Knowledge, Attitudes, and Intentions of Biosolids use in Agriculture: Perspective from the Agricultural Managers of the Dominican Republic

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Abstract **– Biosolids have benefits for soil and crop production and contribute to sustainable development. The use of biosolids in agriculture holds great potential for enhancing the economic development of rural communities. This research aims to analyze the mediating role of attitudes between knowledge and the intention to use biosolids as fertilizer. During the examination process 635 questionnaires were obtained, and statistical analysis was performed using Smart-PLS. The results of the study indicate that attitudes play a mediating role between knowledge and the intention to use biosolids in agriculture. In conclusion, it is emphasized in the need for positive attitudes towards the use of biosolids among agricultural managers, directors, technicians, and farmers. These results benefit the Dominican Republic's Ministry of Agriculture, agricultural professionals, and farmers. The Ministry can shape policies and offer education on biosolid use. Agricultural leaders should consider attitudes alongside knowledge. Farmers should stay informed and adopt biosolid practices for better crop productivity and soil health.**

Keywords **– Knowledge, attitude, intention to use, biosolids, fertilizer.**

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1. Introduction

Biosolids are nutrient-rich organic materials that result from wastewater treatment [1]. The application of biosolids to agricultural and forest lands is a well-established practice in many parts of the world [2]. The use of biosolids in agriculture offers numerous benefits that can potentially improve soil quality, increase crop yields, and reduce the environmental impacts of waste disposal. Biosolids are an important source of organic matter, nitrogen, phosphorous, and other essential nutrients that can improve soil fertility [3]. Also, biosolids can be beneficial in increasing the water holding capacity of the soil and reducing soil erosion. Organic materials in biosolids can improve soil structure, increasing soil porosity, promoting better root development, and facilitating better water infiltration. Additionally, the presence of biosolids can suppress soil-borne diseases, reducing the need for synthetic chemical fertilizers and pesticides. However, certain precautions must be taken in the use of biosolids in agriculture, especially about the potential for pathogen transmission and accumulation of heavy metals in the soil [4], [5]. The successful adoption of biosolids as fertilizer relies heavily on farmers' knowledge, attitudes, and intentions regarding their usage. Understanding farmers' perspectives is crucial for effective implementation and acceptance of biosolids in agricultural practices [6].

The use of biosolids as fertilizer by farmers in rural communities can contribute to the economic development of the region.

Agricultural practices play a significant role in improving the social and economic conditions in rural communities [7]. By intensifying agricultural production and increasing crop yields, farmers can enhance their livelihoods and generate income [7]. Economic efficiency in agriculture is considered a key pillar for rural sustainability and can create favorable conditions for rural development [8]. Sustainable rural agricultural development, including the use of biosolids as fertilizer, can provide new sources of revenue and improve the livelihoods of rural communities [9]. Additionally, incorporating agroecological approaches in agricultural practices aligns with sustainable development objectives and contributes to economic growth in rural areas [10]. Therefore, promoting sustainable agricultural practices and supporting rural communities, biosolids as fertilizer can contribute to the economic development of rural regions [7].

The objective of this research is to analyze whether attitudes towards the use of biosolids is a mediating element between knowledge about the use of biosolids (KUB) and intention to use biosolids as fertilizer (IUB). The research question addressed in this study is how attitudes towards the use of biosolids influence the relationship between knowledge about the use of biosolids (KUB) and intention to use biosolids as fertilizer. In this manner, the study aims to ascertain the mediating role of attitude among farmers, with the objective of gathering insights that can be applied practically to enhance biosolid utilization. The findings from this research can be valuable to both the Dominican Republic's government, specifically the Ministry of Agriculture, and local farmers. They can serve as a catalyst for the development of strategies aimed at utilizing biosolids as fertilizers, thereby contributing to the economic advancement of the region [8]. This study holds significance because, although there have been previous investigations by various authors [11], [12] on the variables under scrutiny here (knowledge, attitude, and intention), it marks a pioneering effort, as per the authors of this research, in exploring this relationship through the lens of farmers' perceptions of biosolid use.

