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Optimizing solid waste management strategies in rural Ecuador

A Estratégias integradas de gerenciamento de resíduos sólidos em áreas rurais do Equador

Estrategias de gestión integral de residuos sólidos en zonas rurales de Ecuador

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The study provides a relevant application of geospatial analysis to identify optimal landfill sites and integrates community perspectives to enhance solid waste management strategies.

ABSTRACT

The canton of Quinsaloma in Los Ríos Province, Ecuador, has a population of 16,476, with 72% residing in rural areas. The current solid waste management system only involves collection, transportation, and final disposal and lacks temporary storage containers. This absence hampers proper waste disposal, with 30% of rural communities lacking collection services, leading to improper disposal methods. This study aims to assess the current state of solid waste management, improve the collection system with temporary storage containers, and suggest an optimal site for a sanitary landfill. A survey of 354 residents, with questions on demographics and waste management practices, revealed that 60.5% are unaware of proper waste handling, but 89% recognize that waste accumulation causes pests, odors, and diseases. The survey showed that plastic bags are the most common waste storage material. Quinsaloma generates 270 tons of solid waste monthly, with 80.2% of residents using the collection truck. Tukey's test indicated significant differences in responses. Data on current collection routes was gathered through daily monitoring. This led to a new proposed route with temporary storage containers, including one urban and three rural routes with morning and evening collections. Due to the lack of a local sanitary landfill, a proposal for an optimal site was developed using a multicriteria analysis with Geographic Information Systems, identifying two suitable areas of 62.39 and 255.11 hectares.

Keywords: Integrated Solid Waste Management; Sanitary Landfill; Rural waste management; Ecuador

RESUMO

O Cantão de Quinsaloma, na Província de Los Ríos, Equador, tem uma população de 16.476 habitantes, sendo que 72% residem em áreas rurais. O sistema atual de gerenciamento de resíduos sólidos envolve apenas coleta, transporte e descarte final e não possui contêineres de armazenamento temporário. Essa ausência dificulta o descarte adequado de resíduos, sendo que 30% das comunidades rurais não contam com serviços de coleta, o que leva a métodos de descarte inadequados. Este estudo tem como objetivo avaliar a situação atual do gerenciamento de resíduos sólidos, melhorar o sistema de coleta com contêineres de armazenamento temporário e sugerir um local ideal para um aterro sanitário. Uma pesquisa com 354 residentes, com perguntas sobre dados demográficos e práticas de gerenciamento de resíduos, revelou que 60,5% não têm conhecimento do manuseio adequado de resíduos, mas 89% reconhecem que o acúmulo de resíduos causa pragas, odores e doenças. A pesquisa mostrou que os sacos plásticos são o material de armazenamento de resíduos mais comum. Quinsaloma gera 270 toneladas de resíduos sólidos por mês, com 80,2% dos residentes usando o caminhão de coleta. O teste de Tukey indicou diferenças significativas nas respostas. Os dados sobre as rotas de coleta atuais foram coletados por meio de monitoramento diário, levando a uma nova rota proposta com contêineres de armazenamento temporário, incluindo uma rota urbana e três rurais com coletas pela manhã e à noite. Devido à falta de um aterro sanitário local, uma proposta para um local ideal foi desenvolvida usando uma análise multicritério com Sistemas de Informações Geográficas, identificando duas áreas adequadas de 62,39 e 255,11 hectares.

Palavras-chave: Gestión de Residuos Sólidos; Vertedero Sanitario; Residuos Rurales; Ecuador

RESUMEN

El cantón de Quinsaloma en la provincia de Los Ríos, Ecuador, tiene una población de 16.476 habitantes, de los cuales el 72% reside en zonas rurales. El sistema actual de gestión de residuos sólidos sólo incluye la recogida, el transporte y la eliminación final, y carece de contenedores de almacenamiento temporal. Esta ausencia dificulta la eliminación adecuada de los residuos, ya que el 30% de las comunidades rurales carecen de servicios de recogida, lo que da lugar a métodos de eliminación inadecuados. Este estudio pretende evaluar el estado actual de la gestión de residuos sólidos, mejorar el sistema de recogida con contenedores de almacenamiento temporal y sugerir un emplazamiento óptimo para un vertedero sanitario. Una encuesta realizada a 354 residentes, con preguntas sobre datos demográficos y prácticas de gestión de residuos, reveló que el 60,5% desconoce el manejo adecuado de los residuos, pero el 89% reconoce que la acumulación de residuos provoca plagas, olores y enfermedades. La encuesta mostró que las bolsas de plástico son el material más común para almacenar residuos. Quinsaloma genera 270 toneladas de residuos sólidos al mes, y el 80,2% de los residentes utiliza el camión de recogida. La prueba de Tukey indicó diferencias significativas en las respuestas. Los datos sobre las rutas de recogida actuales se recopilaron mediante un seguimiento diario, lo que condujo a una nueva ruta propuesta con contenedores de almacenamiento temporal, que incluye una ruta urbana y tres rurales con recogidas por la mañana y por la tarde. Debido a la falta de un vertedero sanitario local, se elaboró una propuesta de emplazamiento óptimo mediante un análisis multicriterio con Sistemas de Información Geográfica, identificando dos áreas adecuadas de 62,39 y 255,11 hectáreas.

Palabras clave: Gestão de resíduos sólidos; aterro sanitário; gestão de resíduos rurais; Equador.

INTRODUCTION

According to Rosas & Gámez (2019) indicate that, globally, inadequate management of urban and rural solid waste and residues has been recognized as one of the high impact environmental problems. In the world, about 2.01 billion tons of Municipal Solid Waste "MSW" are generated annually, and the expectation is that this amount will grow in 2050 to 3.40 billion tons (Yao et al., 2018). The population growth faced by today's society is one of the main causes to which excessive solid waste generation is attributed. From the point of view of Bandara and Osinga (Morilla et al., 2016), it is often considered that greater economic development leads to an increase in waste generation, this, associated to the fact that the increase in purchasing power modifies consumption patterns (Troschinetz & Mihelcic, 2009), although in rural areas there is a strong relationship with the agro-industry (Espinoza-Echeverría et al., 2023). This behavior pattern has led to the generation of millions of tons of municipal solid waste. However, only 9% of the total volume of that waste is recycled in our economies, it is understood that more than 90% of the waste is thrown and/or burned in the open (Montes, 2020).

