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Impact of Green Technology Adoption on Agriculture Performance: Green Development Behavior Mediation and AI Norms Moderation

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This study investigates what factors stimulate the use of green production technologies in the agricultural sector of Saudi Arabia, drawing attention to its contribution to the factors of green development behavior, subjective norms towards AI, and environmental sustainability concerns to enhance agricultural performance. A quantitative cross-sectional design was applied to the study wherein data gathering was made possible with a sample of 239 Saudi farmers and other stakeholders in agriculture. Structural Equation Modeling (SEM) through the application of Stata was used for explaining the given relationships: between agricultural technology adoption intention, green development behavior, subjective norms, perceived environmental sustainability concern, and agricultural performance. All of these measurement scales were adapted from previous reliable research sources. Findings of the study indicated that adoption of green production technology impacts agricultural performance. This study identified green development behavior as a key mediator. Subjective norms toward AI, while environmental sustainability concerns moderated relationships within this model. In general, the importance of social and environmental factors in shaping adoption intentions and agriculture outcomes was underlined. This paper extends the current literature on sustainable agriculture practices by exploring the unique factors driving the adoption of green technology in the farm-level context of Saudi Arabia. It finds there to be practical implications for policymakers on how to encourage sustainability in agriculture and on helping build social norms and raise environmental awareness among farmers to adopt green technology more effectively.

1. Introduction

The adoption of green technology in agriculture is crucially important for sustainable practices which will address world food security, environmental issues, and climate change that have dominated global concerns. Green technologies in agriculture apply various practices, tools, and innovations aimed at reducing the ecological footprint of farming activities, though still improving productivity and resilience under environmental stresses (Shang et al., 2024). The shrinking arable land, unstable climatic circumstances, and continuously rising global populace are among the factors boosting the need for sustainable production systems for food, whilst posing stiff challenges to this modern sector of agriculture (Chen et al., 2024). Therefore, the adoption of green technology is increasingly accepted as the transformational element in efficiently utilizing resources for reduced emissions and minimal wastage to meet these goals (Ha, 2024). The introduction of precision farming, renewable energy integration, organic farming, and proper soil management improves productivity and ecological balance, as advanced by Lin et al. (2024).

The successful integration of green technology in agricultural systems depends on the awareness level of farmers, level of technological knowledge, the environment, and institutional factors as highlighted by (Nasiri et al., 2024). The researchers have stated that knowledge of these factors is essential in developing policies and programs to influence farmers to adopt sustainable practices (Santoso & Hastuti, 2024). In this context, green production technology, like sustainable soil management, crop rotation, and eco-friendly pest control, requires changes in the traditional practices adopted by the farmers, which could pose financial, technical, and knowledge-based problems for the farmers (Arhin et al., 2024). As evident, the implementation of such innovations has been proven to be increasing agricultural productivity and minimizing the environmental footprint simultaneously that it is an essential ingredient for sustainable development in agricultural circles (Erokhin et al., 2024). However, the majority of the farming communities are reluctant to apply green technologies because they sound too complex, costly and are not sure of what results such technologies would guarantee them (Ma et al., 2024). The current study examines factors that influence green technology adoption in agriculture and places much emphasis on behavioral, social, and environmental factors shaping intentions to adopt, with a subsequent influence on agricultural outcome performance.

Empirical research on the adoption of green technology in agriculture brings forth diversified factors affecting choices and outcomes in agriculture (Tripathi & Trigunait, 2024). Studies often reveal that farmers' behavioral intention in adopting the green technology is motivated by awareness of environmental issues, perceived ease of use, and the perceived benefits of the technology (Shehawy, Khan, & Madkhali, 2024). For instance, according to the most recent study by Wilson and Thomas, it was realized that farmers with greater environmental awareness adopted more eco-friendly practices, such as organic farming, renewable energy, and soil conservation (Chowdhury et al., 2025). More than that, many researchers emphasize the factor of perceived usefulness and ease of use since farmers are more likely to adopt useful and easy-to-use technologies (Zhao et al., 2025). TAM is widely used in such research to identify determinants of acceptance and adoption of green agricultural technologies. Findings are that perceived ease of use and perceived usefulness are strong determinants of adoption, respectively (Jafar et al., 2024).

However, while personal and perceptual factors are complemented by the subjective norms, which is social in nature and will have a tremendous influence upon the adoption intention of the farmers, according to research conducted by Rakibe (2024), perception of social influences or even peer, agricultural cooperative or community leader encouragement can move the intention of farmers for sustainable practices (Shang et al., 2024). Besides, environmental sustainability issues have been highlighted through extensive research, and evidence points to the fact that in instances where the value placed on long-run ecological stability surpasses that on short-run benefits, the greater would be the probability of taking on green production technologies for farming (Bhujel & Joshi, 2023). Lastly, an important aspect recently addressed concerns with the role of a green development behavior in filling in the gap between an intention to take on green technology adoption and agricultural performance (Keykhosravi, Dehyouri, & Mirdamadi, 2023). Empirical evidence has it that when green development behaviors such as eco-friendly planting and harvesting have been practiced among the farmers, they gain higher crop yield and environmental benefit.

While green technology adoption in agriculture literature is numerous, different very significant gaps remain to discuss the complex interplays and relationships between behavioral intention about individuals, social norms, considerations of environmental issues, and agricultural yields (Timpanaro et al., 2023). Most of the research works have mainly been concerned with the individual factors affecting green technology adoption, like perceived ease of use and perceived usefulness, without investigating how the factors might interact to collectively affect overall agricultural performance (Nordin et al., 2023). However, much research still remains to be conducted about how this particular set of norms and the more general environmental concern influences the farmer's adoption decision (Wang, Zhang, & Zhang, 2023). A common practice in the extant literature is the handling of subjective norms as a distinct variable, thereby disregarding its moderating role in determining the effect that the green technology adoption intention has on agricultural performance (Bhatti & Juhari, 2023). This gap calls for studies that take into account the dynamic and interactive nature of these factors.

