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RESEARCH ARTICLE

Influences of Environmental Knowledge and Gender on Sustainable Agricultural Practices among Mixed-Cropping Cacao Farmer Communities in Sulawesi

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Abstract

A. K. Parawansa, A. Paramaswary Aslam, and P. J. McMahon. 2025. Influences of Environmental Knowledge and Gender on Sustainable Agricultural Practices among Mixed-Cropping Cacao Farmer Communities in Sulawesi. Int. J. Agric. Nat. Resour. 62-78. To develop sustainable agriculture in Indonesia, there is a need to empower smallholder farmers and promote gender equality in the agricultural sector. A study was conducted among mixed cropping cacao farming households in South, West and Central Sulawesi Provinces (n=435). The aim of the study was to elucidate the relationships between latent variables and farmer understanding of relevant Social Services, Financing, and Household and Community Challenges (SSHFCs) and the implementation of sustainable practices (such as crop diversification). Informed by the theory of planned behavior (TPB), 'Environmental Knowledge' (EK) was incorporated into the study, in addition to other TPB core components, Attitudes (AT) and Subjective Norms (SN). The data collected by the questionnaire reflect these latent variables. The application of a partial least squares-structural equation model (PLS-SEM) demonstrated the reliability and discriminant validity of these data. Path analysis in the model indicated that AT, SN and EK all had significant direct effects on SSHFC or farmers' understanding of available resources for sustainability outcomes. While path coefficients between variables (including indirect effects) were significant for both genders considered separately, attitudes toward sustainable practices did not differ between male and female farmers. However, the indirect effects of SN on SSHFC mediated by EK were significantly greater among men than women, whereas the direct effects of SN on SSHFC were much weaker in men. This suggests that women will seek out support services regardless of their level of environmental knowledge, while men are more likely to access such resources with the mediating effect of environmental knowledge. Nevertheless, EK also enhanced the understanding of available resources (or SSHFC) among women, demonstrating the potentially strong mediating role of EK in seeking sustainable outcomes within these farming communities.

Keywords: crop diversification, environmental knowledge, subjective norms, sustainable

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agriculture, cacao (cocoa), gender.

Highlights

- Examined sustainable farming among cacao smallholders in Sulawesi (n=435).
- Used TPB and PLS-SEM to analyze attitudes, norms, and environmental knowledge.
- Environmental knowledge had a strong mediating effect on resource understanding.
- Subjective norms influenced men and women differently in sustainability pathways.
- Attitudes toward sustainable practices were similar across male and female farmers.

Introduction

Sustainable agriculture in Indonesia involves environmentally friendly, economically viable, and socially responsible farming practices. These methods can minimize environmental harm and ensure the long-term health and productivity of agricultural systems. Indonesia is known for its rich biodiversity and natural resources, making it important to implement sustainable practices to ensure the continued availability of these resources for future generations (Parawansa et al., 2024). Smallholder farmers in Indonesia contribute significantly to agricultural production but face obstacles such as resource constraints and limited market access. Sustainable agriculture programs focus on empowering these farmers through training, access to technology, and encouragement of sustainable practices. These initiatives are vital for preserving Indonesia's natural resources and enhancing food security amid population growth. Sustainability safeguards the environment, enhances farmers' livelihoods, and secures the future of Indonesia's agriculture.

Crop diversification by cacao (*Theobroma cacao*) farmers in Sulawesi is the practice of growing various crops alongside cacao to reduce risk, increase income, and support ecological sustainability. It helps farmers optimize land use, improve soil health, and adapt to market or climate changes by integrating other crops with cacao. Mixed cropping, a form of crop diversification, involves cultivating cacao with two or more crops on the same land. Common in Sulawesi, this system promotes land efficiency, ecological balance, and income diversification. Crop diversification is, therefore, a key strategy to increase sustainability, offering benefits such as increased farm productivity, improved soil health, stable income, and reduced risk (Irfany et al., 2020). Diversifying crops can increase soil fertility, with some plants, such as nitrogen-fixing legumes, and replenishing nutrients. This approach also reduces the dependence on specific soil nutrients, as different crops have varying nutrient requirements. Economically, diversification mitigates the risks associated with relying on a single crop, providing income year-round due to staggered harvest times. Farmers cultivating export crops such as cacao are prone to price fluctuations and productivity challenges from aging trees and pests and often diversify by integrating other crops or livestock. Therefore, this strategy can be used to stabilize income (Rifai et al., 2018).

