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Original Article

Comparative and Quantitative Analysis of Vulnerability in Emergency Situations in Schools for Children Under 13 Years of Age Pre and Post-Pandemic In PERU

Gina León-Untiveros[1], Clara Garcia-Lino[1], Iris Rosales-Pariona[1], José León-Untiveros[2], Ana Huamani-Huaracca[3], Sebastián Ramos-Cosi[3], Alicia Alva-Mantari[3*]

[1]*Professional School of Nursing, Universidad Peruana del Centro, Peru.*
[2]*Professional School of Civil Engineering, Universidad Peruana del Centro, Peru*
[2]*Image Processing Research Laboratory (INTI-Lab), University of Sciences and Humanities, Peru.*

**Corresponding Author : aalva@uch.edu.pe*

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Abstract - *Faced with the problem of educational vulnerability in Peru, where more than 50% of schools have infrastructural deficiencies and 1 in 4 students have experienced school accidents, the research highlights the lack of risk plans in 33% of primary schools and the scarce presence of personnel trained in first aid. Our methodology is based on the use of geographic information systems and statistical programs, using data from the Ministry of Education of Peru and QGIS to interpret filtered and processed information through thematic maps. It is evident that 41.39% of the districts face vulnerabilities in early education, 39.06% in primary and 13% in secondary. There has been a worrying increase in vulnerability, assessed through the student-teacher ratio, from 62.47% to 91.56% in preschool and from 56.85% to 88.2% in primary since 2018. In conclusion, the unequal distribution of vulnerability between rural and urban areas is highlighted, showing that 74.41% of vulnerable schools are located in urban areas. These findings highlight the urgent need to address disparities and develop specific strategies to improve equity and resilience in the Peruvian education system.*

Keywords *- Vulnerability, Schools, Emergency, Students, Geographic Information System.*

1. Introduction

In Peru, more than 50% of schools have infrastructural [1] defects, and one in 4 students has suffered some type of accident in their school [2]. Some data shown by school accidents are muscle injuries, dislocation, accidents caused during school hours and caused by falls within school facilities. They [3]–[6] indicate that one in 3 schools has a risk plan for accidents or disasters in primary school students and that operational controls for prevention or correction are scarce or almost non-existent. In the event of school accidents, the presence of personnel trained in first aid is required to provide immediate attention and safeguard the life and integrity of students [4]. For this reason, it is important to integrate at least one school nurse per school in which the professional can cover the demands of students for the maintenance of their health [7]. However, not all schools have access to a health professional on a permanent basis and there is a need for teaching capacity to take action in an emergency situation. According to the OECD [8], in Latin America, the number allowed per student in a primary education classroom is 20.5. However, through Regional Directorial Resolution No. 0800-2023-DRELM [9] issued in Metropolitan Lima during 2023, it has been proposed to increase the number of students to 35 per classroom due to the educational demand after the school recession produced as a result of the COVID-19 pandemic. On the other hand, The [10] talks about the sustainable social characteristic in Peruvian schools since in the face of seismic risk, high vulnerability factors are generated. That is why, through the analysis of national schools in Comas, SJL and V Salvador, they propose a diagnostic development of seismic risk vulnerabilities by evaluating items such as infrastructure, stability, and district vulnerability. As a result, they found that there was risk mitigation for the sustainable efficiency of schools and schools that provided services below the basic allowable levels. They conclude that a study should be proposed in the following censuses to know the conditions of the schools in order to provide a strategic plan in the face of disaster and social vulnerabilities of public schools. Sassera [11], in his study on inequalities in secondary education in an Argentine city, highlights the importance of analyzing social, political and geographical factors to improve the educational context. He used the Geographic Information System (GIS) to create maps that link qualitative and quantitative variables related to schools. The mapping revealed trends, such as the efficiency of public transport in urban areas compared to rural areas with limited access.

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This methodology was effective in collecting and processing information, locating at-risk establishments, and identifying social and educational inequalities. Freddo and Massera [12] explored territorial and social problems in the use of Geographic Information Systems (GIS) in university extension. They found that GIS was useful for assessing environmental problems improving situational understanding for decision-making and educational quality. Radicelli et al. [13] examined the evolution of Geographic Information Systems in the integration of social sciences and education. Their study noted that, over time, these systems had favored the social sciences, providing access to geographic information to study specific variables and strengthen research. Contributing to the educational field, Geographic Information Systems offer an accessible information compendium, benefiting the development of the potential of university students.