Furthermore, this research is relevant due to the increasing importance of sustainable agricultural practices and the potential benefits of using biosolids as fertilizer. Overall, this study aims to fill a research gap by examining the mediating role of attitudes between knowledge and intention to use biosolids in agriculture, specifically from the perspective of agricultural managers, directors, and technicians. By understanding the factors that influence farmer acceptance and adoption of biosolids, practical implications can be derived for improving their utilization.

The findings of this study will provide valuable information for the government, agricultural entrepreneurs, agricultural technicians, and farmers, facilitating the development of effective strategies and policies for the safe and efficient use of biosolids in agriculture. Thus, this research contributes to the broader field of environmental research and sustainable agricultural practices, promoting a more holistic approach to waste management and soil fertility improvement, while contributing to the economic development of rural communities.

2. Literature Review

Knowledge encompasses the collection of facts and principles that humanity has gathered in a specific field, encompassing both declarative and procedural knowledge [13]. Declarative knowledge pertains to the understanding of facts, concepts, and the connections between them, which can be conveyed through language or reside within mental models. In contrast, procedural knowledge pertains to the ability to apply this knowledge in practical actions [14]. Knowledge can be categorized as either objective or subjective, with objective knowledge denoting the actual information retained in an individual's mind, reflecting their true understanding of a product, issue, or subject. Subjective knowledge, on the other hand, refers to an individual's personal assessment of their own knowledge and expertise [15]. Farmers' knowledge about the composition, benefits, and potential risks associated with biosolids significantly impacts their decision-making process [16]. Educating farmers about the source, treatment, and regulatory guidelines governing the use of biosolids is essential in dispelling misconceptions and ensuring informed choices [17]. Studies have shown that farmers with greater knowledge of biosolids tend to have more positive attitudes and are more likely to use them as a fertilizer. However, knowledge gaps and concerns about potential environmental impacts, such as heavy metal accumulation or microbial contamination, may hinder their acceptance [16].

Attitudes encompass one's beliefs and emotions regarding an object, which subsequently influence one's consistent actions toward that object [18]. Essentially, attitudes revolve around feelings and pre-established opinions about something [19]. Lian *et al*. [20] suggested that an attitude represents an individual's inner inclination toward an external object, serving as the starting point and groundwork for subsequent actions. Consequently, an attitude constitutes a multifaceted psychological process that incorporates inclinations towards perception, emotions, and behaviour, characterized by enduring and uniform traits [21].

Following Vandamme [22], attitude is the feeling that an individual has about something. Therefore, attitudes play a vital role in shaping farmers' perception and acceptance of biosolids as a viable fertilizer option. Positive attitudes are often influenced by perceived benefits such as enhanced soil fertility, improved crop yield, and reduced reliance on synthetic fertilizers [16]. Additionally, farmers who prioritize environmental sustainability and resource conservation are more inclined to view biosolids favorably [17]. On the other hand, negative attitudes can stem from concerns related to odor, appearance, public perception, and potential health risks [23]. Farmers' attitudes are also influenced by social and cultural factors, as well as experiences with other organic fertilizers [24].

Behavioural intention is defined as the examination of how individuals, groups, and organizations go about the processes of selecting, acquiring, using, and disposing of products, services, experiences, or ideas to meet their needs, and the consequences of these processes on individuals and society [25]. Consequently, behaviour serves as a broad term encompassing all of an individual's activities [26]. According to Manzo and Perkins [27], aspects such as place identity, a sense of community, and social capital are integral components of interactions between individuals and their environment, which promote community development across physical, social, political, and economic dimensions. This is due to the emotional connections people have with places, which motivate them to seek, stay, protect, and enhance locations of significance to them. Consequently, this encourages their involvement in enhancing their community and participating in local planning efforts. In relation to the intention of using biosolids in agriculture, intentions are influenced by a multitude of factors, including economic considerations, accessibility, perceived effectiveness, and regulatory support. Economic viability plays a crucial role, as farmers need to assess the cost cost-effectiveness effectiveness of acquiring, transporting, and applying biosolids compared to traditional fertilizers [17]. Additionally, farmers may consider the logistical aspects, such as the availability and proximity of treatment facilities or the compatibility of biosolids with their existing farming practices. Furthermore, farmers' intentions are influenced by the perceived effectiveness of biosolids in achieving desired outcomes [24]. Scientific evidence showcasing the positive effects of biosolids on soil quality and crop productivity can bolster farmers' confidence in their efficacy [28]. Supportive policies and regulations that ensure the safety and quality of biosolids can also instill trust and encourage farmers to adopt them [29].