In Sulawesi, some cacao farmers have turned to other crops in the face of productivity decline, soil exhaustion, and economic challenges (Wijaya et al., 2018). However, additional social factors are important to decision-making on issues related to environmental sustainability. These include personal and socially held beliefs and an associated understanding of environmental benefits (environmental knowledge). A community with a high level of environmental knowledge is likely to adopt sustainable practices such as crop diversification. By increasing the use of available social, financial and government services (such as programs for agricultural extension or access to finance), environmental knowledge, as well as other factors, could impact the ability of farmers to manage challenges to improve sustainability. This, in turn, could promote the application of sustainable farming practices. Gender may also play a role in decisions related to sustainability. According to Badan Pusat Statistik (2025) the agricultural sector is the largest in Indonesia, comprising the most employment, with a share of 28.54 percent, Women significantly contribute to agricultural tasks such as seed preparation, planting, nurturing, harvesting certain crops, and postharvest activities. Recognizing and leveraging women's potential in agriculture is crucial for sustainable practices and food security. Empowering women in agriculture requires concerted efforts from national and provincial governments, along with all stakeholders, to ensure food security locally and globally. However, women often face gender-based constraints that limit their participation and decision-making power in the agricultural sector (Ahmed et al., 2020; Quisumbing & Doss, 2021).

Gender equity and inclusion are pivotal for the effectiveness of sustainable agricultural practices (Quisumbing et al., 2022). Gender roles in agriculture vary significantly, with women frequently taking charge of food production, processing, and marketing. Women contribute distinct viewpoints and priorities that can effectively address the specific challenges and needs of female farmers and rural communities (Tourtelier et al., 2023; Wang & Jiang, 2020), whereas the males in farming families are directly involved in productivity activities (such as pruning, weeding and fertilizer application) to a greater extent than women are (Mulyoutami et al., 2015; Syafruddin & Risal, 2024). When women have access to resources, knowledge, and opportunities in agriculture, they are better able to adopt sustainable practices and contribute to improved crop yields, increased food security, and enhanced resilience to climate change. Women have other important roles in the agricultural sector, especially in financial decisions and the management of productive assets (Musa et al., 2024). Thus, women play a critical role, as they manage farm finances and the profits obtained from harvests, which can be allocated for family needs and farm activities, such as planting.

Currently, gender equality issues have received increasing attention, leading to greater awareness of the involvement of women in the agricultural sector (Akter et al., 2017). Gender disparities persist in various aspects of agricultural communities, for example, in farmer meetings and training. Women's participation is limited by other responsibilities, with less flexibility in commitments than men have. Men generally have better access to technology and training programs across regions. Analyzing gender dynamics in agriculture could enhance the understanding of sustainable practices, considering diverse social and cultural influences on decision-making. Although interest in the relationship between gender and the environment is increasing (Unay Gailhard, 2021), the relationship between gender and agriculture and, more specifically, between gender and sustainable agriculture has not been widely discussed in the published literature. There is little research on how gender influences farmers' practices and livelihoods (Danso-Abbeam et al., 2020; Jamal et al., 2021). Research on women's roles in sustainable agriculture explores their ideological motivations for farming rather than looking at the structural conditions underlying their participation (Pilgeram & Amos, 2015).

Factors such as attitudes toward sustainable practices, environmental knowledge and gender play critical roles in decision-making both in the workplace and within communities and families (Tourtelier et al., 2023). This is particularly important in relation to decisions in making changes in farming practices that aim to improve sustainability, both on the farm and in the wider environment. These critical factors have received little attention in relation to improved agricultural sustainability in Indonesia. Therefore, a study was conducted among cacao farming families who practice crop diversification. The aim was to identify key variables influencing the implementation of sustainable practices, taking gender into account.

The study was based on an analysis of data collected from cacao farmers in three provinces of Sulawesi, with the aim of identifying the influence of environmental knowledge, attitudes, subjective norms and gender inclusion on decision-making and the implementation of sustainable practices, particularly crop diversification.

Material and Methods

Model development

A model was developed for this study on the basis of the theory of planned behavior (TPB). This theory is a model for predicting and understanding human behavior according to the theory of reasoned action (Ajzen, 1991). It consists of components such as behavioral attitudes, normative beliefs, subjective norms, perceived behavioral control, behavioral intentions, and behavior. The TPB is commonly used in studies of farmer behavior, such as crop residue management, purchasing choices, and chemical usage (Bagheri et al., 2021; Ge et al., 2023; Tama et al., 2021). It is a flexible model that can incorporate additional variables, such as environmental knowledge, to enhance its predictive power in specific contexts, such as promoting pro-environmental behavior. Previous research has shown a strong link between environmental knowledge and pro-environmental actions (Ge et al., 2023; Tama et al., 2021). However, the TPB has been criticized for overlooking external factors such as resource access, the cultural context, and environmental awareness. It also tends to focus on rational decision-making, potentially ignoring emotional, habitual, or situational influences on behavior. In this study, environmental knowledge was added to the TPB model to investigate the willingness of smallholder farmers of different genders to meet the challenges of applying sustainable practices, for example, through access to the government and other services.

The model was developed to elucidate the relationship of Environmental Knowledge and two other variables (Subjective Norms and Attitudes) with household (behavioral) outcomes (such as financial management). To test these relationships, a structural equation model (SEM) was developed using partial least squares (PLS) analysis. In contrast to other SEMs, this approach allows for small sample sizes and the inclusion of non-normal data. Furthermore, relationships can be evaluated simultaneously. The relationship between latent and observable variables was defined as reflective. In other words, the measurable indicators are seen as a reflection (outcome) of latent variables, such as attitudes. In a reflective approach, the underlying concept exists independently of the specific measures used to quantify it. Even if one of the measures is removed from the analysis, the latent variable remains present. Various studies in business and similar fields rely on reflective measurement approaches (Coltman et al., 2008).