The second understudied mediating role is the one of green development behavior between green technology

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adoption intention and agricultural outcome effects, according to (Al-Sharafi et al., 2023). Most studies focus more on the direct impact that an adoption intention has on performance, without considering whether or not actively engaging with green behaviors may amplify that effect (Gao et al., 2022). A further area of related under-research is the moderating role of environmental sustainability concern which can strengthen the linking impact between adoption intention and agricultural performance through the realization of long-term benefits of using adopting green technology. Addressing these gaps would be crucial in developing a more nuanced understanding of the variables and pathways that influence green technology adoption in agriculture, thus facilitating the design of targeted interventions and policies to promote sustainable practices in the sector (Savari, Sheheytavi, & Amghani, 2023).

The relationships between green technology adoption intention, green development behavior, and agricultural performance can be understood through various behavioral and environmental theories (Li, Qiao, & Yao, 2023). According to Suroso, Tandra, & Haryono (2023), the Theory of Planned Behavior has relevance to the present context as it postulated that attitudes, subjective norms, and perceived behavioral control determine a person's behavior intentions. TPB is adopted in the present research as a guiding theory as it can measure the effects of farmers' attitudes toward green technology that is combined with subjective norms on adoption intention. TAM has also been used in determining whether the perceived ease of use and the perceived usefulness play a role in the adoption of green production technology by farmers. The approach incorporates elements from TPB as well as TAM that will be holistic in conclusions reached (Joo & Hwang, 2023).

According to Social Cognitive Theory, people learn and perform behavior by observing others and through the evaluation of the potential consequences of that behavior (Dong, Wang, & Han, 2022). Using SCT, it is hypothesized that green adopting farmers would influence not only their own outcomes but also become role models in their communities, thereby potentially improving agricultural performance. The study is anchored on the environmental sustainability framework, that accounts for long-run ecological effects in decisions with regard to the adoption of technology. The research will attempt to empirically test these theoretical relationships and determine how behavioural intentions, green development behavior, as well as social and environmental factors may converge to enhance agricultural performance. The findings from this research should fill the gaps of existing research and, at the same time, provide actionable insights for policy makers and practitioners looking for avenues of how to advance sustainable agricultural practices.

1.1 Objectives

- To assess the intention of farmers in Saudi Arabia to adopt agricultural green production technologies.
- To evaluate the impact of this adoption on agricultural performance.
- To analyze the mediating role of green development behavior in this relationship.
- To examine how subject norms towards AI and perceived environmental sustainability concerns influence these dynamics.

2. Literature Review

There has been much hype surrounding green technology adoption in agriculture as it emerges as the sustainable means through which productivity gains can be enhanced without harming the environment (Sarkar et al., 2022). Evidence shows that green technologies, such as precision farming, the use of renewable energy, organic inputs, and water-efficient systems, are those that benefit yield improvement and environmental sustainability, respectively (Yang, Zhou, & Deng, 2022). Precision agriculture is, for instance, a data-driven strategy that maximizes resource use. It has reduced dependency on overuse of fertilizers and pesticides, therefore damaging the soil and water ecosystems (Shariff et al., 2022). There is proof that irrigation and agricultural mechanisations with the incorporation of renewable energy sources by the usage of solar systems and energy-efficient agricultural machineries will cut down carbon footprints and assure the timely availability of resources in the countryside (Rathakrishnan et al., 2022). It also suggests that organic fertilizers tend to replace chemicals more in order to enhance soil health and fertility over time and thus supports crop growth (Rathakrishnan et al., 2022). These green technologies, according to the scholars, help farmers achieve higher yields as they attempt to adjust to climate change-considered to be of prime importance in regions prone to drought or temperature variability (Neves, Oliveira, & Santini, 2022).

However, there are many challenges ahead in the implementation of this green technology in agriculture, such as economic barriers, knowledge gaps about technologies, and minimal infrastructure (Cao et al., 2022). For example, from the studies, it is indicated that a small-scale farmer, mainly in the developing regions, finds it difficult to pay the initial costs incurred in applying such technologies like high-tech machinery, sensors, and renewable energy systems (Chi, 2022). It has also been reported that farmers lack enough training and support, thereby negating their capabilities to utilize and maintain green technology properly towards best impact in agricultural productivity improvement (Moons et al., 2022). Most of the rural areas are poorly equipped infrastructures on renewable sources of energy and precision agriculture equipment. However, government subsidies, agricultural extension services, and partnerships with private technology firms have been recognized as essential facilitators in this regard, and allowing farmers to gradually increase their operations with green technologies (Shang et al., 2024). Increasing agricultural resilience and productivity, by greener methods, is promised even amid increasing environmental pressures (Ha, 2024).

2.1 Theoretical Foundation

This research thus bases its hypotheses on the Theory of Planned Behavior (TPB) and the Technology-Organization-Environment (TOE) Framework, from which a comprehensive understanding is derived regarding the adoption of green technologies in agriculture (Nasiri et al., 2024). The TPB postulates that one's behavior is influenced through attitudes, subjective norms, and perceived control over behavior (Arhin et al., 2024). Applied here, TPB suggests that the attitude towards adopting green technology in combination with subjective norms with regard to AI and environmental concerns could energize the behavior of sustainable agriculture (Ma, Liu, & Zhang, 2024). This theory supports the idea of dual persuaders at the micro-and macro levels of influence that can drive the adoption intentions and subsequent behavior of farmers. The TOE framework contextualizes this adoption further into the broader organizational and environmental environment within which agriculture is carried out. According to Shehawy et al. (2024), the TOE framework emphasizes that technological adoption depends on organizational readiness, technological suitability, and environmental conditions. In agriculture, this framework underlines that green technology adoption is not merely an individual decision but is influenced by external factors such as environmental sustainability concerns and social norms towards innovation (Zhao et al., 2025). Such theoretical approaches collectively provide support for complex interdependencies between adoption intentions and agricultural behavior and performance, indicating that such hypotheses are useful for the pursuit of sustainable agriculture (Rakibe, 2024).

