JOURNAL OF INTERNATIONAL CRISIS AND RISK COMMUNICATION RESEARCH
ISSN: 2576-0017
2024, VOL 7, NO S12

Circular Economy and Sustainability: NFU in the Ecuadorian Land Force

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Abstract
The improper handling of end-of-life tires represents an environmental, social and health challenge worldwide. In Ecuador, the Land Force faces this problem with an extensive vehicle fleet, generating a volume of waste that, if not properly managed, affects the quality of the soil, air and water, in addition to increasing the risk of diseases and pollution. Based on a mixed approach that combined surveys of 350 military personnel, focus groups and a review of international experiences, this study evidenced the lack of information on the final destination of tires, the lack of knowledge of environmental regulations and the lack of optimization processes. However, a high interest in participating in environmental initiatives, the ability to adapt to circular economy models and the need to improve internal communication, technical training and the implementation of monitoring and inventory systems were detected. The recommendations include establishing awareness programs, technical training, effective internal communication, efficient information management, and adaptation of circular economy models to the institutional context.
Keywords: Used tire management, environmental regulations, environmental education, internal communication, solid waste.

1 Introduction

The management of end-of-life tyres has become a cross-cutting challenge worldwide, where environmental, socio-economic and health factors converge. Due to its composition, the natural degradation of a tire can last for decades, releasing pollutants into the soil, water, and air (EPA, 2020). In addition, the inadequate stockpiling of tires generates environments conducive to the proliferation of disease vectors such as mosquitoes that transmit dengue, Zika, or chikungunya and increases the risk of fires whose emissions contain toxic compounds (Cicero-Fernández et al., 2020). These conditions hinder the achievement of local and global environmental goals, and affect ecological stability, resilience to climate change, and the health of communities (UNEP, 2019).

In Ecuador, with an annual generation of solid waste that exceeds five million tons (PNGIDS, 2014), the problem of used tires acquires special relevance from the environmental, social and institutional perspectives. The Ecuadorian Land Force, one of the most important operational entities in the country, has an extensive vehicle fleet that, throughout its useful life, generates a volume of disused tires. The proper management of this waste transcends the merely operational aspect, becoming a strategic component that links environmental protection, social responsibility, military logistical efficiency, and alignment with national public policies (MAE, 2014), as well as with international commitments framed in the Sustainable Development Goals (United Nations, 2015).

To understand the adoption (or lack thereof) of pro-environmental behaviors in military personnel, it is pertinent to frame this problem in Ajzen's (1991) theory of planned behavior (TPB). This theory states that the intention to perform a behavior depends on three factors: attitudes towards the behavior (positive or negative perception of the action), subjective norms (perceived social influence) and perceived behavioral control (ease or difficulty that the individual perceives to carry out the action). In the context of used tyre management, greater knowledge about environmental impacts, clear regulations and the availability of technical and training resources can improve attitudes and perceived control, while institutional support and the example of leaders and colleagues could strengthen subjective norms. By increasing the understanding of these three factors, the intention and probability of adopting sustainable practices is enhanced (Steg et al., 2014; Kaiser, 2020).

Along the same lines, the circular economy emerges as a conceptual framework to reconfigure tire management (Ghisellini et al., 2016; Kirchherr et al., 2017). Unlike the traditional linear model of "take, make, and dispose", the circular economy proposes to extend the useful life of products, reduce the extraction of virgin resources, and reincorporate materials into the production chain through recycling, reuse, energy

recovery, and remanufacturing (Ellen MacArthur Foundation, 2013). In the case of tires, this approach includes making them a secondary raw material for the asphalt industry, construction, and the manufacture of sports products, as well as fostering technological innovation in shredding processes, pyrolysis, and other valorization methods. The circular economy mitigates environmental impact, and generates business opportunities, local value chains and green jobs, aligning waste management with climate goals and responsible production and consumption (SDGs 12 and 13).

The successful application of the circular economy and extended producer responsibility in countries such as the United States, Canada, Germany and Argentina offers valuable references for the Ecuadorian context. It then discusses how different countries have approached the management of NFU, highlighting practices and policies that could be exemplary or areas where challenges remain. Thus, in the United States, NFU management has evolved towards advanced recycling and reuse systems. More than 80% of discarded tires are recycled, turning them into useful products such as modified asphalt, playground materials, and other recycled rubber products. This high level of efficiency is attributed to the combination of strict legislation, technological innovation, and an extended producer responsibility system that incentivizes manufacturers to actively participate in the life cycle of products (EPA, 2020).

