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ORIGINAL

Digital technologies applied to the monitoring and sustainable management of natural resources

Tecnologías digitales aplicadas al monitoreo y gestión sostenible de los recursos naturales

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ABSTRACT

Introduction: Digital transformation allows new ways of maximizing environmental management, although its functionality will depend on the use given to the information generated and its monitoring for decision-making. Objective: To explore the relationship between the adoption of digital technology, the effectiveness of environmental monitoring, and the sustainable management of natural resources in Decentralized Autonomous Governments. Methodology: Quantitative, non-experimental, cross-sectional and correlational-explanatory study applied to 172 officials, technicians and professionals. An 18-item Likert-type questionnaire at the five-point level was used. Results: Significant relationships were found between technology adoption and environmental monitoring (r = 0.68), technology adoption and sustainable management (r = 0.61), environmental monitoring and sustainable management (r = 0.74). The model explains 59% of the variability. Conclusions: Environmental monitoring had greater predictive weight than the adoption of technology, which shows that sustainability lies in the use of the information generated.

Keywords: digital technologies; environmental monitoring; natural resources; sustainability; environmental management.

RESUMEN

Introducción: La transformación digital permite nuevas formas de maximizar la gestión ambiental, aunque su funcionalidad dependerá del uso que se dé a la información generada y de su monitoreo para la toma de decisiones. Objetivo: Explorar la relación entre la adopción de la tecnología digital, la eficacia del monitoreo ambiental y la gestión sostenible de los recursos naturales en los Gobiernos Autónomos Descentralizados. Metodología: Estudio cuantitativo, no experimental, transversal y correlacional-explicativo aplicado a 172 funcionarios, técnicos y profesionales. Se utilizó un cuestionario de 18 ítems tipo Likert de nivel de cinco puntos. Resultados: Se hallaron relaciones significativas entre adopción de la tecnología y monitoreo ambiental (r = 0.68), adopción de la tecnología y gestión sostenible (r = 0.61), monitoreo ambiental y gestión sostenible (r = 0.74). El modelo explica un 59 % de la variabilidad. Conclusiones: El monitoreo ambiental tuvo mayor peso predictivo a diferencia de la adopción de la tecnología, lo que pone de manifiesto que la sostenibilidad radica en la utilización de la información generada.

Palabras clave: tecnologías digitales; monitoreo ambiental; recursos naturales; sostenibilidad; gestión ambiental.

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INTRODUCTION

One of the main challenges faced by institutions responsible for territorial and environmental planning is the sustainable management of natural resources, due to the increasing pressure on water, land, biodiversity and other components of ecosystems. In this context, digital transformation has become strategic to enable new ways of collecting, processing and interpreting environmental information. Technologies such as artificial intelligence, the Internet of Things, cloud computing, and big data analytics are changing traditional environmental management processes and expanding the possibilities for implementing sustainability-oriented strategies [1].

Among these tools, Earth observation technologies and machine learning-based systems provide capabilities useful for identifying environmental changes, recognizing spatial and temporal patterns, and generating information to support decision-making. Their incorporation enables the processing of large volumes of data from multiple sources and the transformation of environmental records into useful information for assessing the state and evolution of natural resources [2]. Similarly, Earth observation has become prominent in monitoring sustainable development indicators, providing geospatial information that can be incorporated into institutional planning, monitoring, and evaluation processes from national to local scales [3].

The development of deep learning algorithms has further expanded the possibilities for leveraging satellite and geospatial data. The combination of Earth observation and advanced analysis techniques enables addressing issues related to sustainable cities, climate change, food security, and biodiversity conservation, among other areas [4]. Additionally, remote sensing and geographic information systems have become consolidated as instruments for natural resource management by enabling territorial characterization, identification of changes in land cover, and monitoring of environmental phenomena; however, their effectiveness depends on the quality of available data and its integration with information obtained directly in the field [5].

Environmental monitoring constitutes the operational link between technological incorporation and sustainable management. Contemporary systems integrate wireless sensor networks, unmanned aerial vehicles, and distributed information acquisition mechanisms, thereby increasing the spatial and temporal coverage of observations [6]. Sensor networks, particularly when articulated with Internet of Things architectures, enable continuous recording of environmental variables and transmission of information for processing, offering alternatives to overcome limitations derived from sporadic or exclusively manual measurements [7].