Based on the information above, this research presents the following research hypotheses:

- H1: Knowledge about the use of biosolids (KUB) is positively associated with intention to use biosolids as fertilizer (IUB).
- H2: Knowledge about the use of biosolids (KUB) and intention to use biosolids as fertilizer (IUB) is positively mediated by attitudes towards the use of biosolids (AUB).

3. Materials and Methods

In this session the research methodology is presented. First, the sample and the design of the questionnaire are described, and then the survey measures and preliminary statistical data are presented.

3.1. Sample and Questionnaire Design

A quantitative instrument has been used, duly structured and based on items adapted from previously conducted studies [12], [30], [31], [32], [33], [34]. The survey collection period covered the months of September to December 2022 (both months inclusive). The place of collection of the surveys was in the northwestern region of the Dominican Republic (Valverde, Santiago Rodríguez, Dajabon and Motecristi provinces), the main organic banana producing area in the country. The structure of the questionnaire is divided into four clearly differentiated parts. On the one hand, a first initial part where issues related to farmers' knowledge about the use of biosolids as fertilizer were addressed; secondly, a block with questions related to the attitude of farmers regarding the use of biosolids; a third block with questions related to the intentions of using biosolids as fertilizer and, finally, in the fourth block, questions related to the sociodemographic profile of the sample. The first three blocks dealt with questions to be answered in the Likert scale modality of five (5) points, where one (1) referred to "strongly disagree", five (5) referred to "strongly agree" and, finally, three (3) "neither disagree nor agree). The last block included questions about the sociodemographic profile of the sample. Of a total of 670 questionnaires collected, only 635 were valid after an initial filtering of questionnaires.

The questionnaires were applied in the agricultural farms and managers, directors and agricultural technicians participated. Agricultural workers were not surveyed, since their performance is based on the planning of managers, directors, and technicians. The questionnaire was applied in Spanish. Thus, one crucial consideration in designing research is ensuring the validity of the methodology employed, as biases can potentially compromise its integrity.

For instance, participants may exhibit a tendency to offer positive self-reports and conform to social expectations when completing questionnaires for data collection. To mitigate the influence of such biases, researchers have implemented procedural remedies [35]. These remedies encompass several approaches, including the use of familiar and straight forward concepts, avoiding complex syntax that could confuse participants. Furthermore, respondents are assured of anonymity and explicitly informed that there are no right or wrong answers.

3.2. Measures

As there are no specific items to analyze the knowledge, attitude, and intention to use biosolids, the authors designed a questionnaire adapting the items from previous studies on different topics (mentioned above). However, the reliability of the items was guaranteed previously (Cronbach's alpha) and in the analysis of the results (measurement model assessment). The scales used in the research have been the following:

- Knowledge about the use of biosolids. Composed of 20 indicators obtained from previous studies. The associated Cronbach's alpha level was 0.821, a value well above the minimum value established by reference authors [36].
- Attitudes towards the use of biosolids composed of 21 indicators obtained from previous works. The reliability analysis of the scale yielded a Cronbach's alpha of 0.782, being an optimal result.
- Intention to use biosolids as fertilizer. Composed of 6 indicators obtained from previous studies. The associated Cronbach's alpha value was 0.873.

3.3. Statistical Analysis

The statistical support used were the SPSS version 24.0 programs for the tabulation of the data and the preliminary reliability analysis of the scale, while the Smart-PLS program in its version 3.2.8 was used to carry out the structural model with mediation. The use of the methodology based on partial least squares (PLS) presents advantages with respect to the so called models based on covariance (CB-SEM) such as LISREL or SPSS AMOS. In this sense, authors such as Chin [37] or Fornell and Larcker [38] advise the use of PLS due, among other reasons, to the fact that it does not add sampling distributions (for example, normality - see Table 1) and the estimation of the models can be carried out through both reflective (Mode A) and formative (Mode B) constructs, in addition to avoiding identification problems. The objective of this study is to verify the existence or not of mediation of the variable attitudes towards the use of biosolids between the knowledge about the use of biosolids and the intention to use biosolids as fertilizer. For this, an explanatory analysis has been carried out based on obtaining the coefficient of determination, as well as the statistical inference of the path coefficients, through which we will identify the significant or nonsignificant effect of the variable mediator mentioned above.