The structural model was based on path analysis with the aims of elucidating the effects of individual Attitudes and Subjective Norms on other latent variables, i.e., Environmental Knowledge and the ability to manage financial and other challenges using available resources, and quantifying the direct and indirect relationships between variables (Figure 1). This approach was applied to evaluate the key factors that impact farmer decisions in developing sustainable practices. Data were collected from a sample population. Demographic data were collected on the farmers, as well as their socioeconomic status and the crops planted on the farm. Questions were prepared to evaluate farmer attitudes and the subjective norms in the family or community, providing the observable indicators in the model. In this study, we refer to Attitudes (AT) as personal opinions or beliefs related to crop diversification, Subjective Norms (SN) as individuals' perceptions of what others expect them to do or behave in a certain way, and Environmental Knowledge (EK) as an understanding of the environmental benefits of crop diversification. Implementing strategies on the farm, such as crop diversification, entails meeting challenges, changing farming practices, accessing services (such as agricultural extensions provided by the government or Non-Governmental

Organizations (NGOs) and financial management, including accessing sources of finance. The category 'Social Services, Finances, and Household and Community Challenges' (SSHFC) refers to the level of understanding of available supporting social services and financial support and, consequently, the willingness to take action to improve sustainable practices. Therefore, this category was theorized as an outcome of other latent variables in the model. Finally, the TPB model was constructed to investigate the factors influencing farmers' inclination to diversify their crop selection, considering differences in gender.

Therefore, the model was applied to explore the factors influencing smallholder farmers' willingness to diversify their crops using an extended theory of planned behavior (TPB) framework. The main research question in the study was how Attitudes, Subjective Norms, and Environmental Knowledge, including mediating effects, influence behavioral outcomes related to implementing sustainable practices on the farm.

Specifically, the hypotheses (H) tested by the model were as follows:

H_1: Attitudes influence Environmental Knowledge.

H_2: Attitudes influence understanding of Social Services, Finances, and Household and Community Challenges.

H_3: Subjective Norms influence Environmental Knowledge.

H_4: Subjective Norms influence understanding of Social Services, Finances, and Household and Community Challenges.

H_5: Environmental Knowledge influences understanding of Social Services, Finances, and Household and Community Challenges.

H_6: Environmental Knowledge has a mediating effect on the relationships among Attitudes and understanding of Social Services, Finances, and Household and Community Challenges.

H_7: Environmental Knowledge has a mediating effect on the relationships between Subjective Norms and understanding of Social services, Finances, and Household and Community Challenges.

An additional research question was how gender influences the results generated by the model and,

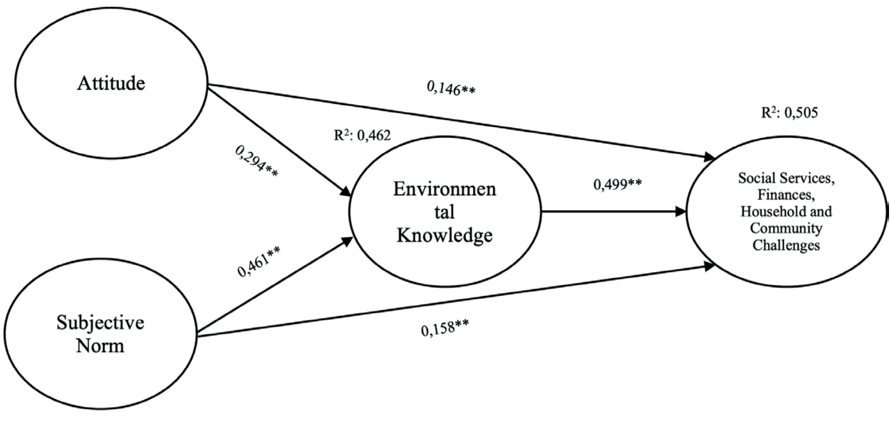

Figure 1. Structural Model Testing of the Conceptual Model.

The solid lines represent direct effects; dashed lines represent indirect effects. Note: Standardized path coefficient ($p < 0.05$); significance **0.01, *0.05.

therefore, potentially affects the implementation of sustainable solutions on the farm. Gender-based differences were identified through multigroup analysis. Multigroup analysis was applied to separate the direct and indirect effects of variables in the model for male and female farmers. Direct effects account for the relationship between variables without considering intermediaries, whereas indirect effects indicate the impact of one variable on another through intervening variables (mediators).