The main justification for a modification in student capacity is the educational leveling of students who, due to the impact of the social context, their quality of learning has been compromised [14]–[16]. On the other hand, the number of students has been established considering $1.5m^2$ as the average occupational space within the classroom [17], the same that ensures the use and development of each student. In this sense, school vulnerability is generated when there are 20 or more students in a classroom for each teacher [18]; this situation represents a latent danger due to the permanent need for security that childcare demands [16].

Geographic Information Systems (GIS) is a set of tools to favor the interpretations of large amounts of data where quantifiable aspects can be manipulated and modeled [19]. Likewise, the system allows the organization of information by locality in specific geographical spaces for better processing and visualization of the results [20]. Therefore, the elaboration of the map generates a differentiated analysis, which in turn influences improving decision-making and problem-solving capacity. GIS stores large amounts of data, and for this, they are compatible with massive databases, in addition to having the possibility of accusing a cloud of updating this data in real time [21].

In addition, out of concern about the excessive number of students per section, they devised a method for risk control. To do this, they intended to use a geographic information system to relate students and teachers in terms of the vulnerability generated by having classrooms full of students. Methodologically, they apply to Qgis 3.8.0 with data from the Ministry of Education of Peru and then filter and create maps. As a result, they obtained maps where they categorize schools where they have a large influx of students at the kindergarten and primary levels. Finally, they conclude that the reports generated show a state of vulnerability in the risk of students creating mechanisms for teacher training and linking to the other ministries of the state. They [23] also needed a way to distribute food to public schools and wanted to come up with a plan for food distribution in Andhra Pradesh. To do this, they used Qgis as a simplified method, with the use of its interactive platform as well as a FIREBASE, to link the geolocated data with the amount of food to be distributed. As a result, they obtained an app that showed parents where they could pick up their food belonging to their district and near a public school.

This concludes the use of Qgis for decision-making in the face of vulnerable issues in public schools. For all these reasons, this research aims to determine the vulnerability of school students in Peru by relating the number of students per classroom and teachers also comparing it with data already registered in 2018. To this end, geographic information systems will be used, as well as statistical programs where the MINEDU databases will be related, in order to find the vulnerability of students to any disaster that occurs in the country. On the other hand, vulnerability for this research will be defined as any risk situation where students are exposed to some danger [24].

In order to compare the state of vulnerability of students in Peruvian educational institutions, an analysis of the situation in which they were prior to the start of the COVID-19 [25]–[31] pandemic described in a study carried out in 2018 is proposed, to then compare the indicators with the post-pandemic results obtained during the present study of 2023 [32]. Through this procedure, it will be possible to identify the variations that have arisen due to the global problem and to determine the current state of danger for schoolchildren in order to develop strategies for improvement [33]. This work is structured as follows: First, section II covers the research materials and methods used for the organization, preparation, and justification of the work. Section III presents the descriptive results obtained through the available tools and the observation of the maps corresponding to the variables studied. Section IV presents the discussion of the data identified in the previous stage. Then, a comparison is made with previous work to identify changes or trends with respect to existing information. Section V describes the conclusions that respond to the problems raised during this research. Finally, section VI organizes the bibliographic references that support the research.

2. Methodology

The methodological procedure takes into account 3 important steps that are presented sequentially (Figure 1). This includes the search for information, followed by a filtering algorithm, and finally, the graphic stage for the display of the information systems and the proposed relationships.

2.1. Data Acquisition

The public data obtained come from the educational services of statistics for educational quality and the Ministry of Education of Peru (MINEDU) [34]. This platform houses geographic information on the educational centers registered by the Regional Directorates of Education (DRE), the Regional Managements of Education (GRE) and the Local Educational Management Units (UGEL).

According to the most recent update on the number of educational institutions provided by MINEDU in 2023, a total of 65,535 educational centers have been registered in Peru. It is important to note that these centres cover various educational modalities.