2.2 Hypothesis Development

Agricultural green production technology adoption intention is the willingness or intent of farmers and agricultural stakeholders to adopt green production technologies (Bhujel & Joshi, 2023). These are environmentally friendly methods, practices, and tools meant to improve agricultural productivity in a sustainable manner. Performance in agriculture generally means effectiveness and productivity in undertaking agricultural activities, most commonly measured through the yield quantity, quality of produce, and efficiency in resource use, taking into account the least amount of adverse environmental impact (Nordin et al., 2023). Empirical studies in the area of sustainable agriculture show that the use of green technologies in production increases its productivity and its resilience to environmental stressors (Bhatti & Juhari, 2023). These studies show that farmers who use these technologies, such as precision irrigation, organic fertilizers, and renewable energy sources, obtain better crop yields and low operational costs with reduced ecological footprints (Gao et al., 2022). For instance, in the scientific literature, it has been shown that the use of precision irrigation systems can increase water-use efficiency by as much as 50% and, therefore, improve crop yields in water-scarce regions (Savari et al., 2023). Moreover, better soil quality and crop quality had been correlated with the application of organic fertilizers; after a long period, their agricultural performance would be improved (Suroso et al., 2023). Since results were positive coming from previous studies, it would not be farfetched to forecast that by choosing green production technologies for implementation, improved agriculture performance would likely follow (Joo & Hwang, 2023). Those farmers who have a strong intention to adopt these technologies are likely to implement practices that enhance productivity while reducing environmental degradation hence achieving more sustainable agriculture performance (Gao et al., 2022). Therefore this hypothesis presents the idea that intention to adopt green technologies is a key driver for improved performance in agriculture.

H1: Agricultural green production technology adoption intention significantly influences the agriculture performance.

Green development behavior in agriculture refers to activities and practices that are supportive of sustainable development goals, including pesticide use reduction, water conservation, and biodiversity enhancement in farming systems (Yang et al., 2022). Agriculture performance remains a measure of the productivity and ecological impact of these activities, including outputs such as yield, efficiency, and environmental preservation (Rathakrishnan et al., 2022). Research on agricultural sustainable development practices shows that green behavior is positively related to both productivity and environmental resilience (Neves et al., 2022). For example, studies have proven that less chemical pesticide usage reduces the pollution of soil and water, resulting in better crop health in the long run and improved yield stability (Chi, 2022). In addition to crop rotation and organic farming, crop yield and resistance towards pests will be improved through better soil structure and content. Beyond that, studies show that farmers experiencing better resource efficiency also show enhanced performance in resource-constrained environments (Chen et al., 2024). Green development behaviors, therefore, will be hypothesized to positively affect the performance of agriculture. When farmers practice sustainability, they help enhance both short-term yields and long-term soil health, thereby increasing productivity overtime (Lin et al., 2024). Therefore, this hypothesis is very exciting in terms of researching whether adopting green development behaviors raises agricultural performance dramatically.

H2: Green development behavior significantly influences the agriculture performance.

It has been claimed that green development behavior will mediate between the technology adoption intention toward green production and agriculture performance in this context (Santoso & Hastuti, 2024). As mentioned earlier, the green development behavior is all about adopting sustainability-enhancing activities that enhance productivity for the long term, and the readiness to adopt technologies is related to the adoption intention toward green technologies (Erokhin et al., 2024). Previous research has confirmed that there is a necessity of intention in using green technology, but the effect appears only when the activities become green. It can be easily concluded that what differentiate the outcomes from simple intention might actually be the activity culminating in specific green behavior, some like organic fertilizer and others, precision-farmed crops (Tripathi & Trigunait, 2024). For example, Chowdhury et al. (2025) argued that actual practice of the adoption intention of sustainable green technologies is essential in realizing important yield and efficiency improvements. In this regard, by utilizing the insights gained above, this hypothesis proposes that green development behavior could mediate the relationship between adoption intention and agricultural performance (Jafar et al., 2024). While the intention to take up green technologies is very crucial, the implementing of green development behaviors holds real performance benefits (Shang, Wu, & Schroeder, 2023). It thus makes green development behavior be an important process through which the intention to adopt technology in the agricultural sector is inextricably linked to outcomes, with the status as a mediator in this relationship underlined.

H3: Green development behavior significantly mediates the relationship of agricultural green production technology adoption intention and the agriculture performance.

Subjective norms to AI are the perceived social pressure or influence which makes an individual adopt AI technologies in practice that in turn boost efficiency and decision-making in agriculture (Keykhosravi et al., 2023). This subjective norm may serve as a moderating variable that influences the green production technology adoption intention-agriculture performance strength of the relationship (Timpanaro et al., 2023). According to research, subjective norms are one of the integral factors in a decision of adoption of new technology, or at least promise having an AI (Wang et al., 2023). Provided that he perceives that his social environment supports adopting AI, then his intention to use technology is increased, and subsequently, the expected outcome for his performance is enhanced (Al-Sharafi et al., 2023). Social facilitation exists even with AI usage in agriculture, for example peer assistance among farmers or community efforts that have been set up to allow entry of high-order tools, resulting in increased productivity and sustainability. Base on these empirical supports, the hypothesis of subjective norms on AI is that subjective norms about AI moderate the relationship between the intention to adopt green production technology and agriculture performance. According to Li et al. (2023), if farmers believe that there is a high social support for AI adoption, they might implement green technologies more effectively, enhancing agricultural outcomes. In such concerns, subjective norms toward AI may further strengthen the influence of adoption intention on performance.

H4: Subject norms towards AI significantly moderates the relationship of agricultural green production technology adoption intention and the agriculture performance.

This environmental sustainability perception is an expression of individual consciousness and concern regarding the ecological impacts of farming, which include soil erosion, water scarcity, and carbon emissions

(Dong et al., 2022). It can therefore be considered as a mediating variable in the extent through which adoption of green technology impacts agricultural performance (Shariff et al., 2022): Past research has indicated that those who are more environmentally conscious exhibit higher adaptation natures regarding sustainable technologies and practices (Sarkar et al., 2022). For instance, it is demonstrated that an increase in environmental knowledge for farmers have a positive influence on the intention of the adoption of sustainable practices. It will result in even more desirable consequences (Rathakrishnan et al., 2022). The environmentally aware farmer would give much importance to resource use efficiency and ecological impacts reduction with the support of sustainable productivity (Cao et al., 2022). According to the results, this hypothesis assumes that the perceived environmental sustainability concern moderates the relationship between the adoption intention of green technology and agricultural performance (Moons et al., 2022). Such high environmental concerns by farmers may result in greater commitment toward green technologies' successful implementation by making the intention fruitful in turning into good agricultural practices to improve agricultural performance (Ha, 2024). Perceived environmental sustainability concern is likely to reinforce the relationship between adoption intention and agricultural performance.