Likewise, Canada has implemented extended producer responsibility (EPR) programs that have proven effective in achieving high rates of NFU recycling. These programs ensure that tires are collected and treated appropriately, and promote the use of recycled tires in various industrial applications, reducing reliance on virgin materials and promoting the circular economy (Rubber Association of Canada, 2019). In Germany, the tire recycling rate is exceptionally high due to strict regulations and a well-established recycling infrastructure. The German Rubber Manufacturers Association (WDK, 2020) reports that a large number of end-of-life tires are transformed into rubber granules and crumbs, which are used to manufacture technically advanced products. This system reflects the commitment to sustainability and the circular economy, motivating manufacturers to participate in the product life cycle.

Spain has implemented a comprehensive NFU management system that involves all actors in the supply chain, from manufacturers to consumers. Through organizations such as SIGNUS and TNU, Spain has achieved remarkable recycling and reuse rates, with programs that address NFU management, and educate the public about the importance of recycling and sustainability (European Commission, 2015). On the other hand, in Argentina, the management of NFU has progressed through the implementation of local initiatives and pilot projects that promote the reuse of tires in asphalt mixtures and other construction materials. However, the country faces challenges related to the need for greater coordination and regulatory support to establish a comprehensive national system that covers all provinces and allows the established recycling goals to be achieved (Botasso, 2018).

In the case of Brazil, significant progress has been made through the RECICLANIP program, which has established an extensive network of NFU collection points and encouraged the reuse of recycled materials. This program has improved NFU's environmental management, and has contributed to job creation and economic development in areas related to recycling and waste management (Kirchherr et al., 2017). Therefore, these international experiences demonstrate that, with clear regulatory frameworks, smart economic incentives, public-private partnerships, continuous training and effective communication, it is possible to transform an environmental problem into an opportunity for innovation, efficiency and sustainable development. The circular economy, supported by the theory of planned behavior, suggests that, by improving perception, knowledge and institutional conditions, the adoption of pro-environmental behaviors and organizational change towards more resilient and competitive models are facilitated.

In Ecuador, the National Plan for the Integrated Management of Solid Waste (PNGIDS, 2014) and current environmental regulations establish guidelines for a more responsible and efficient management of waste, including used tires. However, information gaps, shortcomings in technical training, and communication limitations persist that hinder the adoption of sustainable practices (MAE, 2014). In the military, these barriers can be exacerbated by hierarchical dynamics, diversity of roles, and the need to reconcile operational objectives with environmental goals. In this sense, the Land Force faces the challenge of strengthening its institutional capacity to manage used tires, minimizing negative impacts, and taking advantage of the potential of the circular economy. This involves promoting specialized training of personnel, designing clear

internal communication channels, making information transparent through monitoring systems and inventories, and adapting international experiences to the national context, considering the cultural, logistical and regulatory particularities of the defense sector.

The present study aims to assess the current state of knowledge, attitudes, and practices of Land Force personnel in relation to the management of used tires, identifying barriers, motivations, and opportunities for change. A mixed methodological approach is adopted that combines quantitative surveys, qualitative focus groups and a comparative review of international experiences. This comprehensive design makes it possible to quantify the level of knowledge and willingness of the staff, and to understand the reasons underlying the observed behavioural patterns. This study is based on the research project "Management of end-of-life tires (NFU) of the Land Force in the framework of Social Responsibility".

Based on the results, the research is oriented towards the formulation of proposals that encourage the adoption of circular economy principles: incorporation of training programs on environmental regulations and recycling technologies, improvements in internal communication to disseminate clear and accessible information, implementation of monitoring systems and digital inventories, promotion of pilot projects that demonstrate the feasibility of reintroducing recycled rubber in different applications, and the reinforcement of environmental awareness from a practical and contextualized approach. These actions contribute to compliance with national policies, mitigation of negative impacts, institutional strengthening, and alignment with the SDGs.