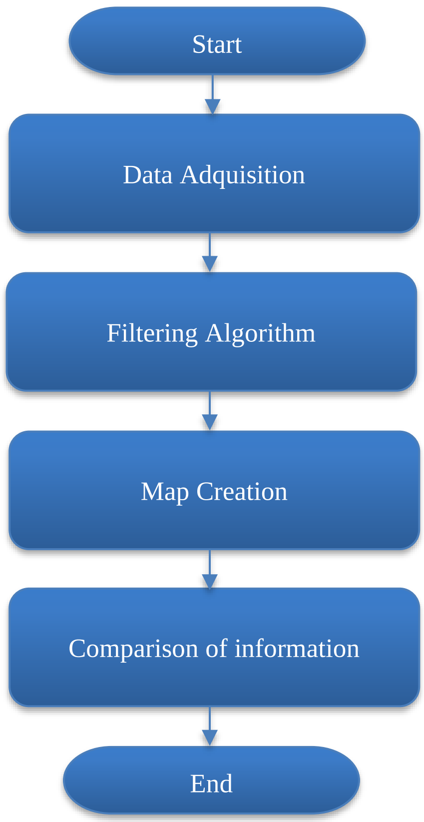

Fig. 1 Methodological flowchart

Table 1. Classification of schools

Type of Management	Directly Managed Public, Privately Managed, Private
Level	Initial, Primary, Secondary, Alternative Basic, Special Education, Higher Pedagogical, Higher Artistic, Higher Technological, CETPRO
Form of Care	Schooled and out-of-school

According to Table 1, the research focuses on highlighting management and specific characteristics at levels such as Initial, Primary, and Secondary. It has been decided not to include in the research the levels of Basic Alternative, Special Education, Higher Pedagogical, Higher Art, Higher Technological, and CETPRO due to their lower quantity and lower exposure to vulnerabilities [18]. This approach makes it possible to understand the specific particularities and challenges of the most widely distributed levels of education in the country. The categorization of schools according to age ranges and priority levels provides a solid basis for a comprehensive and strategic analysis of the field of education in Peru [35].

2.2. Algorithm, Filtering and Processing of Information

Data processing must ensure proper handling of information and apply justified selection criteria [36]. In the debugging phase, the exclusion of inconsequential data due to their limited contribution to the study is considered. After adjusting the procedures according to the established methodology, it is possible to obtain precisely the essential data to give continuity to the process. This milestone marks the beginning of the next methodological step, which involves the construction of a specific database related to the classification of vulnerable districts according to the prioritized educational levels, preschool and primary, and including the secondary level as aggregate data [37]. This approach projects a systematic advance towards the achievement of the objectives established in the research, providing a solid basis for analysis and evaluation in later phases of the study.

In this section, aggregate and filtered information will be collected and comprehensively analyzed to assess vulnerability situations in schools at the national level. This analysis will be carried out in comparison with previous research carried out in 2018, providing a valuable perspective on the evolution of vulnerability over time.

2.3. Graphic Stage

This phase is distinguished by the presentation of GIS maps for the graphical interpretation of the results based on the information obtained [38]. For this reason, it starts with the classification by regions and districts. Subsequently, through the use of a Geographic Information System (GIS), the export of graphs in a visual format is facilitated, thus contributing to an effective visual representation of geospatial information.

2.3.1. Classification by Regions and Districts

The methodology adopted involves the use of cartography based on the census data of the INE corresponding to the year 2022. In this context, district, provincial and departmental boundaries are delineated without specific assignment to a particular jurisdiction [39]. This layered approach provides a detailed view of vulnerability in various educational areas, allowing the identification of those that require priority attention. The selection of these areas is based on the evaluation of the student-teacher relationship and its possible impact in disaster situations, thus establishing a robust methodological basis to guide specific educational actions and policies [40]. As a continuation of this work, an exhaustive analysis is planned that involves the monitoring and evaluation of the identified areas, contributing to the formulation of efficient educational strategies.

2.3.2. QGIS

QGIS (Quantum GIS), in Peru, stands out as an open-source GIS crucial for measuring and analyzing educational data. Its intuitive interface makes it popular for input, editing, analyzing, and visualizing geographic data [38]. With the ability to handle various formats, advanced spatial analysis tools, generation of thematic maps, and a user-friendly interface, QGIS is useful in the Peruvian educational field for detailed analyses on the distribution of schools, student accessibility, and areas of vulnerability, informing decisions in educational policies and programs. In QGIS, a variety of tools are used to create and visualize maps [41]. The point layer or raster generates heat maps with color gradients to show locations or densities of points.