The integration of different information sources is also relevant for transforming collected data into concrete management instruments. Systems capable of combining IoT stations and satellite imagery have been developed to support environmental monitoring and management processes, showing that the usefulness of digital technologies depends not only on having devices, but on their interoperability and the institutional capacity to convert data into information applicable to decision-making [8]. This approach allows conceptual differentiation between technological adoption and the effectiveness of environmental monitoring, because greater availability of technology does not by itself guarantee that the information produced is timely, accurate, and useful for management.

In Colombia, experiences demonstrate the applicability of these tools in urban contexts. The development of portable, low-cost Internet of Things devices to monitor air quality in the city of Ibarra demonstrated the possibility of integrating sensors, data processing, and digital systems to characterize local environmental conditions [9]. This type of experience is relevant for subnational governments, whose territorial competencies require updated information to support processes of prevention, control, planning, and protection of natural resources.

The incorporation of digital technologies must nevertheless be analyzed from a perspective that transcends the availability of technological infrastructure. Artificial intelligence can contribute to achieving multiple sustainable development objectives through improvements in the analysis, prediction, and optimization of processes, although its contribution depends on appropriate institutional, regulatory, and social conditions [10]. Similarly, machine learning applications offer opportunities to address complex environmental problems through prediction, optimization, and information processing, but they must be integrated with specialized knowledge and appropriate decision-making mechanisms [11]. Consequently, technology constitutes a means to strengthen management capacities, not a sustainable outcome in itself.

This relationship is particularly relevant to the management of natural resources. Available evidence indicates that digitalization and technological innovation can promote more sustainable use of these resources by strengthening eco-efficiency and improving capacities to plan and control their use; however, factors related to infrastructure, human capacities, policies, and innovation condition the scope of these benefits [12]. Thus, it is pertinent to jointly study the adoption of digital technologies, the effectiveness achieved in monitoring processes, and the perceived results in terms of sustainable management.

The context of local governments deserves particular attention because of their proximity to the environmental problems of their territory and their participation in planning, regulation, and service provision processes linked to sustainability. Empirical evidence has shown that the use of digital technologies can improve the efficiency of local environmental governance, although its effects depend on institutional capacities and the conditions under which these tools are incorporated into public administration [13]. In this sense, analyzing the phenomenon from the perspective of officials and professionals involved in environmental management allows an examination of not only the level of technological use but also its articulation with institutional monitoring and decision-making processes.

Despite the advancement of technologies applied to environmental management, there remains a need to generate contextualized empirical evidence that simultaneously examines how technological adoption relates to monitoring capacity and sustainable management within territorial public institutions. This perspective is particularly pertinent to the municipal and provincial decentralized autonomous governments of Colombia, in which differences in technical capacities, available resources, and incorporation of digital tools can result in different levels of utilization of environmental information.

Consequently, the objective of this research is to analyze the relationship among the adoption of digital technologies, the effectiveness of environmental monitoring, and the sustainable management of natural resources among officials and professionals of the municipal and provincial Decentralized Autonomous Governments of Colombia. The general hypothesis is that there is a positive and statistically significant relationship among the three variables, such that higher levels of adoption of digital technologies are associated with greater effectiveness of environmental monitoring and, in turn, with better levels of sustainable management of natural resources.

METHODS

Research Design

The research was conducted using a quantitative approach, with a non-experimental and cross-sectional design. A correlational-explanatory scope was adopted, as the aim was to determine the magnitude and direction of the relationships among the adoption of digital technologies, the effectiveness of environmental monitoring, and the sustainable management of natural resources, without deliberate manipulation of the variables. The information was collected at a single point in time through the application of a structured questionnaire.

The study variables were adoption of digital technologies, effectiveness of environmental monitoring, and sustainable management of natural resources. The analytical model enabled examination of both the bivariate relationships among these variables and the joint explanatory capacity of technological adoption and environmental monitoring for sustainable management.

Population and Sample

The target population consisted of officials, technicians, and professionals from municipal and provincial Decentralized Autonomous Governments of Colombia, engaged in activities related to environmental management, natural resources, territorial planning, water and sanitation, risk management, information systems, land-use planning, or related areas.

The sample consisted of 172 participants from municipal and provincial GADs. Non-probabilistic purposive sampling was used based on eligibility criteria, considering the need to include participants with knowledge or institutional experience related to the analyzed variables.

The inclusion criteria were as follows: working as an official, technician, or professional in a municipal or provincial GAD; performing functions directly or indirectly related to environmental management, natural resources, monitoring, territorial planning, or the use of technologies for institutional management; having at least 6 months of tenure in the institution; and voluntarily agreeing to participate in the study. Incomplete questionnaires and responses from personnel whose functions were not related to the environmental or technological processes examined were excluded.

