Migration Letters

Volume: 21, No: 4, pp. 1620-1631

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)
www.migrationletters.com

Principal Component Analysis and Causal Modeling in the Valorization of Banana Pseudostems for Biodegradable Materials

Erika Jadira Romero Cardenas[1], Xiomara Leticia Zúñiga Santillán[2], Byron Ramiro Romero Romero[3], Diego Wladimir Tapia Núñez[4], Edwuin Jesús Carrasquero Rodríguez[5]

Abstract

The study focused on evaluating the opinions of banana producers in Ecuador regarding the use of natural fibers from banana plant pseudostem as a sustainable alternative to produce biodegradable materials. Expert-validated surveys were conducted with 197 managers and owners of banana farms in Zone 5. The research employed a quantitative methodology for data collection. A descriptive analysis of the survey instrument items assessed the distribution and dispersion of the data, along with a correlation analysis between instrument categories. A multivariate PCA was used to condense the data and identify the principal components that explain variations in responses. A causal model based on these principal components was then created and tested for statistical fit.

The findings revealed that participants generally viewed the identified elements-initiatives and sustainability mechanisms-favorably. The research indicates that banana pseudostems could be a viable option to produce biodegradable products, addressing the growing waste problem in the banana industry.

Keywords: *recycling; sustainability; sustainable development; biodegradable products.*

Introduction

According to the Food and Agriculture Organization of the United Nations (FAO), in 2021, bananas were the most consumed fruit worldwide, with a production of 125 million (FAO, 2022). By January 2023, Ecuador saw a 7.98% increase in banana exports, translating to 35.01 million boxes of bananas (AEBE, 2023). In addition, this growth directly impacted the production of waste materials such as leaves, pseudostems, sheaths, pith, and more (Padam et al., 2014).

The banana plant's pseudostem is a unique structure formed from rolled leaves and is responsible for supporting the weight of the fruit bunch. The fibers obtained from it can be used as reinforcement in the manufacturing of composite materials. These pseudostems vary depending on the region; they might be absent, appear as a single structure, or as multiple structures. The shape of the pseudostems, the size of the leaves, and the presence or absence of stipules were also observed as significant variables (Swennen et al., 1995).

The application of appropriate soil management techniques, as well as the adoption of ecologically responsible options, can contribute to increasing agricultural productivity

[1] Universidad Estatal de Milagro
[2] Universidad Estatal de Milagro
[3] Universidad Estatal de Milagro
[4] Universidad Estatal de Milagro
[5] Universidad Estatal de Milagro

without negatively affecting the health of the ecosystem. This has become a priority within consumer products, given the importance of the world becoming more aware of the importance of preserving the environment (Pereira et al., 2014). Banana pseudostem has emerged as an eco-sustainable option and in conjunction with the principles of the circular economy provides an environmentally responsible and economically viable solution to produce biodegradable materials (Blomsma & Brennan, 2017)

To promote the circular economy (Schroeder et al., 2019), it is important to implement innovative solutions to reuse existing resources. For example, banana pseudostem contains useful components for biodegradable products, such as cellulose, hemicellulose, and lignin. These resources can be used to create biodegradable products, extending their lifespan, and reducing waste. This solution is an important step towards promoting the circular economy and sustainability. Additionally, by closing life cycles and reducing resource extraction, this solution can also contribute to a more efficient economy (Silva-Alvarado et al., 2023).

The contribution of research to the achievement of the Sustainable Development Goals is of paramount importance. This contribution is essential for moving towards a better future for humanity and the planet. Scientific and technological research is an essential tool for addressing global challenges, as it provides innovative and evidence-based solutions that can help improve the situation, which is vital for taking effective action (Keesstra et al., 2018). In this context, SDGs 12 and 13 stand out as priority areas where research can have a significant impact. SDG 12 of the SDGs (ONU, 2015a) can be achieved by promoting the circular economy, innovation, and research to find new sustainable solutions for consumer products (Rinaudo et al., 2021). Promoting banana pseudostem as a sustainable alternative for consumer products is a key step towards achieving this goal. SDG 13 of the SDGs (ONU, 2015b) the use of biodegradable products such as banana pseudostem can contribute to reducing greenhouse gas emissions by reducing resource demand and extending product lifespan.

