

## Article

# The Ecuadorian Banana Farms Managers' Perceptions: Innovation as A Driver of Environmental Sustainability Practices

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**Abstract:** This article aims to explore the perceptions of banana farms managers towards environmental sustainability practices through the impact of innovation, adoption of information systems, and training employees through a case study in the province of El Oro (Ecuador). Furthermore, the paper assesses how farmers' perceptions could guide public policy incentives. PLS-Structural Equation Modeling are used as the framework by which the constructs is represented within the model. The model explained 59% of the environmental sustainability practices of Ecuadorian banana farms. The results indicate that environmental sustainability practices were positively influenced mainly by training employees, innovation, and adoption of information systems. Additionally, both the adoption of information systems and training employees indirectly influenced sustainable practices through innovation as a mediator. We may conclude that in the Ecuadorian banana farms, changes in environmental practices are derived from innovation strategies as an axis of development of useful information and training employees in public policies.

**Keywords:** adoption of information systems; Ecuador; environmental sustainability practices; innovation; PLS-SEM; training employees



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## 1. Introduction

Agriculture is under strong pressure to tackle the second and twelfth sustainable development goals of hunger eradication and meet the global demand for food in an environmentally sustainable way [1]. Agricultural systems are considered a positive activity to meet global and local food needs and a negative source of impact on the environment, so emphasizing ecosystem services for human well-being is a must [2]. Research on sustainability from agro-food activities has been addressed since the 1960s under diverse viewpoints. The concept of sustainability from agro-food activities is composed of complex and link sets of dimensions. The human and local dimension of development is one of the pillars of the economic and business sustainability approach that helps policymakers value the relationship between the person and the territory [3]. With the advance of globalization and the greater integration of agricultural markets, the food-nutrition-agriculture nexus recognizes the differences between developed and developing countries [4] and an urgent implication is finding the most appropriate metrics for their evaluation [5]. Maintaining the structure and diversity of ecosystems is an issue of great importance for protecting soil and water uses [6–9] and, in general, the resilience of natural resources. Global adoption of more sustainable agricultural practices protects the health of ecosystems [10,11], benefiting farmers and rural areas where they operate [12]. From an environmental sustainability perspective, natural ecosystem services are the most difficult facet to consider. Responses to different environmental forms and problems are interrelated, so environmental sustainability needs a whole approach that maximizes the synergies of conservation and resilience of

ecosystems without forgetting a management framework for agricultural farms to achieve profitable and sustainable production.

Some articles have been published that analyze the characteristics of the activity sector and its influence on the concept of environmental sustainability. Angelakoglou and Gaidajis [13] analyze the methods they use to assess environmental sustainability in industrial systems. Pulido-Fernández et al. [14] showed the impact of the tourism sector on environmental sustainability, while Moyano-Fuentes et al. [15] do so for the high-tech sector. Other investigations have studied specific aspects of environmental sustainability, such as Lioutas and Charatsari [16], to highlight the parameters that motivate the adoption of green innovation in agriculture. There have been studies that consider other aspects, such as the value of training or information systems [17,18], with the environmental effect. However, they measured the value of specific indicators individually without providing a comprehensive vision. This leads to an incomplete assessment of sustainability as a socio-ecological system, reflecting only the unconnected pieces among the large-scale characteristics of agricultural activities. Studies are needed that holistically model the various variables that impact environmental sustainability by promoting it. This article expands on previous research offering an analysis of the interconnections between environmental sustainability in agriculture and the development of innovations, the integration of employee training, and the use of agricultural information, configuring a more complete and complex socio-ecological system.

Agricultural managers face significant challenges in their decision-making process to be socially responsible with the environment while achieving competitive advantages. The knowledge, perceptions, skills, and environmental values of farmers are of particular interest, as they can influence the sustainable development of their environment, not only through their personal behavior but also as innovative leaders, through the development of new products and services or improving the information-oriented to sustainability. Therefore, it is important to better understand the factors determining farmers' environmental behaviors. Models of behavior, such as the theory of planned behavior [19], investigates how knowledge forms perception, which leads to practice in human decisions; or environmental frameworks, such as Herman Daly's theory of strong, weak, and intermediate levels of sustainability [20] that investigates crucial actions that influence the maintenance of economic, environmental, and social capital, are the disciplinary antecedents of this research.

In this paper, a case study is developed to explore farm managers' perceptions of El Oro province's environmental sustainability practices (Ecuador). In exploring the motivations for sustainable agricultural development and their impact on ecological, economic, and social outcomes, the case study approach has been used by several researchers [21–24]. As far as we know, there are few studies in agricultural contexts that empirically assess how a farmers' perception could guide public policy incentives. Our research allows the incorporation of a multidimensional approach that could be useful for public authorities as an external motivator to adopt sustainable agricultural practices. When we focus on the environmental dimension of sustainability, we have to highlight the role of ecosystems as providers of basic services (provisioning, supporting, regulating, and cultural) [10]. Concerning the above, the limits of the planet's natural resources are well known [25], so its consideration as an environmental sustainability item connects local and global issues. Besides, as a management control system, farmers adopt environmental certifications such as ISO 14,001 or Global Gap standards [26,27] to gradually integrate their commitment to the changes that their activities have in the new current socio-economic scenario.

Our structural equation model is completed with other variables where innovation is one of the most important variables. Two antecedent variables of the innovation processes of banana farms were the adoption of information systems and employee literacy and training activities. Besides, it is identified a causal relationship between these two variables and innovation, which suggests a mediating role of innovation in the relation among

adoption of information systems and employee training in environmental sustainability practices.