Data Collection Instrument

The information was obtained through a structured questionnaire designed to measure the 3 study variables. The instrument consisted of 18 items, evenly distributed across 3 scales of 6 items each.

The dimension of adoption of digital technologies evaluated the institutional use of tools such as geographic information systems, sensors, the Internet of Things, remote sensing, digital platforms, automated systems, and tools for the processing and analysis of environmental information.

The environmental monitoring effectiveness scale evaluated aspects associated with timeliness of information, accuracy of records, territorial coverage, monitoring continuity, ability to detect environmental changes, and availability of information to support decision-making.

The sustainable management of natural resources variable considered aspects related to the efficient use of resources, prevention and reduction of environmental impacts, conservation, information-based planning, institutional response capacity, and incorporation of sustainability criteria in decision-making.

The items were rated using a 5-category Likert-type scale: 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree. Higher values indicated higher levels of the variable evaluated.

Additionally, the questionnaire included questions to characterize the participants, including type of GAD, work area, professional experience duration, and institutional seniority.

Validity and Reliability of the Instrument

Content validity was established through expert judgment. Specialists with experience in research, environmental management, natural resources, and quantitative methodology participated, evaluating each item according to the criteria of clarity, pertinence, coherence, and relevance.

Inter-rater agreement among expert ratings was examined using Aiken's V coefficient. Items that did not achieve satisfactory levels were reworded or eliminated before the final administration of the instrument.

Subsequently, a pilot test was conducted with participants who had characteristics similar to the target population and who were not part of the final sample. This phase served to verify comprehension of the items, identify possible ambiguities, and make adjustments prior to the final data collection.

The internal consistency of the scales was evaluated using Cronbach's alpha coefficient and McDonald's omega, considering values equal to or greater than 0.70 as indicators of satisfactory reliability.

To examine the internal structure of the instrument, the adequacy of the data was initially verified using the Kaiser-Meyer-Olkin (KMO) index and Bartlett's test of sphericity. Subsequently, an exploratory factor analysis was performed to verify the grouping of the items according to the three theoretically proposed variables.

Procedure

Data collection was conducted after identifying the officials and professionals who met the established criteria. Participants received information about the academic objective of the research, the voluntary nature of their participation, and the confidential handling of their responses.

The questionnaire was administered using a structured form. Before its administration, informed consent was presented, and only records from participants who voluntarily agreed to participate were included in the analysis.

After data collection was completed, the database was reviewed to detect incomplete records, inconsistencies, and outliers. Subsequently, responses were coded and scores for each of the three variables were calculated.

Statistical analysis

The analysis was initially performed using descriptive statistics. For quantitative variables, the mean, standard deviation, minimum, and maximum values were calculated, while participant characteristics were summarized using frequencies and percentages.

Before the correlational analysis, the distribution of the scores and compliance with the main statistical assumptions were examined. The relationship between the variables was evaluated using Pearson's correlation coefficient (r).

Three main relationships were analyzed: adoption of digital technologies with effectiveness of environmental monitoring; adoption of digital technologies with sustainable management of natural resources; and effectiveness of environmental monitoring with sustainable management of natural resources. The magnitude of the correlations was interpreted considering both the absolute value of the coefficient and its direction.

Subsequently, a multiple linear regression model was developed, using sustainable management of natural resources as the dependent variable and the adoption of digital technologies and effectiveness of environmental monitoring as predictor variables. The standardized coefficients, coefficient of determination, overall significance of the model, and statistical contribution of each predictor were examined.

For all inferential analyses, a significance level of $p < 0.05$ and a 95% confidence interval were established.

Ethical considerations

The research adhered to the principles of voluntary participation, confidentiality, and exclusive academic use of the information. No data intended to individually identify participants were collected. Before responding to the instrument, each participant was informed about the study objectives, data handling, and their right to withdraw without any consequence. The information obtained was analyzed in an aggregated manner and used only for the purposes established in the research.

RESULTS

The sample consisted of 172 officials, technicians, and professionals from municipal and provincial Decentralized Autonomous Governments of Colombia. The psychometric evaluation showed an adequate structure of the instrument, with a Kaiser-Meyer-Olkin (KMO) index of 0.89 and a statistically significant Bartlett's test of sphericity ($\chi^2 = 1864.27$, df = 153, $p < 0.001$), results that supported the joint analysis of the items corresponding to the three variables.