Table 1. Descriptive analysis of the variables and analysis of the measurement model

	Mean	**SD**	**Norm.**	**Mode A**	**Mode B**	
				λ	**W**	**VIF**
Knowledge about the use of biosolids (KUB) (r_A: 1.000; CR: n/a / AVE: n/a)						
KUB1 – I have a solid understanding of what biosolids are	4.25	0.771	0.000[C]	n/a	0.108	1.216
KUB2 – The use of biosolids in agriculture promotes sustainable development	3.48	1.054	0.000[C]	n/a	0.095	1.211
KUB3 – I am familiar with the different methods of treating biosolids	3.91	1.022	0.000[C]	n/a	0.037	1.189
KUB4 – I understand how biosolids are generated in the wastewater treatment process	4.37	0.774	0.000[C]	n/a	0.089	1.299
KUB5 – The application of biosolids requires farmers to behave responsibly	4.10	0.957	0.000[C]	n/a	0.050	1.266
KUB6 – The use of biosolids in agriculture contributes to improving the environment	3.90	0.923	0.000[C]	n/a	0.183	1.247
KUB7 – I am informed about the benefits of using biosolids in agriculture	3.96	0.955	0.000[C]	n/a	0.087	1.188
KUB8 – Environmental protection must be ensured when using biosolids in agriculture	4.53	0.747	0.000[C]	n/a	0.101	1.503
KUB9 – Water conservation must be ensured when using biosolids in agriculture	4.40	0.834	0.000[C]	n/a	0.056	1.442
KUB10 – I can distinguish between quality biosolids and unfit to use biosolids	4.02	1.317	0.000[C]	n/a	0.057	1.141