Municipal solid waste, particularly its management, presents risks to the environment and collective health (Foradori, 2020; Yang et al., 2015; Das & Bhattacharyya. 2015; Hannan et al., 2020). According to Barragán et al. (2010) its management is related to the education levels of the population. Ecuador has suffered a strong social deterioration in recent years, falling from 64th to 73rd place in the Human Development Index ranking. The main problem is a high level of poverty, reaching 67% in rural areas and 40% in urban areas (MAE, 2012). People agglomeration and their unplanned distribution within the cities causes an increase in the costs of waste collection, transportation and final disposal, which also hinders the management carried out by the GADs as it is part of their competencies. In Ecuador, the current solid waste situation follows the same structure as in developing countries with an average urban production of 0.81 kg of waste per inhabitant per day, of a total of approximately 58829 tons per week produced in the 24 provinces, only 20% is disposed of in adequate conditions, the remaining percentage is distributed among open dumps, controlled dumps, dumps on roads, streams and rivers (Solíz, 2015). Municipal solid waste management is an important but complex logistical problem (Munguía-López et al., 2020).

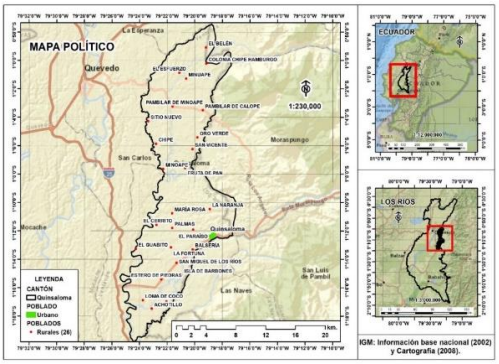
Quinsaloma is a canton in the province of Los Ríos, with a population of 19,470 inhabitants, 72% of whom live in the rural sector and 23% in the urban area. Problems related to solid waste management predominate in the rural area of the canton because there is little waste collection, causing people to deposit their waste in abandoned lots or incinerate it in the open air. In addition, the lack of a sanitary landfill that meets the necessary standards and guarantees proper waste treatment means that the waste generated in the canton is disposed of in the Quevedo canton's emerging cell.

This research details data from the diagnosis of the management of urban solid waste generated in the canton of Quinsaloma, in addition to proposing a collection route that includes the location of containers for the temporary storage of waste and the location of the optimal site for the location of a sanitary landfill that meets the needs of the population of Quinsaloma.

MATERIALS AND METHODS

The study area is the canton of Quinsaloma, in the province of Los Ríos, Ecuador. Its internal border is: to the north with the canton of Valencia (Los Ríos Province); to the south with the canton of Ventanas; to the east with the cantons of Pangua (Cotopaxi Province) and Las Naves (Bolívar Province); and to the west with the cantons of Quevedo and Mocache (Los Ríos Province).

Figure 1. Location map of the Quinsaloma canton.



Source: Offical Quinsaloma map

The Quinsaloma canton is located between Latitude 1°12'22 "S and Longitude 79°18'52 "W, with an average altitude of 30 meters above sea level, an extension of approximately 280 km, an average annual temperature that ranges between 8°C - 15°C, it also has 44 precincts, with 11 urban neighborhoods.

Diagnosis of the current management of solid waste generated in the canton of Quinsaloma

To carry out the diagnosis, it was necessary to resort to information gathering techniques through the use of a checklist, for which an interview was conducted with the technician in charge of the Environmental Management Department of the Decentralized Autonomous Government of the Quinsaloma canton; the questions were focused on the responsibilities of the Municipal Decentralized Autonomous Governments in relation to the integrated management of waste and/or solid waste established in national regulations such as the Unified Text of Secondary Legislation of the Ministry of the Environment.

To diagnose the current situation of solid waste management in the canton of Quinsaloma, on-site visits were conducted for 6 days with the collection vehicle to verify in the field the sectors where waste and/or solid waste is collected, in order to obtain a descriptive and photographic record of the management phases that take place in the canton.

Similarly, information established in the Development and Land Management Plan and other bibliographic sources was reviewed in order to strengthen the information provided by the environmental authority of the canton. In addition, to strengthen the information obtained, a survey was applied to the population of the canton, which allowed to know the perception and opinion of people in relation to the solid waste management service of the canton Quinsaloma. To determine the sample size, data was taken from the urban population of Quinsaloma canton, this information was obtained from INEC as a result of the 2010 population and housing census:

Equation 1. Sample Size Formula

$$n = \frac{Z^2 Npq}{e^2(N-1) + Z^2 pq}$$

Where: n "Sample size sought"; N "Population size or Universe (4573)".

Z: "Statistical parameter that depends on the Confidence Level (1.96)"; e "Maximum accepted estimation error (0.05)"; p "Probability in favor (0.50)"; q "(1-p) being the Probability against (0.50)". And based on the equation presented above, the data necessary for the development of the research were determined:

$$n = \frac{(1.96)^2(4573)(0.5)(0.5)}{(0.05)^2(4573-1) + (1.96)^2(0.5)(0.5)} = \frac{4391.91}{12.39} \approx 354 \text{ residents}$$

With the sample size, the information was collected through online surveys conducted by Google Forms to residents of the canton Quinsaloma, whose results were processed in SPSS statistical software.

Collection route and location of temporary solid waste storage centers in the canton of Quinsaloma

Masaquiza (2019) mentions that to obtain information on the current waste collection route, daily trips were made in the collection vehicle and coordinates of the streets where the vehicle transits were taken, which were then processed in the GIS program (ArcGIS). The establishment of the collection route was done using the Network Analyst tool, first a Nertwork Dataset must be created (Table 2).

Initially, the different neighborhoods and precincts that make up the canton of Quinsaloma were identified, in order to make an appropriate treatment to the matrix (Origin-Destination); then, a spatial calculation of the route traveled daily by the solid waste collector was made and a map of the route calculated through the Solve tool was prepared; Subsequently, the road network of the canton was developed with the attributes of each of the roads, as well as the construction and evaluation of routes; The sectors with the greatest mobility problems were determined and an alternative route was developed to improve the efficiency of the collection system; the frequency of collection and the number of sectors through which the collector will make his rounds were established; the type of collection vehicle and the type of container to be used were defined; finally, the number and locations of temporary storage containers were established (Serna et al., 2016).

Table 2. Main processes performed by phase in the Network Analyst tool

Processes performed in the Network Analyst tool	
Layer processing	Digitization of roads. Georeferencing Inclusion of track attributes
Dataset	Elaboration of the Network Dataset. Configuration of parameters, evaluation functions and restrictions
Control points	Locate Control Points Execute the routing
Analysis	Evaluation of current route and route traced by Network Analyst Comparison of measurements Conclusions

Source: own elaboration (2024)

Location of a sanitary landfill for the proper disposal of solid waste in the canton of Quinsaloma.