This research addresses the analysis of the knowledge that banana producers have about the benefits to minimize waste and greenhouse gas emissions within their companies (Ramírez-Orellana et al., 2021), it is closely related to the active participation of researchers who evaluate the environmental impact and decomposition of banana pseudostem, for these reasons the importance of promoting the use of the possible products that can be obtained from the pseudostem is reflected, generating in this way other sustainable alternatives. (Mohapatra et al., 2010).

Considering the importance of banana fiber in Ecuador and the potential of Zone 5 for its production, a study was conducted to evaluate the quality of banana fiber in this region. This Zone of Ecuador, see Figure 1, represents 15.253% of the total agricultural production of the country, for this reason it was selected as the study area for this research. The region is the second most productive in Ecuador, hosting a wide range of crops, including major export products such as bananas, cocoa, coffee, and rice (INEC, 2019).

Figure 1. Map of Ecuador's Zone 5

Materials and Methods

This study aims to analyze the perception of sustainability initiatives and mechanisms related to carbon reduction (Roibás et al., 2016) of banana waste, using natural fibers from banana pseudostems as a solution, an eco-sustainable alternative for obtaining biodegradable materials. To this end, a quantitative approach was implemented for data collection through surveys. The respondents were managers and owners of farms and estates in Ecuador's Zone 5. It is worth noting that the data involved in the study are strictly used for the benefit of research.

The level of lack of knowledge of farm owners or managers about these fibers was explored, with the aim of better understanding their perception and attitude towards this sustainable option. It is recognized that lack of knowledge about the circular economy is a barrier that prevents maximizing the value of resources, minimizing waste, and reducing environmental impacts (Moraga et al., 2019).

In addition, we explore whether the implementation of the circular economy would help producers to understand the environmental impact of their banana production activities. We also explore the potential of technology (Deng et al. 2020) optimize production processes, improve efficiency, and reduce environmental impacts associated with resource utilization.

To have a solid and well-founded vision on the use of natural fibers from the pseudostem of the banana plant as an eco-sustainable alternative to obtain biodegradable materials, a questionnaire with 16 items was designed. Of these, 9 were based on a five-point Likert scale, with response options ranging from "totally disagree" to "totally agree." The other 7 items were categorical. Subsequently, a panel of experts in the field validated the questionnaire. The participants in the expert panel included PhDs and Masters with extensive experience in areas such as Environmental Management, Agroindustrial Production, and Biochemistry, which generated a final questionnaire. After pilot tests were conducted, it was applied to a significant sample of n=197. In Table 2, we can observe the items corresponding to the questionnaire used to evaluate the perception of producers in Zone 5 of Ecuador.

Table 2. Banana Pseudostem Natural Fiber Sustainability Perception Questionnaire (CPS-FNPB)

ÍTEM	QUESTIONS	LIKERT SCALE				
		1	2	3	4	5
3	Do you know the various uses of banana pseudostem?					
4	Have you received any proposals for the acquisition of banana pseudostems?					
5	Have you received training from organizations such as MAGAP or MIPRO on the use of banana pseudostems?					
6	Do you believe that banana waste should be utilized?					
7	Are you interested in exploiting banana pseudostems, entering the production of alternative products?					
8	Would you support a project that would utilize banana waste?					
9	Do you think that selling banana pseudostems would generate another source of income?					
11	Would you be willing to sell banana pseudostems?					

A descriptive analysis of the items of the instrument was performed to measure the distribution and dispersion of the data. This analysis allows for an overall view of the mean ratings and variation of responses in each of the evaluated aspects.

Subsequently, a correlation analysis was performed between the categories of the instrument. This analysis allows examining possible relationships between the variables being measured and determining if there is any significant association between them. In addition, a principal component analysis was applied to identify the underlying factors that represent the perception of the initiative and the sustainability mechanism. This analysis allowed us to reduce the size of the data and identify the key components that explain the most variation in the responses (Hotelling, 1936). Finally, a causal model was designed based on the principal components obtained. This model was subjected to statistical goodness-of-fit tests, including chi-square tests, to evaluate the fit and significance of the model.