The internal consistency analysis also showed satisfactory values. For adoption of digital technologies, Cronbach's alpha was 0.88 and McDonald's omega was 0.89; for effectiveness of environmental monitoring, both coefficients reached 0.90; and for sustainable management of natural resources, α was 0.91 and ω was 0.92.

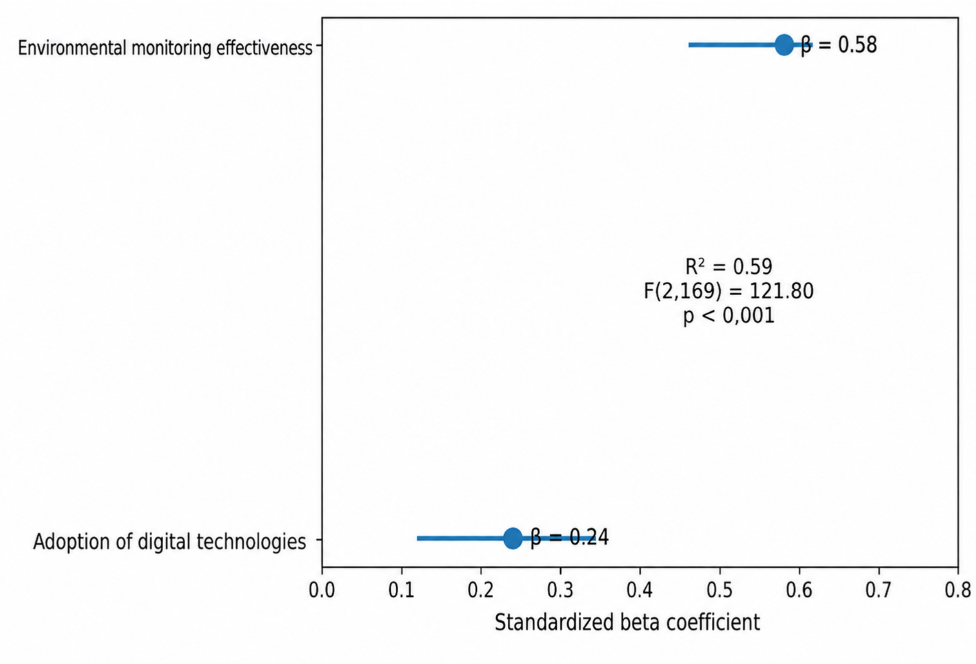
The descriptive results showed scores above the midpoint of the scale for all three variables. Sustainable management of natural resources had the highest mean (M = 3.81; SD = 0.65), followed by effectiveness of environmental monitoring (M = 3.74; SD = 0.68) and adoption of digital technologies (M = 3.62; SD = 0.71). The observed differences were moderate, although technological adoption registered the lowest relative level.

Table 1. Descriptive statistics and internal consistency of the study variables

Variable	Items	Mean	DE	Min.	Max.	Cronbach's alpha	McDonald's omega
Adoption of digital technologies	6	3,62	0,71	1,67	5,00	0,88	0,89
Effectiveness of environmental monitoring	6	3,74	0,68	1,83	5,00	0,90	0,90
Sustainable management of natural resources	6	3,81	0,65	2,00	5,00	0,91	0,92

Note. DE = standard deviation. Own elaboration.

Figure 1. Comparative profile of the study variables

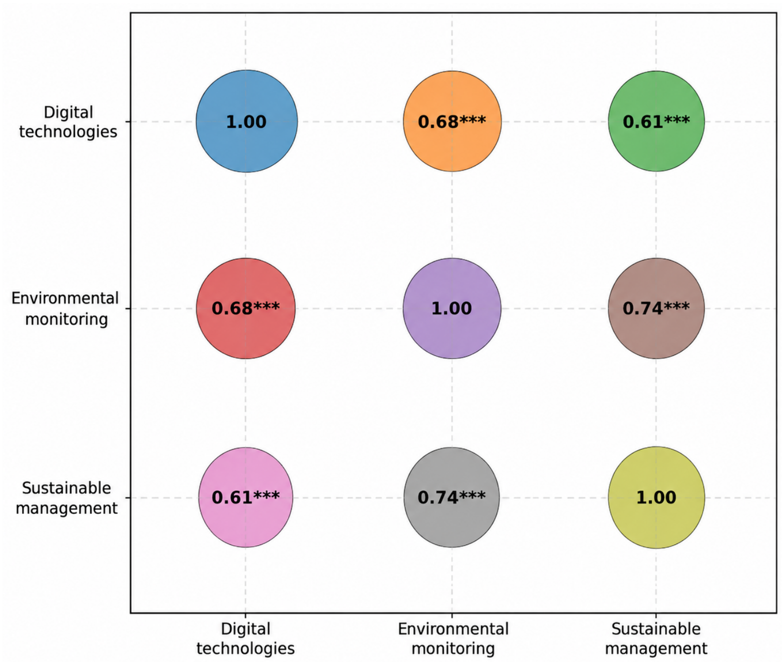


Note. The scores represent the mean values obtained for each variable on a Likert scale from 1 to 5. Own elaboration.