Multicriteria analysis using GIS tools: In order to geographically determine the feasible areas for the landfill site, a multicriteria analysis was carried out using ArcGIS, which allowed the structuring, design, evaluation and prioritization of decision alternatives (Malczewski, 2006). Criteria based on current environmental regulations were considered, these are linked to the factors stipulated by the Ministry of Environment, such as: environmental, technical and social (MAE, 2015). Once the variables to be considered were established, we proceeded to work in the GIS software (ArcMap) for the application of the multicriteria analysis, for this, in the first instance a Buffer was applied to the water bodies and settlements and they were designated as 1km buffer zones, then, the multicriteria analysis was applied to the variables: water table, soil texture, gradients and drainage according to the values in Table 3. Next, we proceeded to use the Erase tool, in order to obtain the areas that were out of buffer (suitable zones), with which we proceeded to convert the vector coverages to raster, in order to facilitate the manipulation of the variables (Palacios, 2018).

Table 3. Criteria for variables considered in the multicriteria analysis

Criteria	Reclassification scale			Influence
	1	2	3	(weight)
Water table	>1 m	1.00 m - 0.50 m	< 0.50 m	25%
Soil texture	Fina	Media	Thick	25%
Gradient	<15°	15°	>15°	25%
Drainage	Low	Moderate	High	25%

Source: own elaboration (2024)

A reclassification into three classes was handled, the value 1 (optimal) was given for the areas that met the given specifications, the value of 2 (acceptable) for those areas that moderately met the desired requirements, and the value 3 (not suitable) for those areas that did not meet the requested requirements, all this was done with the Reclassify tool; at the end what was obtained were the raster of the different variables to be related (Palacios, 2018), once obtained the results in raster were transformed to vector by means of the Raster to Polygon tool, with the purpose of knowing the area of the identified optimal zones and proceeded to perform the verification in the field (with the use of a navigator equipment to contrast the modeled place). It is worth mentioning that, for the selection of the optimal site, the standards for using the fill were verified and the geomorphology of the site was verified by field inspection, observing that it does not affect nearby bodies of water, rural populations and forests.

RESULTS AND DISCUSSION

Diagnosis of the current management of solid waste generated in the canton of Quinsaloma

The following is a step-by-step description of the current situation of solid waste management in the canton of Quinsaloma according to what was observed during one week in the waste collection vehicle, complemented with the information obtained through an interview with the person in charge of the Environmental Management Department of GAD Quinsaloma:

-Generation and separation: In the interview conducted with the head of environment of the canton Quinsaloma, she stated that the rate of solid waste generation collected daily is around 9 to 10 tons daily and monthly amounts to 270 tons, according to studies conducted by the municipal administration.

-**Storage**: There are currently no bins or containers for solid waste storage.

-**Collection and transportation**: Collection is carried out from Monday to Sunday; the service covers the entire urban area and 70% of the rural area; due to the lack of personnel and collection vehicles, it is not possible to reach the most remote areas of the canton. Currently, a 5-ton collection vehicle is used, which travels twice a week in the urban area and once a week in certain sectors of the rural area, and a dump truck is also used to make trips only in rural areas where the collector does not have access.

-**Treatment and use**: At the moment, the GAD has not promoted activities that encourage the use of waste, although there are people who do collect some plastic and cardboard waste, but it is an activity that is not very common in the canton.

-**Final disposal**: The canton of Quinsaloma is a member of the "Mancomunidad Mundo Verde" and used to dispose of its solid waste in the Quevedo emerging cell, but since February 2021, the canton has moved to the Ventanas emerging cell, where two trips are made daily.

The following is the schedule of personnel and equipment in charge of cleaning in the different management areas of the Environmental Management Office of GAD Quinsaloma:

Table 4. Personnel for maintenance of green areas:

Individual	Day	Sector	Schedule
1	Monday	Canton Green Areas	07:00 - 12:00 pm and
1	to Friday	Canton Green Areas	13:00 - 16:00 pm

Source: own elaboration (2024)

Table 5. Personnel for cleaning streets and sidewalks

Individual	Day	Sector	Schedule
1	Monday to Friday	Municipal Market Las Mercedes Neighborhood Sector 5 corners Until May 3 Pangua Avenue	07:00 - 12:00 pm and 13:00 - 16:00 pm
1	Monday to Friday	Central Park 3 de Mayo Street to the synthetic field Mogrovejo College El Progreso Street	07:00 - 12:00 pm and 13:00 - 16:00 pm
1	Monday to Friday	Food Court Transversal Via al Paraíso Miguel Infante Avenue	07:00 - 12:00 pm and 13:00 - 16:00 pm

Source: own elaboration (2024)

Table 6. Vehicles used for the collection of solid waste

Vehicle	Plate	Capacity
Hino 500 pickup truck	REI- 2075	5000 kg (5 Tons)
Hino 500 dump truck	REC-0159	7140 kg (7 Tons)

Source: own elaboration (2024)

The following is the checklist used in the interview with the technician in charge of the Environmental Management Office of the GAD of Quinsaloma canton:

Table 7. Instrument

Legal aspects in accordance with the provisions of Agreement 061 Reform of Book VI of TULSMA	Complies		Remarks
	Yes	No	
Art. 57 Responsibilities of the Autonomous Municipal Governments			
Develop and implement a Municipal Integrated Solid Waste Management Plan.	X		They have the Integrated Solid Waste Management Plan of the "Mundo Verde" Community of Municipalities to which they belong.
Promote the implementation of educational programs to foster a culture of waste minimization, separation at the source, collection, cleaning of public spaces and GIRS.	X		Training plans have been carried out in educational institutions and in certain neighborhoods of the canton.
Promote the installation of solid waste recovery centers to encourage recycling.		X	
Ensure that the territory provides a safe and efficient waste collection service, sweeping and cleaning of sidewalks and other spaces.	X		Street sweeping and sidewalk cleaning is performed daily.
Develop ordinances for waste and/or solid waste management.	X		
Assume responsibility for the provision of public services of integrated waste and/or solid waste management in urban and rural areas.	X		In urban area 100% In rural areas 70% (lacking sectors further away from the canton).
Eliminate existing open dumps in the canton by means of technical closures endorsed by the AAC.	X		
Keep a record of technical, environmental, social and financial indicators for the provision of non-hazardous ISWM services in the canton.	X		
Ensure adequate final disposal of waste and/or solid waste generated in the canton in sites with technically adequate conditions.	X		
Determine in their PDOT the sites foreseen for the final disposal of waste and/or solid waste.	X		