The innovation process is a set of interrelated activities that must be seen as a series of changes in a complete system, not only of technologies but also of the market environment, production facilities and knowledge, and the social contexts of innovation in the organization [28]. For its part, information management in the company is linked to information and communication technologies, where the internet has become a source for the modernization and innovation of the company, since it keeps it informed and related in a global context and is capable of creating international connections, thus generating marketing opportunities around the world [29]. In this sense, all types of information, publications, and presentation of research results and scientific advances are estimated to promote innovation in private companies and public institutions [30]. Finally, in a globalized world, training becomes a business challenge due to the constant changes generated by technological, social, and political advances. Besides, intrinsic motivations such as personal development allow reaching training goals to generate favorable results for the company [31]. Therefore, continuous improvement in production and distribution processes is a real challenge over time, so it is necessary to evaluate it to identify failures in production processes so that workers must be in constant training and learning [32].

This article contributes to scientific knowledge by providing a further model for the evaluation of the determinants that stimulate the introduction of sustainable practices and by representing the relationships between these determinants and key elements of innovation in agriculture, showing empirical evidence as an axis of the relationship between adoption of information system and employee literacy and training in sustainability. Moreover, it supports how farmers' perceptions in El Oro could guide public policy incentives of regional and local Ecuadorian institutions, considering how their attitudes towards knowledge and information can guide the innovative intention towards sustainable behavior.

The rest of the article is organized as follows: In Section 2, we explain the causal relationships of our model based on the previous literature, and we develop the hypotheses. Section 3 describes the methodology to be followed. The results obtained are shown in Section 4 to conclude with the presentation of the discussion and conclusions in Sections 5 and 6, respectively.

## 2. Literature Background and Hypotheses

### 2.1. Environmental Sustainability Practices and Adoption of Information Systems

Nowadays, the importance of the adoption of IS as a vehicle linking business development with environmental considerations is recognized [33]. The development of the digital economy has been an opportunity for farmers to obtain information about agricultural sustainability quickly. Through IS, the planning of sustainable development is sought where, among others, studies on agricultural frontiers, awareness about the care of natural resources, mainly land, water, and forests, that are carried out in the productive farms of farmers [17,34,35].

Previous research identifies the relationship between IS and several specific aspects of sustainability. For instance, Bentley et al. [17] presented the free digital platform called Access Agriculture to collect practical information on sustainable agricultural innovations. Intelligent irrigation management systems based on the Internet of Things (IoT) can help to achieve optimal use of water resources [36]. Chibanda et al. [37] detailed in Germany a method based on fundamental farm information that quantifies their data, to provide advice to policymakers, producers, and agribusinesses. A study in Thailand presented a web-based application that handles the details of crop data and field information [34], suggesting that applying technological IS contributes to environmental sustainability. Strassemeyer et al. [38] presented the SYNOPS-WEB online tool as an example at the European level, with a particular focus on minimizing environmental risks. Finally, Trinh et al. [39] revealed the influence IS to explain the socio-technical change.

We argue that focusing on the adoption of IS allows us to change the actions that managers could take to guide an organization's environmental strategy. Consequently, we hypothesize:

**Hypothesis H1.** *The adoption of information systems positively influences environmental sustainability practices.*

Deichmann et al. [40] reviewed the literature regarding information technology effects in the agriculture industry in developing nations. In this sense, mobile phones and the Internet encourage higher participation in the whole economy, increase efficiency, and promote innovation through minor operating costs. Wolfert et al. [35] indicated that big data makes it possible to make predictions about agricultural results and to support decision-making in time, adapting to changes in the context, while Mostafaeipour et al. [41] did so by focusing on an artificial intelligence model to reduce energy in wheat production. Clarkson et al. [42] researched the effect of a TV program as a stimulant of agricultural innovation among smallholder farmers in East Africa. They concluded media had a wider effect on behaviors and insights, together with cognizing and awareness.

Consequently, previous works suggest that the adoption of IS affects innovation. As we hypothesized that innovation in production and marketing processes affects the environmental sustainability practices, it is intended that this variable have an indirect effect on it. Thus, we hypothesize:

**Hypothesis H2.** *The innovation of agricultural companies mediates the relationship between the adoption of information systems and environmental sustainability practices.*

## 2.2. Environmental Sustainability Practices and Innovation in Processes

Innovation activities in agriculture are considered as a response to reduce the environmental impact, in the business sector [43]. The OECD [44] differentiates four types of innovation: product innovation, organizational innovation, innovation in production processes, and innovation in marketing processes. This research focuses on the latest ones, innovation in production, and marketing processes.

Process innovations are related to changes in different ways of production and commercialization, that is, the reorganization of the production process, the consumption of new inputs, or the search for new market niches or strategies. Different research shows the impact innovation has on environmental sustainability practices [43,45] evidencing that innovation activities in production and commercialization processes lead to positive environmental sustainability practices [46].

Numerous studies suggest that a higher use of input consumption (i.e., irrigated water, fertilizers, fuels, or pesticides) characterize agriculture [47], which influences the environmental impacts on agriculture [48]. In the peasant community of the Lake Pátzacuaro in Mexico, it was observed that low input agricultural systems, usage-based of crop rotation and organic fertilizers, performed better outcomes in terms of ecological and economic factors than those used a high-income chemical model. Nevertheless, innovation in search of new market niches also guarantees the economic sustainability of farms [49]. Wollni et al. [23] showed that Honduran farms belonging to farmers' associations were more prone to operate in market niches of green products.

As a consequence, we consider that SME farms that innovate in their production and marketing processes will improve their environmental sustainability practices. Consequently, we hypothesize:

**Hypothesis H3.** *Innovation in the production and marketing processes of agricultural companies has a positive effect on their environmental sustainability practices.*

### 2.3. Environmental Sustainability Practices and Training of Employees

Some research highlights the importance of training employees to implement tools that improve environmental sustainability practices [18]. Barth and Melin [50] studied for thirty-four farms in Sweden the benefits of implementing group and individual training activities for farmers to adopt a green lean-approach.

Beltrán-Esteve et al. [51] showed that agricultural professional training and university education of employees enhance the likelihood of a change to a green farmer. Research using psychological frameworks confirmed that employee efficacy and capacitation played relevant functions in adopting sustainable practices [52].