Therefore, the study is not limited to diagnosing the current situation, but seeks to draw a roadmap towards a comprehensive and circular model of tire management in the Ecuadorian Land Force. This model is based on available human capital, continuous learning, transparent communication, regulatory support and the transfer of international best practices, thus generating a synergy that drives organizational change and positions the institution as a benchmark in the adoption of innovative, responsible and sustainable approaches.

2 Theoretical Framework

2.1 Circular Economy and Tire Recycling

The circular economy is based on the reduction, reuse and recycling of materials to minimise waste and maximise sustainability. In the case of tire recycling, this approach offers an opportunity to close the product life cycle through innovative and sustainable strategies. The circular economy drives tire recycling as a means of reducing the environmental impact associated with their disposal. Discarded tires contain valuable materials such as rubber, steel, and textile fibers, which can be recovered and reused. This recycling contributes to reducing dependence on virgin resources and reduces greenhouse gas emissions.

An example of this relationship is the reuse of recycled rubber powder in the manufacture of new products, such as shoe soles, sports surfaces, and asphalt mixtures, promoting an economic model that fosters sustainability (Genovese et al., 2021). Some strategies for NFU recycling are:

- *Shredding and Granulation Technologies:* Shredding allows mechanics to convert tires into small fragments and coria powder, which are used in asphalt mixtures or as filler material. This technology is efficient and widely adopted (Jones et al., 2020).

- *Pyrolysis:* A thermochemical process where tires are broken down under conditions of low oxygenation to produce gas, oil, and carbon black. These by-products are reused as energy or raw materials (Benedetti et al., 2022).
- *Direct Reuse:* Tires in suitable conditions can be retreaded and reused, extending their useful life and reducing resource consumption.
- *Incorporation of Recycled Rubber in Construction*: Material derived from recycled tires is used in road construction, as part of modified asphalts that increase strength and durability.

In countries such as Spain, the use of asphalt modified with rubber powder from recycled tires has been a success in terms of durability and sustainability. This approach not only reduces the need for new materials, but also provides a solution for waste management (González et al., 2019). Another notable example is the

"Rubber Roads" project in the United States, which has shown that the use of recycled rubber in pavements reduces traffic noise and improves resistance to cracking (Smith et al., 2023).

2.2 Sustainability and Recycling of Tires

Sustainability involves meeting present needs without compromising resources for future generations, balancing environmental, economic and social aspects. In this context, tyre recycling is presented as a strategy to minimise the negative impacts of their disposal, reduce the extraction of natural resources and promote the circular economy. Tires represent an environmental challenge due to their volume, resistance to degradation and the potential pollution they generate. However, when recycled, it becomes problematic waste into reusable resources, such as rubber, steel, and fibers, contributing to the United Nations Sustainable Development Goals (SDGs), especially in sustainable material management and climate action (UNEP, 2020). Some strategies for Tire Recycling are:

- *Pyrolysis for Energy Recovery*: Pyrolysis allows used tires to be converted into products such as oil, gas, and carbon black under controlled temperature and pressure conditions. This process reduces waste in landfills and generates products for the energy industry (Zabaniotou et al., 2022).
- *Use of Recycled Rubber in Infrastructure*: Shredded rubber is used in asphalt mixtures and pavements. This practice not only extends the lifespan of roads, but also improves their properties, such as crack resistance and noise reduction (González et al., 2019).
- *Production of Derived Products*: Recycled rubber is used in consumer products such as shoe soles, sports materials, and carpets, promoting the reduction of the use of virgin materials and fostering a circular market (Smith et al., 2021).
- *Local Recycling Initiatives*: Promoting local recycling programs can strengthen community sustainability, creating green jobs and reducing reliance on traditional disposal systems such as incineration.

An exemplary case is the project implemented in India, where discarded tires are pyrolysed to produce oil that is reused in local industries. This process has been shown to reduce accumulated waste and reduce dependence on conventional oil, creating an economical and sustainable alternative (Sharma et al., 2023).

3 Methodology

This study employed a mixed approach (quantitative-qualitative) with the purpose of exploring in depth the management of used tires in the Ecuadorian Land Force, identifying gaps in environmental knowledge and practices, and proposing strategic guidelines based on circular economy principles. The methodology was structured in three complementary phases: (1) Diagnosis of the current state through surveys and statistical analysis, (2) Review of international good practices, and (3) Qualitative exploration through focus groups. This comprehensive approach made it possible to contrast internal perceptions with international references, as well as to delve into the motivations and barriers underlying organizational change.