Legal aspects in accordance with the provisions of Agreement 061 Reform of Book VI of TULSMA	Complies		Remarks
	Yes	No	
Promote alliances for the formation of commonwealths with other municipalities for ISWM.	X		
Generation phase			
Make the annual declaration of the generation and management of waste and/or non-hazardous solid waste to the National Environmental Authority.	X		A month 270 tons are collected, and 9-10 tons are taken to the emergent daily, distributed in 2 trips per day.
Promote social initiatives to reduce or minimize waste generation.	X		
Source separation phase			
Generators deliver their waste and/or residues in a sorted manner.		X	
Temporary storage phase			
There are containers for waste storage within the canton.		X	
The containers have a capacity in accordance with waste generation, and are well located and covered.		X	
Collection phase			
Waste and/or solid waste is collected manually, semi-mechanized and mechanized.	X		Manual
Collection is carried out using the following methodologies: corner collection, curbside collection, intra-household collection and container collection.	X		The collection is done from house to house and the ordinance stipulates that people should take out their garbage when the collection vehicle passes by.
During collection, operators collect all of the waste, avoiding leaving residues or leachates on the public streets.	X		
The collection service covers the entire urban and rural perimeter.	X		
Transport phase			
The collection equipment and transport vehicles are appropriate for the efficient development of the service.	X		
Collection equipment and vehicles are maintained.	X		
Local collection is for household waste only.	X		
Exploitation phase			
There are waste recovery sites		X	
Final disposal phase			
The canton has its own emerging cell or sanitary landfill.		X	Dispose of your waste in the windows canton pop-up cell
The canton is part of a commonwealth for ISWM.	X		It is part of the Commonwealth "Mundo Verde".

Source: own elaboration (2024)

General information of respondents: The survey was conducted among 354 inhabitants of Quinsaloma canton, being the main neighborhoods of the canton as Quinsaloma center (14.69%), San Miguel (12.43%) and 12 de Octubre (7.34%), who showed more interest in collaborating with their answers.

Table 8. Place of residence of respondents and significance of questions.

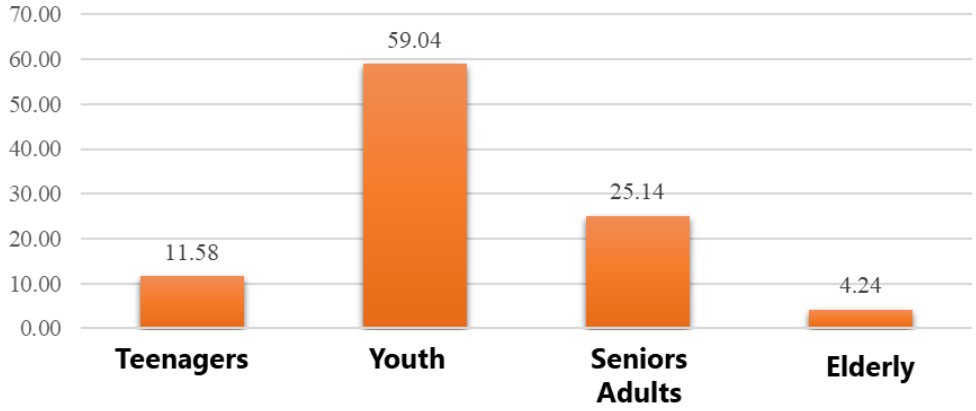
Residence	Number of respondents		Significant Difference "S" and Not Significant Difference "NS".								
			A	B	C	D	E	F	G	H	I
October 12th	26	7.34%	a	a,b	a	a,b	a,b	a	a,b,c	a,b,c,d,e	a,b
Rafting	20	5.65%	a	a,b	a	a,b	a,b	a	a,b,c	a,b,c,d	a.b
Manabita Colony	4	1.13%	a	b	a	a	a,b	a	a,b	a,b,c,d,e	a
El Mirador	19	5.37%	a	a,b	a	a,b	a,b	a	a,b	a,b,c,d,e	a,b,c
El Paraíso	16	4.52%	a	a,b	a	a	a,b	a	a,b	c,d,e	a,b
Estero de Piedras	8	2.26%	a	a,b	a	a,b	a,b	a	a,b	a,b,c	a,b
La Fortuna	5	1.41%	a	a	a	a	a,b	a	a,b	a,b,c,d,e	c
La Lorena	3	0.85%	a	a,b	a	a	a	a	c	d,e	a,b
La Merced	14	3.95%	a	a,b	a	a,b	a,b	a	a,b,c	b,c,d,e	a,b
La Morelia	4	1.13%	a	a,b	a	a,b	a,b	a	a,b	a,b,c,d,e	a
La Naranja	8	2.26%	a	a,b	a	a	a,b	a	a,b,c	d,e	a
Las Crucitas	20	5.65%	a	a,b	a	a	a,b	a	a,b,c	a,b,c,d,e	a,b
Las Palmitas	22	6.21%	a	a,b	a	a,b	a	a	a,b	a,b,c,d,e	a
Loma de Coco	11	3.11%	a	a,b	a	a	a,b	a	a,b,c	a,b	a,b,c
Los Angeles	22	6.21%	a	a,b	a	a,b	a,b	a	a,b	b,c,d,e	a,b
Los Cerritos	9	2.54%	a	a,b	a	a,b	a,b	a	a	a,b,c,d,e	a,b
Maria Rosa	5	1.41%	a	a,b	a	a	a	a	bc	a	b,c
Miraflores	17	4.80%	a	a,b	a	a	a,b	a	a,b,c	a,b,c,d,e	a

Residence	Number of respondents		Significant Difference "S" and Not Significant Difference "NS".								
			A	B	C	D	E	F	G	H	I
Quinsaloma Center	52	14.69%	a	a	a	a	a,b	a	a,b,c	a,b,c,d,e	a
San Miguel de Los Rios	44	12.43%	a	a,b	a	a	a,b	a	a,b,c	a,b,c,d	a
St. Lucia	2	0.56%	a	a,b	a	a	a,b	a	a	e	a,b,c
Santa Rosa 1	17	4.80%	a	a,b	a	a,b	a,b	a	a,b,c	a,b,c,d,e	a
Santa Rosa 2	6	1.69%	a	a	a	a	a,b	a	a,b,c	a,b,c,d,e	a
Result	**354**	**100.00%**	**NS**	**S**	**NS**	**S**	**S**	**NS**	**S**	**S**	**S**

Source: own elaboration (2024)

According to the data obtained, it was determined that the largest group participating in the survey is the youth (59.04%) between 19-27 years of age, and the smallest group participating in the survey is the elderly (4.24%).