Importing data from Excel is done with "Add Layer", uploading CSV files to the project. For thematic maps, QGIS offers symbolization tools with configurations to represent qualitative or quantitative data. In heat maps, color gradients are applied to areas with a higher concentration of points. QGIS provides advanced styling features and tagging tools to add information to maps.

2.4. Comparison of Information

The previously graphed information will be subjected to a comparative analysis with the data collected in 2018. The importance of this comparison lies in assessing whether, in recent years of political management and educational improvements, substantial improvements have been achieved in the quality of students and their vulnerability to disasters in various regions and districts of Peru [32], [42]. To make these comparisons, algorithms in R language will be used, integrating with QGIS and its corresponding extensions. This approach will make it possible to generate graphical representations that highlight the most significant temporal differences in relation to the objectives mentioned above. R, as a statistical programming language and environment, provides advanced packages for statistical analysis. On the other hand, Google Sheets, a cloud-based app, makes it easy to organize and collaboratively analyze data [43][44][22].

In this context and with the new data, Google Sheets is useful for organizing and debugging data before importing it into QGIS or R. Subsequently, in R, detailed statistical analyses are carried out on the new data, calculating educational indicators or comparing trends over time. The integration of R into QGIS allows you to combine statistical analysis with geospatial data. In the approach of highlighting vulnerabilities, QGIS is used to create maps that visualize the spatial distribution of key educational indicators, highlighting areas with vulnerabilities. The combination of these programs provides a complete platform for analyzing and visualizing education data, facilitating a deeper understanding of vulnerabilities in districts and schools. The integration of Google Sheets, R, and QGIS contributes to more informed decision-making in education.

Table 2. Filtering of educational institutions

Excluded Educational Institutions	
Total Institutions in Peru	65535
Inactive Institutions	15873
Higher Pedagogical Institute	571
Productive Technical Institution	957
Educational Institution without Students	738
Educational Institutions with 10 students or less	7127
Night Shift Educational Institutions	304
Higher Pedagogical School	0
Higher Institute of Technology	158
Advanced Alternative Basic Education Institution	500
Institution of Basic Education Alternative Initial Intermediate	214
School of Artistic Training	31
Total Educational Institutions after filtering: 39062	

3. Results

In line with the methodology, the presentation of results aims to display in a detailed and quantified manner all the processed information contained in the database of the Ministry of Education (MINEDU). This initial step lays the groundwork for a comprehensive comparison that will allow for a thorough analysis of the findings and the evaluation of potential trends or significant changes in the education data.

3.1. Data Acquisition

It is essential to identify educational institutions without educational staff or students, as well as to quantify schools with sufficient teaching staff but without students to benefit from it, and vice versa. Table 2 represents the result of the data purification process carried out to ensure the quality and relevance of the information analyzed in the study. The initial set of 65,535 educational institutions underwent selection criteria, excluding various categories that were deemed inconsequential or would not contribute significantly to the analysis. Inactive institutions, those without students, night shifts, and other specific categories, such as higher pedagogical institutions, productive techniques, and basic education alternatives, were excluded from the main analysis. This careful filtering resulted in a total of 39,062 educational institutions that are considered relevant and representative of the ongoing study. The process ensures that the data analyzed accurately and meaningfully reflects the educational reality that is the object of the research.

3.2. Algorithm, Filtering and Processing of Information

The study is carried out at the district level, covering a total of 1672 districts considered viable, with the aim of carrying out a comprehensive analysis of the number of students prone to risks in various regions of the country. In addition, the ratio of the number of students to the teachers assigned in each district is evaluated to determine the total number of students in vulnerable situations. Within the methodological analysis of the 1672 districts considered viable, a thorough evaluation of the relationship between the number of students and teachers was carried out. Using the critical metric of 20 students per teacher, established since the 2018 study, the educational vulnerability was classified for the year 2023. This comparative approach has revealed that 41.39% of the districts have a vulnerable situation in the field of Early Childhood Education, followed by 39.06% in Primary Education and 19.55% in Secondary Education. On the other hand, it is necessary to monitor the impact of the pandemic, evaluate implemented policies, and identify vulnerable areas. Because of this, a table is produced whose usefulness extends to strategic planning and provides key information to various stakeholders, promoting informed decision-making.