Some other research showed the important role of experts working with farmer groups. For example, in Australia, Cotching et al. [53] reported on social learning, and how the reduction of agricultural intensification impacted the health of the soil and the agriculture resource-efficient; individual training of employees and advice, together with group actions, led to success for farmers in their decision making.

Consequently, and based on previous research we hypothesize:

**Hypothesis H4.** *Training of employees has a positive effect on the environmental sustainability practices in agricultural companies.*

The agricultural sector faces capacitation challenges in response to innovation-centered strategies. Moschitz and Home [54] showed the relationship between learning networks and innovation for sustainable agriculture through a methodology applicable in European research projects. Jack et al. [55] explored the implications of the relationship between skills and innovation in Northern Ireland agri-food sector concluding that training is useful to realize how to make things when firms must react to environmental changes. Liu et al. [56] disclosed a significant positive correlation between professional skills and the decision-making of low carbon technologies by Chinese rice producers. Marra et al. [57] reviewed the role of training employees to adopt new agricultural technologies. They commented that identifying individual learning behavior is essential since learning leads to skill improvement, reduces uncertainty, and improves decision making. Meijer et al. [58] concluded that taking up agro-technologies is an intricate procedure impacted by extraneous and inner variables, where understanding plays its part.

Consequently, previous works suggest that the training of employees affects innovation. As we hypothesized that innovation in production and marketing processes affects environmental sustainability practices, it is intended that this variable have an indirect effect on it. Thus, we hypothesize:

**Hypothesis H5.** *The innovation of agricultural companies mediates the relation between the training of employees and environmental sustainability practices.*

## 3. Materials and Methods

### 3.1. Statistical Procedure

Figure 1 represents the research model. We tested our model using a Partial Least Squares Structural Equation Model (PLS-SEM). We applied traditional PLS-SEM because it is a particularly appropriate method to be used when the normality assumption cannot be assessed [59], and it is important to identify key constructs [60]. Furthermore, we adopted a predictive approach [61,62] by using SmartPLS 3.2 software [63]. We executed the measurement model in Mode A due to the high correlation among predictors, and results will not be distorted by removing measurements due to possible collinearity and inflated standard errors issues [64].

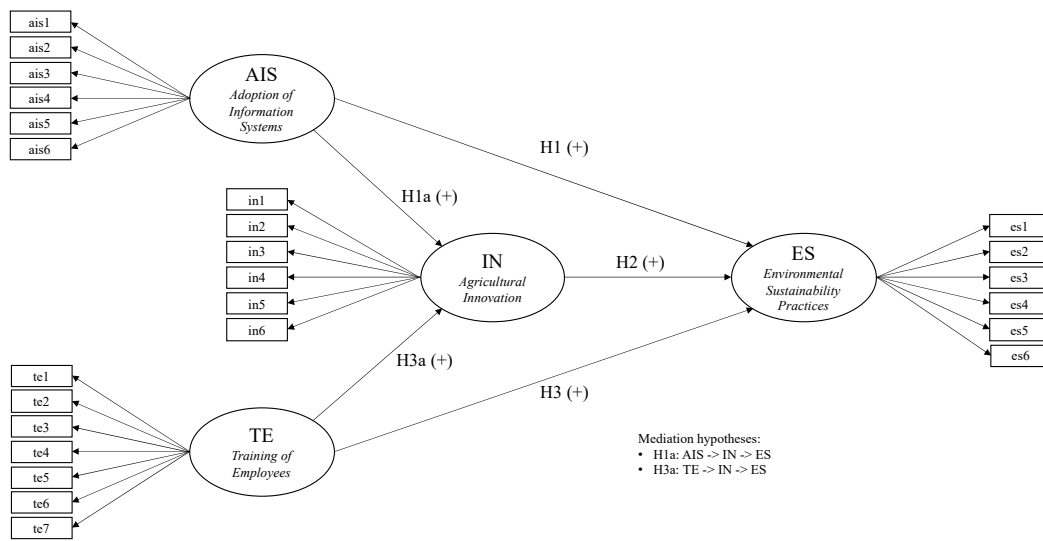


Figure 1. Research model.

Mediation is a manner to set up what extent a precedent variable affects a dependent variable, through an indirect effect [65]. To the extent that adoption of IS and training of employees indirectly impact environmental sustainability practices through innovation, we maintain that innovative activity serves as a mediator between both adoption of IS and training, and environmental sustainability practices.

Figure 2 represents the workflow process to validate the hypotheses.

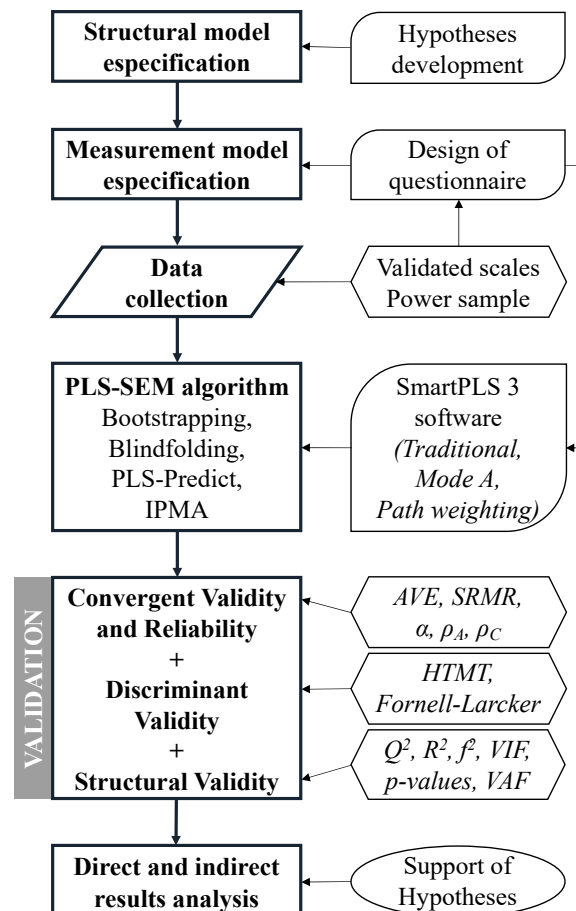


Figure 2. Workflow process.