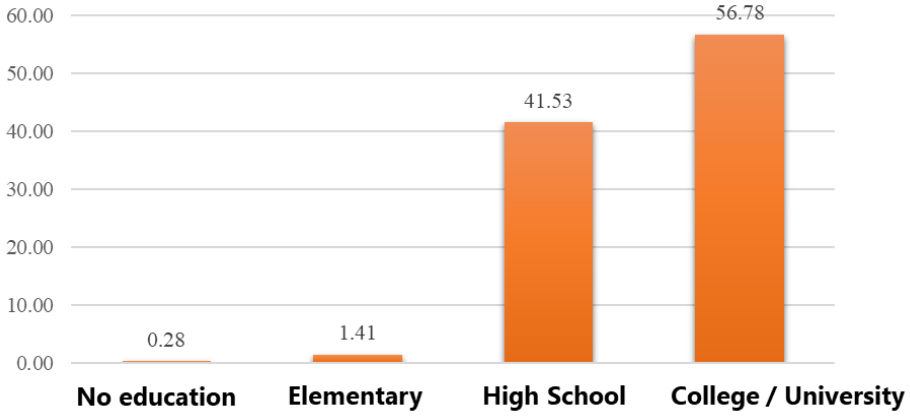
Figure 2. Respondent age groups



Source: own elaboration (2024)

Knowledge of solid waste management: According to the data obtained in the survey, 56.78% of the respondents had a higher education, while 0.28% had no education at all.

Figure 3. Level of education.



Source: own elaboration (2024)

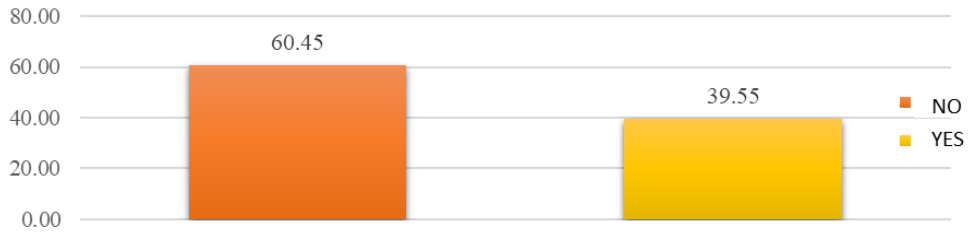
Question "A": Do you know how the solid waste generated by the population of Quinsaloma Canton is managed? According to the data obtained in the survey, it was determined that 60.50% of the surveyed population indicated that they do not know how the waste they generate is managed, while 39.50% mentioned that they know about the management of this waste.

Question "B": Do you know the environmental impact caused by the accumulation of waste? According to the data obtained, it was found that 73.73% of people are aware of the impact generated by the accumulation of solid waste, while 26.27% are not aware of this issue.

Question "C": Have you received information on issues related to solid waste? Based on the survey conducted among the population of Quinsaloma canton, it was found that the criteria among the respondents is divided, of which (50.85%) have not received any type of information on Solid Waste, while (49.15%) of the people have expressed that they have not received information that allows them to learn about this topic, in addition, after performing the Tukey test (95% confidence intervals), it was determined that there were no significant differences in the answers.

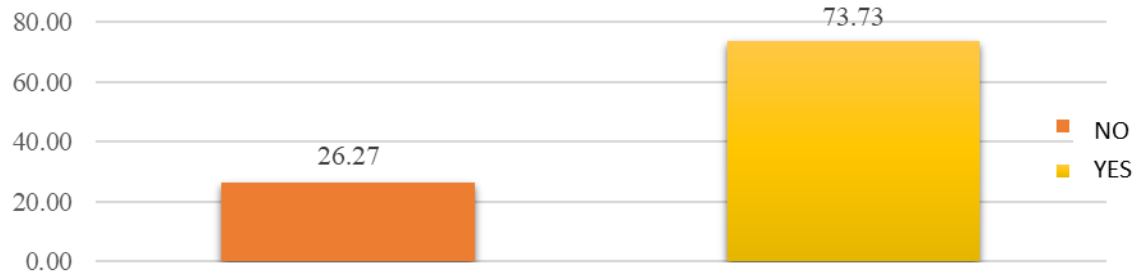
Question "D": Do you believe that the presence of waste is related to the proliferation of pests and diseases? The data from the survey of the inhabitants of Quinsaloma canton showed that 88.98% of those surveyed believe that the presence or accumulation of waste is closely related to the proliferation of pests, while the remaining 11.02% believe that the presence of pests is not related to the accumulation of solid waste, and the Tukey test (95% confidence intervals) showed that there are significant differences in the means.

Figure 4. Knowledge on MSW management (Question A)



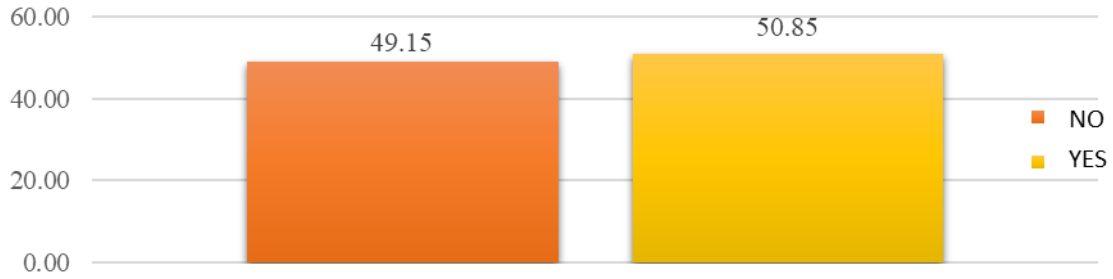
Source: own elaboration with the research data (2024)

Figure 5. Knowledge of environmental impact due to MSW accumulation (Question B)