Table 3. Classification of vulnerable districts by educational level

Total districts: 1672	**No**	**%**
Initial	692	41.39%
Primary	653	39.06%
High school	327	19.55%
Total	1672	100%

Table 4. Pre- and post-pandemic spatial distribution

	2018		**2023**	
	Preschool	**Primary**	**Preschool**	**Primary**
N° of Students	970714	2490806	775342	2658519
N° of Teachers	52634	140152	42430	146069
N° of places	23492	28539	10616	21359
N° students in vulnerable areas	606426	1415964	709872	2344975
N° Schools in Vulnerable Areas	6208	5605	8573	15285
N° of teachers in vulnerable schools	24597	57595	37554	119916
N° non-vulnerable students	364288	1074842	65470	313544
N° of schools in non-vulnerable areas	17285	22934	33857	130784
N° of teachers in non-vulnerable schools	28037	82557	26938	98557

The table emerges as a comprehensive tool to assess changes in educational indicators and address disparities, driving educational equity. Accurate interpretation of the data is essential to understanding the factors influencing the observed variations. Table 4 presents a detailed distribution of all the data addressed in the information filtering section, highlighting significant numbers such as the total number of students, the number of professors and the availability of places. It is crucial to highlight the separation of students in vulnerable areas, the number of schools in rural areas, underlining the concern for rural education in the country, and the number of teachers working in these same areas. In addition, information is provided on the number of non-vulnerable students, schools in non-vulnerable areas, and the number of teachers in the latter. This approach makes it possible to understand not only the situation of vulnerable areas but also to identify those educational institutions that efficiently manage the relationship between students and teachers.

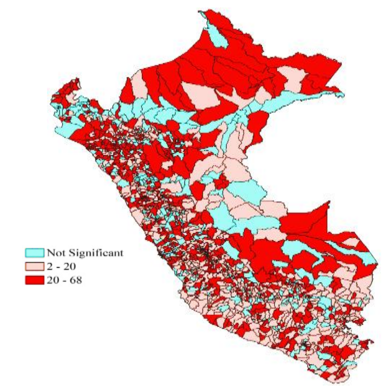

Fig. 2 Initial vulnerability

3.3. Graphic Stage

With more filtered and processed data, we will move on to the GIS program, where the districts vulnerable to emergency situations were selected through symbolization and color gradients. Finally, we export the image in a format that is compatible with the later one. In the map corresponding to the preschool level (Figure 2), districts with a student-teacher ratio that exceeds 20 are highlighted in red, even reaching a maximum of 65 in certain schools. The total population of students in this region amounts to 775,342, and vulnerability, assessed through the student-teacher ratio, reaches 91.56%. This data reveals a critical situation in relation to the group of preschool students. The map also shows the areas where the student-teacher ratio remains within normal limits, contrasting with vulnerable areas. It is important to note that some areas were excluded due to records considered erroneous, as explained above.

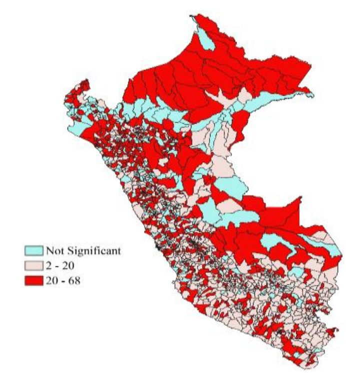

Fig. 3 Primary vulnerability

In the map corresponding to the primary level (Figure 3) in schools nationwide, districts with vulnerable students are highlighted in red, evidencing a student-teacher ratio that exceeds 20, reaching a maximum of 68 in certain schools. This situation indicates a notorious level of vulnerability, especially in emergency situations. The total population of students in this region is 2,658,519, representing 88.20% of the primary student population in vulnerable conditions.

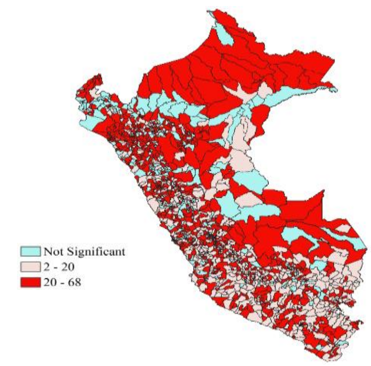

Fig. 4 Initial and primary vulnerability

In addition, the map illustrates areas where the student-teacher ratio is within normal limits, contrasting with vulnerable areas. Some areas were excluded due to records considered erroneous, as explained above.