Pearson correlation analysis revealed positive and statistically significant associations among the three variables. Adoption of digital technologies was positively correlated with the effectiveness of environmental monitoring ($r = 0.68$; $p < 0.001$) and with sustainable management of natural resources ($r = 0.61$; $p < 0.001$).

The strongest association was found between the effectiveness of environmental monitoring and sustainable management of natural resources ($r = 0.74$; $p < 0.001$). These results indicate that higher levels of environmental monitoring effectiveness were associated with higher levels of sustainable management in the studied GADs.

Figure 2. Pearson correlation matrix between the study variables

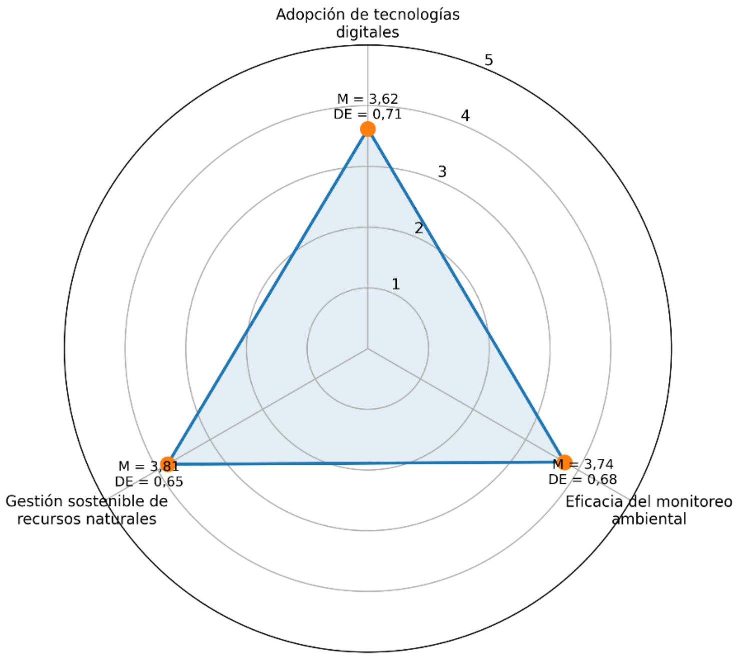


Note. The size of the bubbles represents the magnitude of the correlation coefficient. *** p < 0.001. Own elaboration.

Finally, the multiple linear regression model was statistically significant ($F(2,169) = 121.80$; $p < 0.001$) and explained 59% of the variability in sustainable management of natural resources ($R^2 = 0.59$; adjusted $R^2 = 0.58$).

The effectiveness of environmental monitoring was the strongest predictor in the model ($\beta = 0.58$; B = 0.55; EE = 0.06; t = 9.29; $p < 0.001$). Moreover, adoption of digital technologies also had a positive and statistically significant effect ($\beta = 0.24$; B = 0.22; EE = 0.06; t = 3.81; $p < 0.001$).

Figure 3. Effect of predictor variables on the sustainable management of natural resources



Note. The points represent the standardized beta coefficients and the horizontal lines represent their respective 95% confidence intervals. The dependent variable was the sustainable management of natural resources. Own elaboration.

Overall, the results showed that the three variables were significantly related and that both technological adoption and monitoring effectiveness contributed to explaining sustainable management. However, environmental monitoring had the greatest statistical weight, suggesting that the usefulness of digital technologies for sustainability depends largely on their capacity to strengthen effective processes for generating and using environmental information.

DISCUSSION

The results showed that adoption of digital technologies, effectiveness of environmental monitoring, and sustainable management of natural resources exhibited positive and statistically significant relationships in the analyzed Decentralized Autonomous Governments. In particular, the association between technological adoption and environmental monitoring was of moderate-high magnitude ($r = 0.68$; $p < 0.001$), indicating that greater integration of digital systems is linked to improved institutional capacities to generate, process, and use environmental information. This result coincides with experiences in which the integration of sensors, the Internet of Things, and satellite imagery allowed the expansion of observation capacity and supported decisions related to environmental management [14].