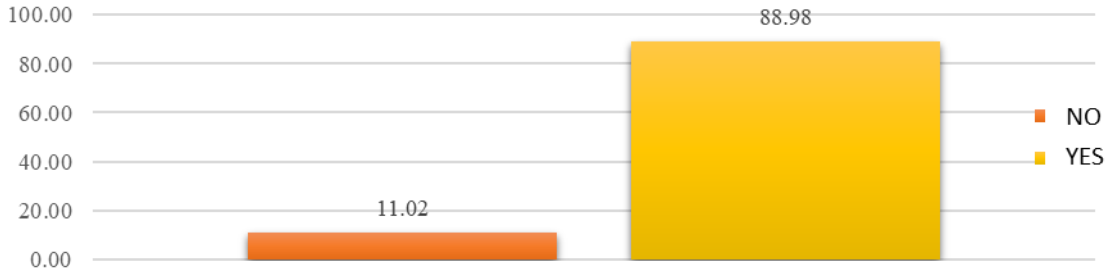
Source: own elaboration with the research data (2024)

Figure 6. Information and/or training on MSW (Question C)



Source: own elaboration with the research data (2024)

Figure 7. Proliferation of pests and diseases (Question D)



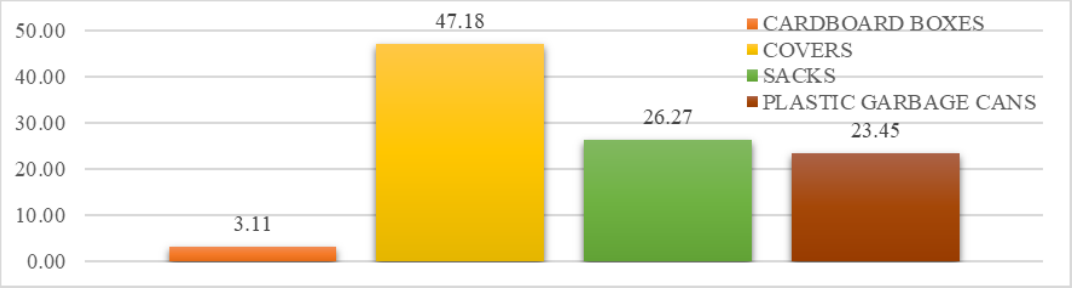
Source: own elaboration with the research data (2024)

Question "E": What material do you use to store your waste until the collection vehicle comes to collect it? According to the survey conducted among the inhabitants of Quinsaloma county, it was determined that the material most used to store waste are bags (47.18%), followed by sacks (26.27%) and plastic tubs (23.45), while the material least used by people are cardboard boxes (3.11%), which have a low presence due to their fragility in the face of leachate generated by the leachate.11%), with a low presence due to their fragility in the face of the leachates generated by the waste. Once the Tukey test was performed (95% confidence intervals), it was possible to identify that there were significant differences in the means.

Question "F": To what extent do you consider it necessary to implement temporary storage containers to avoid the accumulation of waste on street corners and facilitate the collection process? According to the data obtained in the survey and performing the Tukey test (95% confidence intervals), it was identified that there are no significant differences in the means, in addition, the question posed allowed to identify that the population strongly agrees (70.34%) in implementing waste containers; while a very low amount of the population disagrees (1.13%) with this type of ideas that allow optimizing the service provided.

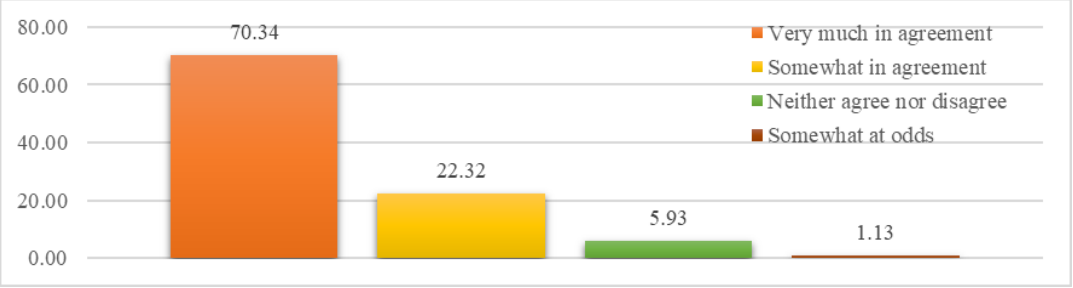
Question "G": How do you perceive the solid waste collection service provided by the municipality? According to the data obtained in the survey used to determine the degree of satisfaction by performing the Tukey test (95% confidence intervals), it was identified that there are significant differences in the means, and it was also identified that the collection system is mostly well rated in the urban area and part of the rural area, with (30.51%) agreeing somewhat, strongly agreeing with (28.81%), while (5.08%) of those surveyed strongly disagree with the service provided.

Figure 8. Material used for MSW storage (Question E)



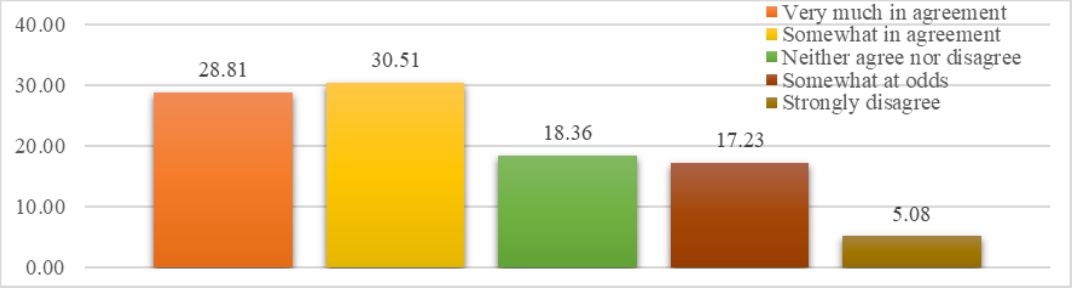
Source**:** own elaboration with the research data (2024)

Figure 9. Implementation of Temporary Storage Containers (Question F)



Source**:** own elaboration with the research data (2024)

Figure 10. Evaluation of the collection service (Question G)



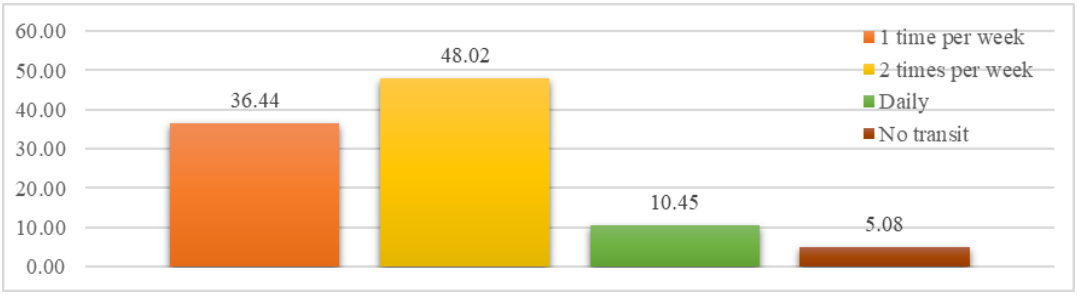
Source**:** own elaboration with the research data (2024)