H5: Perceived environmental sustainability concern significantly moderates the relationship of agricultural green production technology adoption intention and the agriculture performance.

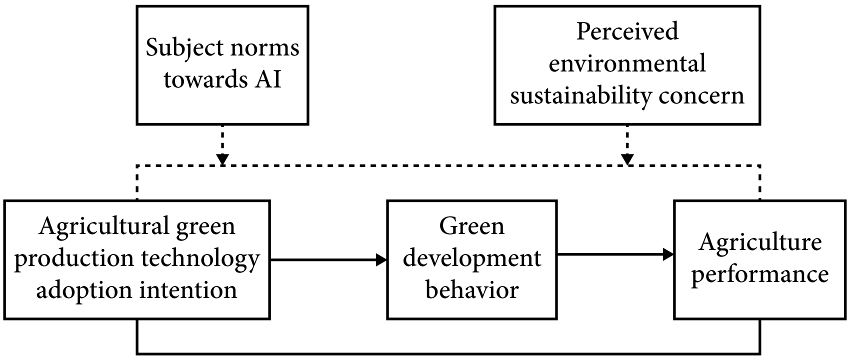

Figure 1: Research Model.

3. Methodology

This study aimed to identify the factors that influence the adoption of agricultural green production technologies by farmers and other agricultural stakeholders across various regions in Saudi Arabia. The quantitative research approach was a cross-sectional survey design. Data were collected from a representative sample of Saudi farmers. This method was chosen to facilitate the comprehensive collection of data pertaining to different regions and farming practices in Saudi Arabia to gain an understanding of the overall attitudes and conduct of the farmers towards green production technology. It targeted farmers actively involved in agricultural activities across many regions in Saudi Arabia. A total of 239 farmers were sampled purposively to represent different kinds of farmers with varied agricultural backgrounds, scales of operations, and experiences in the green agricultural practices. In earlier studies in this area, such a sample size was adequate and well within the range of minimum required cases in structural equation modeling analysis that usually needs a minimum of 200 cases to ensure the robustness of statistical power. A structured tool was administered in person to all participants to survey. The research assistants were trained and familiar with the local language and agriculture context so that participants could then respond accurately and thus minimize confusion.

3.1 Measures

All the scales applied in this study were borrowed from the existing literature to ensure validity and reliability of measurement. A multi-item scale was used to measure each of the constructs, and all the responses were measured using a Likert-type scale with a range of 1 (strongly disagree) to 5 (strongly agree). The survey mainly measured the following major constructs: Agricultural Green Production Technology Adoption Intention, Green Development Behavior, Subjective Norms towards AI, Perceived Environmental Sustainability Concern, and Agricultural Performance. The items of each scale had been taken from previous studies that had shown robust psychometric properties, including very high internal consistency and validity coefficients, in comparable contexts to the research.

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Table 1: Measures of the Study.

Agricultural green production technology adoption intention	Three	(Yu et al., 2024)
Green development behavior	Thirteen	(Li et al., 2023)
Subjective norms towards AI	Five	(Ahmed, Ekman, & Lind, 2024)
Perceived environmental sustainability concern	Five	(Ratilla, Dey, & Chovancová, 2024)
Agriculture Performance	Three	(Yaghoubi Farani et al., 2024)

3.2 Data Analysis

The data were analyzed using the Structural Equation Modeling (SEM) method in Stata, which was adopted due to its robustness in handling complex multivariate relationships and suitability for hypothesis testing. SEM is appropriate for this study as it enables one to simultaneously test several relationships among latent constructs and observed variables with a holistic view of the theoretical model. The analysis of data was done in two stages: a confirmatory factor analysis was performed to test the validity of the measurement model. All constructs were evaluated in terms of reliability and validity. In this regard, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) were used as threshold values for satisfactory reliability and convergent validity at 0.7 for Cronbach's alpha and CR and 0.5 for AVE. After applying the CFA, structural model was tested to validate the assumed relationships between the constructs. Paths coefficients were checked for the power and significance of each hypothesized link by applying bootstrapping technique for the estimation of the standard errors and confidence interval of each path coefficient. The fit of the Model was evaluated by applying Standard goodness-of-fit indices with the Chi-square test, standardized Root Mean Square Residual-SRMR, and several other relevant statistics. The level of significance at which each hypothesis was tested is 0.05. The direct, indirect, and moderating effects, as hypothesized in the model, were determined. Findings from this research are valuable in understanding what factors influence the adoption of green production technologies by Saudi Arabian farmers and how social and environmental considerations are important factors in promoting sustainable agricultural practices. This methodological approach comes with rigorous testing of theory through robust data collection and advanced statistical analysis techniques to give valid results.

4. Results

Table 2: Reliability and Validity of All Variables Measured Cronbach's Alpha Composite Reliability AVE The study measured the reliability and validity of each variable. For the reliability of each variable, Cronbach's Alpha and Composite Reliability are used. According to Cronbach's Alpha and Composite Reliability, all the variables have good internal consistency as their values are greater than the commonly accepted value of 0.70. For instance, "Agriculture Performance" has the maximum Cronbach's Alpha score at 0.862 with high reliability. Agriculture Green Production Technology Adoption Intention has slightly lower alpha value but also acceptable with alpha value of 0.762.

Table 2: Variables Reliability and Validity.

Variable	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Agricultural green production technology adoption intention	0.762	0.724	0.599
Green development behavior	0.831	0.850	0.543
Subjective norms towards AI	0.847	0.793	0.525
Perceived environmental sustainability concern	0.835	0.823	0.576
Agriculture Performance	0.862	0.837	0.612

In addition, Composite Reliability of all variables exceeds the minimum accepted standard of 0.70, hence every single construct reliably measured the concept for which they were proposed. From here, AVE values proved valid for convergent validity when all the variables get to values higher than the acceptable one of 0.50, thus indicating over 50 percent of their corresponding variance in these variables were explained by their related indictors. "Agriculture Performance" tops AVE once more, where it got 0.612 while "Green Development Behavior" has only validity at 0.543. From this overall reliability and validity of measurement scales, it is proved that the variables are reliable and valid for further analyses.