### 3.2. Data Collection and Representativeness

We defined our population as banana producers with more than 5 hectares of farms placed in the province of El Oro (Ecuador), located along the southwestern coast of Ecuador (see Figure 3), mainly supported by the production of bananas [66]. Although there are 42,340 Hectares of banana cultivation managed by 22,115 farms, only 1115 met the criterion described above (5 hectares). The population directory was provided by the Tax Administration of Ecuador. We surveyed an initial sample of 600 banana growers through personal interviews within the second semester of 2017. We visited each agricultural farm to collect data after contacting them through the main Associations of Banana Producers, Agricultural Centers, and Collection Centers. The final sample included a total of 416 valid responses (response rate of 69.3%).

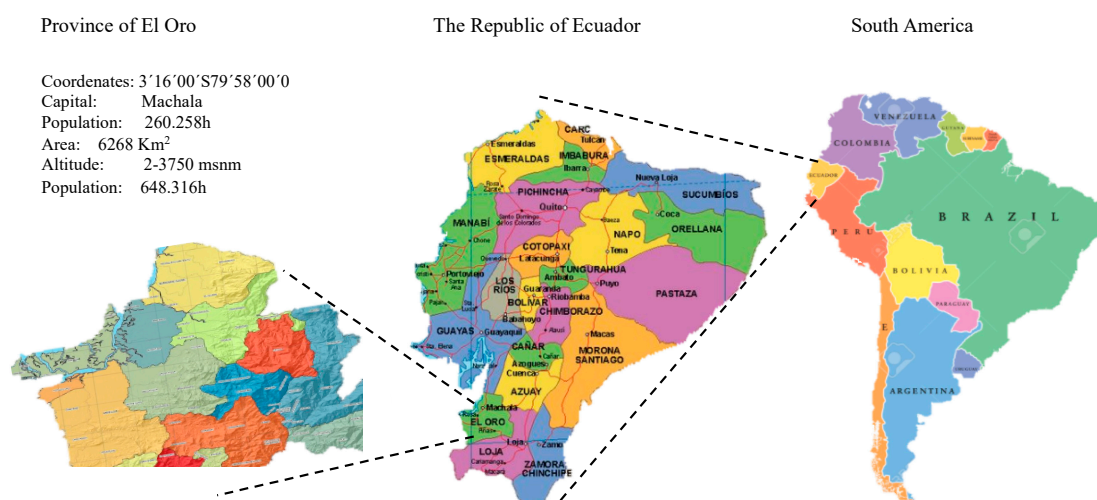


Figure 3. Geo-referenced map of the study area.

We carried out a pre-test evaluated by experienced [67] to verify its viability, modifying those suggestions that improved the interpretation of the questionnaire [68]. The final questionnaire consisted of 26 Likert-scaled items (1: Absolutely disagree, 7: Absolutely agree), and several questions regarding the demographic distribution of the participants. Table 1 summarizes the distribution of the sample.

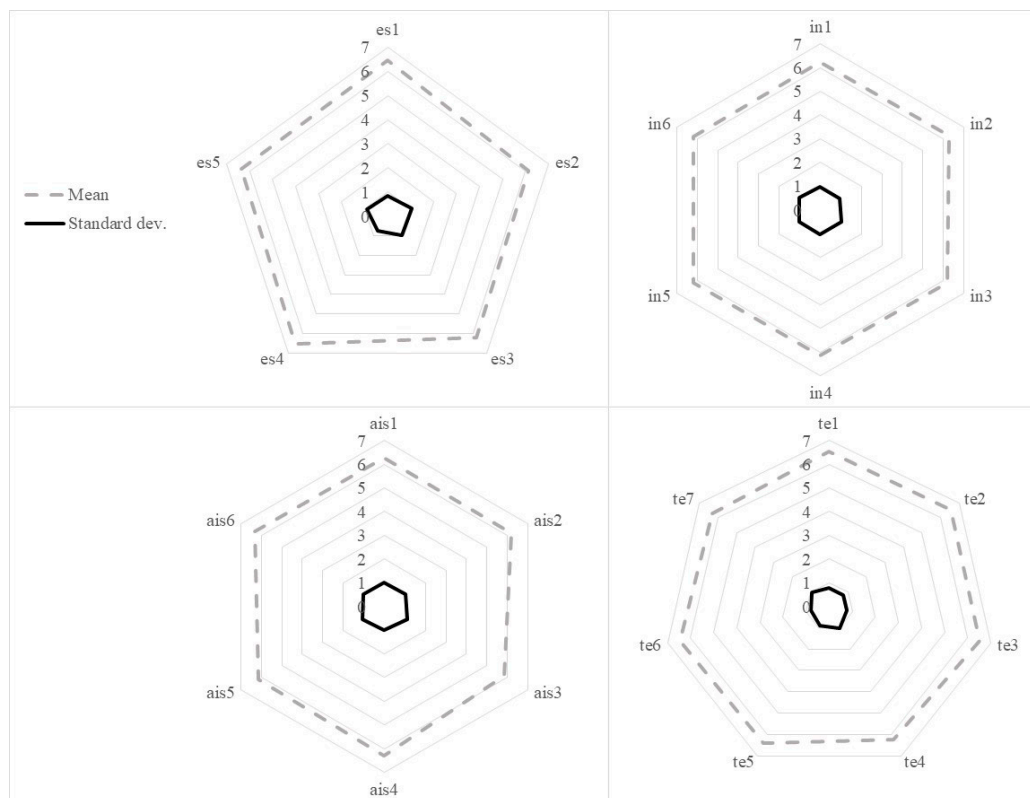
Table 1. Demographical characteristics of the sample.

