The El Niño phenomenon and its implications in Peru

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Executive summary

Climate change is probably one of the main causes of the warming of the surface waters in the Pacific Ocean (Naciones Unidas, 2017), which generates the climate event known as the El Niño phenomenon, in addition to accentuating its recurrence and consequences on the coastal countries of the eastern Pacific. Among the impacts of the phenomenon, the significant impacts on agriculture, fisheries, health and the economy of various regions stand out, both in South America and in other parts of the world. In Peru, El Niño occurred in 1982-1983, 1997-1998, 2017, and 2023 off its northern coast, causing intense rainfall and also affecting the central coast and the northwestern region (Instituto Nacional de Defensa Civil [INDECI], 2023b).

Understanding these impacts and implementing preparedness and mitigation measures, and effective response to El Niño events are critical to reducing vulnerability and associated risks in vulnerable communities and ecosystems.

KEYWORDS
El Niño Phenomenon; Coastal El Niño; Southern Oscillation (ENSO); Climate Change; Climate Change in Peru.

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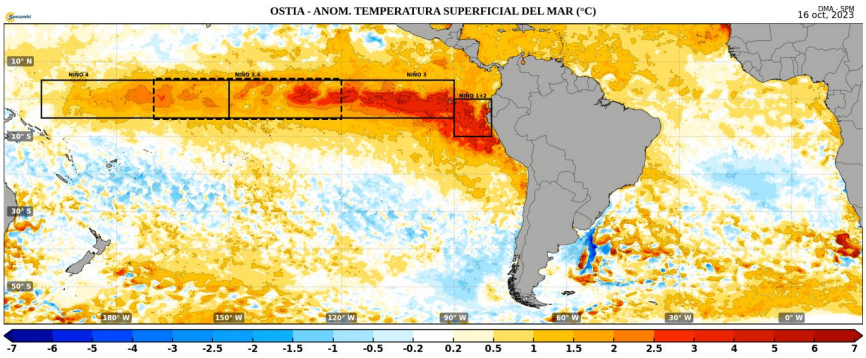
1. Introduction

The El Niño phenomenon (FEN, for its acronym in Spanish) is a climate event that occurs periodically in the equatorial Pacific region, with significant effects on global climate. It is characterized by an anomalous warming of the surface waters of the tropical Pacific Ocean, which generates changes in weather patterns in various regions of the world (Picture 1).

Picture 1. Sea Surface Temperature Anomalies in the Pacific



Source: Servicio Nacional de Meteorología e Hidrología del Perú [SENAMHI] (2023a).

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The FEN originates from the complex interaction between the atmosphere and the ocean in the equatorial Pacific region. Its causes are related to changes in atmospheric and oceanic circulation patterns (SENAMHI, 2014). These changes occur more frequently as a result of climate change. Some of the key causes of El Niño are:

1. **Decreased trade winds:** the trade winds, which generally move east-west along the equator, weaken or even reverse during an El Niño event. This decrease in the trade winds' intensity allows the western Pacific's warm waters to move eastward.
2. **Warm water accumulation in the Central and Eastern Pacific:** decreased trade winds allow warm waters to accumulate in the Central and Eastern Pacific, resulting in anomalous sea surface warming in these regions.
3. **Southern oscillation changes:** El Niño is associated with changes in the Southern Oscillation (ENSO[2]), which is a complex weather pattern involving interactions between the atmosphere and the ocean in the equatorial Pacific.

These atmospheric and oceanic conditions interact with each other to create a cycle that may

2. The El Niño-Southern Oscillation (ENSO) is a climate pattern that consists of the oscillation of the meteorological parameters in the equatorial Pacific every certain number of years. It presents two opposite phases, one of warming and rainfall in the eastern Pacific known as the El Niño phenomenon and the other phase of cooling called La Niña. This temperature oscillation is oceanic and atmospheric and is in turn related to the atmospheric phenomenon called the Southern Oscillation, which consists of an oscillation of atmospheric pressure in the Western Pacific. The relationship or coupling between these phenomena brings great climatic consequences in much of the world (Reyes, 2001, translated).

cause the FEN. Although scientists have better understood the factors that contribute to its emergence, research is still being carried out to understand its dynamics and causes.