The research design combined quantitative and qualitative methods following the mixed paradigm (Creswell, 2014). This approach made it possible to quantify the level of knowledge, attitudes and practices regarding tire management, and to understand the reasons behind the identified patterns, incorporating a contextualized, dynamic and adaptive perspective.

Phase 1: Diagnosis of the Current State (Quantitative)

This first stage was aimed at characterizing the level of knowledge, attitudes and practices of the Land Force personnel regarding the management of used tires, as well as their willingness towards the incorporation of circular economy processes. To this end, the following techniques were used:

Structured Surveys

- An additional questionnaire of 14 items was designed, addressing dimensions: knowledge of the fate of end-of-life tires, familiarity with environmental regulations, risk perception, recycling assessment, and willingness to be trained in sustainable practices. The construction of the instrument was based on previous literature (Ajzen, 1991; Steg et al., 2014) and considered adaptability to the military context.

- The sample was calculated using the formula for finite samples, ensuring a confidence level of 95% and a margin of error of 5%. The study covers the logistics units of Logistics Command No. 25 "Reino de Quito" and Logistics Command No. 72 (Shyris).
- The data were processed in the SPSS version 26.0 software, performing descriptive and correlational analyses to identify patterns and relationships between the variables.
- The surveys were administered in printed format, ensuring the confidentiality of the responses. Clear instructions were provided and doubts were resolved in situ to ensure data quality.

Statistical analysis

- Frequencies and percentages were calculated to identify general patterns of knowledge, attitudes, and practices.
- In order to detect associations between variables (e.g., knowledge of the fate of tires and participation in environmental activities), Chi-square tests were used. These partnerships helped identify critical areas where communication, training, or regulation could be strengthened.

Phase 2: Review of International Good Practices (Documentary)

The second phase focused on exploring successful experiences in the management of used tires in international contexts, in order to draw lessons applicable to the Ecuadorian case:

Font Selection

- Reports, scientific articles and institutional reports from countries with recognized experiences in tire management, such as the United States, Canada, Germany and Argentina, were analyzed.

Review Criteria

- Examples that integrate the recycling, reuse and recovery of tires were prioritized, strengthening the reduction of waste and the efficient use of resources.
- It examined how the existence of clear regulations promoted the adoption of good practices, the involvement of the private sector and the generation of value chains.
- The adaptability of the revised measures to the reality of the Land Force was considered, taking into account its hierarchical structure, operational functions and internal dynamics.

Phase 3: Qualitative Exploration through Focus Groups

In order to complement the quantitative information and delve into the motivations, perceptions and internal barriers, a qualitative phase was carried out through focus groups. This stage was essential to understand the internal dynamics that the polls could not fully capture:

Selection of Participants

- Four focus groups were formed, each with 8 to 12 members of the Ground Force. The selection was made through purposive sampling, looking for heterogeneity in ranks, areas of work (technical, logistical, administrative) and levels of experience in resource management. This criterion broadened representativeness and guaranteed diversity of perspectives.

Structure of the Sessions

Sessions of approximately 90 minutes were moderated by an external researcher with expertise in qualitative research and environmental communication. The question guide addressed:

- Knowledge of the life cycle of tires and their final disposal.
- Perceptions of internal communication regarding regulations, recycling and pollution prevention.
- Motivations, incentives and barriers to participate in training programmes and adopt sustainable practices.
- Understanding of the national regulatory framework and its applicability.
- Receptivity to the concept of circular economy and adaptation of international models.

  This approach made it possible to capture the spontaneous responses, personal experiences and suggestions of the staff, enriching the understanding beyond the merely quantitative dimension.

Qualitative Data Analysis

- The sessions were recorded in audio and transcribed verbatim. Transcripts were coded using thematic analysis (Braun & Clarke, 2006), supported by specialized software.
- Emerging categories (e.g., perception of regulations, internal communication, tire valorization, environmental risks, circular economy) were identified and grouped by conceptual affinity.
- These categories were contrasted with survey results and with theories on environmental behavior (Ajzen, 1991) and circular economy (Ghisellini et al., 2016). This triangulation made it possible to understand the reasons behind the figures and propose better-founded solutions.