Size of the Farm	Years of Exploitation			Ownership		Total Sample
	0 to 5	6 to 15	16 or More	Familiar	Non-Familiar	
5 to 10 Has.	53	72	61	154	32	186
11 to 30 Has.	24	67	41	68	64	132
31 or more Has.	5	48	45	65	33	98
Total sample	82	187	147	287	129	416

Source: Own elaboration.

### 3.3. Measures

We used validated scales from previous studies. Table 2 and Figure 4 provide the descriptive statistics of measurement variables. Table 2 also provides the questionnaire content of each measurement. There were no outliers or missing data. More specifically, the following model constructs were explained:



**Figure 4.** Measurements descriptive.

- Environmental Sustainability Practices (ES) combines six indicators (from es1 to es6) about the concern for the use of soil and its preservation, the use of water through technologies, the boundaries of natural resources, in short, the efficient use of ecosystem services, environmental certifications, and good management of toxic inputs [46,69]. These six items represent the different facets that reflect the central variable to be explained in our model. This approach should test the perception that agricultural managers have of sustainable practices.

- Agricultural Innovation (IN) gathers six observed variables (from in1 to in6) regarding changes or improvements in production and commercialization processes, which is typical in studies of developing countries [70]. These measures involve several aspects of innovation in production and marketing processes, according to previous research [71–73].

- Adoption of IS (AIS) groups six measures (from ais1 to ais6) in a latent variable involving how agricultural companies use the IS to improve innovation and environmental sustainability practices. The construct is based on previous studies' descriptive information [33] including the use of the internet, the assistance to fairs and other events, collaboration with technological R&D centers, etc. [74,75].

- Training of Employees (TE) incorporates seven items (from te1 to te7) about the importance for the company of several aspects of training, relating to its objectives (company advance, process improvement, professional development) as well as the different ways to acquire it (i.e., knowledge management, attendance at events, professionalization). Besides, there are intrinsic motivations such as personal development [31]. As a result of training, knowledge is created, and its management must be evaluated [76]. Another way to obtain knowledge is by participating or attending an industrial or scientific fair [77]. Self-training is a key element when managers and workers have the initiative to educate themselves to generate more profitability and sustainability for the company [78].



**Table 2.** Variable's definition and descriptive statistics.

	Mean	sd	Environmental Sustainability Practices (ESP) [46,69]
es1	6.47	0.86	The company carry out fertility tests and soil moisture
es2	6.13	1.05	The irrigation systems used in the company are of the latest technology
es3	6.23	0.98	The cultivation (conventional/ecological) is related to productivity and financial performance
es4	6.54	0.73	Natural resources are used rationally in the company
es5	6.37	0.89	The company have environmental certifications
es6 *	-	-	In the company, they care about good management of toxic inputs
	Mean	sd	Agricultural Innovation (IN) [44,79]
in1	6.25	0.98	The company usually restructure the production process
in2	6.29	0.92	The company usually consider the modernization of the infrastructure for production
in3	6.17	1.03	The company tend to use new inputs and materials for the production process
in4	6.15	1.04	The company consider differentiating its product from other producers
in5	6.17	1.05	The company commonly seek and find new market gaps
in6	6.19	1.02	The company apply any strategies to commercialize the product
	Mean	sd	Adoption of Information Systems (AIS) [33,74,75,79]
ais1	6.27	1.02	The use of the internet is a good source to obtain information to innovate in the company
ais2	6.17	1.02	The advances of science presented at fairs and other events favor innovation in the company
ais3	5.86	1.12	The different levels of government share their skills and information with companies in the sector
ais4	6.29	0.99	To develop a web page is needed for the company to inform customers and suppliers
ais5	6.16	1.06	The information generated in technological R&D centers contribute to the innovative production processes of the firm
ais6	6.32	1.01	The information about the ecological situation, forests, soil resources, and available water is grounded to manage the company
	Mean	sd	Training of Employees (TE) [18,79]
te1	6.54	0.78	Training is a key to the development of the company
te2	6.55	0.76	Learning is a key to improve production processes in the company
te3	6.52	0.77	Knowledge management is a key in the company
te4	6.24	1.02	Attending events fairs is a key to get more knowledge for the staff that works in the company
te5	6.42	0.88	The professionalization of workers and managers is a key in the activities carried out by the company
te6	6.48	0.78	Self-training is a key to personal and professional development of workers and managers in the firm
te7	6.30	0.95	The level of education is a key to the relationship between workers and employers in the company

\*: This indicator was not included in the latent variable due to the convergent criterion of PLS path modeling. All the measures were 7-point Likert-type scales (from 1: absolutely disagree to 7: absolutely agree).

Measurement calibration is not provided because we used previously validated scales in prior literature. Moreover, outer model validation was provided following the procedure recommended for this technique, i.e., checking reliability, convergent validity, and discriminant validity; inner model validation was also tested through the structural validity and predictive power of composites, that contains  $f^2$  index to provide a sensitivity analysis of  $R^2$  parameter (see Figure 2).

### 3.4. Statistical Remedies for Bias

First, non-response bias assessed employing belated respondents to interviews as proxies for non-respondents [80,81]. Results show no significant differences among earliest and belated respondents, suggesting that non-response is not an important issue in this research. Second, we evaluated common method variance using various statistical remedies [82] and a partial correlation procedure [83]. Moreover, Variance Inflation Factors (VIF) of the structural model ranged 1.86–2.43. These results suggest that neither common method bias nor collinearity are relevant in our study.

## 4. Results

We employed a two-step statistical analysis approach [84]. In the first step, we analyzed the reliability and validity of the measurement model. In a second step, we completed the path analysis to test hypotheses.