Jasp statistical software version 0.17.2.1 was used for data processing and evaluation for descriptive, multivariate statistical analysis, and model design.

Results And Discussion

Descriptive data analysis and item reliability for measuring data distribution and dispersion

A descriptive analysis of the instrument items was performed. In general, average to above average ratings were observed in all the evaluated dimensions. Likewise, dispersion indicators show a predominance of platykurtic and negatively skewed distributions. No outliers or missing data were found, see Table 3.

Table 3. Descriptive statistics

	Valid	Missing	Median	Standard deviation	Variance	Skewness	Standard error of skewness	Kurtosis	Standard error of kurtosis
Pr3	197	0	3.000	1.464	2.144	-0.052	0.173	-1.364	0.345
Pr4	197	0	2.000	1.191	1.418	1.138	0.173	0.217	0.345
Pr5	197	0	2.000	1.413	1.996	0.408	0.173	-1.162	0.345
Pr6	197	0	5.000	1.272	1.618	-1.415	0.173	0.938	0.345
Pr7	197	0	4.000	1.330	1.769	-0.931	0.173	-0.289	0.345
Pr8	197	0	5.000	1.145	1.312	-1.394	0.173	1.366	0.345
Pr9	197	0	5.000	1.222	1.493	-1.527	0.173	1.455	0.345
P11	197	0	4.000	1.401	1.963	-0.792	0.173	-0.600	0.345
Pr14	197	0	2.000	1.169	1.368	-0.018	0.173	-1.353	0.345

The reliability statistic used in this case is the "Greatest Lower Bound" (GLB), with an estimated value of 0.662 for the frequent scale. The GLB is a reliability measure like Cronbach's alpha, and 97% confidence intervals for the GLB provide estimated lower and upper bounds for the scale's reliability (Malkewitz et al., 2023). In this case, the 97% confidence interval for the frequent scale is 0.608 to 0.764, which indicates with 97% confidence that the true reliability of the frequent scale lies within this range. Table 4.

Table 4. Frequentist Scale Reliability Statistics.

Estimate	Greatest Lower Bound
Point estimation	0.662
97% CI lower bound	0.608
97% CI upper bound	0.764

Note. The following items correlated negatively with the scale: Pr4, Pr5.

Analysis of Correlations between Items

It is noted that, there is no strong relationship between the items of the instrument, as seen in Table 3. Items 1, 2, 10, 12, 13, 15, and 16 were excluded from the analysis because they did not conform to the required Likert scale structure for the analysis.

The table 5 indicates that there is a significant positive correlation between the variables, this suggests that when the values of one of these variables rise, the values of the other variable tend to do so as well, and vice versa.

Table 5. Kendall's Tau Correlations

Variable	Pr3	Pr4	Pr5	Pr6	Pr7	Pr8	Pr9	P11	Pr14

Table 5. Kendall's Tau Correlations

Variable		Pr3	Pr4	Pr5	Pr6	Pr7	Pr8	Pr9	P11	Pr14
1. Pr3	Kendall's Tau B	—								
	p-value	—								
2. Pr4	Kendall's Tau B	0.040	—							
	p-value	0.506	—							
3. Pre5	Kendall's Tau B	0.129	0.080	—						
	p-value	0.026	0.182	—						
4. Pr6	Kendall's Tau B	0.041	-0.211	-0.066	—					
	p-value	0.495	< .001	0.275	—					
5. P7	Kendall's Tau B	0.050	-0.166	-0.064	0.435	—				
	p-value	0.392	0.006	0.276	< .001	—				
6. Pr8	Kendall's Tau B	0.069	-0.116	0.006	0.333	0.481	—			
	p-value	0.246	0.061	0.918	< .001	< .001	—			
7. Pr9	Kendall's Tau B	7.274×10^{-4}	-0.128	-0.021	0.371	0.322	0.359	—		
	p-value	0.990	0.039	0.729	< .001	< .001	< .001	—		
8. P11	Kendall's Tau B	0.104	-0.126	0.029	0.267	0.356	0.293	0.245	—	
	p-value	0.074	0.038	0.615	< .001	< .001	< .001	< .001	—	
9. Pr14	Tau B de Kendall	-0.007	-0.051	-0.026	0.145	0.056	-0.009	0.005	0.053	—
	p-value	0.901	0.400	0.663	0.018	0.348	0.884	0.929	0.376	—

Principal Component Analysis to measure the perception of the initiative and sustainability mechanism.