Location and population sampling

The research was conducted in the cacao farming communities of South Sulawesi (Luwu, Bone, and Takalar), West Sulawesi (Mamuju, Polewali Mandar and Mamasa), and Central Sulawesi (Donggala and Sigi) Provinces from January 2023 to December 2024. In these farming regions, cocoa beans are sold to local collectors and are generally uncertified. Farming family representatives included in the study were selected according to several criteria, such as farmer households practicing the cultivation of diverse crops (see below). Each respondent was asked to sign a consent form prior to being interviewed. The population sample included 197 respondents in South Sulawesi, 154 respondents in West Sulawesi and 84 respondents in Central Sulawesi, resulting in a final sample of 435 respondents.

The majority of cacao smallholders farmed approximately one hectare. The participants resided primarily in agricultural regions within the study area, with each selected household owning a small farm of one hectare or less. We selected this size because of the diminishing amount of agricultural land in Indonesia, as well as the diminishing amount allocated to cacao (Wijaya et al., 2018). Participants who practiced mixed cropping (growing other crops in addition to cacao) were selected; the criterion used was that farmers grew at least 2 crops that generated some income in addition to cacao.

Measurable indicators for the model were obtained from the sample population. A structured survey with three parts was created to gather data from the respondents. The initial section focused on the socioeconomic backgrounds of the participants, covering factors such as age, gender, marital status, household income, and education level. The second section gathered the farmers' perspectives on crop diversification, including their thoughts on planting a variety of crops and the reasons and challenges associated with diversifying their crops. Twelve questions were created to gather data from farmers. Questions were included to assess Attitudes (with four items), Subjective Norms (with three items), Environmental Knowledge (with three items), and challenges related to Social Services, Finances, Households, and Communities (with two questions).

The study also took a qualitative approach. The purpose of using a mixed-method approach was to provide participants with the opportunity to respond to questions openly and potentially share their personal perspectives while still following the interview guidelines. The guide included four primary questions, with the possibility of asking additional questions on the basis of the individual being interviewed, their profession, their organization, or any relevant points raised during the conversation. The interviews focused on the following:

- Global changes that shape today's agricultural world in relation to the environment.

- The impact of gender on more environmentally friendly agricultural practices and the reasons that might explain it.

- Potential indicators for assessing the impact of gender on sustainable agricultural practices.

Measurement and latent variables

Table 1 outlines the key variables and indicators used to measure farmers' perceptions and contextual factors influencing crop diversification. The variable Attitudes (AT) captures farmers' positive evaluations of diversification, including its ecological benefits (e.g., reducing pests and preserving traditional seeds), economic potential, and role in climate change adaptation. Subjective Norms (SN) assess social influence from family, extension agents, and government support, reflecting perceived encouragement from important referents. Environmental Knowledge (EK) examines respondents' awareness of the environmental and health benefits of diversification, as well as practical knowledge of its methods. Lastly, Social Services, Finances, and Household and Community Challenges (SSFHCC) address external enabling or constraining factors, focusing on farmers' optimism and confidence in accessing social and financial support. Together, these variables provide a comprehensive framework for analyzing behavioral intentions and actual adoption of crop diversification practices.

This study employed a partial least squares-structural equation model (PLS-SEM) as the analysis method with two stages of analysis: outer model analysis and inner model analysis. Smart-PLS software was used to test the relationships theorized in the model (Hair et al., 2017). The outer model analysis was applied to check whether the measurement indicators used were valid and reliable. The inner model examined the structural model formed and examined the relationships between latent variables in the model.

Multigroup analysis

Moderated group analysis (MGA) was applied to elucidate differences between genders by

Table 1. Summarizes the variables measured in the survey.

Variable	Code	Indicators
Attitudes	AT 1	I believe that diversifying crops is beneficial as it helps reduce weed and pest problems
	AT 2	I am of the opinion that planting a variety of crops can lead to higher economic profits.
	AT 3	In my view, diversification is advantageous in combating the effects of climate change
	AT 4	I believe that diversifying crops helps preserve local traditional seeds.
Subjective Norms	SN 1	My family and friends are in favor of expanding the variety of crops grown
	SN 2	Agricultural extension workers actively encourage diversifying crops
	SN 3	The government provides substantial support to farmers in their efforts to diversify crops.
Environmental Knowledge	EK 1	I recognize that crop diversification benefits both soil health and human well-being. Fertile, well-balanced soil produces nutrient-rich crops, directly improving nutrition and health.
	EK 2	I understand that crop diversification is important for preserving the environment
	EK 3	I know that crop diversification can be accomplished through methods such as using a variety of seed species, intercropping, and rotating crops.
Social Services, Finances, and Household and Community Challenges	SSFHCC 1	How optimistic are you about accessing additional social services to assist your household?
	SSFHCC 2	How sure are you that you will be able to access farm credit, subsidies, or other financial assistance?

partial least squares structural equation modeling (PLS-SEM). By applying MGA to two groups in the study (male and female), it is possible to analyze and quantify how gender moderates the relationships within the structural model. Therefore, MGA was applied in PLS-SEM to uncover differences between genders in the relationships between the latent variables in the model and how they influence outcomes relevant to farmers, thus providing insights that are crucial for targeted interventions and policy decisions (Cheah et al., 2020).