### 4.1. Model Evaluation

We evaluated each latent variable (LV) in terms of composition weights, reliability, validity, and composition weights [85], as shown in Table 3. Reliability and convergent validity of latent variables are assessed through Cronbach’s  $\alpha$ , Composite Reliability (CR), and Average Variance Extracted (AVE) indices. CR and  $\alpha$  take values within the expected range of 0.70–0.95, and AVE exceeds its shortcut value of 0.50 [86,87]. Regarding composition weights of LVs, standardized loadings should exceed 0.7 in a majority of measures, but those ranging 0.40–0.70 might be conserved for nomological reasons if deleting them does not improve the model [88]. In this case, only one standardized loading (is4) is nearly below 0.70 (0.69) and all of them were significant by using 10,000 samples bias-corrected bootstrapping procedure [89]. Furthermore, standardized weights were obtained from an Importance-Performance Map Analysis (IPMA). All of them are higher than 0, and there are no great differences between them, informing that the importance of all the measures is similar. Moreover, we verified the model predictive relevance [90] throughout a double-tracking: A cross-validated redundancies blindfolding with an omission distance of 7, and a PLS-predict procedure with 10 folders and 10 repetitions were conducted. The predictive capability could be confirmed since  $Q^2_b$  [91,92] and  $Q^2_{pls}$  [93] values are above 0 for all the measures and constructs.

Table 3. Reliability and convergent validity.

Exogenous		$\lambda$	t	W	Endogenous		$\lambda$	t	$Q^2_b$	$Q^2_{pls}$	W
<b>Adoption of Information Systems (AIS)</b>					<b>Innovation in production and marketing processes (IN)</b>						
$\alpha$ : 0.87	ais1	0.81	40.9	0.22	$\alpha$ : 0.88	in1	0.82	35.6	0.33	0.37	0.22
$\rho_A$ : 0.88	ais2	0.83	36.4	0.21	$\rho_A$ : 0.89	in2	0.70	19.5	0.24	0.33	0.17
$\rho_C$ : 0.90	ais3	0.72	24.4	0.19	$\rho_C$ : 0.91	in3	0.81	31.9	0.31	0.34	0.20
AVE: 0.61	ais4	0.69	17.1	0.17	AVE: 0.63	in4	0.81	36.4	0.37	0.26	0.23
	ais5	0.86	51.0	0.25	$Q^2_b$ : 0.32	in5	0.82	39.9	0.32	0.28	0.22
	ais6	0.76	29.3	0.23	$Q^2_{pls}$ 0.48	in6	0.81	32.2	0.33	0.34	0.22
<b>Training of employees (TE)</b>					<b>Environmental sustainability practices (ES)</b>						
$\alpha$ : 0.92	te1	0.84	32.7	0.16	$\alpha$ : 0.83	es1	0.80	31.3	0.37	0.34	0.28
$\rho_A$ : 0.93	te2	0.88	60.0	0.17	$\rho_A$ : 0.83	es2	0.75	26.0	0.32	0.40	0.26
$\rho_C$ : 0.94	te3	0.84	32.7	0.15	$\rho_C$ : 0.88	es3	0.79	27.8	0.33	0.31	0.26
AVE: 0.68	te4	0.79	30.1	0.19	AVE: 0.60	es4	0.71	19.1	0.29	0.34	0.25
	te5	0.84	32.1	0.17	$Q^2_b$ : 0.32	es5	0.80	19.10	0.29	0.34	0.25
	te6	0.79	22.7	0.16	$Q^2_{pls}$ 0.49						
	te7	0.80	34.4	0.21							

$\lambda$ : Standardized Loading; t: t statistic performed by a 10,000-resampling bias-corrected bootstrapping technique; the significance of all loads were evaluated at  $p < 0.001$ . W: IPMA standardized Weight.  $\alpha$ : Cronbach’s Alpha;  $\rho_A/\rho_C$ : Dijkstra–Henseler’s and Jöreskog’s composite reliability indices; AVE: Average Variance Extracted.

Furthermore, HeteroTrait-MonoTrait (HTMT) [94] and Fornell and Larcker [95] criterion evaluate the discriminant validity. All the HTMT ratios and their upper bounds are below 0.90 [96], and all the LVs correlations are smaller than the squared root of AVEs [95]. Hence, the discriminant validity is confirmed. These reports are shown in Table 4 and Figure 5.

Table 4. Discriminant validity.

		HTMT Ratios				Fornell–Larcker Criterion			
		AIS	TE	IN	ESP	AIS	TE	IN	ESP
AIS	Adoption of IS		(0.68–0.80)	(0.73–0.85)	(0.71–0.85)	0.78			
TE	Training of employees	0.74		(0.60–0.76)	(0.69–0.82)	0.68	0.82		
IN	Agricultural Innovation	0.80	0.68		(0.70–0.84)	0.70	0.63	0.80	
ESP	Environmental Sustainability	0.79	0.76	0.77		0.68	0.68	0.67	0.77

95% Confidence intervals of HTMT ratios over the diagonal (cursive) performed by a 10,000-resampling bias-corrected bootstrapping technique. Fornell and Larcker criterion: inter-construct correlations below diagonal and squared-root of AVE in diagonal (cursive).