Question "H": How often does the waste collection vehicle pass through your sector? Through the data obtained in the survey conducted, performing the Tukey test (95% confidence intervals), it was identified that there are significant differences in the means, in addition, respondents said that mostly 2 times a week (48.02%) the collection vehicle passes

through their homes and 1 time per week (36.44%), also expressed that daily (10.It is worth noting that Table 22 shows the choices of people according to their sectors, where we can see that places such as La Naranja and Los Angeles stand out as being more remote and difficult to access sectors, which is why their population does not receive this service.

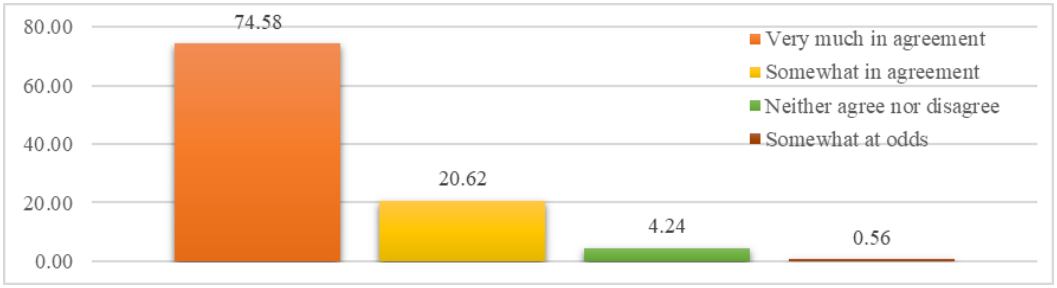
Question "I": Do you think the municipality should invest in new technologies for the treatment and final disposal of waste? According to the data obtained in the survey and applying an analysis of variance and Tukey's test (95% confidence intervals), it was identified that statistically there were significant variations in the means, which allowed determining that most people strongly agree (74.58%) with this type of investment to provide a more efficient service to the population, also (4.24%) are indifferent to the question posed and (0.56%) disagrees with this type of investment.

Figure 11. Frequency of solid waste collection (Question H)



Source**:** own elaboration with the research data (2024)

Figure 12. Investment in technologies for the treatment and final disposal of MSW (Question I)



Source**:** own elaboration with the research data (2024)

Collection route and location of temporary solid waste storage centers in the canton of Quinsaloma

Daily trips were made in the solid waste collector to verify compliance with the collection schedule provided by the Environmental Office of GAD Quinsaloma. Figure 13 shows the current solid waste collection map of Quinsaloma with the respective routes and collection stops in both urban and rural areas according to the aforementioned days of work. Figure 14 shows the map with the four proposed routes for solid waste collection in the canton of Quinsaloma.

Figure 13. Current MSW collection

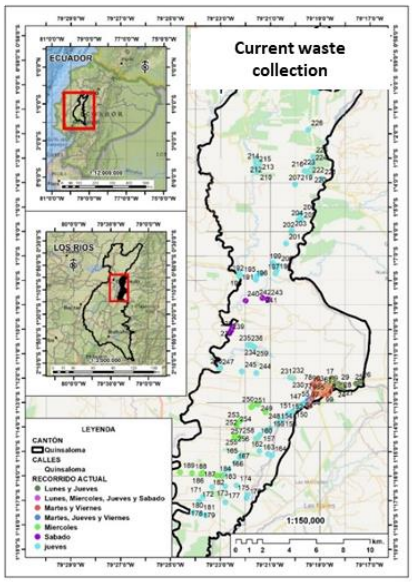
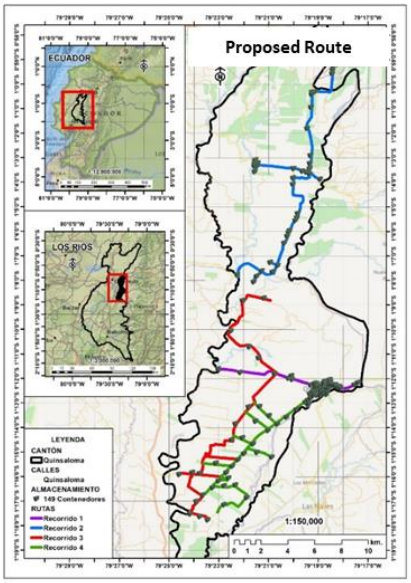


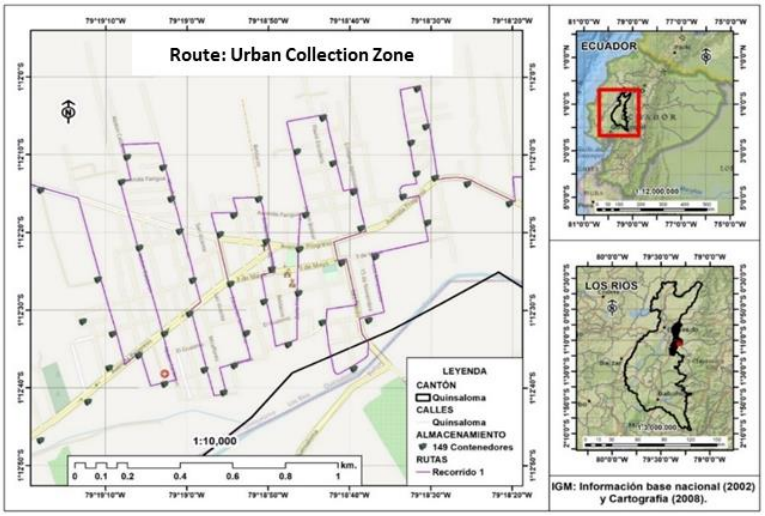
Figure 14. Proposed MSW collection



Source**:** own elaboration with the research data (2024)

The following is the proposed collection route for the urban area (see Figure 15).

Figure 15. Collection route for the Urban Zone of Quinsaloma Canton.



Source**:** own elaboration with the research data (2024)

Location of a sanitary landfill for the proper disposal of waste from the Quinsaloma canton.