Results and Discussion

Demographic data

Table 2 summarizes the demographic profile of the respondents. The respondents consisted of 58.2% men and 41.8% women. Almost half (45.3%) of the total respondents were from South Sulawesi. Most had an elementary school education (46.2%). The majority of respondents (33.6%) had a monthly income ranging from Rp. 4,000,000.00 to Rp. 6,000,000.00 (USD 245-368). Among the respondents, 44.4% were aged 40-49 years. The majority (84.6%) were married. The farmers in the sample grew a number of crops in combination with cacao, including cassava, ginger, chili, Gliricidia (gamal), langsat, coconut, maize and patchouli (Table 2).

a, *Manihot esculenta*; b, *Zingiber officinale*; c, *Capsicum frutescens*; d, *Gliricidia sepium*;

e, *Lansium domesticum*; f, *Cocos nucifera*; g, *Zea mays*; h, *Pogostemon cablin*.

Table 2. Demographic characteristics of the sample.

Demographic	Category	n	%
Gender	Male	253	58.2
	Female	182	41.8
Age	20-29	31	7.1
	30-39	86	19.8
	40-49	193	44.4
	50 or older	125	28.7
Marital Status	Single	19	4.4
	Married	368	84.6
	Divorced/Widowed/Separated	48	11.0
	Elementary school	201	46.2
Education	Junior high school.	96	22.1
	Senior high school	82	18.8
	Bachelor’s degree	42	9.7
	Postgraduate	14	3.2
Income Range (Rupiahs)	Less than 2.000.000	64	14.7
	2.000.000-3.999.999	92	21.1
	4.000.000-6.000.000	146	33.6
	More than 6.000.000	133	30.6
Location	South Sulawesi	197	45.3
	West Sulawesi	154	35.4
	Central Sulawesi	84	19.3
Crop Diversification Type	Cacao - Cassava[a] - Ginger[b]	55	12.6
	Cacao - Cassava - Chili[c]	86	19.8
	Cacao -Gliricidia[d] - Langsat[e]	125	28.7
	Cacao - Coconut[f] - Maize[g]	76	17.5
	Cacao- Coconut - Patchouli[h]	93	21.4

Source: Primary Data Process (2023).

Reliability and validation of the model

The results of the outer analysis of this research model are summarized in Table 3, which demonstrates that the outer model has excellent reliability and validity (Hair et al., 2017). On the basis of construct validity and reliability, all the loading scores were above 0.5, so there were no indicators to be eliminated from the research model. Discriminant validity can be evaluated by looking at average variance extracted (AVE) scores, which must be above 0.5. Table 3 shows that all the AVE scores had acceptable values, and a high composite reliability (CR) was demonstrated, in addition to applying the Fornell and Larcker criterion (see below). These results confirmed the discriminant validity of the model variables.

On the basis of the results of the Fornell–Larcker

Table 3. Construct validity and reliability (see Table 1).

Construct/Item	Loading Factor	Cronbach's Alpha	CR	AVE
Attitudes (AT)		0.870	0.911	0.718
AT1	0.826			
AT2	0.872			
AT3	0.837			
AT4	0.855			
Subjective Norms (SN)		0.865	0.917	0.787
SN1	0.874			
SN2	0.897			
SN3	0.891			
Environmental Knowledge (EK)		0.749	0.855	0.664
EK1	0.830			
EK2	0.767			
EK3	0.845			
Social Services, Finances, and Household and Community Challenges		0.876	0.915	0.731
Social Services (SS)	0.823			
Social Finance (SF)	0.897			
Social Household (SH)	0.903			
Social Community Challenges (SC)	0.791			

Source: Primary Data Processing (2023).

Table 4. Discriminant Validity of Variables (Fornell & Larcker Criterion).

	Attitudes	Subjective Norms	Environmental Knowledge	Social Services, Finances, and Household and Community Challenges
Attitudes	0.848			
Subjective Norms	0.575	0.815		
Environmental Knowledge	0.529	0.685	0.855	
Social Services, Finances, and Household and Community Challenges	0.609	0.640	0.567	0.887

Source: Primary Data Processing (2023).

criterion test, the square root value for AT was 0.849, which was greater than the correlation of the other variables (Table 4). Additionally, the square root values for SSFHC and EK were greater than those of the other variables. This indicates that the requirements for discriminant validity (Fornell–Larcker) were met and are acceptable.

Inner Structural Model Analysis

The second step evaluated the inner structural model (Table 5). The R^2 results demonstrated that a substantial part of the variance of the endogenous latent constructs could be explained by the model. The R^2 values for Environmental Knowledge and Social Services, Finances, and Household and Community Challenges (SSHFC) were 0.477 and 0.500, respectively (Figure 1). Since the explained variances were greater than 30%, the homological validity of the model was deemed satisfactory (Chin et al., 2020).

Table 5. Inner Model Validity (R^2 and Q^2).

	R^2	Q^2
Environmental Knowledge	0.462	0.297
Social Services, Finances, and Household and Community Challenges	0.505	0.359

Source: Primary Data Processing (2023).