The El Niño phenomenon can have a number of significant consequences in different regions of the world, which can vary depending on the intensity and duration of the event. Some of the common consequences of FEN are (SENAMHI, 2014; Morales Casco and Zúñiga González, 2016):

1. **Extreme weather conditions:** El Niño can trigger extreme weather events, such as torrential rains, floods, droughts, storms, and hurricanes, depending on the geographic location. These extreme events can cause material damage, loss of life, and displacement of entire populations.
2. **Impacts on agriculture and food security:** adverse weather conditions associated with El Niño, such as droughts or floods, can reduce agricultural productivity, which in turn can lead to food shortages, rising commodity prices, and food insecurity in affected regions.
3. **Biodiversity loss:** changing weather patterns can affect natural ecosystems, resulting in habitat loss, declining biodiversity, and changes in the natural cycles of animal and plant species.
4. **Impacts on the economy:** the FEN can have negative repercussions on the economy, especially in sectors such as agriculture, fishery, tourism, and infrastructure. The costs of recovery and reconstruction after El Niño-related natural disasters can be significant and put pressure on national budgets.
5. **Public health risks:** extreme weather conditions and disasters associated with El Niño can increase health risks, including waterborne diseases, respiratory illnesses, and mental health problems due to loss of housing and livelihoods.

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These consequences highlight the importance of preparedness, risk mitigation, and effective response to El Niño events to reduce their negative impact on vulnerable communities and ecosystems. Understanding these impacts and implementing preparedness and mitigation measures are critical to reducing vulnerability and risks associated with El Niño in Peruvian territory.

2. The El Niño phenomenon in Peru

In Peru, the FEN was produced in 1982-1983, 1997-1998, and 2017 (Niño Costero, third most intense FEN in recent years). In March 2023, the FEN was produced again due to the warm conditions of the Sea Surface Temperature (SST) off the northern coasts of Peru, causing intense rains and also affecting the central coast and the northwestern region (INDECI, 2023b).

The FEN has several significant impacts on Peru, specifically, ranging from heavy rain conditions to prolonged droughts, depending on the region and the intensity of the event. Some of the harmful effects include the following:

1. **Heavy rainfall and landslides:** the FEN can bring torrential rains and heavy flooding, often resulting in landslides and damage to infrastructure, crops, and homes.
2. **Impacts on agriculture:** floods and droughts associated with El Niño can harm agricultural production. Excessive rainfall can flood fields, while droughts can reduce the availability of water for irrigation and for human and animal consumption.
3. **Disturbances in fishing**: warming marine waters can change fish migration patterns and negatively affect the fishing industry, which can have a significant economic impact on coastal communities that rely on fishing for their livelihoods.

4. **Health risks**: floods and the resulting overcrowded conditions can increase the risk of waterborne diseases, such as dengue, malaria, and diarrhea, as well as respiratory diseases associated with humidity and cold.
5. **Infrastructure and economic impacts:** natural disasters associated with El Niño can cause significant damage to infrastructure, including roads, bridges, and housing, which in turn can have adverse effects on the local and national economy. For example, the El Niño phenomena of 1982-1983 and 1997-1998 caused a decrease in Peru's Gross Domestic Product (GDP) of 11.6% and 6.2%, respectively. The Northern regions were the most affected by floods and mass movements. But also, as part of the effects of El Niño, droughts were recorded, mainly in the southern area.

In Peru, the Multisectoral Commission in charge of the National Study of the "El Niño" Phenomenon (ENFEN, for its acronym in Spanish) has been formed and composed of Peruvian scientific technical entities such as the Peruvian Institute of the Sea (IMARPE, for its acronym in Spanish), the National Meteorology and Hydrology Service (SENAMHI, for its acronym in Spanish), the Geophysical Institute of Peru (IGP, for its acronym in Spanish), the Directorate of Hydrography and Navigation of the Peruvian Navy (DIHIDRONAV, for its acronym in Spanish), the National Institute of Civil Defense (INDECI, for its acronym in Spanish), the National Water Authority (ANA, for its acronym in Spanish) and the National Center for Disaster Risk Estimation, Prevention and Reduction (CENEPRED, for its acronym in Spanish).