This relationship can also be explained by the growing capacity of digital technologies to transform large volumes of data into actionable environmental information. Machine learning, automated systems, and advanced analytical techniques enable the identification of patterns that could hardly be recognized through conventional procedures alone. Reichstein et al. pointed out that the combination of deep learning and knowledge of Earth systems offers relevant opportunities to improve the analysis of complex environmental processes [15]. In this sense, the results suggest that technological benefits within GADs depend not only on possessing certain tools but also on effectively integrating them into institutional monitoring procedures.

The adoption of digital technologies was also significantly related to sustainable management of natural resources ($r = 0.61$; $p < 0.001$). Although this association was slightly lower than that observed with environmental monitoring, it confirms that digitalization constitutes a relevant component for improving processes of planning, prevention, and utilization of environmental information. This result is consistent with the proposal of Rolnick et al., who identify multiple applications of machine learning to address environmental problems through prediction, optimization, and information processing [16]. However, the magnitude of the obtained correlation indicates that technological availability alone does not determine sustainability, since technical, institutional, and organizational capacities also play a role.

This interpretation is particularly important when technologies such as geographic information systems and remote sensing are considered. Sharma et al. highlight that these tools hold great potential for natural resource management, although their effectiveness depends on data quality, field information, and adequate integration among different sources [17]. Therefore, the results of the present study support a view in which digital transformation must be understood as an institutional capacity integrated with monitoring and analysis procedures, rather than solely as the acquisition of technological infrastructure.

The highest correlation was identified between the effectiveness of environmental monitoring and the sustainable management of natural resources ($r = 0.74$; $p < 0.001$). This finding is among the central results of the study, as it shows that the availability of timely, accurate, and territorially representative information is closely linked to better sustainable management. In the context of local governments, the sustainability of digital initiatives requires that implemented tools be effectively incorporated into administrative processes and remain aligned with institutional needs [18]. From this perspective, a technological system gains environmental value when the generated information can be translated into concrete decisions regarding planning, prevention, conservation, and control.

The evidence obtained also relates to applications of geospatial technologies and machine learning in natural resource management. Tiwari et al. demonstrated that the integration of geospatial information and machine learning techniques can contribute to identifying vulnerable areas and improving decision-making related to environmental risks [19]. This helps explain why monitoring showed a stronger relationship with sustainable management than technology adoption itself: monitoring represents the process through which technological resources become functional information for land administration.

The regression model reinforced this interpretation. The adoption of digital technologies and the effectiveness of environmental monitoring jointly explained 59% of the variability in sustainable natural resource management ($R^2 = 0.59$). Within the model, environmental monitoring had the greatest explanatory weight ($\beta = 0.58$), whereas technological adoption made a positive but smaller contribution ($\beta = 0.24$). These results are consistent with recent reviews on the Internet of Things and sustainability, which highlight that the positive effects of digital technologies depend on their ability to produce usable information and strengthen monitoring and decision-making processes [20].

The observed difference between the beta coefficients is particularly relevant. Technology can facilitate access to data, automate activities, and increase processing capacity, but its contribution to sustainability appears to occur mainly when these capabilities strengthen monitoring and management processes. Vinuesa et al. point out that artificial intelligence can support numerous sustainable development objectives, although its benefits depend on the context of application, governance, and available capabilities [21]. Consequently, an institutional strategy focused exclusively on acquiring digital tools, without simultaneously strengthening human and organizational capacities to interpret and use information, could produce limited results.

The findings also have direct implications for territorial governments. Wang and Guo found that digital technologies can improve the efficiency of local environmental governance by reducing limitations associated with information, coordination, and responsiveness [22]. In the Ecuadorian GADs, this would imply prioritizing investments that integrate technology, monitoring, and decision-making within the same institutional system. Rather than implementing isolated tools, it would be necessary to promote interoperability among databases, geographic information systems, sensors, monitoring platforms, and territorial planning mechanisms.

Finally, the results align with an international trend that recognizes the growing role of Earth observation data in monitoring sustainable development goals and in generating environmental information for decision-making [23]. The main contribution of this study is to empirically show that, in the context of municipal and provincial GADs in Colombia, the relationship between digitalization and sustainability appears to strengthen when technologies are translated into effective monitoring capabilities.

This allows us to argue that environmental digital transformation should be evaluated not only by the number or sophistication of available tools, but also by their actual capacity to improve information generation and support sustainable decisions.