The Chi-square test is performed by calculating the $\chi 2$ value, to assess whether there are significant differences between two or more groups. In our case, the Chi-square, table 6, value is 87.330, with 19 degrees of freedom (df) and a p-value of less than 0.001 (< .001). We applied a varimax orthogonal rotation, with a saturation of no more than 0.04. This indicates that there is a probably significant relationship between the variables analyzed.

Table 6. Chi-squared Test

	Value	df	p
Model	87.330	19	< .001

Two principal components were obtained, supported by the scree plot; see Figure 2, which account for 41% of the total variance, using the varimax method. The first principal component was named sustainability initiative, and it is comprised of items 6, 7, 8, 9, and 11, which represent the interest in embarking on projects with environmental responsibility. The second principal component was named sustainability mechanisms, and it includes items 3, 4, and 5, which represent practical knowledge to innovate sustainability methods, see Table 7.

The analysis conducted allows for the identification of patterns and relationships among the original variables through the recognition of two components. These components represent linear combinations of the original variables, and by examining the contribution of each component to the total variance, the relative importance of each factor in the data structure could be determined. This provided a better understanding of the data structure and the underlying meaning of each factor.

Table 7. Component Characteristics

	Unrotated solution			Rotated solution		
	Eigenvalue	Proportion var.	Cumulative	SumSq. Loadings	Proportion var.	Cumulative
Component 1	2.471	0.275	0.275	2.469	0.274	0.274
Component 2	1.239	0.138	0.412	1.241	0.138	0.412

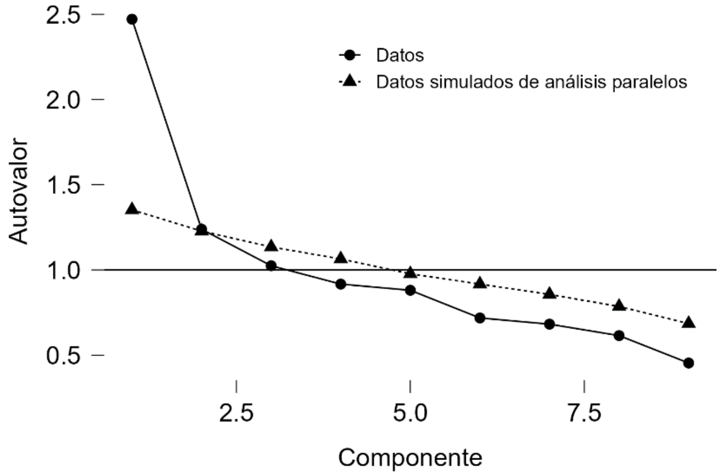
The component loadings indicate the relationship between the original variables and the identified components. The variables P7, P6, P8, P9, and P11 have a component loading close to 0.8 on the first component, suggesting they are moderately associated with this component. The variables P3, P5, and P4 have a component loading close to 0.8 on the second component, indicating they are moderately associated with this component, see Table 8.

Table 8. Component Loadings

	PC1	PC2	Uniqueness
Pr7	0.773		0.400
Pr6	0.736		0.454
Pr8	0.647		0.580
P11	0.640		0.544
Pr9	0.588		0.654
Pr3		0.723	0.462
Pr5		0.681	0.536
Pr4		0.443	0.703
Pr14			0.958

Note. Applied rotation method is varimax.