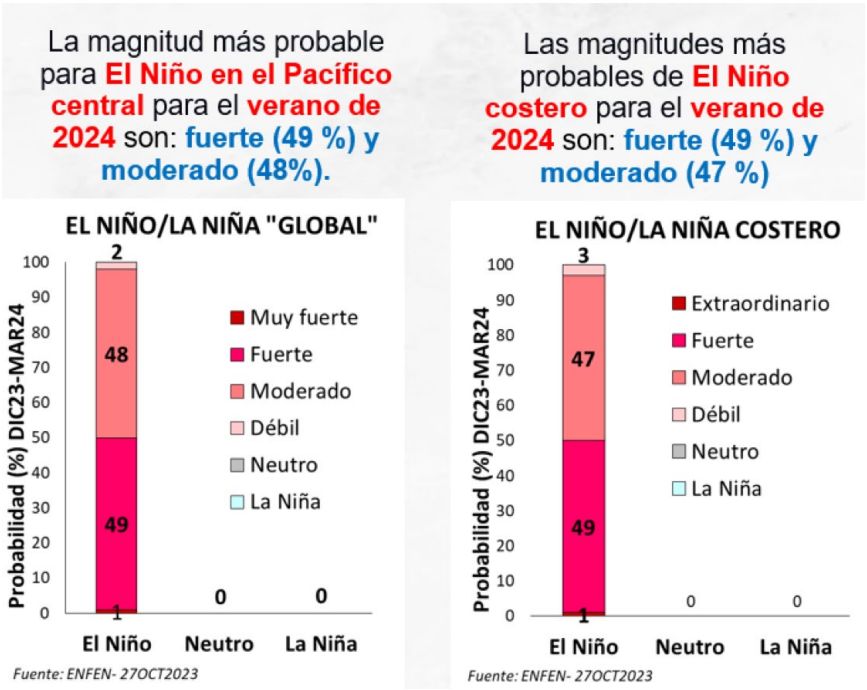
This commission maintains constant monitoring and predictions of the development of El Niño-Southern Oscillation (ENSO), periodically reporting the monitoring analysis of ocean-atmospheric parameters in the equatorial, southeastern Pacific, with emphasis on the coast of Peru. It also performs the monitoring analysis of marine ecosystem impacts, reporting the fertility and productivity indicators of some hydrobiological resources of the Peruvian sea, the response of the main resources and fishing activity. Moreover, the ENFEN constantly monitors the hydrological impact associated with rainfall and sudden increases in the flow of the main rivers of the Peruvian territory. Finally, this commission formulates the forecast of the main indicators associated with ENSO, with emphasis on the El Niño phenomenon, in the short, medium and long term.

In this regard, the ENFEN Technical Report is prepared based on the collegiate analysis of the Multisectoral Commission scientific technical group, considering the monthly reports of each entity that is a member of this commission and that monitors and forecasts ocean-atmospheric conditions, as well as their manifestations and impacts in the Peruvian sea and in the national territory.

According to the latest official ENFEN statement (2023), coastal El Niño (Niño 1+2 region) is expected to continue at least until early autumn 2024, as a result of the evolution of El Niño in the central Pacific. Likewise, the aforementioned document communicates that strong warm conditions are more likely to remain until February. By next summer 2024, on average, the most likely magnitudes of coastal El Niño are strong (49%) and moderate (47%).

It is also reported that in the central Pacific (Niño 3.4 region) El Niño is expected to continue for the time being until mid-autumn 2024, reaching its maximum intensity at the end of the year. The most likely magnitudes of El Niño in the central Pacific for the summer are strong (49%) and moderate (48%), as described in Picture 2.