4 Results

4.1 Survey Analysis

Knowledge of the NFU Destination

The survey applied to 350 members of the Land Force revealed that 84.4% do not know the final destination of the tires once they have reached the end of their useful life, while only 15.6% indicated that they have information about it. This result highlights a gap in knowledge transfer within the institution. The lack of information on the disposal of used tyres limits the adoption of good recycling practices, and influences the ability of staff to understand the relevance of environmental policies and their own contribution to institutional sustainability. The lack of clarity on the whereabouts of this waste reflects a weakness in internal communication, as well as the lack of environmental education programs specifically designed for military personnel. The literature underlines that ignorance is a factor that hinders the adoption of pro-environmental behaviors (Ajzen, 1991). Therefore, it is urgent to implement training and awareness strategies that allow members of the Land Force to understand the complete life cycle of tires and the economic, social and environmental advantages of their correct management.

Knowledge of environmental regulations

74.6% of those surveyed in the logistics units report not knowing the current environmental regulations, while only 35.5% consider that they help to conserve the environment. On the other hand, 53.6% affirm that they apply basic practices for environmental preservation. 59.4% stated that they did not know of a management system that avoided environmental pollution, although 76.3% identified pollution as a critical problem. This regulatory gap is critical, since compliance with regulations such as the National Plan for the Integrated Management of Solid Waste (PNGIDS) constitutes a fundamental pillar to guide decision-making and institutional practices. The lack of knowledge about the legal provisions prevents the coherent application of recycling programs, reduces the capacity for innovation in the circular economy and limits the efficiency in the comprehensive management of end-of-life tires.

Process Knowledge for NFU Optimization

83% of the sample is unaware of specific processes to optimize end-of-life tires, in contrast to 17% who said they had some knowledge about it. This lack of information limits the incorporation of technologies and practices aimed at the reuse, reconditioning, retraining or recycling of tyres. Without appropriate technical knowledge, staff cannot identify the possibilities offered by end-of-life tyres: from their potential as an input for other products to their use in civil infrastructure (e.g. in asphalt mixtures or protective barriers). The transfer of technical knowledge is essential to enable practical and sustainable solutions. Practice-oriented training, the exchange of experiences with other institutions or the use of international success stories could generate substantive changes in internal management and promote continuous improvement.

Knowledge of NFU volume

84.4% do not know the amount of tires in poor condition present in the facilities of the Land Force, while only 15.6% have this information. This finding reveals the absence of efficient monitoring systems and records. Without accurate data, it's difficult to plan procurement, preventative maintenance, and waste reduction strategies. Likewise, the lack of information limits the ability to respond adequately to environmental or health contingencies derived from the prolonged storage of unusable tires. The introduction of digital inventories, the use of traceability technologies, and the assignment of staff responsible for data management could improve responsiveness and decision-making, as well as support regulatory compliance and internal transparency.

Participation in environmental conservation

90.5% expressed interest in participating in environmental conservation activities, while only 9.5% showed no willingness. This data is extremely encouraging, as it indicates that, despite the gaps in knowledge, there is a human potential to promote environmental initiatives. This result confirms that the Land Force has motivated human resources that are likely to be actively involved in sustainable programs and projects, as long as they are offered the necessary information, tools, and opportunities. The theory of planned behavior suggests that the intention to participate can be translated into effective action when informational and logistical barriers are removed (Ajzen, 1991). Therefore, the high level of interest observed lays the foundations for the development of training plans, awareness campaigns and specific tasks in which staff can be involved.

Knowledge of systems to avoid environmental pollution

74.8% do not know if the Land Force has systems to prevent environmental pollution, while 25.2% do know of any system implemented. This finding reveals a failure in the internal dissemination of the environmental measures that are already being carried out. Lack of communication about preventive and corrective systems affects staff's perception of institutional efforts, and reduces the ability to leverage or improve such systems. If the staff is not aware of the tools available, it is difficult for them to actively participate in their maintenance, improve their operation or propose innovations. The solution lies in assertive and permanent communication, using accessible formats, varied channels and clear institutional references.

Importance of NFU Recycling Regulation

89.8% consider it important that the Ministry of the Environment regulates tire recycling in the country, while 10.2% consider the opposite. This strong support for regulation suggests awareness of the need for a regulatory framework that ensures responsible tire handling, establishes clear standards, and assigns responsibilities to both public institutions and private actors. Regulation can act as a catalyst that fosters innovation, investment and inter-institutional collaboration. By having specific rules, the Land Force would align with national policies, and could play an exemplary role in sustainable waste management, motivating other sectors to adopt similar practices.