KUB11 – I know the regulations and standards related to the management of biosolids	4.02	0.984	0.000[C]	n/a	0.118	1.243
KUB12 – Maintaining biodiversity is possible with the use of biosolids in agriculture	4.05	0.864	0.000[C]	n/a	0.114	1.502
KUB13 – I understand the importance of proper handling of biosolids	4.05	0.991	0.000[C]	n/a	0.169	1.340
KUB14 – I know the recommended practices for the storage and transport of biosolids	4.40	0.785	0.000[C]	n/a	0.081	1.332
KUB15 – I know the positive effects of biosolids on soil fertility	4.14	0.805	0.000[C]	n/a	0.115	1.324
KUB16 – I know the different methods of applying biosolids in agriculture	3.99	0.880	0.000[C]	n/a	0.125	1.345
KUB17 – I know how contaminants in biosolids are reduced during treatment	4.55	0.721	0.000[C]	n/a	0.020	1.418
KUB18 – Education on the use of biosolids in agriculture, necessary for sustainability	4.42	0.774	0.000[C]	n/a	0.134	1.517
KUB19 – Improving agricultural opportunities contributes to sustainability	4.29	0.789	0.000[C]	n/a	0.166	1.420
KUB20 – I am aware of current scientific research related to biosolids	4.04	1.077	0.000[C]	n/a	0.132	1.176
Attitudes towards the use of biosolids (AUB) (r_A: 1.000; CR: n/a / AVE: n/a)						
AUB1 – The use of biosolids in agriculture is beneficial to improve soil fertility	4.59	0.744	0.000[C]	n/a	0.196	1.431
AUB2 – I want to use biosolids in my crops to reduce the need for chemical fertilizers	4.08	0.980	0.000[C]	n/a	0.137	1.207
AUB3 – Excessive use of chemical fertilizers is a serious threat	4.06	1.049	0.000[C]	n/a	0.130	1.229
AUB4 – We require laws and regulations on the use of biosolids in agriculture	4.51	0.760	0.000[C]	n/a	0.126	1.410
AUB5 – The use of biosolids is a sustainable practice	4.09	0.888	0.000[C]	n/a	0.146	1.267
AUB6 – Regulatory organizations ensure the safe use of biosolids	4.12	0.879	0.000[C]	n/a	0.222	1.292
AUB7 – Information on the benefits/risks of biosolids is essential for decision-making	4.15	1.124	0.000[C]	n/a	0.031	1.236
AUB8 – I am open to receiving technical advice on the use of biosolids in agriculture	4.50	0.854	0.000[C]	n/a	0.044	1.307
AUB9 – The use of biosolids can contribute to reducing poverty	4.43	0.808	0.000[C]	n/a	0.047	1.365
AUB10 – The use of biosolids should be a national priority	4.18	0.891	0.000[C]	n/a	0.075	1.427
AUB11 – I feel that the use of biosolids can improve the profitability of my farm	2.82	1.417	0.000[C]	n/a	0.011	1.332
AUB12 – The use of biosolids contributes to improving agricultural production	2.42	1.460	0.000[C]	n/a	0.008	1.282
AUB13 – Environmental education could contribute to improve the use of biosolids	4.20	0.866	0.000[C]	n/a	0.043	1.256
AUB14 – By harnessing biosolids, we protect ourselves and future generations	4.64	0.661	0.000[C]	n/a	0.056	1.685
AUB15 – I am aware of the possible presence of contaminants in biosolids	4.68	0.702	0.000[C]	n/a	0.091	1.821
AUB16 – The protection of the environment is directly related to the use of biosolids	4.16	0.898	0.000[C]	n/a	0.108	1.490
AUB17 – Environmental protection is more important than the growth of agribusiness	4.00	1.024	0.000[C]	n/a	0.062	1.175
AUB18 – Society should promote equal opportunities and gender in agriculture	4.41	0.769	0.000[C]	n/a	0.092	1.413
AUB19 – I believe that the use of biosolids can contribute to the circular economy	3.83	0.959	0.000[C]	n/a	0.120	1.347
AUB20 – The use of biosolids can improve the diseases and pests of my crops	4.12	0.817	0.000[C]	n/a	0.170	1.502
AUB21 – The use of biosolids can improve water retention in the soil and reduce erosion	3.81	0.998	0.000[C]	n/a	0.068	1.122

Intention to use biosolids as fertilizer (IUB) (r_A: 0.885; CR: 0.904 / AVE: 0.612)						
IUB1 – I am willing to use biosolids in my banana agricultural crops	4.02	1.047	0.000[C]	0.819	n/a	n/a
IUB2 – I want to participate in experiments to improve the use of biosolids in agriculture	4.12	0.936	0.000[C]	0.824	n/a	n/a
IUB3 – I am looking for opportunities to obtain quality biosolids to use in my crops	3.74	1.066	0.000[C]	0.760	n/a	n/a
IUB4 – I want to know the experiences of other farmers with the use of biosolids	3.94	1.017	0.000[C]	0.798	n/a	n/a
IUB5 – I want to establish collaboration with wastewater treatment plants to obtain biosolids	4.05	0.934	0.000[C]	0.726	n/a	n/a
IUB6 – I am consulting with my clients and consumers about their willingness to buy agricultural products grown with biosolids	4.14	0.903	0.000[C]	0.761	n/a	n/a

Notes: r_A: Dijkstra-Henseler' composite reliability; CR: Dillon-Goldstein' composite reliability; AVE: Average Variance Extracted; sd: Standard Deviation; Norm.: Normality test; L: Loads; W: Weights; VIF: Variance Inflation Factor; n/a: Not applicable. [C]: Lilliefors significance correction.

4. Results

This section presents the reliability of the proposed model and its structural analysis, including the contract of the proposed hypotheses.

4.1. Measurement Model Assessment

The measurement model presents three compounds, one of them conformed as mode A (intention to use biosolids as fertilizer) and two as mode B (knowledge about the use of biosolids and attitudes towards the use of biosolids). Table 1 shows the descriptive statistics of each of the three compounds that make up the model (mean, standard deviation, and Kolmogorov-Smirnov normality test). The evaluation of the measurement model at the indicator level (mode A compounds) has been carried out through factor loadings [39]. For the mode B compounds, it has been evaluated through the weights and their significance, and the variance inflation factor (VIF) [40]. At the construct level, for the mode A compounds, the composite reliability of both Dillon-Goldstein and Dijkstra and Henseler [41] and the AVE [38] have been analyzed. In Table 1, no multicollinearity problems are observed in the indicators related to the mode B compounds. On the other hand, the factorial loads associated with the mode A compounds are well above the minimum value required [39].