Criteria based on current environmental regulations were considered, such as: environmental, technical and social. Once the variables to be considered were established, a buffer was applied to the bodies of water and towns and they were designated as buffer zones with a radius of 1 km, after which a multi-criteria analysis was applied to the variables: water table, soil texture, gradients and drainage, with a percentage of importance of 25%. Subsequently, the Erase tool was used to obtain the areas that were outside the buffer (suitable zones). Finally, the vector information was converted to raster using the Raster to Polygon tool, in order to determine the hectarage of the optimum zones identified.

The maps below show the distribution of the criteria used to determine the optimal site (Figure 16) and the result of the multi-criteria analysis (Figure 17), which provided two suitable areas for the landfill site, the first with an area of 255.11 hectares and the second with 62.39 hectares, both of which meet the criteria shown in Table 3.

Figure 16. Distribution of criteria

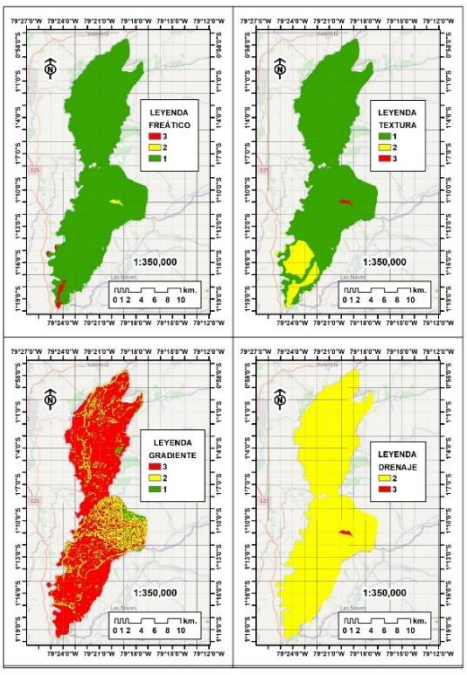
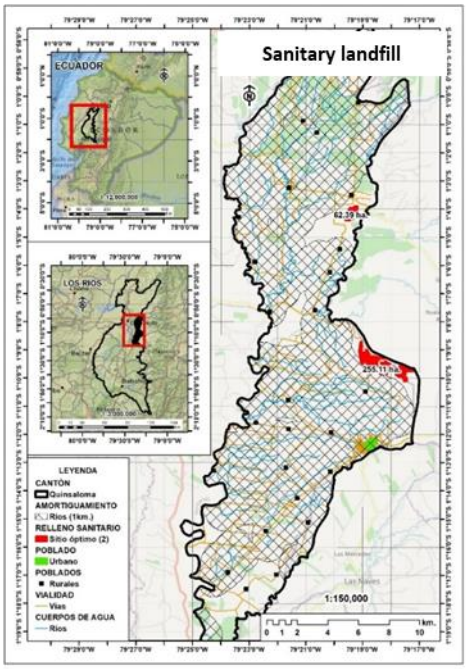


Figure 17. Optimal site for RS



Source**:** own elaboration with the research data (2024)

FINAL REMARKS

According to the research conducted and the results obtained, it was possible to identify the management of solid urban waste in Quinsaloma canton, which was found to be composed of 4 phases: generation, collection, transport and final disposal; collection covers the entire urban area and 70% of the rural area; in addition, the surveys conducted revealed the good valuation of waste collection by the beneficiaries of this service, combined between very much in agreement and somewhat in agreement obtained 59.In the surveys conducted, 59.3% of the beneficiaries agreed with the service, with a predominance of 48% in the urban areas and 36.4% in the rural areas of the canton, with a predominance of collection twice a week (48%) and once a week (36.4%).

According to the research process conducted, it was found that collection is done curb to curb in compliance with the provisions of Art. 66 of Book VI of the TULAS, which indicates the types of collection to be performed by the operators, also identified the materials used for the storage of solid waste, being the most used bags with 47.1% and the least used are the cartons with 3.In addition, it was determined that the people surveyed are very interested in the implementation of temporary storage containers with 70.3%, since they consider that the use of these containers will reduce the accumulation of waste on street corners and will be sources for the generation of pests and bad odors; in addition, the collection service will become more efficient.

Once the analysis of the collection route was carried out using the Network Analyst tool, four routes were obtained, the first of which is for the urban area, consisting of night-time routes for three days, Monday, Wednesday and Friday, with a distance of 20.47 km per day, and three routes for the rural sector, with waste collection three times a week, with a total distance of 121.18 km.

A number of containers was established according to the places with the highest generation of solid waste, being the urban sector the one with the highest amount 59 and in the rural area the distribution of containers was made according to the number of stops and precincts to which the waste collection service is provided, route two 41 containers, route three 17 containers and route four 32 containers.

Once the information obtained from literature related to the subject was selected and organized, a table of criteria such as: water table, soil texture, gradient and drainage was prepared, using weights ranging from 1 optimal, 2 acceptable and 3 unsuitable, to determine the ideal site for the sanitary landfill.

The multi-criteria analysis carried out in ArcGIS software allowed us to create a map with the two optimal sites for the sanitary landfill, the larger one with an area of 255.11 hectares and the second one 62.39 hectares, both of which meet the criteria established in previous processes.

Limitations of the study and future research

The study mainly focuses on how solid waste is managed in a specific area of Ecuador. The findings may not apply to other regions. The study relies on self-reported survey data, which could be influenced by people wanting to give socially acceptable answers or by memory issues, affecting the accuracy of the information about how residents dispose of their waste. Also, the study doesn't consider how waste generation and collection efficiency change throughout the year, which affects the proposed waste management strategies. Future research should include studies in different parts of Ecuador to make broader conclusions and improve the reliability of the findings. It would also be helpful to study the long-term effects of waste management strategies and to use advanced geospatial analysis and socio-economic data to better understand where waste management is a challenge and where there are opportunities. Finally, looking into community-based participatory approaches could lead to new, culturally appropriate solutions for managing waste in rural and semi-urban areas.

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Contribution of each author to the manuscript:

	% of contribution of each author				
Task	**A1**	**A2**	**A3**	**A4**	**A5**
A. theoretical and conceptual foundations and problematization:	20%	20%	20%	20%	20%
B. data research and statistical analysis:	20%	20%	20%	20%	20%
C. elaboration of figures and tables:	20%	20%	20%	20%	20%
D. drafting, reviewing and writing of the text:	20%	20%	20%	20%	20%
E. selection of bibliographical references	20%	20%	20%	20%	20%
F. Other (please indicate)	-	-	-	-	-

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