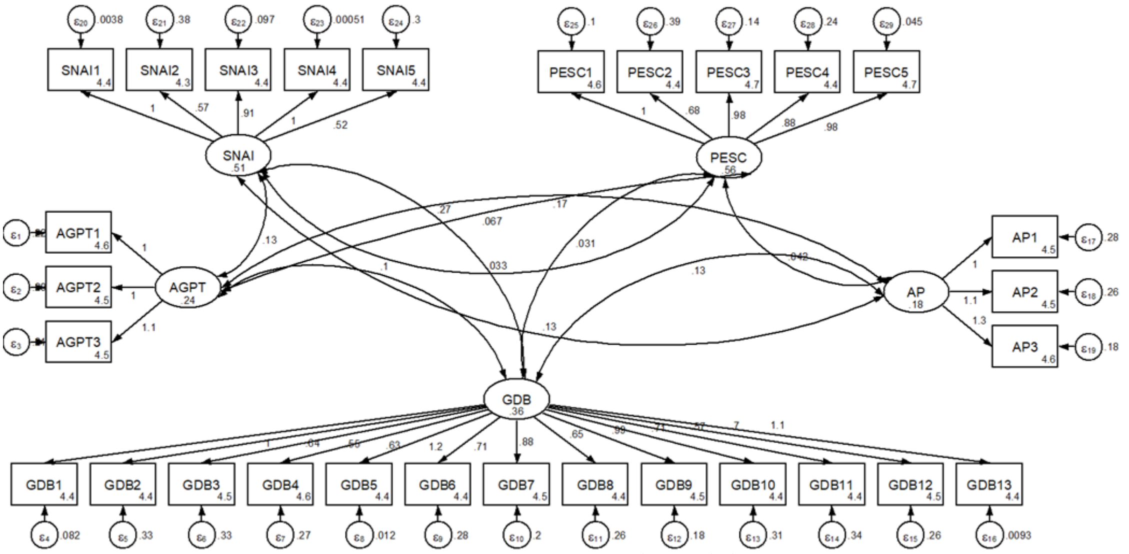

Figure 2: Estimated Model.

The standardized coefficients, standard errors, z-scores, and confidence intervals for each measurement item have been shown, which express the factor loadings and statistical significance of each item to its respective construct. All the indicators have high z-scores and p-values less than 0.05, which means each item significantly contributes to its respective construct. For example, the second indicator of "Agricultural Green Production Technology Adoption Intention" (AGPT2) has a coefficient of 0.743 with a z-score of 10.575, which reflects that the item makes a strong contribution to the overall construct. Similarly, the loadings of indicators under "Green Development Behavior" such as GDB13 are all strong, and GDB11 achieved 0.889 with a z-score of 12.467. These indicate that there is a good capture of the construct. Overall, the CFA confirmed each item in the measurement model fitted well with its respective latent variable, thus justifying the constructs' dimensionality and relevance in the research framework (see Table 3).

Table 3: Confirmatory Factor Analysis.

Measurement	OIM Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
AGPT1	1	(constrained)				
AGPT2	0.743	0.068	10.575	0.000	0.608	0.877
AGPT3	0.546	0.061	8.721	0.000	0.426	0.666
GDB1	1	(constrained)				
GDB2	0.869	0.080	10.662	0.000	0.713	0.830
GDB3	0.805	0.076	11.358	0.002	0.663	0.817
GDB4	0.568	0.066	9.465	0.005	0.473	0.780
GDB5	0.318	0.063	4.897	0.000	0.194	0.443
GDB6	0.846	0.080	11.940	0.002	0.697	0.859
GDB7	0.597	0.070	9.950	0.005	0.498	0.820
GDB8	0.594	0.063	9.189	0.000	0.470	0.718
GDB9	0.787	0.064	12.028	0.000	0.662	0.912
GDB10	0.705	0.082	8.350	0.000	0.544	0.866
GDB11	0.889	0.070	12.467	0.000	0.752	0.830
GDB12	0.806	0.064	11.757	0.000	0.681	0.745
GDB13	0.871	0.057	14.984	0.000	0.760	0.787
SNAI1	1	(constrained)				
SNAI2	0.779	0.064	11.256	0.000	0.653	0.904
SNAI3	0.606	0.063	8.927	0.000	0.482	0.729
SNAI4	0.732	0.069	13.751	0.000	0.688	0.885
SNAI5	0.776	0.064	11.384	0.000	0.651	0.901
SNAI6	0.753	0.064	10.935	0.000	0.626	0.879
PESC1	1	(constrained)				
PESC2	0.674	0.058	10.857	0.000	0.561	0.787
PESC3	0.785	0.065	11.347	0.000	0.658	0.912
PESC4	0.813	0.064	11.852	0.000	0.687	0.751
PESC5	0.804	0.063	11.918	0.000	0.681	0.928
AP1	1	(constrained)				
AP2	0.303	0.060	4.658	0.000	0.185	0.421
AP3	0.861	0.063	12.629	0.000	0.737	0.799

Table 4 presents fitness statistics by each measurement item used for the assessment of the construct, with values representing sample loads for each item from the original sample. Notice that most items have higher loadings on their appropriate constructs, especially for items like "Green Development Behavior" (GDB6=0.943), a strong representation of the same construct. Items for "Agricultural Green Production Technology Adoption Intention" all showed medium-to-high levels of fit. In loadings, both AGPT1 and AGPT2 scored relatively high with loads of 0.813 and 0.803. But at times, specific items' loads have somehow decreased - the example case in this respect would be for "Agriculture Performance" through the AP1 item wherein its loading only scores.570. Overall, the high loading values across the constructs suggest a general fit in terms of items representing fairly well the underlying theoretical construct and validating the constructs themselves.

Table 4: Measurement Items Fitness Statistics.

Variable	Indicator	Original Sample
Agricultural green production technology adoption intention	AGPT1	0.813
	AGPT2	0.803
	AGPT3	0.716
Green development behavior	GDB1	0.773
	GDB2	0.832
	GDB3	0.857
	GDB4	0.883
	GDB5	0.794
	GDB6	0.943
	GDB7	0.873
	GDB8	0.587
	GDB9	0.780
	GDB10	0.774
	GDB11	0.806
	GDB12	0.824
	GDB13	0.670
Subjective norms towards AI	SNAI1	0.648
	SNAI2	0.857
	SNAI3	0.883
	SNAI4	0.794
	SNAI5	0.801
	SNAI6	0.753
Perceived environmental sustainability concern	PESC1	0.880
	PESC2	0.830
	PESC3	0.854
	PESC4	0.769
	PESC5	0.582
Agriculture Performance	AP1	0.570
	AP2	0.603
	AP3	0.885

Table 5 Model Fit Statistics Chi-square Values and SRMR for Both Saturated and Estimated Models. All the values of SRMRs were within acceptable range with values at 0.052 saturated and 0.069 for the estimated. Both the likelihood ratio and the chi-square showed adequate fit for the model by its very low pvalues which approach zero. Hence, it is assured that the structure of the model fitted the data quite adequately. This good model fit indicates that the selected variables and model specifications were appropriate in representing the interconstruct relationships.

