.

Wang, C.H. (2019) 'How organizational green culture influences green performance and competitive advantage: the mediating role of green innovation', *Journal of Manufacturing Technology Management*, Vol. 30, No. 4, pp.666–683.

Wang, N., Bao-Cun, L. and Yue-Bing, S. (2020) ‘Problems in the agricultural environment of China and innovation of future science and technology’, *Journal of Agriculture Resources and Environment*, Vol. 37, No. 1, p.1.

Wang, S. (2015) *Research on Technology Spillover Effects on Agricultural Productivity in China*, Thesis, China.

Xiong, H., Dalhaus, T., Wang, P. and Huang, J. (2020) ‘Blockchain technology for agriculture: applications and rationale’, *Frontiers in Blockchain*, Vol. 3, No. 7, pp33–45.

Yang, M.G. (2013) *Developing a Focal Firm’s Sustainable Supply Chain Framework: Drivers, Orientation, Practices and Performance Outcomes,* The University of Toledo, USA.

Yu, S., Ali, J., Zhou, S., Ren, G., Xie, H., Xu, J., ... and Zhang, Q. (2022) ‘From green super rice to green agriculture: Reaping the promise of functional genomics research’, *Molecular Plant*, Vol. 15, No. 1, pp.9–26.

Zhang, Y., Sun, J., Yang, Z. and Wang, Y. (2020) ‘Critical success factors of green innovation: Technology, organization and environment readiness’, *Journal of Cleaner Production*, Vol. 264, No. 5, p.121701.

Zhu, X., Yuan, X., Zhang, Y., Liu, H., Wang, J. and Sun, B. (2022) ‘The global concern of food security during the COVID-19 pandemic: Impacts and perspectives on food security’, *Food Chemistry*, Vol. 370, No. 2, p.130830.