Figure 2. Scree plot



Model Design

From the principal components obtained, a causal model was designed. From this, it is inferred that the model's fit is appropriate. The χ^2 value for Model 1 is 11817.541, with 27 degrees of freedom (df). This value is significantly different from 0, indicating that the model can account for the observed variability in the data. The p-value for Model 1 is less than 0.001, suggesting that it is highly unlikely for the χ^2 value to be this high if the model were not accurate.

The $\Delta\chi^2$ value for the difference contrast is 11817.541, with 27 degrees of freedom. This value is also significantly different from 0, indicating that the model can detect differences between groups. The p-value for the difference contrast is less than 0.001, suggesting that it is highly unlikely for the $\Delta\chi^2$ value to be this high if the model were not accurate.

The $\Delta\chi^2$ value is a measure of the difference between the χ^2 values for two different models. A high $\Delta\chi^2$ value indicates a significant difference between the two models. In this case, the $\Delta\chi^2$ value is very high, with a relatively small number of degrees of freedom. This suggests that the model can detect differences between groups. Moreover, the p-value is very low, indicating that it is highly unlikely that the model cannot detect differences between groups. See Table 9.

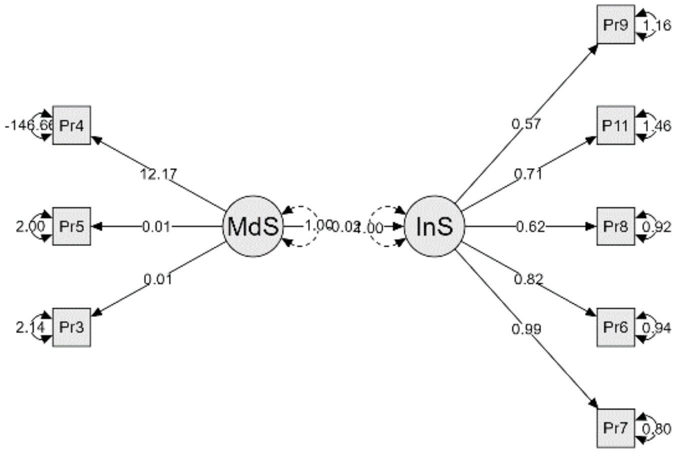
Table 9. Model fit

				Baseline test			Difference test		
	AIC	BIC	n	χ^2	df	p	$\Delta\chi^2$	Δdf	p
Model 1			197	11817.541	27	< .001	11817.541	27	< .001

Note. The AIC, BIC and additional information criteria are only available with ML-type estimators

Based on the results of the baseline contrast and the difference contrasts, the adjusted model demonstrates a good fit to the analyzed data, supported by significant values. Although significance is evident, there is a low relationship between the two principal components with R2 = 0.02, see Figure 3.

Figure 3. Path diagram



Principal component analysis established two components that interpret 41% of variance and were named sustainability initiative and sustainability mechanisms, respectively. In the evaluation of the statistical causal relationship of the empirical model, no significant relationship was found, given that the R2 is less than 0.02, this is because in the sustainability initiative component of the items 6, 7, 8, 9, and 11 there is an observable motivation; this is not related to the sustainability mechanism in the items 3, 5, and 4 where a lack of knowledge is observed due to lack of methods or tools for the implementation of sustainability initiatives.

The results of the study indicate that there are significant differences in the sustainability initiative component between certain items of the questions posed. Specifically, an observable motivation was observed in the items that refer to taking advantage of banana waste, using banana pseudostem to produce alternative products, supporting a project in which banana waste is used, considering that selling the banana stem would generate another source of income, and being willing to sell banana pseudostems. These items indicate that participants show an interest and willingness towards the use of banana pseudostem in different applications, which indicates an observable motivation in relation to sustainability.

However, it was observed that there is a limited knowledge about the methods and tools necessary to carry out sustainability initiatives related to banana pseudostem. This was demonstrated by the lack of knowledge that the participants presented when asked about the different uses of banana pseudostem, if they received training from organizations such as MAGAP or MIPRO, and if they received any purchase proposal for the pseudostem. In general, it can be concluded that the participants have an interest in sustainability, but they are lacking information on how to carry it out in relation to banana pseudostem.