Table 5: Chi-square Fit Statistics.

Fit Statistic	Value	Description	Saturated Model	Estimated Model
SRMR			0.052	0.069
Likelihood ratio	13661.839	model vs. saturated		
p > chi2	0.000			
chi2_bs(2356)	12723.552	baseline vs. saturated		
p > chi2	0.001			

Table 6 gives R-Square for two important dependent variables. It shows the percentage of variance explained by the model. "Green Development Behavior" has an R-Square of 0.596, meaning that about 60% of its variance can be explained by the predictor variables in the model. In the same vein, "Agriculture Performance" reports an R-Square of 0.550 that means the model explains approximately 55% of its variance. These values therefore confirm the explanatory power and effectiveness of the model in predicting the outcomes of interest thereby validating the relevance and robustness of the hypothesized relationships.

Table 6: R-square statistics Model Goodness of Fit Statistics.

Variable	R Square
Green development behavior	0.596
Agriculture Performance	0.550

Table 7: Path Analysis Results: Description of the Relationships Among the Variables. All the path coefficients are statistically significant at the level of p-value less than 0.05. It means that all the hypothesized relationships are supported by very strong evidence. For instance, the coefficient for "Agricultural Green Production Technology Adoption Intention" with "Agriculture Performance" is 0.826, and it means the positive and substantial impact is quite obvious. Similarly, "Green Development Behavior" affects "Agriculture Performance" significantly, as is also evident from a coefficient of 0.853. Also, "Green Development Behavior" was also significant in mediation as its coefficient was 0.277, thereby confirming the mediation hypothesis of the model.

The moderation effects of "Subject Norms towards AI" and "Perceived Environmental Sustainability Concern" on the link between adoption intention and performance are also significant, suggesting that these variables enhance the primary relationships in the model. These results collectively establish the hypothesized relationships that green production technology adoption, development behavior, and subjective norms towards sustainability all considerably improve agricultural performance outcomes.

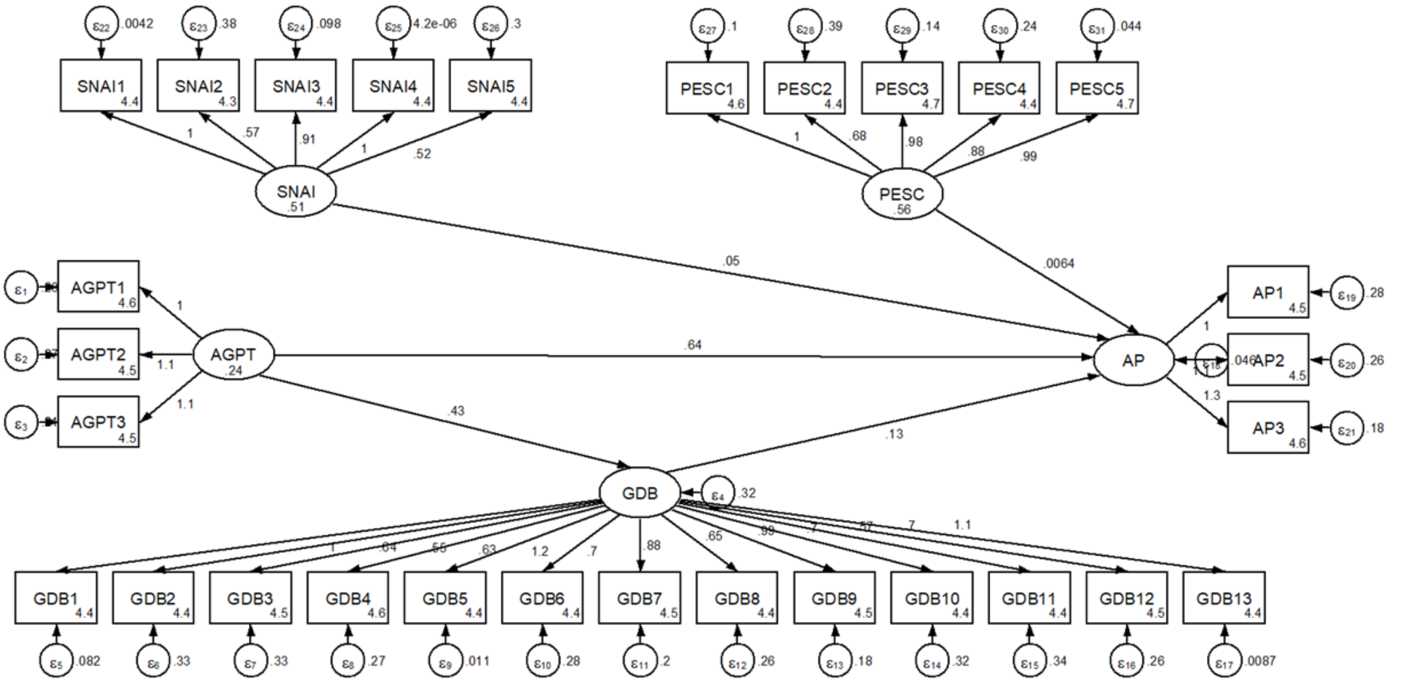

Figure 3: Structural Model for Path Analysis.

Table 7: Path Analysis.