3.4. Comparison of Information

Under the same methodology and interpretation, a significant degree of vulnerability is observed, particularly in emergency situations. In this section, a comparison of the information with the previous study is made, providing a framework for assessing the evolution of vulnerability over time. The total population of preschool and primary school students in these areas amounts to 3,433,861.

When contrasting these data with those of 2018, an alarming increase in vulnerability is detected, with a notable jump from 62.47% to 91.56% at the preschool level and from 56.85% to 88.2% at the primary level. This change emphasizes the imperative need to provide urgent attention to address and mitigate the factors that contribute to the growth of vulnerability at these levels of education.

3.5. Preschool

At the preschool level, the number of students decreased from 970,714 in 2018 to 775,342 in 2023. In addition, the number of teachers saw a reduction from 52,634 to 42,430, and the number of schools dropped significantly from 23,492 in 2018 to 10,616 in 2023. With regard to vulnerability, the percentage of growth between 2018 and 2023 has been calculated. At the preschool level, an increase of 46.63% is observed, going from a vulnerability index of 62.47% in 2018 to 91.56% in 2023. These changes reflect a significant transformation in educational dynamics, highlighting the need to understand and address the factors that contribute to vulnerability at this level of education.

3.6. Primary

At the primary level, the number of students varied from 2,490,806 in 2018 to 2,658,519 in 2023. Likewise, the number of teachers went from 140152 to 146069, and the number of schools decreased from 28539 to 21359. Educational vulnerability has experienced a significant increase of 54.82%, rising from 56.85% to 88.2%. These results reveal a notable increase in vulnerability compared to 2018 data, highlighting the urgency of addressing these changes to promote a more equitable and resilient educational environment.

3.7. Vulnerability Classification by Area

For a better analysis of school vulnerability at the national level, it is necessary to identify the situation of schools belonging to different geographical areas. In this sense, a classification is made considering rural and urban areas. In Peru, there are a total of 22,165 rural schools, which represents 56.75% of the total number of schools nationwide. On the other hand, there are 16,896 urban schools, equivalent to 43.26% of the total number of schools in the country. When delving into the nature of these schools, it is observed that 25.59% of vulnerable schools are located in rural areas, while 74.41% of schools in vulnerable situations are located in urban areas.

Table 5. Classification of schools by geographical area

	Schools 2023		**Vulnerable Schools 2023**	
Rural	22165	56.74%	2158	25.59%
Urban	16896	43.26%	6275	74.41%
Total	39061	100%	8433	100%

This analysis highlights the unequal distribution of educational vulnerability between rural and urban areas, underscoring the need for specific strategies to address disparities in both contexts.

4. Discussion

Based on the above, we can affirm that the methodology played a crucial role in guiding and structuring each of the procedures to acquire, process, quantify, interpret and compare the information of educational centers that could face situations of vulnerability to possible dangers and risks in Peru. This includes phenomena such as cold, droughts, earthquakes, and exposure to the Andes Mountains. The relevance of this methodology lies in its ability to provide an organized and targeted approach, allowing a deeper understanding of the vulnerability of schools in the face of various challenges, which is essential for informed decision-making and the implementation of effective mitigation measures.

However, information gaps were identified that led to possible misinterpretations, such as the generation of negative values or the presence of more teachers than students. These errors could be mitigated and optimized by implementing machine learning algorithms or clustering prediction techniques, which represent advanced technologies to achieve a more accurate interpretation of the information in the process of this extensive database. Through the results obtained during the year, the need to incorporate these innovative analytical tools to improve the quality and accuracy of data interpretation, thus strengthening the validity and reliability of the results, is highlighted.

Through the results obtained in 2023, significant variations can be observed compared to the situation studied in 2018. At the preschool level, there was a decrease in both the number of students and teachers, as well as in the number of schools, which was reduced by more than half. At the same time, there was an increase in the proportion of students in vulnerable areas, the number of schools in vulnerable areas, teachers in vulnerable schools and schools in non-vulnerable areas.