The discriminant validity analysis is measured through the Fornell-Larcker criterion. The results related to the reliability analysis of the measurement model are presented in Table 2. At the composite level, the model presents good internal consistency, each construct measuring its own or there being no interference between constructs.

The above tables show that the reliability and validity analysis of the measurement model is satisfactory.

Table 2. Discriminant validity. Fornell–Larcker criterion

	AUB	KUB	IUB
AUB			
KUB	0.779		
IUB	0.429	0.374	0.782

4.2. Structural Model Assessment

The power analysis [37] and predictive relevance [42] of the model show a substantial predictive power of the endogenous variable attitudes towards the use of biosolids, which implies a high effect of the knowledge about variable the use of biosolids on the previous endogenous variable. This indicates that knowledge about the use of biosolids contributes to explaining 60.7% of the variability of the variable attitudes towards the use of biosolids. Significant predictive relevance has also been observed in the model at the composite level of the two endogenous variables of the model: attitudes towards the use of biosolids ($Q^2 = 0.137$) and knowledge about the use of biosolids ($Q^2 = 0.109$). All the results related to predictive power and relevance are presented in Table 3.

The hypothesis contrast carried out (Table 4) contributes to the significance of the direct and indirect effects, the result of the mediation of the variable attitudes towards the use of biosolids between knowledge about the use of biosolids and the intention to use biosolids as fertilizer. For this, said hypothesis contrast was carried out through confidence intervals, a non-parametric test. This technique has been used because the data do not follow the normality requirements of the variable [37]. Confidence interval with bias correction has been included.

Table 3. Power and predictive relevance

Endogenous variable	Exogenous variables	R^2	Explained variance	Q^2	f^2(Sig.)	Interpretation f^2
AUB	KUB	0.607	60.70%	0.137	1.543(0.000)	Big effect
IUB	AUB KUB	0.188	15.01% 3.81%	0.109	0.059(0.009) 0.005(0.262)	Small effect Without effect

Notes: AUB: Attitudes towards the use of biosolids; KUB: Knowledge about the use of biosolids; IUB: Intention to use biosolids as fertilizer.

Table 4. Summary of mediating effects tests (hypothesis contrast)

	Coefficient	**Bootstrap 95%**			
		PERCENTILE		**BC**	
Direct effects					
H_1: c'	0.102^{NSIG}	-0.011	0.217	-0.009	0.219
a_1	0.779^{SIG}	0.728	0.808	0.736	0.816
b_1	0.350^{SIG}	0.219	0.448	0.232	0.461

Indirect effects	**Point estimate**	**Percentile**		**BC**		**VAF**
H_2: a_1b_1	0.273^{SIG}	0.166	0.351	0.179	0.364	72.8%
Total indirect effects	0.273^{SIG}					72.8%

Notes: SIG = Significant; NSIG: Not significant; BC: Bias Corrected; VAF: Variance accounted for.

The results derived from the previous table reveal the existence of a total mediation [43] of the variable attitudes towards the use of biosolids (VAF = 72.8%) between the other two variables that make up the model: knowledge about the use of biosolids and the intention to use biosolids as fertilizer. Therefore, the model analyzed in this research has shown that attitudes towards the use of biosolids mediates the relationship between knowledge about the use of biosolids and the intention to use biosolids as fertilizer. The research supports the theory that the existence of intention to use biosolids as fertilizer on the part of agricultural managers is not enough with the existence of knowledge about the use of biosolids, but rather that it is necessary to have a proactive attitude towards the use of biosolids in the agriculture. Thus, it becomes clear that it is vital that agricultural managers have positive attitudes about the use of biosolids. The final structural mediation model is presented in Figure 1.