Knowledge of NFU recycling as a raw material

65.3% recognize that used tires can be used as raw material for other products, while 34.7% do not know. This indicates that there is a moderate level of awareness about the potential value of tires, but it is still insufficient. A greater understanding of the opportunities offered by waste recovery could encourage participation in recycling and reuse chains, as well as in the search for strategic allies (suppliers, recycling companies, among others). Greater dissemination of success stories, workshops with practical examples and visits to recycling plants could consolidate this knowledge and translate it into action.

Knowledge of the risks of storing NFU

57.8% are unaware of the risks associated with the storage of tires in poor condition, while 42.2% are informed. Risks include the proliferation of disease vectors, the accumulation of standing water, the risk of fires, and the gradual release of toxic substances into soil and water. A greater understanding of these risks is essential for environmental protection, and for safeguarding the health of staff and nearby communities. Environmental education in this regard should combine technical information with concrete examples, emphasizing the direct consequences on the ecosystem and human health.

Knowledge of environmental risks due to poor disposal of NFU

60% are aware of the environmental risks associated with poor tire layout, while 40% are unaware of them. This partial balance shows that, although there is some awareness, there is still a need to strengthen environmental education. Understanding these risks can increase motivation to adopt more responsible behaviors, such as proper separation, stockpiling in designated areas, and timely reporting of unused tires to appropriate areas. Recurrent training programs, integrated into the work routine, could contribute to raising the level of understanding and generating sustainable habits.

Support for recycling training programs

80% were in favour of participating in training programmes on recycling, while 20% were not interested. This high degree of acceptance indicates the feasibility of implementing training initiatives that combine theory

and practice, reinforce normative and technical understanding, and encourage participation. The opportunity to train staff is strategic, as the adoption of new practices depends, to a large extent, on the competence and confidence acquired through continuous training.

Feasibility of applying international recycling models
48% considered it feasible to implement international recycling models in the Land Force, while 52% expressed doubts or lack of knowledge. This finding shows the need to present success stories adapted to the national context, demonstrating their practical applicability. Exposure to international experiences can serve as inspiration, provided cultural, logistical and normative factors are contextualized. A well-designed knowledge transfer process can help overcome skepticism and consolidate internal acceptance of models tested in other countries.

NFU Inventory Registration
64% are unaware of the existence of an inventory record of used tires, while 36% are aware of its existence. This data shows the need to make information on tire stocks transparent and socialized, which would facilitate strategic planning, the calculation of future demand and the prevention of environmental or health risks. Knowledge management is essential; An up-to-date, accessible, and easy-to-consult inventory system can become a critical decision-making tool.

Importance of implementing circular economy processes
84% consider it important for the Land Force to incorporate circular economy processes, while 16% do not see it as necessary. This overwhelming majority shows the will to move towards a more efficient management system, which reintroduces tyres into the production chain and reduces dependence on virgin resources. The circular economy brings social, environmental and economic benefits, and its implementation can project a positive image of the institution, aligning it with international environmental agendas and the most innovative trends in resource management.

4.2 Chi-square Analysis and Associations
Through Chi-square analysis, seven associations were identified between the survey variables, which show the interconnection between environmental knowledge, attitudes and practices. These relationships make it possible to identify critical factors and design strategic interventions:

1. There is a strong connection between knowing what happens to end-of-life tires and a willingness to get involved in environmental activities. The more information, the greater the willingness to act.
2. Those who are aware of the possibilities of reusing rubber are also more aware of the dangers of poor disposal. This suggests that spreading the potential of recycled tyres also increases environmental sensitivity.
3. The value of regulation is associated with awareness of the problem of inadequate storage. Understanding the negative consequences drives support for regulation.
4. The lack of knowledge about environmental regulations is related to ignorance in optimization processes. Knowing the regulations guides compliance, and stimulates the search for practical solutions.
5. Misinformation about the volume of tires in poor condition is accompanied by a lack of knowledge about internal systems to prevent contamination. Having up-to-date data allows you to identify gaps and take preventive measures.
6. Those who perceive the risks associated with poor tyre disposal are more willing to participate in training, demonstrating that raising awareness of environmental hazards promotes active learning.
7. Support for the implementation of circular economy processes increases among those who understand the destination of tires. Clarity on waste management stimulates the adoption of circular approaches.