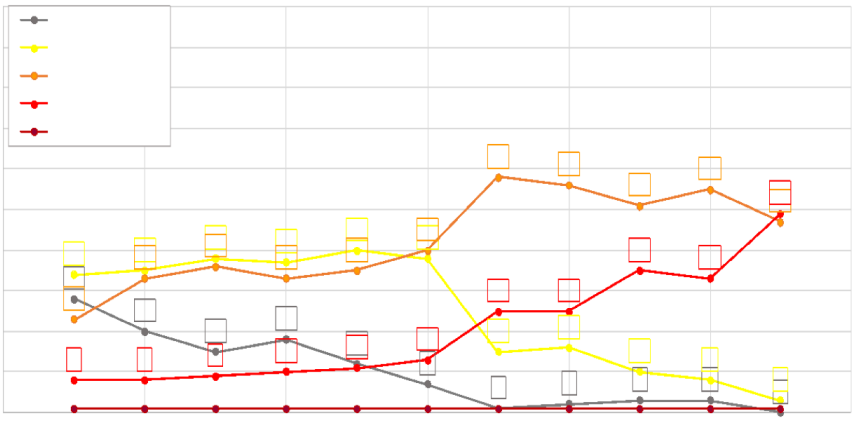
Picture 2. Most Likely El Niño Magnitudes for Summer 2024



Source: ENFEN (2023).

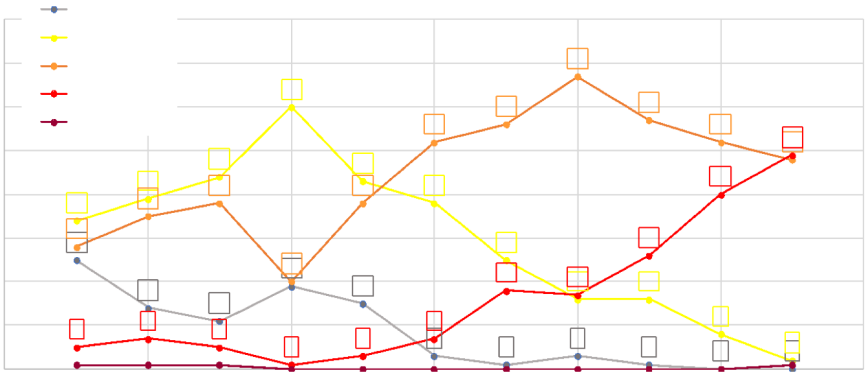
Likewise, it is estimated that between November 2023 and January 2024, there will be the persistence of warm air temperature conditions along the coast. Rainfall is more likely to exceed its normal accumulated values mainly on the north coast, central coast and northern highlands. By the summer of 2024, considering the rainfall scenario, in the context of coastal El Niño (Niño 1+2 Region), it is likely that above-normal rainfall will occur in the northern and central coast of Peru, as well as the northern highlands, without ruling out intense rainfall in these sectors (Picture 3). Considering the El Niño scenario in the central Pacific (Niño 3.4 Region), below-normal rainfall is expected in the Andean region, particularly in the south-eastern highlands (Picture 4).

Picture 3. Probabilistic Forecast for the Magnitude of the Coastal El Niño Event: Dec 2023 – Mar 2024 (Niño 1+2 Region)



Source: ENFEN (2023).

Picture 4. Probabilistic Forecast for the Magnitude of El Niño Event: Dec 2023 – Mar 2024 Central Equatorial Pacific (Niño 3.4 Region)

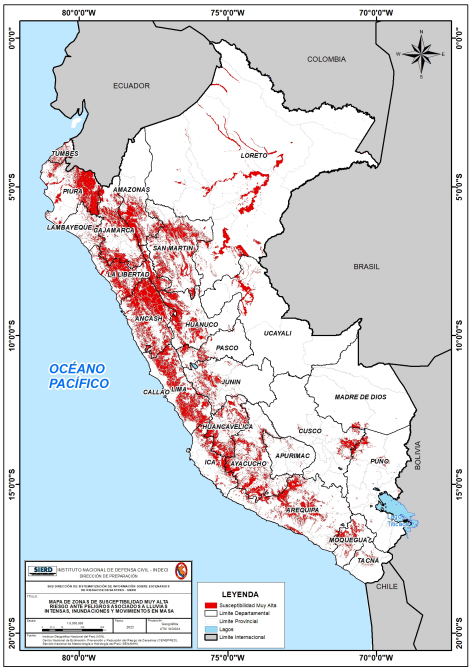


Source: ENFEN (2023).