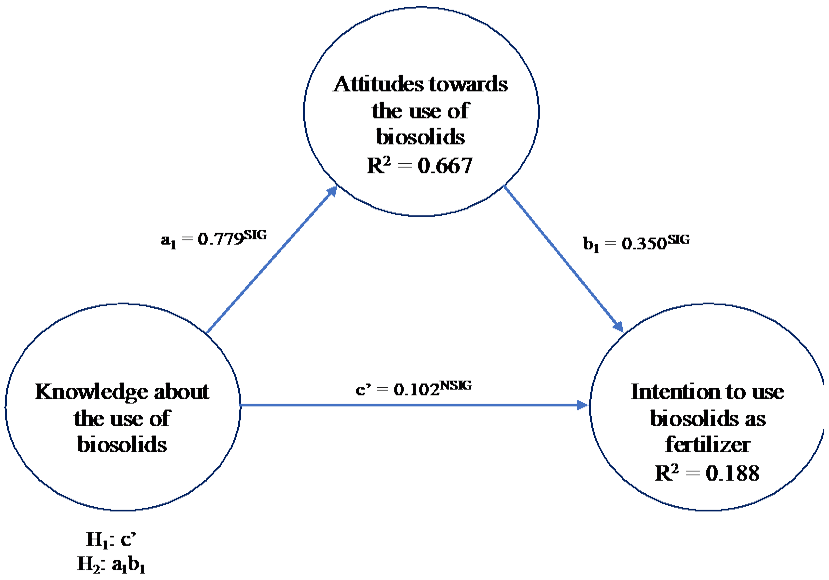

Figure 1. Final proposed mediated model
Source: the authors.

5. Discussion

The research findings suggest that attitudes toward the utilization of biosolids are a significant factor in the connection between one's knowledge about biosolids and the inclination to employ them as a fertilizer. The study reveals that individuals with a strong grasp of biosolids, coupled with favourable attitudes and a willingness to use them as a fertilizer in agricultural practices, are prevalent. Therefore, the positive perception of the decision makers of this region on the use of biosolids promotes the sustainable development of the region, above all, socioeconomic development [44]. The use of biosolids as fertilizer improves crop productivity. In addition, biosolids offer numerous benefits for soil fertility, which improves crop yields in future harvests. When biosolids are harnessed, farmers can improve their farming practices, increase yields, and boost economic growth in several ways [7], [45].

Thus, biosolids serve as a valuable source of essential nutrients such as nitrogen, phosphorous, and potassium. These nutrients are vital for plant growth and are often limited in rural agricultural areas. Byusing biosolids as fertilizer, farmers can replenish nutrient levels in their soils, thus improving soil fertility and overall crop productivity. Improved crop yields translate directly into increased agricultural production, which can contribute to increased revenue and income for farmers. The economic benefits are particularly significant in regions where traditional fertilizers can be expensive or difficult to access, as biosolids offer a cost effective alternative [7].

Furthermore, the use of biosolids promotes sustainable agricultural practices, which have long-term economic benefits. Biosolids represent a circular economy approach, as they use a byproduct of wastewater treatment that would otherwise go to waste [46]. Thus, when biosolids from landfills are recycled into the agricultural system, farmers reduce waste and contribute to environmental sustainability [47]. This not only benefits the local ecosystem, but also enhances the region's reputation as an environmentally conscious and responsible agricultural producer [8]. Such a positive perception can lead to increased market demand for locally grown products, boosting the agricultural sector and creating opportunities for value-added products and agrotourism [48].

The use of biosolids also offers indirect economic benefits through job creation and local economic activity. The implementation of biosolids management programs requires the development of infrastructure, including facilities for collection, treatment, and application [9].

These projects create employment opportunities in construction, operation, and maintenance, provide jobs for residents, and stimulate economic activity within the region. Additionally, as biosolids are applied to farmland, there is a demand for specialized equipment and services, such as application machinery and consulting services [49]. This creates business opportunities for local vendors and service providers, further strengthening the rural economy [50].