	OIM Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Agricultural green production technology adoption intention significantly influences the agriculture performance.	0.826	0.063	12.238	0.000	0.703	0.763
Green development behavior significantly influences the agriculture performance.	0.853	0.062	12.827	0.000	0.732	0.788
Green development behavior significantly mediates the relationship of agricultural green production technology adoption intention and the agriculture performance.	0.277	0.359	3.485	0.000	0.392	0.747
Subject norms towards AI significantly moderates the relationship of agricultural green production technology adoption intention and the agriculture performance.	0.832	0.076	10.211	0.000	0.683	0.795
Perceived environmental sustainability concern significantly moderates the relationship of agricultural green production technology adoption intention and the agriculture performance.	0.358	0.115	6.759	0.000	0.483	0.762

5. Discussion

Amongst growing global pressures on environmental sustainability and resource conservation, modern agricultural research has emerged as an important concern in the adoption of green production technologies and sustainable practices in agriculture. This research contributes to the emerging literature by investigating how the intention to adopt green technology, green development behavior, and factors such as social norms and environmental concern impact agricultural performance. By analyzing such relationships through empirical analysis, this research reiterates the importance of sustainable behaviors and their roles as driving factors that influence productivity in a more environmentally conscious manner. A fact that all the hypotheses agreed on is the adoption of the practices and the significant role for internal motivations and social external circumstances, which is a multiplicity of strategies to effectively achieve higher performance in the agricultural sector with sustainability.

The first hypothesis, postulating that agriculture performance varies significantly with agriculture green production technology adoption intention, confirms the empirical study's conclusions. The more an individual accepts this hypothesis, the more it further enforces the idea that the strong intention to adopt green technologies indeed manifests into tangible productivity improvements. It has been shown from past literature that intention is more often the basis of behavior, especially when one talks about technology adoption in agriculture. Those with a strong adoption intent tend to adopt high adoption of the latest green technologies more vigorously. This can be, for example, in tools used for precision agriculture, equipment using renewable energy sources, and techniques on managing soil organically. Results of this study further validated the intentional behavior resulting in efficiency in resources utilization, yield quality, and minimization of impacts to the environment- all factors essential for the assessment of performance of an agricultural business. The current findings support the robust adoption intention-performance relationship, hence underlining the motivational dimension as a precursor to sustainable transformation in the agricultural sector (Arhin et al., 2024).

The second hypothesis was that green development behavior positively affects agriculture performance. In this study, empirical support was found for the same. The results indicate that the green development behavior with its activities such as minimal use of pesticides, water conservancy, and crop rotation practices positively contributes to agriculture performance. This practice is aligned with the literature to enhance long-term soil health, maximize resource use, and minimize pollution. Such sustainable agriculture practices have benefits for immediate productivity while also contributing to the durability of operations through the preservation of essential environmental resources (Shehawy et al., 2024). This study proves that green development behaviors that are thought to only gain environmental results are effective, positively influencing yields and efficiency in operation. Therefore, these environmental-conscious and responsible resource-using behaviors come out as the critical drivers of performance improvements in a sustainable manner. This evidence thus reveals that the large-scale adoption of green behavior has the potential to significantly raise individual and industry-wide agricultural outcomes.

The third hypothesis states that green development behavior acts as a mediator in the relationship between agricultural green production technology adoption intention and agriculture performance. This leads to light against the importance of behavioral translation towards the realization of adoption intentions in green technology. Findings of this research will show that intention starts the path to its adoption; it is through active green development behaviors (Rakibe, 2024). This mediating role of green development behavior therefore suggests that mere intention will not suffice to improve performance unless accompanied by concrete sustainable practices. In this regard, previous studies support this view as they opine that without the behavioral application of technology, its adoption will remain a passive concept with limited practical benefits. However, a mediation effect which is prevalent in this study suggests green development behaviors is the only functional link that exists in the gap between intention and performance outcome where most the promised performance gain of Green Technology relies upon its full implementation. There is indeed a call for motivational driver that would harmonize with doable action of behavior through work within agriculture sustainability.

This is where the acceptance of the third hypothesis, which claims that green development behavior significantly mediates the relationship between adopting intentions of agricultural green production technology and agriculture performance, proves interesting. The implication here is that green practices' adoption intention without consistent application cannot suffice for performance. This suggests that farmers' technology adoption is satisfied whenever their intention is translated through the enactment of water-conserving methods, organic crop management, and chemical application reduction. Overall, past research emphasized that the intention had to be translated into action because this is when someone would be expected to generate a sizeable productivity benefit (Timpanaro et al., 2023). In this respect, green development behavior is the operating feature of adoption intention. In this case, when intentions to adopt technology are paired with committed sustainable practices, it maximizes the benefits of sustainable technology. In so doing, the findings expand the literature to demonstrate that green development behaviors not only benefit in themselves but also are fundamental to realizing the full potential of green technology intentions in agriculture.

Subjective norms toward AI significantly moderate the relationship of agricultural green production technology adoption intention with agriculture performance as postulated in the fourth hypothesis. If this is accepted, then it means that social influence concerning AI acceptance does indeed affect how high or low the farm performance outcome from the adoptions of green technologies in agriculture would be. This moderating effect illustrates the idea that with social support or obligation toward AI and other modern technologies, farmers tend to translate intention into action. In this light, therefore, people may emulate actions regarded as acceptable according to perceived social expectations, more so in technology-influenced environments, according to postulations of the theory of social norms. This research reveals that subjective norms toward AI might intensify the impact of adoption intentions on performance in agriculture, further shedding light on the role of social influences as an external motivator for farmers to maximize exploitation of green technology. Perhaps the fostering of a positive social climate related to AI in agriculture would fortify the impact of effectiveness for strategies of green technology adoption.

Overall, the combined findings of the third and fourth hypotheses indicate that both behavioral and social factors are integral to converting the adoption intentions of green technology into performance improvements. It indicates that while green development behaviors operationalize the intentions of green technology adoption, subjective norms surrounding AI further empower farmers by fostering a supportive social context for such behaviors. Together, these conditions create an enabling environment to enhance agricultural productivity and sustainability. The significance of such findings lies in the integrated approach they promote: a strategy for improving agricultural performance needs to consider both individual commitment to sustainable practices and social support for technology adoption (Suroso et al., 2023). This interplay of mediating and moderating effects portrays a strong framework in advancing sustainable agriculture and further infers that holistic approaches encompassing both behavioral application and social influence are integral for the successful realization of the potential offered by green technology in agriculture.