3. Consequences of the FEN in Peru

Given this communication, the National Center for Disaster Risk Estimation, Prevention and Reduction (CENEPRED) prepared the risk scenario for mass movements in the face of rainfall associated with FEN based on the following territorial conditioning factors: slope, geomorphology, lithology, hydrogeology, and vegetation cover. Areas of very high and high susceptibility are mainly characterized by mountainous reliefs, steep slopes, and little or no vegetation cover (Picture 5). CENEPRED also developed the flood risk scenario for rainfall associated with the FEN (Centro de Estimación, Prevención y Reducción de Riesgos de Desastres [CENEPRED], 2023a). Both scenarios were prepared based on the technical information generated by the Geological, Mining, and Metallurgical Institute (INGEMMET, for its acronym in Spanish), the National Meteorological and Hydrometeorological Service (SENAMHI, 2023), and the National Water Authority (ANA, 2023).

Picture 5. Map of areas of very high-risk susceptibility to dangers associated with heavy rains, floods, and mass movements



Source: INDECI (2023a).

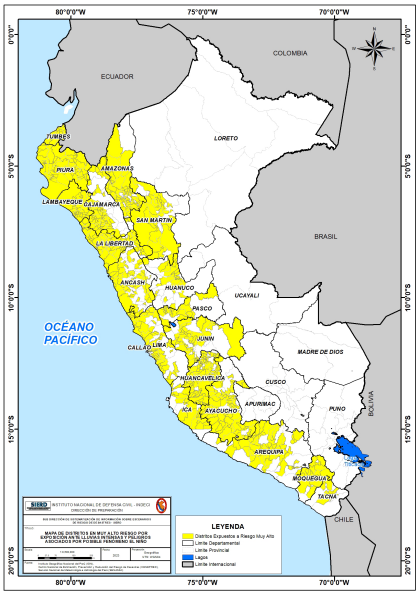
The National Institute of Civil Defense (INDECI, for its acronym in Spanish), based on the risk scenario information prepared by the CENEPRED regarding susceptibility to floods and mass movements, as well as the statistical analysis of damage caused by the El Niño phenomenon at the national level in previous years, has systematized the information on risk scenarios considered at "very high risk due to exposure to dangers associated with intense rains" levels. Thus, they have identified 18 departments, 139 provinces, and 856 districts at very high risk due to exposure to dangers associated with intense rainfall by the FEN, identifying those elements that are exposed within the scenario of dangers caused by rainfall greater than normal, determining that the population exposed to very high danger due to dangers associated with rainfall is 14,326,109 inhabitants and 4,376,208 homes (Pictures 6 and 7).

Picture 6. Districts at very high risk due to exposure to heavy rainfall and associated dangers due to the expected FEN 2023-2024

Departament	Nº of Provinces	Nº of Districts	Population	Homes
AMAZONAS	7	66	110,198	34,067
ANCASH	20	62	638,422	213,389
AREQUIPA	7	61	410,412	164,420
AYACUCHO	11	77	288,957	145,511
CAJAMARCA	11	62	611,792	194,876
HUANCAVELICA	7	87	306,334	152,164
HUÁNUCO	8	21	136,088	40,223
ICA	5	24	401,508	145,304
JUNÍN	9	48	334,245	138,302
LA LIBERTAD	12	76	1,625,453	428,063
LAMBAYEQUE	3	38	1,197,260	354,617
LIMA	10	73	5,833,925	1,583,495
MOQUEGUA	2	15	90,870	48,151
PASCO	3	21	160,098	59,237
PIURA	8	65	1,856,809	559,592
SAN MARTÍN	10	38	90,689	26,940
TACNA	3	9	8,186	7,115
TUMBES	3	13	224,863	80,742
TOTAL	**139**	**856**	**14,326,109**	**4,376,208**

Source: INDECI (2023a).

Picture 7. Districts at very high risk due to exposure to heavy rainfall and dangers associated with the expected FEN 2023-2024



Source: INDECI (2023a).