In rural communities, where agriculture often plays a central role, the adoption of biosolids as a fertilizer can foster community resilience and economic diversification. By improving soil fertility and crop productivity, farmers can expand their production capacity, diversify their crops, and explore value-added opportunities [10]. This diversification reduces dependence on a single crop and allows farmers to access new markets and sources of income. For example, higher yields can support the establishment of farmer cooperatives or agribusiness companies, allowing rural communities to capture more value from their agricultural products and boost economic growth [51].

In addition, the ecological and sustainable nature of the biosolids use can attract investment and financing for agricultural development projects [52]. Governments, non-profit organizations, and private investors are increasingly prioritizing initiatives that promote sustainable practices and rural development [10]. In this way, if a commitment to sustainable agriculture using biosolids is demonstrated, rural communities can access funding opportunities and attract investment aimed at improving infrastructure, improving agricultural practices, and supporting entrepreneurship [50].

6. Conclusions

The research findings indicate that attitudes towards the use of biosolids mediate the relationship between knowledge about the use of biosolids and the intention to use them as fertilizer. This theory supports the idea that it is not enough for agricultural managers, directors, and technicians to have knowledge about the use of biosolids, but it is also necessary that they have a proactive attitude towards their use in agriculture. Therefore, it is vital that agricultural managers, directors, and technicians have positive attitudes towards the use of biosolids [53], [54]. This study contributes to the theoretical understanding of the factors that influence the adoption of biosolids in agriculture. It emphasizes the crucial role of the attitudes of decision makers in agriculture (managers, directors, and agricultural technicians), since attitudes encompass their feelings, opinions and perceptions towards biosolids.

This group is the one who plans the actions carried out by farmers and, therefore, their perceptions (knowledge, attitudes, and behaviors) are vital to know the acceptance of the use of biosolids in agriculture. Attitudes are influenced by several factors [55], including perceived benefits such as improved soil fertility, higher crop yields, and reduced reliance on synthetic fertilizers. On the other hand, negative attitudes can arise from concerns related to odor, appearance, public perception, and potential health risks. In addition, they highlight the importance of attitudes and positive perception towards the use of biosolids as a determining factor in the decision-making of agricultural managers. This suggests that it is necessary to develop education and communication strategies that promote positive attitudes towards the use of biosolids in agriculture.

In addition, these results have practical ideas for the Ministry of Agriculture of the Dominican Republic, agricultural managers, directors and technicians, and farmers. First, the Ministry of Agriculture can use these results to develop and adjust policies that encourage the safe and appropriate use of biosolids in agriculture. They can also implement training and education programs aimed at agricultural entrepreneurs and farmers to promote a positive attitude towards the use of biosolids and provide them with the necessary knowledge for their proper application. For agricultural managers, directors and technicians, these results indicate the importance of considering not only knowledge about the use of biosolids, but also attitudes towards them when making decisions related to their use as fertilizer. Agricultural supervisors, executives, and technicians have the opportunity to explore ways to incorporate biosolids into their agricultural activities, capitalizing on the advantages they provide in terms of enhanced crop productivity and soil sustainability. Meanwhile, for farmers, these findings underscore the significance of staying informed about biosolid utilization and maintaining a favourable stance towards its adoption. Farmers can seek information and training on best practices for safely and effectively using biosolids on their crops.

Like any study, this research has some limitations. First, the study is approached from the perspective of agricultural managers, directors, and technicians, making it difficult to obtain data from other relevant stakeholder groups, such as government technicians, farmers, or agricultural experts. Also, the length of the instrument may have had some negative implication on the responses of the sample and, for this reason; an exhaustive filtering procedure has been applied to eliminate the items or surveys that presented doubts. In addition, the data obtained refer to a specific geographical area.

Although the Cibao Northwest region is the main banana production area, the results cannot be generalized to the entire Dominican Republic or to agricultural crops, since the sample of this research was directly related to banana production. In the future, the research can be replicated in other areas of the Dominican Republic where other crops stand out. Finally, in future research, it is recommended to explore the factors that shape attitudes towards the use of biosolids in more detail. Investigating the role of sociocultural, psychological, and contextual factors can provide a deeper understanding of the determinants of positive attitudes among agricultural managers, directors and technicians. Also, other sectors and stakeholders that benefit from agriculture, such as tourism [56], should be analysed to find out their perceptions about the purchase of products that have considered biosolids as fertilizers.

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