Table 1
Most Relevant Partnerships

Variable 1: Questions	Variable 2: Questions	Chi-Square	P-Value
Do you know the fate of end-of-life tyres?	Do you currently help with the conservation of the environment?	277.77	2.30e-62
Do you know if tires can be used as raw materials?	Do you know the environmental risks due to poor tire disposal?	125.66	3.64e-29
Do you think it is important for the Ministry of the Environment to regulate tire recycling?	Do you know the problems of storing bad tires?	95.60	1.40e-22
Do you know about current environmental regulations?	Do you know of any process for optimising end-of-life tyres?	43.98	3.33e-11
Do you know the volume of tires in poor condition?	Do you know if the institution has systems to avoid environmental pollution?	41.21	1.37e-10
Do you know the environmental risks of poor tire disposal?	Would you support training programs in recycling at the institution?	22.78	1.80e-05
Do you think it is important for the land force to implement circular economy processes?	Do you know the fate of end-of-life tyres?	18.40	9.90e-05

These associations suggest that the increase in environmental, normative, and technical knowledge has multiplying effects on attitudes and behaviors, which coincides with theoretical approaches to pro-environmental attitudes and the influence of knowledge on the adoption of sustainable practices (Ajzen, 1991; Ghisellini et al., 2016; Steg et al., 2014).

4.3 Results of the Focus Groups

The focus groups, used as a qualitative methodology complementary to the quantitative survey, have revealed deep-seated aspects of the perceptions, motivations, and barriers faced by Land Force personnel in relation to the management of end-of-life tires (ELT). This qualitative approach is necessary to interpret the statistics obtained and to design more effective interventions that address the real needs of the staff.

The information collected through the focus groups has been organized into a table that summarizes the main topics discussed, the findings, and suggestions for improving environmental practices in the institution. Each entry in the table directly reflects staff concerns and suggestions, providing a solid foundation for future policies and training programs.

Table 2
Findings from the Focus Groups on NFU Management

Variables	Finds	Improvement Actions
Knowledge and Availability of Information	High levels of ignorance about the fate of NFUs, not due to lack of interest but due to lack of accessible information.	Implement didactic materials, internal signage, infographics and interactive workshops.
Internal Communication and Information Channels	Internal communication is perceived as deficient; Technical messages are not accessible to all levels.	Improve the frequency and clarity of communication using audiovisual media and talks, and designate environmental references.
Hands-on Training and Direct Experimentation	Need for practical training highlighted, with strong support for trainings that include direct experiences.	Organise visits to recycling facilities and pilot projects that allow for hands-on learning.
Perception of Environmental and Health Risks	Lack of knowledge about the risks arising from improper storage of NFU, but greater predisposition after being informed.	Raise awareness of the environmental and health consequences through education and exposure to real risks.
Environmental Regulations and Circular Economy	The complexity of regulations often reduces their effectiveness; The concept of circular economy is well received.	Simplify the language of regulations and present practical examples of circular economy adapted to the military context.

The findings suggest that improving access to information and training can have a direct impact on the effectiveness of environmental policies. The table provides a clear summary of critical areas requiring

attention and serves as a guide for developing targeted interventions that can improve both NFU management and the overall sustainability of the institution.

5 Discussion

The results of the survey reveal a marked lack of knowledge about the handling and final destination of end-of-life tires in the Land Force, a problem that appears to be common in several regions of the world but has been effectively addressed through innovative regulations and practices in countries such as Germany and Canada. The international comparison allows us to understand that the adoption of advanced NFU management systems can enhance institutional capacities and respond to environmental challenges more effectively.

The need to strengthen education and training within the Land Force is evident in order to close the identified knowledge gap. Inspired by models from countries such as Canada, where educational programs and public awareness campaigns have been instrumental in improving recycling rates, a similar strategy is proposed. This strategy should include workshops, seminars and educational material that address everything from current legislation to NFU recycling and reuse techniques.