Findings from this research depict that the relationship between adoption intentions for green technology is complex yet powerful with sustainable behaviors and contextual factors including social norms and environmental concerns. Each hypothesis verifies that the adoption of green technology alone does not make agriculture sustainable, but rather a need to grow a whole ecosystem of supporting behaviors and social influences. This study shows the meaning of green development behavior as both mediator and outcome and, further, subjective norms and concerns with environmental sustainability as moderator factors to move towards improving productivity without compromising integrity in an ecological context. These findings point the development of sustainable practices and can contribute to the conceptual knowledge regarding how individual- and society-level factors catalyze sustainable advancement for agricultural fields, thereby also facilitating the scope for related additional studies and practical field developments on agricultural sustainability issues.

5.1 Implications of the Study

The theoretical contributions of this research are significant in terms of widening the horizon on the factors determining the adoption of agricultural green production technology and its later consequences for agricultural performance. It brings concepts of green development behavior, subjective norms about AI, and perceived concern for environmental sustainability into its fold, making this insight into how those variables operate within the agriculture sector. This means that findings are on social and environmental influences on technology adoption in agriculture. The study further supports the relevance of social cognitive theory and environmental concern frameworks in the analysis of agricultural technology adoption. The richness in literature from this study, empirically testing the moderation of subjective norms and environmental sustainability concern, shows that agricultural practice is not only based on technological efficacy but also upon social perception and environmental motivations. Therefore, the research has offered a well-rounded theoretical model by integrating the dimensions of technological, behavioral, and environmental, giving a balance to form a basis for further studies on sustainable agriculture practices.

The kinds of results obtained have multifaceted implications in practice for policymakers, agricultural practitioners, and environmentalists to foster the implementation of sustainable agriculture practices. In short, by establishing the influence that green development behavior and concern with environmental sustainability have on adoption behavior regarding green agricultural technology, it means policy initiatives, while advocating technological solutions, would further highlight changes in behavior and raise awareness of the environment. These findings may be helpful to agricultural stakeholders in that they focus on training programs with environmental impact in respect to green technology and the creation of social marketing campaigns to reshape the subjective norms revolving around sustainable practices. The consideration of the mediating role of green development behavior could suggest that interventions that enhance it might make the positive impacts of the adoption of technology on agricultural performance more powerful. Therefore, this research shall act as a guide for some practical strategies which are brought into an alignment of productivity of agriculture with goals of sustainable development in offering steps toward an environmentally responsible sector.

5.2 Limitations and Future Research Directions

While this study offers much insight, it is not without limitations. For one, the cross-sectional design of the study prevents drawing causal inferences between variables because data were collected at only one point in time. Longitudinal studies might further discuss the dynamics of how green development behavior and technology adoption change over time, establishing a more dynamic perspective. Other than that, self-report data may also indicate the study's limitation, and the respondents may not report accurately, since the nature of social desirability prevails responses to be about behavior or intentions rather than what the actuality would be. Future studies should combine both self-reports and objective performance metrics when validating these relationships found in this paper. Because of the contextual cultural and geographical location within which this research was carried out, results may not generalize immediately into another region with contrasting agricultural practice and environmental policy. Further research in this model of cross-cultural comparisons could be carried out to verify whether the results are repeated in other settings, bringing a more global understanding toward sustainable agricultural practices.

Yet another possible route for future study would be to explore further mediating and moderating variables, which may contribute to an association between the intention of adopting technology and agricultural performance. For instance, considerations like economic incentives, accessibility of resources, or support programs by governments might explain the influence of further key factors, which shape green technology adoption in agriculture. Future research could expand in scope to include the roles of digital transformation and AI-based solutions in optimizing sustainable agriculture. As these technologies grow more sophisticated, further exploration of how AI intersects with the adoption of green technology as an entry point for new insight into how modern digital tools may complement sustainable development in agriculture would be useful to further work toward more holistic models of agricultural sustainability.

6. Conclusion

This research has made visible the fact that the three most significant contributors are: green development behavior, subjective norms toward AI, and perceived environmental sustainability concern. The results reflect the need to create an environment where sustainable behaviors are encouraged and the collective social responsibility toward environmental sustainability in agriculture is recognized. It presents holistic modelling of individual and social dimensions needed in adopting sustainable agricultural technology toward improving agricultural performance. Generally, such research has held very strong views regarding the need for social, environmental, and technological conditions in guaranteeing sustainable agriculture development. The results reveal that agricultural performance is much more than a result of the adoption of technology alone; rather, it reflects more complex social and environmental considerations. As agriculture drifts towards greener behavior, future policies and practices have to incorporate such multi-dimensional approaches, one which not only has to pay homage to technological innovation but sustainable behavioral and environmental objectives. This study opens the avenue for further investigation into the holistic frameworks that encourage sustainable agriculture and therefore support environmental conservation in the world.

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Appendix 1

Agricultural Green Production Technology Adoption Intention

1. My intention to adopt diversified crop rotation.
2. My intention to adopt organic farming.
3. My intention to adopt straw return to the field.

Green Development Behavior

1. Follow strict cleanliness requirements
2. Select and improve environmentally friendly equipment
3. Choose green building design
4. Actively build a green brand
5. Actively seek partners to achieve energy saving and emission reduction goals
6. Conduct environmental and energy audits of suppliers' internal management
7. Require suppliers to provide products that meet environmentally friendly design
8. Evaluate the environmentally friendly behavior of suppliers
9. Look at other companies' green technologies in the supply chain
10. Purchase environmentally friendly materials
11. Actively share energy-saving and emission reduction technologies with other companies in the supply chain
12. Choose suppliers who have passed third-party environmental management system certification
13. Actively communicate information about by-products between companies in the supply chain

Subject Norms Towards AI

1. I feel that my family encourages me to increasingly use digital tools on my farm.
2. I think my peers and other farmers I know increasingly rely on digital tools for dairy farm management.
3. On-farm advisers approve of the use of digital tools for my farm management.
4. When I think about investing in a digital tool, I investigate how other farmers' experiences of that specific tool is.
5. I believe that the accessibility of local service technicians affects my choice of digital tools.

Perceived Environmental Sustainability Concern

1. Respects the environment.
2. Concerned with the reduction of consumption of natural resource.
3. Recycling is well managed.
4. Inform guests of its environmental practices.
5. Consume environmentally friendly renewable energy.

Agriculture Performance

1. Increasing customer.
2. Increasing sale.
3. Increasing profit.

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