However, the results should be interpreted in light of some limitations. The cross-sectional design prevents establishing definitive causal relationships between the variables, and the use of self-reported information may introduce biases associated with participants' perceptions. Likewise, purposive sampling limits statistical generalization to all GADs in the country. Future studies could incorporate longitudinal designs, objective indicators of environmental performance, and comparisons between GADs with different levels of digital maturity. Despite these limitations, the consistency of the identified associations and the explanatory capacity of the model support the relevance of jointly strengthening institutional digitalization, environmental monitoring, and sustainable management of natural resources.

CONCLUSIONS

The adoption of digital technologies showed a positive and significant correlation with the effectiveness of environmental monitoring ($r = 0{,}68$; $p < 0{,}001$), revealing that greater adoption of digital tools in the GAD corresponds to better capacities to collect, process, and use environmental information.

Sustainable management of natural resources showed a significant relationship both with the adoption of digital technologies ($r = 0.61$; $p < 0.001$) and with the effectiveness of environmental monitoring ($r = 0.74$; $p < 0.001$). The stronger relationship observed for monitoring confirms that the availability of environmental information, which is timely and useful as perceived by the GADs, is a particularly relevant component for sustainable territorial management.

The regression model explained 59% of the variability of sustainable management of natural resources, which reveals a substantial joint explanatory capacity of the studied variables. However, the effectiveness of environmental monitoring showed a greater relative weight ($\beta = 0.58$) than the adoption of digital technologies ($\beta = 0.24$), indicating that the value assigned to technology is largely subordinated to the effective use of tools in environmental monitoring practices.

The results suggest that the digital transformation of GAD should not only be oriented toward acquiring platforms, sensors, geographic information systems, and other tools, but also toward integrating these tools into institutional processes of monitoring, analysis, and decision-making. The usefulness of these technologies increases when the data can be converted into information applicable to planning, conservation, and prevention of environmental impacts.

In the context of municipal and provincial GADs in Colombia, strengthening sustainable management involves a coordinated strategy among institutional digitalization, environmental monitoring, and technical capacity to manage the generated information. Due to the non-experimental and cross-sectional nature of the study, the results permit establishing associations and assessing explanatory capacity, but they do not provide evidence of causality; therefore, future research should incorporate longitudinal designs and objective data on environmental performance.