It is important to consider these differences in the interpretation of the results, as they indicate the existence of an observable motivation, but also a lack of knowledge in certain aspects related to the sustainability of banana pseudostem.

The research conducted by Sherwood (2020) highlights the importance of reducing waste and greenhouse gas emissions in the banana industry, emphasizing the role of banana producers in this process. It is argued that the promotion of the use of products obtained from banana pseudostem can generate sustainable and beneficial alternatives for the environment.

Research and producer participation are essential to assess their environmental impact, promote their application, and develop strategies that promote the adoption of eco-sustainable alternatives where the circular economy could be adopted as a tool that contributes to the execution of various plans. Banana pseudostem offers both environmental and economic benefits, and its composition makes it suitable to produce biodegradable products.

The recommendation for researchers is that they can contribute to promoting the use of banana pseudostem as an eco-sustainable option in the following ways:

- Conduct more research on the environmental and economic benefits of using banana pseudostem.
- Develop new technologies to process banana pseudostem efficiently and economically.
- Educate banana producers, businesses, and consumers about the benefits of using banana pseudostem.

Conclusion

Despite the enthusiasm of participants to harness the potential of banana pseudostems for sustainable initiatives, it has been found that insufficient knowledge of the appropriate methods and tools to achieve these goals is an obstacle to progress. Therefore, it is necessary to provide more information on how to develop and apply these tools, to allow for a wider and more effective use of banana pseudostems for sustainable purposes.

To address this situation, it is necessary to provide training and education to producers and farmers about the uses and benefits of banana pseudostems, as well as to promote the implementation of sustainability projects focused on waste utilization. This will help improve farmers' perceptions of the sustainability of banana pseudostems and increase their knowledge of the tools and methods for implementing sustainability initiatives.

The use of banana pseudostems as an eco-sustainable option for obtaining biodegradable products is an interesting proposal. However, a more comprehensive analysis is required to assess its viability and potential impact in economic, social, and environmental terms.

This type of sustainable alternative for consumer products is in line with the United Nations Sustainable Development Goals (SDGs) 12, 13, and 14. By promoting the circular economy, reducing greenhouse gas emissions, and protecting marine life, it contributes to the achievement of the global sustainable development goals set by the United Nations.

While the study highlights the potential benefits of banana pseudostems as an eco-sustainable option, it is important to consider some aspects, such as availability and demand, as well as certifications and regulations, impact on soil quality, life cycle assessment, and community participation. In addition, it is essential to consider the potential socioeconomic impacts to adapt innovative and sustainable business models that can generate employment in the local economy.

References

AEBE, A. (2023). Fortaleciendo la sostenibilidad del sector bananero ecuatoriano. (Issues XVII-N158). https://www.aebe.com.ec/_files/ugd/f4cd67_cdf6995d5eeb4d67b2955cdc97a332e8.pdf?index=true

Blomsma, F., & Brennan, G. (2017). The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity: The Emergence of Circular Economy. Journal of Industrial Ecology, 21(3), 603–614. https://doi.org/10.1111/jiec.12603

Deng, G., Sheng, O., Bi, F., Li, C., Dou, T., Dong, T., Yang, Q., Gao, H., Liu, J., Zhong, X., Peng, M., Yi, G., He, W., & Hu, C. (2020). Metabolic Profiling in Banana Pseudo-Stem Reveals a Diverse Set of BioactiveCompounds with Potential Nutritional and Industrial Applications. Phyton, 89(4), 1101–1130. https://doi.org/10.32604/phyton.2020.010970

FAO, O. de las N. U. para la A. y la A. (2022). Banano - Análisis del Mercado 2021. Organizacion de las Naciones Unidas para la Alimentación y la Agricultura. https://www.fao.org/3/cc1610es/cc1610es.pdf

Hotelling, H. (1936). Simplified calculation of principal components. Psychometrika, 1(1), 27–35. https://doi.org/10.1007/BF02287921

INEC, I. N. D. E. E. Y. C. (2019). Directorio de Empresas. In INEC. https://produccion.ecuadorencifras.gob.ec/QvAJAXZfc/opendoc.htm?document=empresas_test.qvw&host=QVS%40virtualqv&anonymous=true

Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z., & Cerdà, A. (2018). The superior effect of nature based solutions in land management for enhancing ecosystem services. Science of the Total Environment, 610–611, 997–1009. https://doi.org/10.1016/j.scitotenv.2017.08.077

Malkewitz, C. P., Schwall, P., Meesters, C., & Hardt, J. (2023). Estimating reliability: A comparison of Cronbach's α, McDonald's ωt and the greatest lower bound. Social Sciences & Humanities Open, 7(1), 100368. https://doi.org/10.1016/j.ssaho.2022.100368

Mohapatra, D., Mishra, S., & Sutar, N. (2010). Banana and its by-product utilisation: an overview. 69.

Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., De Meester, S., & Dewulf, J. (2019). Circular economy indicators: What do they measure? Resources, Conservation and Recycling, 146, 452–461. https://doi.org/10.1016/j.resconrec.2019.03.045

ONU, O. de las N. U. (2015a). Sustainable Development Goal 12: Producción y consumo responsables Naciones Unidas en Ecuador. In ODS 12- PRODUCCIÓN Y CONSUMO RESPONSABLES. https://ecuador.un.org/es/sdgs/12

ONU, O. de las N. U. (2015b). Sustainable Development Goal 13: Acción por el clima Naciones Unidas en Ecuador. In ODS 13- ACCIÓN POR EL CLIMA. https://ecuador.un.org/es/sdgs/13

Padam, B. S., Tin, H. S., Chye, F. Y., & Abdullah, M. I. (2014). Banana by-products: an under-utilized renewable food biomass with great potential. In Journal of Food Science and Technology (Vol. 51, Issue 12, pp. 3527–3545). Springer. https://doi.org/10.1007/s13197-012-0861-2

Ramírez-Orellana, A., Ruiz-Palomo, D., Rojo-Ramírez, A., & Burgos-Burgos, J. E. (2021). The Ecuadorian Banana Farms Managers' Perceptions: Innovation as a Driver of Environmental Sustainability Practices. Agriculture, 11(3), 213. https://doi.org/10.3390/agriculture11030213

Rinaudo, T., McKenzie, S., Huynh, T.-B., & Sterrett, C. L. (2021). Farmer Managed Natural Regeneration: Community Driven, Low Cost and Scalable Reforestation Approach for Climate Change Mitigation and Adaptation. In Handbook of Climate Change Management: Research, Leadership, Transformation (Vol. 5, pp. 4319–4351). https://doi.org/10.1007/978-3-030-57281-5_281

Roibás, L., Elbehri, A., & Hospido, A. (2016). Carbon footprint along the Ecuadorian banana supply chain: Methodological improvements and calculation tool. Journal of Cleaner Production, 112, 2441–2451. https://doi.org/10.1016/j.jclepro.2015.09.074

Schroeder, P., Anggraeni, K., & Weber, U. (2019). The Relevance of Circular Economy Practices to the Sustainable Development Goals. Journal of Industrial Ecology, 23(1), 77–95. https://doi.org/10.1111/jiec.12732

Sherwood, J. (2020). The significance of biomass in a circular economy. Bioresource Technology, 300, 122755. https://doi.org/10.1016/j.biortech.2020.122755

Silva-Alvarado, P. M., Orozco-Crespo, E., Verduga-Alcívar, D. A., Diéguez-Santana, K., Ruiz-Cedeño, S. del M., Sablón-Cossío, N., Silva-Alvarado, P. M., Orozco-Crespo, E., Verduga-Alcívar, D. A., Diéguez-Santana, K., Ruiz-Cedeño, S. del M., & Sablón-Cossío, N. (2023).

Prospective of the circular economy in a banana agri-food chain. Tec Empresarial, 17(1), 34–52. https://doi.org/10.18845/te.v17i1.6475

Swennen, R., Vuylsteke, D., & Ortiz, R. (1995). Phenotypic Diversity and Patterns of Variation in West and Central African Plantains (Musa Spp., AAB group Musaceae). Economic Botany, 49(3), 320–327. https://doi.org/10.1007/BF02862352