These changes reflect substantial transformations in the education landscape, highlighting the need to take a hard look at the reasons behind these variations and consider appropriate measures to address them. At the primary level, there have been significant changes, with a reduction in the number of educational institutions and non-vulnerable students. Conversely, there has been an increase in the total number of students, teachers, students in vulnerable areas, schools in vulnerable areas, teachers in vulnerable schools, and schools in non-vulnerable areas. These modifications underscore the evolving dynamics of the educational environment at this level, highlighting the importance of carefully analyzing these adjustments and considering appropriate strategies to address them effectively. Managing a large number of students, especially in early childhood education, raises significant concerns, especially in emergency situations. The significant reduction in teachers and the decrease to less than half in the number of schools at the initial level could be related to the closures caused by the pandemic, especially in less accessible districts. This could lead to less complete representations of data due to school closures in those areas.

Primary schools are complex, evidencing an increase in the student population that poses challenges in the distribution of resources and institutional capacity. The high student-teacher ratio, as high as 68 in some schools, suggests a significant burden on teachers, possibly indicating the need for more staff.

In addition, the decrease in the number of schools can affect accessibility to education and support for students. The geographic concentration of vulnerable students highlighted in red signals additional challenges in equity and resource distribution. The high percentage of 88.20% of the primary school student population in vulnerability underscores the magnitude of the challenge, emphasizing the need for specific policies and actions to address educational problems, especially in emergency situations.

In the Peruvian educational context, the existence of rural and urban schools poses unique challenges in terms of vulnerability. Schools located in rural areas face potential resource and access limitations, which could affect the quality of education and the ability to respond to adverse situations. The concern lies in ensuring that these rural schools receive the attention and resources necessary to provide students with equitable educational opportunities. On the other hand, urban schools, despite being in more developed environments, can also be vulnerable due to factors such as population density and the complexity of educational management in urban areas. It is essential to address vulnerability in both contexts, considering the specific needs of each in order to achieve a more equitable and resilient education system.

The pandemic led to the closure of numerous schools in less populated districts, while central schools in more densely populated areas received a considerable increase in students. This change in the distribution of students has contributed to the increase in vulnerability in these educational institutions, generating the need to address the resulting disparities to ensure an equitable educational environment that is resilient to future challenges.

5. Conclusion

To determine the vulnerability of students in schools in Peru, it was possible to establish relationships between the number of students per classroom and teachers and compare these data with previous records from 2018. The methodology used included the use of geographic information systems and statistical programs, integrating the databases provided by MINEDU. This approach made it possible to identify the vulnerability of students to possible disasters in the country. For the purposes of this research, vulnerability was defined as any risky situation that exposed students to potential dangers. The research clarified and highlighted critical aspects of educational security, providing a solid basis for future initiatives and improvements in the Peruvian education system.

In retrospect, it was observed that, in the region analyzed, which had a total population of 775,342 students, vulnerability, measured through the student-teacher ratio, reached a significant 91.56%. At the primary level, with a student population of 2,658,519, 88.20% were in vulnerable conditions. In addition, it was highlighted that 25.59% of vulnerable schools were located in rural areas, while 74.41% of schools in vulnerable situations were concentrated in urban areas. These results highlight the importance of addressing disparities in educational vulnerability, especially by focusing efforts on urban areas with a higher proportion of schools in vulnerable situations.

Compared to the 2018 results, the need to intervene becomes evident due to increases in vulnerability, which could have a negative impact on access to quality education. It is essential to implement effective education strategies and policies to counter this increase, thus ensuring an inclusive educational environment that provides the necessary support to students in these areas. When contrasting the 2023 results with pre-pandemic records, a significant increase in the percentage of vulnerability is evident. At the initial level, this indicator increases from 62.47% to 91.56%, while at the primary level, vulnerability shows a substantial increase, from 56.85% to 88.21%.

The analysis of the distribution of institutions by geographical area showed that the schools with the greatest vulnerability are concentrated in urban areas. On the other hand, in less populated areas, many institutions closed their doors due to the global problem and this is evidenced by the decrease in schools in rural areas. As a result, there has been an agglomeration of students in urban areas, leading to greater vulnerability in 2023.

The conditions of vulnerability found in this study are extremely high; for this reason, it is essential to implement a systematized method of prevention against possible dangers and to adapt first aid knowledge in teachers so that through the establishment of these guidelines, they can face the risks raised in the educational environment.

As a perspective for future research, we propose to use the information collected in this study as a basis for a new line of social research, employing systematic analyses. It seeks to explore new relationships in students' vulnerabilities through emerging technologies such as machine learning or artificial intelligence, with the aim of predicting student growth and developing innovative strategies for risk mitigation in developing countries.

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