The CENEPRED also developed the water deficit risk scenario, including the analysis of susceptibility to meteorological droughts according to their intensity and frequency, and also based on characteristics of the social, economic, and environmental dimensions. The integration of both products results in risk scenarios for the occurrence of meteorological droughts, categorized as moderate, severe, and extreme. According to SENAMHI (2023b, p. 38), the hydrological perspective will prolong the deficient water conditions in the Titicaca Hydrographic Region for the coming months, with categories “far below normal” to “below normal”, being the most critical levels of deficiency in the characterization of flows. In the rivers of the South Pacific Hydrographic Region and the Central and Southern Amazon Hydrographic Region, there was variation with categories between “below normal” to “far above normal”.

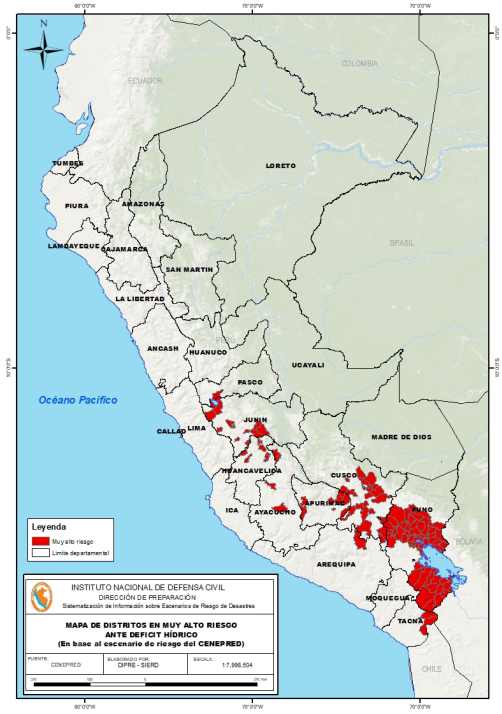
Likewise, based on the risk scenario information prepared by the CENEPRED in the face of the imminent danger due to water deficit, INDECI determined the areas of exposure, identifying 9 departments, 42 provinces, and 130 districts at very high risk, with a total population of 1,008,028 inhabitants at very high risk due to water deficit (Pictures 8 and 9).

Picture 8. Districts at very high risk due to exposure to water deficit by FEN 2023-2024

Departament	Nº of Provinces	Nº of Districts	Population	Homes
APURIMAC	3	9	38,508	12,300
AREQUIPA	1	1	3,697	777
AYACUCHO	4	4	16,272	3,128
CUSCO	10	22	160,539	46,106
HUANCAVELICA	4	7	33,037	10,238
JUNÍN	6	16	57,387	16,824
PASCO	1	1	3,877	1,151
PUNO	11	68	689,089	243,780
TACNA	2	2	5,622	1,482
Total	**42**	**130**	**1,008,028**	**335,786**

Source: INDECI (2023a).

Picture 9. Map of districts at very high risk due to exposure to water deficit



Source: INDECI (2023a).

4. Actions in the face of the FEN

Facing these risk scenarios, the Peruvian Government has made State of Emergency Declarations in several districts of provinces of the departments of Amazonas, Ancash, Arequipa, Ayacucho, Cajamarca, Huancavelica, Huánuco, Ica, Junín, La Libertad, Lambayeque, Lima, Moquegua, Pasco, Piura, San Martín, Tacna and Tumbes, for "imminent danger before the rainy period 2023-2024 and the expected El Niño Phenomenon" (Gobierno de Perú, 2023b, 2023c, 2023e and 2023f). The Government has also made Declarations of State of Emergency in districts of provinces of the departments of Ancash, Apurímac, Arequipa, Ayacucho, Cusco, Huancavelica, Huánuco, Ica, Junín, La Libertad, Lima, Pasco, Puno and Tacna, due to "imminent danger of water deficit as a result of the expected El Niño Phenomenon 2023-2024" (Gobierno de Perú, 2023a and 2023d). Based on these declarations, the regional governments, ministries, and other involved public and private institutions will execute the immediate and necessary emergency measures and actions to reduce the very high existing risk, as well as actions of response and rehabilitation, if required.

"Moreover, based on the State of Emergency Declarations, the Peruvian Government prepared the Multisectoral Plan 2023 – 2024 as a mechanism for coordination and articulation of interventions between the Ministries, its public agencies, and public universities..."