REFERENCES

1. Feroz AK, Zo H, Chiravuri A. Digital transformation and environmental sustainability: a review and research agenda. Sustainability. 2021;13(3):1530. https://doi.org/10.3390/su13031530
2. Ferreira B, Iten M, Silva RG. Monitoring sustainable development by means of earth observation data and machine learning: a review. Environ Sci Eur. 2020;32:120. https://doi.org/10.1186/s12302-020-00397-4
3. Kavvada A, Metternicht G, Kerblat F, Mudau N, Haldorson M, Laldaparsad S, et al. Towards delivering on the Sustainable Development Goals using Earth observations. Remote Sens Environ. 2020;247:111930. https://doi.org/10.1016/j.rse.2020.111930
4. Persello C, Wegner JD, Hänsch R, Tuia D, Ghamisi P, Koeva M, et al. Deep learning and earth observation to support the Sustainable Development Goals: current approaches, open challenges, and future opportunities. IEEE Geosci Remote Sens Mag. 2022;10(2):172-200. https://doi.org/10.1109/MGRS.2021.3136100
5. Sharma S, Beslity JO, Rustad L, Shelby LJ, Manos PT, Khanal P, et al. Remote sensing and GIS in natural resource management: comparing tools and emphasizing the importance of in-situ data. Remote Sens. 2024;16(22):4161. https://doi.org/10.3390/rs16224161
6. Fascista A. Toward integrated large-scale environmental monitoring using WSN/UAV/crowdsensing: a review of applications, signal processing, and future perspectives. Sensors. 2022;22(5):1824. https://doi.org/10.3390/s22051824
7. Ouni R, Saleem K. Framework for sustainable wireless sensor network based environmental monitoring. Sustainability. 2022;14(14):8356. https://doi.org/10.3390/su14148356
8. Phan VH, Pham DPH, Pham TV, Qureshi KN, Pham-Quoc C. An IoT system and MODIS images enable smart environmental management for Mekong Delta. Future Internet. 2023;15(7):245. https://doi.org/10.3390/fi15070245
9. Alvear-Puertas VE, Burbano-Prado YA, Rosero-Montalvo PD, Tözün P, Marcillo F, Hernandez W. Smart and portable air-quality monitoring IoT low-cost devices in Ibarra City, Ecuador. Sensors. 2022;22(18):7015. https://doi.org/10.3390/s22187015
10. Vinuesa R, Azizpour H, Leite I, Balaam M, Dignum V, Domisch S, et al. The role of artificial intelligence in achieving the Sustainable Development Goals. Nat Commun. 2020;11:233. https://doi.org/10.1038/s41467-019-14108-y
11. Rolnick D, Donti PL, Kaack LH, Kochanski K, Lacoste A, Sankaran K, et al. Tackling climate change with machine learning. ACM Comput Surv. 2022;55(2):42. https://doi.org/10.1145/3485128
12. Pang J, Bai K, Solangi YA, Magazzino C, Ayaz K. Examining the role of digitalization and technological innovation in promoting sustainable natural resource exploitation. Resour Policy. 2024;92:105036. https://doi.org/10.1016/j.resourpol.2024.105036
13. Wang H, Guo J. New way out of efficiency-equity dilemma: digital technology empowerment for local government environmental governance. Technol Forecast Soc Change. 2024;200:123184. https://doi.org/10.1016/j.techfore.2023.123184
14. Bibri SE, Alexandre A, Sharifi A, Krogstie J. Environmentally sustainable smart cities and their converging AI, IoT, and big data technologies and solutions: an integrated approach to an extensive literature review. Energy Inform. 2023;6:9. https://doi.org/10.1186/s42162-023-00259-2
15. Reichstein M, Camps-Valls G, Stevens B, Jung M, Denzler J, Carvalhais N, et al. Deep learning and process understanding for data-driven Earth system science. Nature. 2019;566(7743):195-204. https://doi.org/10.1038/s41586-019-0912-1
16. Bekele H, Raj S, Singh A, Joshi M, Kajla T. Digital transformation and environmental sustainability in the hospitality industry: a three-wave time-lagged examination. J Clean Prod. 2024;484:144263. https://doi.org/10.1016/j.jclepro.2024.144263
17. Goel A, Masurkar S, Pathade GR. An overview of digital transformation and environmental sustainability: threats, opportunities, and solutions. Sustainability. 2024;16(24):11079. https://doi.org/10.3390/su162411079
18. Sigurjonsson TO, Jónsson E, Gudmundsdottir S. Sustainability of digital initiatives in public services in digital transformation of local government: insights and implications. Sustainability. 2024;16(24):10827. https://doi.org/10.3390/su162410827
19. Tiwari A, Nanjundan P, Kumar RR, Soni VK. A framework for natural resource management with geospatial machine learning: a case study of the 2021 Almora forest fires. Fire Ecol. 2024;20:78. https://doi.org/10.1186/s42408-024-00293-9
20. Valencia-Arias A, Ramírez Dávila J, Londoño-Celis W, Palacios-Moya L, Hernández JL, Agudelo-Ceballos E, et al. Research trends in the use of the Internet of Things in sustainability practices: a systematic review. Sustainability. 2024;16(7):2663. https://doi.org/10.3390/su16072663
21. Liu K, Lu J, Cai D. Digital governance for regional environmental sustainability: configurational paths and mechanisms of local governments in China based on the TOE framework. Environ Syst Res. 2026;15:34. https://doi.org/10.1186/s40068-026-00480-4
22. Guan B, Yu Y. Debunking the digital myth: can digital governance embedding enhance local governments' environmental governance efficiency? The role of implementation burden. Governance. 2025;38(4):e70063. https://doi.org/10.1111/gove.70063
23. Zhao Q, Yu L. Advancing Sustainable Development Goals through Earth Observation satellite data: current insights and future directions. J Remote Sens. 2025;5:0403. https://doi.org/10.34133/remotesensing.0403

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CONFLICT OF INTEREST

It does not exist.

AUTHORSHIP CONTRIBUTIONS

Conceptualization: Ramon Gabriel Aguilar Vega.
Data curation: Ramon Gabriel Aguilar Vega.
Formal analysis: Ramon Gabriel Aguilar Vega.
Research: Ramon Gabriel Aguilar Vega.
Methodology: Ramon Gabriel Aguilar Vega.
Supervision: Ramon Gabriel Aguilar Vega.
Validation: Ramon Gabriel Aguilar Vega.
Visualization: Ramon Gabriel Aguilar Vega.
Writing – original draft: Ramon Gabriel Aguilar Vega.
Writing – review and editing: Ramon Gabriel Aguilar Vega.