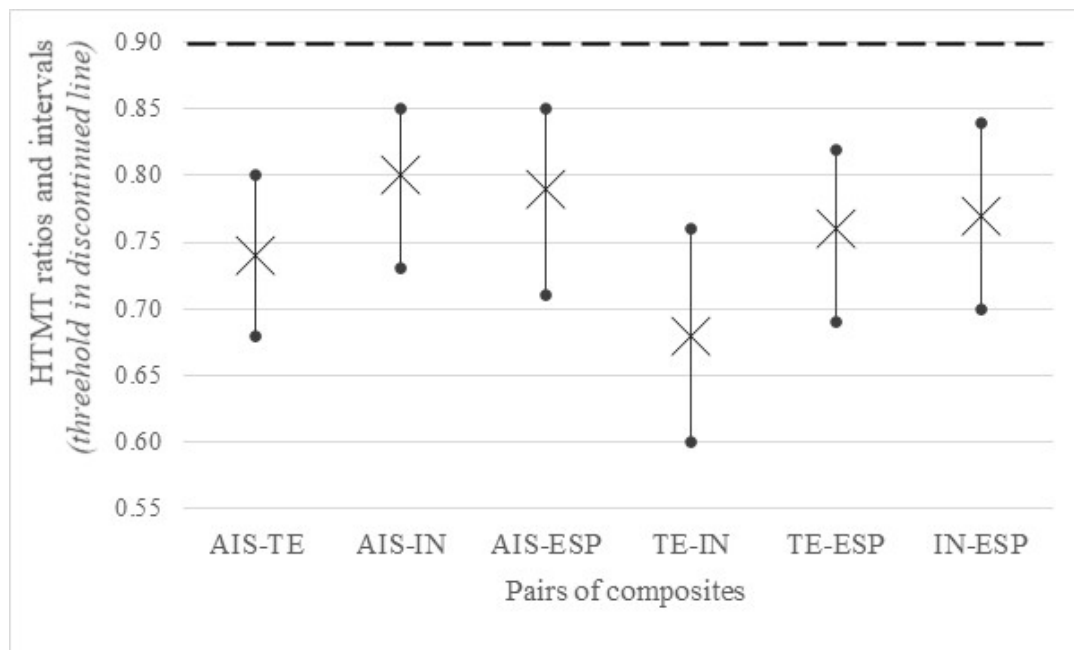


Figure 5. Convergent validity.

4.2. Hypotheses Testing

Figure 6 and Table 5 describe the inner model results in terms of standardized paths, significance, 95% confidence interval, Cohen’s  $f^2$ , Variance Inflation Factors (VIF), as well Variance Accounted For (VAF) for Indirect effects. Likewise, SRMR does not go beyond its shortcut of 0.08 [97,98], whilst the endogenous constructs achieved an  $R^2$  ranging from 0.54–0.59.

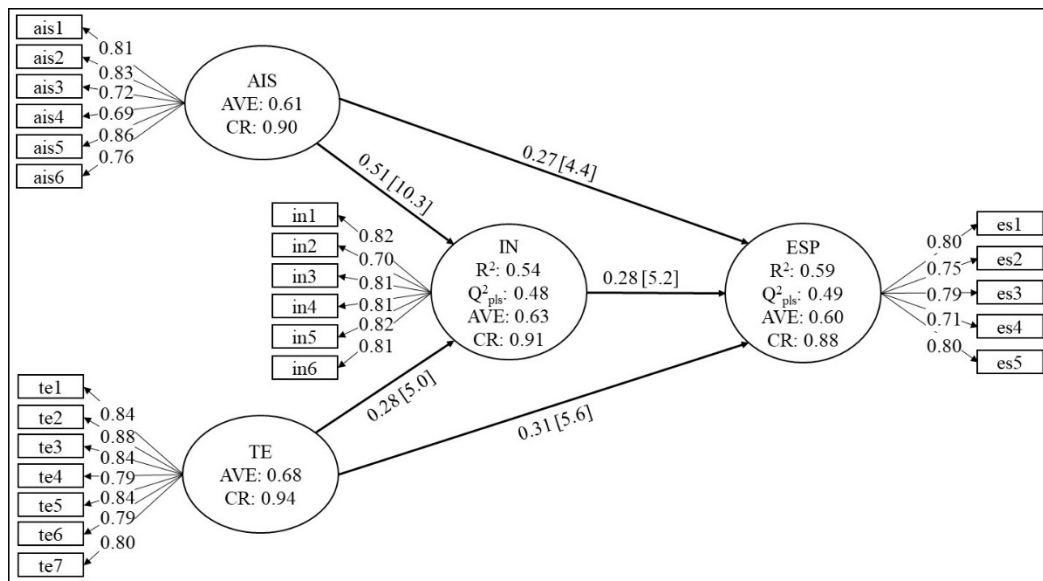


Figure 6. Results.

Table 5. Results.

	Path	t	Lo95	Hi95	f <sup>2</sup>	VIF
<b>Direct effects</b>						
Training of employees → Environmental sustainability	0.31	5.65	0.20	0.42	0.12	2.03
Training of employees → Agricultural Innovation	0.28	4.98	0.17	0.39	0.09	1.86
Adoption of IS → Environmental sustainability	0.27	4.36	0.15	0.39	0.07	2.43
Adoption of IS → Agricultural Innovation	0.51	10.29	0.41	0.61	0.09	1.86
Innovation → Environmental sustainability	0.28	5.17	0.18	0.39	0.30	2.15
<b>Indirect effects</b>						
<b>VAF</b>						
Training → A. Innovation → Environmental sustainability	0.08	3.49	0.04	0.13	20.3%	
Adoption of IS → A. Innovation → Env. sustainability	0.14	4.50	0.09	0.21	35.0%	
<b>Validation criteria</b>						
	<b>R<sup>2</sup></b>	<b>R<sup>2</sup><sub>adj</sub></b>				
Environmental sustainability	0.59	0.58				
Agricultural Innovation	0.54	0.53				

Standardized betas are reported; t statistics and confidence intervals were performed by a 10,000-resampling bias-corrected bootstrapping procedure; f<sup>2</sup>: Cohen’s effect size. VIF: Variance Inflation Factors. All the direct and indirect effects are significant at  $p < 0.001$ .

Our findings imply that either the adoption of IS (AIS) and training of employees (TE) had a significant positive effect on environmental sustainability practices (ESP) ( $\beta = 0.27^{***}$  and  $\beta = 0.31^{***}$ , respectively). Hence, H1 and H3 are supported. Moreover, agricultural innovation in production and marketing processes (IN) affects ESP in a positive and significant way ( $\beta = 0.28^{***}$ ), supporting H2.