The structural model was also assessed to determine its ability to predict the endogenous latent variable indicators, referred to in the PLS-SEM literature as cross-validated redundancy measures. Subsequently, the Q^2 values and the predominant measures of predictive relevance were obtained by blindfolding procedures (Tenenhaus, 2008) (Table 5). The Q^2 values for EK and SSHFC were 0.302 and 0.370, respectively. Q^2 values above 0.35 indicate substantial predictive relevance for explaining the variable studied (Henseler et al., 2012).

PLS Estimates and Hypotheses for Testing the Structural Model

After the outer model was tested, the direct effect between variables and the indirect effects were tested, with Environmental Knowledge (Figure 1) as the mediator, as shown in Table 6.

On the basis of the results, all hypotheses (H) were accepted; in each case, a significant relationship occurred between variables. In the following discussion, path coefficients (see Table 6 and Figure 1) are shown in parentheses.

This study provides evidence of the importance of farmers' attitudes in improving agricultural environmental knowledge, which is key for addressing climate change. The first hypothesis, H1, was accepted, indicating that Attitude significantly influences Environmental Knowledge (0.275). Positive attitudes toward sustainable practices and environmental protection can lead to increased

Table 6. Hypothesis testing for the total sample.

Variable	Direct		Indirect		Total	
	Path Coefficient	T statistic	Path Coefficient	T statistic	Path Coefficient	T statistic
H1: AT → EK	0.294	5.191**	-	-	0.294	5.191**
H2: AT → SSFHC	0.146	2.419**	-	-	0.146	2.419**
H3: SN → EK	0.461	8.204**	-	-	0.461	8.204**
H4: SN → SSFHC	0.158	2.248**	-	-	0.158	2.248**
H5: EK → SSFHC	0.499	7.144**	-	-	0.499	7.144**
H6: AT → EK → SSFHC	0.294	5.191**	0.147	3.766**	0.441	5.191**
H7: SN → EK→ SSFHC	0.461	8.204**	0.230	4.978**	0.691	8.204**

Source: Primary Data Processing (2023).

Note. AT: Attitudes, SN: Subjective Norms, EK: Environmental Knowledge, SSFHC: Social Services, Finances, and Household and Community Challenges; significance **0.01, *0.05.

knowledge and more informed decision-making among farmers. This includes selecting climate-resilient crops, improving water management, and reducing greenhouse gas emissions. This result is consistent with the findings of Ge et al. (2023). This can ultimately lead to more sustainable and environmentally friendly farming practices, which are essential for mitigating the impacts of climate change and preserving the long-term viability of agriculture. We can conclude that encouraging farmers to care for the environment can help improve sustainability in agriculture and combat climate change. By sharing their knowledge, farmers can inspire others to follow suit and create a positive impact in their communities. Notably, farmers have been exposed to the government, companies and other training programs, which could influence their responses.

With respect to H2, the results indicate that Attitudes significantly influence active measures to address financial, household and community challenges and access social services (0.140) i.e. SSFHC. The results show that farmers with a positive attitude toward sustainability are more likely to seek information on social services, finances, and community challenges. In Sulawesi, cocoa farmers practicing agroforestry actively pursue knowledge of soil conservation, pest management, and climate-resilient crops. They engage in workshops, collaborate with NGOs, and participate in government programs, enhancing their knowledge and addressing socioeconomic issues. Their commitment to sustainability reflects a broader interest in improving both environmental and community well-being (Kurdyś-Kujawska et al., 2021). Hypothesis 3 was accepted, showing a significant effect of Subjective Norms on Environmental Knowledge in the sample (0.481). An example of cocoa farmers in Sulawesi benefiting from community and government support might be a group of farmers in a local cooperative that receives training from the government on sustainable farming practices. These farmers, encouraged by their peers and families, may decide to diversify their crops by planting cocoa alongside food crops such as bananas, rambutan, or langsat. This approach can not only improve soil health and reduce pest problems but also increase biodiversity. With continued support from a farmer group and local agricultural extension services, farmers are more likely to adopt long-term, sustainable practices, leading to higher yields and better environmental outcomes. This exchange of information by community members supports the goals of the Ministry of Agriculture (Kementerian Pertanian, 2020) in Indonesia, i.e., to provide support and incentives for farmers to diversify their crops. Local communities offer knowledge, resources, and encouragement. Additionally, if consumers value and demand sustainably grown produce, farmers may be more inclined to adopt diversification practices to meet market demands. Overall, a positive relationship between Subjective Norms and Environmental Knowledge can lead to increased awareness and adoption of crop diversification, ultimately benefiting the environment, the community, and the farmers themselves.