The implementation of technical training is necessary, taking Germany as an example, where specialized technical training has made it possible to optimize recycling processes. It is suggested to establish training programs that cover the basic aspects of recycling, and advanced techniques such as pyrolysis and other methods of energy recovery. To effectively visualize and compare knowledge levels and areas for improvement, the following table is included summarizing the survey data and showing correlations between different variables related to environmental knowledge and sustainability practices:

Table 3
Correlations between Knowledge and Environmental Practices

Variable Compared	Correlation with	Chi-Square	P-Value
Knowledge of the NFU Destination	Conservation Engagement	277.77	2.30e-62
Knowledge of NFU Uses	Risk awareness	125.66	3.64e-29
Support for recycling regulation	Knowledge of storage issues	95.60	1.40e-22
Regulatory knowledge	NFU Optimization Knowledge	43.98	3.33e-11

These data suggest that increased knowledge about NFU is strongly associated with greater participation in and commitment to environmental sustainability practices. Clarity in understanding the regulations and the final destination of NFUs, as well as awareness of their potential applications and risks, are critical to strengthening the culture of recycling and conservation within the Ground Force. These findings underpin the need to design educational interventions that convey information, and foster a proactive attitude towards sustainability.

Reflecting strategies of countries with high recycling rates, such as Spain, it is recommended to improve internal communication channels using modern technology to ensure that information on NFU management is accessible to all. The implementation of a centralized information management system would facilitate the dissemination of policies, regulations and good practices. Creating digital inventory and monitoring systems, similar to those used in advanced industries, would allow the Land Force to accurately track NFUs and properly plan for their recycling or final disposal.

6 Conclusions

The integration of tyre recycling into a circular economy model offers environmental benefits, and drives innovation in industrial and infrastructure sectors. However, to achieve an impact, public policies, investments in technology and social awareness must be promoted. Tire recycling is a strategy to move towards sustainability, as it addresses environmental issues while encouraging innovative economic solutions.

The implementation of modern technologies and supportive policies can enhance the benefits, transforming waste management into an opportunity for sustainable development.

The management of used tires in the Ecuadorian Land Force presents significant challenges, but also opportunities for the adoption of more sustainable practices aligned with circular economy principles. The quantitative and qualitative results obtained show an institutional panorama where the lack of knowledge about the final destination of tires, the lack of information on environmental regulations, the absence of data on the volume of tires in poor condition and the lack of technical knowledge for their optimization limit the implementation of effective strategies. This context is aggravated by insufficient internal communication, the lack of accessible teaching materials and the limited dissemination of successful experiences that demonstrate the feasibility of the proposed solutions.

The high interest of staff in participating in environmental activities, the majority willingness to train, the recognition of the importance of regulations and the awareness of the potential benefits of the circular economy constitute a solid foundation on which to build positive change. The findings show that staff are not apathetic, but require informational and training tools, clear communication channels, practical examples, and opportunities for concrete engagement to translate their pro-environmental intentions into sustainable behaviors.

The international experience of countries such as the United States, Canada, Germany and Argentina shows that transformation is possible through strong regulatory frameworks, extended producer responsibility, adequate economic incentives, inter-institutional alliances, continuous technical training, effective communication and the implementation of pilot projects that demonstrate the economic, social and environmental value of recycling and reuse of tires.

In this way, the study underscores the need for a comprehensive intervention that articulates the strengthening of internal communication, the development of technical training programs, the improvement of monitoring and registration systems, risk awareness and the adaptation of successful international models to the institutional reality of the Land Force. This roadmap will reduce the environmental impact of used tyres, and project an institutional image that is consistent with public policies, the sustainable development goals and global trends in sustainability.

Research focused on comparing the performance of the Land Force with other branches of the Armed Forces or with civilian organizations with similar vehicle fleets could identify contextual divergences, more effective strategies, and opportunities for collaboration. These studies would serve to establish reference indicators and facilitate the exchange of good practices, contributing to homogenize the management of used tires in different institutional environments. With these actions, the Land Force could become a benchmark in responsible waste management, strengthening its environmental role and contributing to the fulfillment of national and international goals in terms of sustainability

Deepening the perceptions, values and social norms that shape the environmental behavior of personnel would contribute to designing more effective interventions in terms of communication, environmental education and organizational strengthening. Studies that explore psychosocial and cultural factors would allow the development of highly contextualized awareness strategies, optimizing the adoption of sustainable behaviors.

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