Moreover, based on the State of Emergency Declarations, the Peruvian Government prepared the Multisectoral Plan 2023 – 2024 as a mechanism for coordination and articulation of interventions between the Ministries, its public agencies, and public universities, in the districts identified as being at very high risk in the face of intense rains and associated dangers, as well as of a water deficit due to the expected FEN 2023-2024, with the aim of carrying out a series of actions and interventions in the territory in order to reduce and mitigate the risks of the determined vulnerabilities (Presidencia del Consejo de Ministros, 2023).

This typical multisectoral approach plan allowed the allocation of financial resources for the acquisition of machinery of the yellow line and the white line, the development of emergency projects and activities such as dredging of the riverbeds and streams (Picture 10), defense of structural riverbanks and dynamic barriers, acquisition of 3,765 tons of food aid and 1,610 tons of non-food aid (roof, shelter, tools, toilet kits, cleaning kits, household items, pots, kitchens, among others). The resource was also used for the replenishment of the National Warehouses of the National Institute of Civil Defense; training and technical assistance in Disaster Risk Management to local and regional authorities; contracting technical assistance for the formulation of Preparedness Plans, Emergency Operations, Rehabilitation, Heavy Rain Contingency, and Operational Continuity; the training of brigade members in reactive management; as well as monitoring the corresponding actions.

Picture 10. Dredging of the riverbed in the northern part of Peru

Source: Diario Oficial EL Peruano (2023).

5. Final considerations

The Peruvian state has the legal framework to deal with imminent dangers and disasters caused by natural phenomena through Law Number 29664 "Law that creates the National System for Disaster Risk Management (SINAGERD)" (Gobierno del Perú, 2011), which aims to identify and reduce the risks associated with dangers or minimize their effects. This law also seeks to avoid the cause of new risks and to be prepared and attentive to disaster situations through the establishment of principles, policy guidelines, components, processes, and instruments of Disaster Risk Management, of mandatory application and compliance for all public entities and companies at all levels of government, as well as for the private sector and citizens in general.

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Among the guidelines of the National Disaster Risk Management Policy, they consider that the country must have an adequate capacity to respond to disasters, with criteria of effectiveness, efficiency, learning, and permanent updating. Communities and public entities' resilience and response capacities must be permanently strengthened, fostered, and improved. Also, the public entities of the Executive Branch must establish and maintain the strategic and operational mechanisms that allow an adequate response to emergency situations and large-scale disasters. Regional and local governments are responsible for developing Disaster Risk Management actions.

To comply with this law, the Ministry of Economy and Finance is in charge of evaluating and identifying the appropriate and cost-efficient mechanisms that allow the Peruvian state to have the financial capacity to manage large-scale disasters and their respective reconstruction, as well as the relevant disaster risk financial management mechanisms (Gobierno del Perú, 2011). In this sense, the Budgetary Program 0068 "Reducción de la Vulnerabilidad y Atención de Emergencias por Desastres" ("Vulnerability Reduction and Disaster Emergency Response") is provided of a multisectoral nature in the Public Sector Budget, under the guidance of the Presidency of the Council of Ministers (PCM), as the main financial mechanism and contingency fund of the State Disaster Risk Management.

"...the Armed Forces and the National Police of Peru participate in Disaster Risk Management in terms of preparedness and response to disaster situations, in accordance with their competencies and in coordination and support to the appropriate authorities."

Likewise, in accordance with article 17 of the SINAGERD Law, the Peruvian state has the Armed Forces and the National Police of Peru that participate ex officio in the attention of emergency situations that require immediate response actions, carrying out the tasks that fall to them even when a state of emergency has not been declared, which is why they always act as first response entities. Moreover, the Armed Forces and the National Police of Peru participate in Disaster Risk Management in terms of preparedness and response to disaster situations, in accordance with their competencies and in coordination and support to the appropriate authorities.

Therefore, the Peruvian state is in a position to guarantee its primary duty to protect the population from threats to their security and promote their general welfare in accordance with Article 44 of the Political Constitution of Peru (Congreso de la República, 1993).

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