A significant path coefficient (0.148) provided support for H4, revealing a positive effect of Subjective Norms on seeking resources related to Social Services, Finances, and Household and Community Challenges. The results from the tested model indicated that Subjective Norms positively affect farmer decision-making. Consequently, it can be surmised that they see the benefits of growing a variety of crops instead of just focusing on one type, and seek resources accordingly. For example, governments may provide funding or technical assistance for farmers to diversify their crops, or they may create policies that incentivize diversification (Isbell et al., 2021). Surrounding communities may also play a role in supporting farmers by providing market access for a diverse range of crops, creating a demand for locally grown and diverse produce. This positive relationship among farmers, community and family members, and governments can help address various challenges that farmers may face, such as financial constraints, household food security issues, and community resilience. By working together to promote crop diversification, all parties involved can contribute to a more sustainable and resilient agricultural system that benefits both farmers and society as a whole. This can help improve soil health, reduce pests and diseases, and provide a more stable income. Support for H5 in the model shows that Environmental Knowledge has a significant effect on Social Services, Finances, and Household and Community Challenges in the study sample (0.508). A good level of environmental knowledge means that farmers understand and value the importance of sustainable farming practices, the conservation of natural resources, and ways to minimize their impact on the environment. This mindset can have a positive impact on various aspects of their lives, including social services, finances, household management, and community challenges.

Two further hypotheses focused on mediation effects. Significant indirect effects were identified, supporting H6 and H7 (Table 6). Figure 1 presents the structural model, showing the path coefficients for the direct and indirect effects determined in the analysis. H6 was supported by the model, indicating that Environmental Knowledge can mediate the relationship between Attitudes and access to Social Services, Finances, and Household and Community challenges (SSFHC) by influencing individuals' understanding of the impacts of their actions on the environment. People with greater environmental knowledge may be more likely to support social services that promote sustainability, such as recycling programs or community gardens. They may also be more aware of the financial benefits of implementing energy-efficient practices in their homes and communities. Additionally, individuals with greater environmental knowledge may be more inclined to consider the environmental consequences of their actions when making financial decisions, such as choosing sustainable products or investing in renewable energy sources. This awareness can also extend to household practices, such as reducing waste or conserving water and energy (Ge et al., 2023). Overall, environmental knowledge can help individuals make more informed and sustainable choices in all aspects of their lives, leading to more positive impacts on both the environment and their communities. It also encourages individuals to become involved in activities that promote sustainability and resilience in the face of environmental issues. With a greater understanding of environmental issues, people can make better choices in areas such as social services, finances, household practices, and dealing with community challenges. Increasing environmental knowledge can lead to more informed decisions that benefit both individuals and their communities.

Finally, the results of the study support H7, showing that Environmental Knowledge can play a mediating role between Subjective Norms and active engagement in Social Services, Finances, and Household and Community Challenges (SSFHC). Subjective Norms (such as socially held beliefs) directly affect SSHFC, but a significant indirect effect occurs by the mediator of Environmental Knowledge. Individuals with higher levels of environmental knowledge may be more likely to understand the interconnectedness of social, economic, and environmental systems, supporting subjective norms that prioritize sustainable solutions in addressing various challenges and, in turn, access resources, such as services or available finance. Individuals with greater environmental knowledge may be more inclined to support the implementation of renewable energy sources to address energy affordability issues in households, recognizing the long-term benefits for both the environment and the economy (Middendorf et al., 2021). Similarly, understanding the impacts of waste production on the environment may lead individuals to support recycling programs to address community challenges related to waste management.

Generally, the results of the study indicate the importance of Environmental Knowledge in its mediating role for farmers seeking out more sustainable practices on the farm. By prioritizing Environmental Knowledge, farmers may be more likely to seek out and benefit from social services that support sustainable practices and provide resources for implementing them. This could lead to improved access to training, equipment, and funding opportunities that help them to protect the environment while also increasing their productivity and profitability (Nidumolu et al., 2022). Farmers who understand the importance of the environment are more likely to make sustainable choices that can benefit their finances, households, and communities in the long run. They may save money by using fewer resources, having healthier soil for their crops, and creating market opportunities for eco-friendly products. By leading by example, they can also inspire others in their community to adopt sustainable practices and help create a healthier future for everyone.

In conclusion, evidence provided in support of the proposed hypotheses shows that environmental knowledge is essential for informed decision-making and can shape attitudes toward a wide range of issues, including social services. By understanding the interconnectedness of environmental issues and social challenges, individuals can work toward creating more sustainable and equitable solutions that benefit both people and the planet. It is important for individuals, communities, and policy-makers to continue prioritizing environmental education and awareness to build a more resilient and sustainable future for all. Farmers who care about sustainability see themselves as caretakers of the land and community. They look for ways to manage their farms better and overcome challenges. They may seek financial help for sustainable practices, learn about social services, and address household and community issues. Farmers who embrace sustainability are more likely to use resources to improve their farming and quality of life.

The Moderating Role of Gender in Farmers' Crop Diversification

The rationale applied to this part of the study was that gender norms and expectations also influence perceptions of roles in farming, with environmental knowledge and innovation typically being channeled more toward men. Addressing these gender disparities is crucial for promoting more inclusive and effective adoption of sustainable agricultural practices.