Furthermore, AIS and TE positively and significantly affect IN ( $\beta = 0.51^{***}$  and  $\beta = 0.28^{***}$ , respectively). These results agree with the mediation hypotheses H4a and H4b. In this sense, both indirect effects of AIS and TE can be addressed by the product of the standardized coefficients of the independent variable on the mediator, and the mediator on the dependent variable [65]. Hence, mediation hypotheses are supported since the indirect effects are positive and significant ( $\beta = 0.14^{***}$  and  $\beta = 0.08^{***}$ , respectively). We have applied a bootstrapping method because it imposes no assumptions about the sampling distribution [99]. These results support H4a and H4b. In this sense, the proportion mediated

through innovation is up to 20% in TE to ESP total effect, while it represents about 35% in the AIS to ESP total effect, evidencing the existence of both partial mediations together as their direct effects are also significant.

## 5. Discussion

Our structural equations model has allowed us to check the perception that managers of the SME farms have about this particular and complex socio-ecological system looking for environmental sustainability. For this, we have based on the ecosystem from the province of El Oro (Ecuador).

The results evidence that innovation activities in production and commercialization processes lead to positive environmental sustainability practices [46]. Likewise, the results suggest that conservation of ecosystem services through the use of technologies for soil and water, the chosen form of cultivation, and the implementation of environmental certifications are the most important criteria in the perception of environmental sustainability by farmers giving support for incorporating the rational use of ecosystem services [10] and certifications [26] as positive factors in the agriculture company's environmental strategy. Indeed, the farm managers seek to monitor alternative practices by conducting soil fertility and moisture analyzes, showing that the irrigation systems used, the form of cultivation (conventional/ecological), and the rational use of natural resources contribute to appreciating their environmental commitment helping farmers to forge a professional identity and negotiate a new social contract that gives them the right to the renewal of their political and economic status [100,101].

The six-item scale of measurement of the construct of environmental sustainability practices (ESP, Figure 1) reflects all facets, except for factor 6 (Figure 6). This factor refers to the use of xenobiotic inputs and pesticides. The measurement analysis of this construct shows that the surveyed farmers did not perceive that the good management of toxic inputs is a fact that builds their environmental sustainability practices.

The effects of the adoption of IS, which include the use of the internet, assistant to fairs and other events favor innovation in the company, sharing skills and information with other companies in the sector, develop a web page that informs customers and suppliers, create or sharing technological R&D and capture information about the ecological situation, forests, soil resources, and available water is grounded to manage the company seems impact agriculture innovation and improve environmental sustainability.

In the same way, training of employees is perceived by SME farm managers as a key factor to develop the firm, improving production processes, and favoring knowledge and professionalization for the managers and staff and, thus interacting with innovation to improve environmental sustainability.

Both the adoption of IS and training of employees, not only contribute to environmental sustainability [18,33], they also are important factors for innovation. Nowadays, the importance of the adoption of IS as a vehicle linking business development with environmental considerations is recognized [33]. Our research confirms previous research and expands the results to SME farms. The perception of agricultural managers was affected by the adoption of IS and training of employees when formulating their attitude toward the environmental practices and the innovation, supporting research reported by Trinh et al. [39], and Zhang and Zhu [102].

Our study also suggests that the indirect effects of the adoption of IS and training of employees are relevant, representing mediating effects. In this sense, managers and stakeholders should take into account those activities that might influence the innovational changes to environmental sustainability. We can conclude that both adoption of IS and training of employees are two instruments that wrap and push toward environmental changes. They do directly and indirectly. Adoption of IS seems to help to a better perception and understanding of environmental change. Training of employees is the instrument that drives them to understand better and capture changes. This article also puts into value the important role of these two variables through innovation. Both influence innovation and,

as it is well known, innovation constitutes the backbone of development, particularly in the agrarian system. Consequently, understanding these relationships is of special interest to both managers/owners of agricultural firms and for governments and other stakeholders.

## 6. Conclusions

Environmental sustainability is calling attention in the last decades with particular emphasis on rural areas and agricultural firms, which constitute particular socio-ecological systems. The main goal of this research was to explore the perceptions of SME farm managers about the environmental sustainability practices through the adoption of IS and training of employees as well as the influence of the innovations, particularly in production and commercialization processes. We made three research questions: (a) Does the adoption of IS favor environmental sustainability? (b) Does the training of employees enhance their environmentally sustainable practices? (c) How does agricultural innovation in SME farms affect these relationships? Furthermore, we also check how the innovation of agricultural companies related to production and commercialization processes mediates the relationship among the adoption of information systems and training of employees, and environmental sustainability practices.

For the SMEs farms, this research shows a path to make the change towards environment sustainable agriculture compatible with the profitability that will allow them to survive in a globalized and continuously changing economy. For governments, local or general, it also shows some critical variables in which they have to concentrate on helping agricultural firms (family or not). The knowledge of these relationships also contributes at a global level favoring a more sustainable planet. Public strategies designed at promoting environmentally sustainable practices must regard the dynamic character of the determinants that interact and activate innovation and change.

Some limitations can be found in our study. First, a questionnaire was applied to a particular ecosystem, the province of El Oro (Ecuador) and different ecosystems may give different results. So, it is of interest to develop new research with other respondents and different eco-systems. Second, we focused on the adoption of IS and the training of employees, but we understand that these are not the only variables that affect agricultural innovation and environmental sustainability. Nevertheless, the results are not invalidated for these constraints.

In future research, it may be appropriate to value the relationships of these variables in the performance and to evaluate the influence of incorporating new variables such as organizational culture or the risk orientation to innovate. Furthermore, it would be interesting to incorporate a moderating variable related to the family nature of the agricultural farms studied to discern the existence of interaction effects in this regard.

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