We examined the moderating role of gender in crop diversification. This analysis was conducted by dividing the samples into male and female respondents (farmers) who practiced crop diversification. Multiple (or moderator) group analysis (MGA) was applied to the two groups (Cheah et al., 2020). Table 7 shows the direct, indirect and total effects among the variables in the model for both genders, along with the differences in effects between men and women.

Consistent with the path coefficients reported in Table 6, Attitudes (AT) significantly influenced Environmental Knowledge (EK) and Social Services, Finances, and Household and Community Challenges (SSHFC) in both genders (Table 7), with

Table 7. MGA Results: Gender Comparison in the PLS-SEM

Variable	Men			Women			Difference		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
AT → EK	0.270**	-	0.270**	0.356**	-	0.356**	-0.086ns	-	-0.086ns
AT → SSFHC	0.207**	0.138**	0.345**	0.078ns	0.175**	0.253**	0.129ns	-0.037ns	0.092ns
SN → EK	0.593*	-	0.593*	0.281**	-	0.281**	0.312**	-	0.312**
SN → SSFHC	0.084ns	0.304**	0.388**	0.225**	0.139**	0.363**	-0.141ns	0.166**	0.025ns
EK → SSFHC	0.513**	-	0.513**	0.493**	-	0.493**	0.020ns	-	0.020ns

Source: primary data processing (2023).

Notes: AT: Attitudes, SN: Subjective Norms, EK: Environmental Knowledge, SSFHC: Social Services, Finances, and Household and Community Challenges; ns refers to nonsignificant effects at the 0.05 level. All other effects were significant at a p value < 0.05.

no significant difference found between the two genders. Additionally, significant pathway coefficients between EK and SSFHC for both genders suggest that farmers with some environmental knowledge were likely to seek out government and financial services to implement sustainable methods. The analysis suggests that individuals' attitudes toward the environment are not strongly influenced by their gender. Instead, attitudes toward the environment and environmental knowledge are more likely to be influenced by other factors, such as education, personal beliefs, and cultural background. These results differ from those reported in a previous study by Unay Gailhard (2021). Female farmers in Slovenia were more inclined to embrace innovation, seek out new information, and demonstrated a greater eagerness to secure government funding. In contrast, our study implies that individuals' views on the environment and their understanding of environmental issues are not heavily influenced by their gender, but rather by factors such as education, personal beliefs, and cultural upbringing.

Second, the data show that Subjective Norms (SN, peer influences, social and community values) directly influenced EK (or understanding of environmental issues) in both genders and that this effect was even greater in men than women, indicated by the significant difference in path coefficients of 0.312 (Table 7). The higher participation of men in farmer group meetings and their exposure to training by agricultural extension staff could partly explain this difference.

Third, the results of the analysis revealed that a significant difference in pathway coefficients (0.166) occurred between genders in the indirect effect of Subjective Norms (SN) on Social Services, Finances, and Household and Community Challenges (SSHFC). A greater indirect effect in men than in women shows that Environmental Knowledge (EK, as a mediator between SN and SSFHC) affected men much more than women in the sample (Table 7). This is supported by the weak direct effect of SN on SSHFC in men, suggesting that some environmental knowledge is required before men actively seek services in the community. On the other hand, the relationship between SN and SSHFC among women shows that these women are more likely to seek such services, whether or not the relationship is mediated by EK. However, while women are influenced (more so than men) by peers and community expectations (i.e. SN) to seek out external services, such as financing or other community support systems (i.e. SSHFC), a greater awareness or knowledge of environmental issues (EK) enhances this effect, as shown by the significant indirect pathway coefficients for the effect of SN on SSFHC in both genders.

Taken together, the results indicate the strong mediating role played by EK on outcomes such as accessing external services and financing (SSFHC) and potentially seeking to implement sustainable methods on the farm. Males in farming families may have greater exposure to extension services and community (farmer) meetings, but the results indicate that although women are strongly influenced by peers in the community (i.e., SN), their behavior is also influenced (or mediated) by their level of environmental knowledge (i.e., EK). This study focused on farming families, and within individual families both genders influence each other. Further research is needed to elucidate such intrafamily effects.

By examining how gender influences the relationship between Subjective Norms and Environmental Knowledge, researchers can better tailor interventions and strategies to promote sustainable farming practices and environmental stewardship among farmers. Additionally, understanding these moderating effects can help inform policy decisions and initiatives aimed at fostering a more sustainable agricultural industry.

Policymakers and service providers must understand and address these pressures to ensure equitable access to resources and support for all individuals. By recognizing and addressing subjective norms, it is possible to create a more inclusive and supportive environment for women farmers and other marginalized populations in need of social services.

Conclusion

In conclusion, this study revealed that the relationships among attitudes, subjective norms, environmental knowledge, and gender play a significant role in shaping individuals' behaviors and responses to accessing social services and financing and overcoming household and community challenges, which are necessary for the implementation of sustainable practices such as crop diversification. In addition, we found that gender not only impacts how individuals approach farming but also has broader implications for agricultural practices and community dynamics. Recognizing and addressing gender-related differences in approaching sustainable practices is essential for developing effective agricultural policies and support programs in Sulawesi.

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