RISK ESTIMATION OF MUD FLOWS BY HEAVY RAINS IN A RURAL POPULATION OF THE CENTRAL PERUVIAN ANDES

Marco Andrés Moreno Tapia
Universidad Nacional Federico Villarreal
Av. Oscar R. Benavides No. 450 – Lima, Cercado – Perú
MMoreno.GRD@Gmail.com

Colaboradores:
Juan Carlos Sulca Jota[1]
Luis A. Céspedes Reyes[1]
Grace Trasmonte Soto[2]
[1]*Universidad Nacional Mayor de San Marcos*
[2]*Instituto Geofísico del Perú*

Abstract

This study is focused on risk assessment in a rural community in the central Peruvian Andes, associated with heavy rains, which act as the main source for landslides, mud flows and floods. These phenomena are intensified during the peak of the rainy season, January to March in our study's area. It analyzed an event that occurred in the Puquio river (intermittent river), which when it is activated often results in mud flows into the area, causing damage to roads and housing and putting at risk the lives of the community's people.

This situation worse for the absence of knowledge in the population about the impact of heavy rain on them and for the lack of access to information about this issues too. This study hopes to contribute in understanding these kinds of events to help mitigate their effects.

Keywords: Risk estimation, heavy rain, Peruvian Andes

Introduction

The towns located in the Central Andes of Peru are subject to frequent natural phenomena such as heavy rains and threats arising from this. The rural community of San Juan de Jarpa, located on the left bank of the Mantaro Valley, located in Cunas subbasin, this town is no stranger to this problem, especially in summer (December-March). The months of maximum precipitation are January, February and March, April rainfall decreases abruptly. 83% of the precipitation per year occurs between the months of October to April (IGP, 2005). Moreover, few studies in the area have assessed the risk of mud flows due to heavy rains. Currently, the proyect MAREMEX-Mantaro of the Geophysical Institute of Peru, is carrying out research in this community with the aim of strengthening the capacity of the risk management extreme weather events (heavy rains). (MAREMEX, 2011).

This research is a preview of what is being done to the community of San Juan de Jarpa. Its main objective is to contribute to reducing the effects of mudflows or "huaycos" in the area, estimating the risk level of these flows occurred in the Puquio microbasin, through hazard identification and analysis vulnerability. The term "huayco" (or "lloclla" the most correct in the Quechua language) is a term of Peruvian origin, derived from the Quechua word "huayco" which means "ravine", what technically is called flood in terms of the geology (INDECI , 2010).

The Puquio microbasin is between the coordinates 75.45 ° W / 75.41 ° W and 12.13 ° S / 12.16 ° S (Figure 1). There lies the rural community of San Juan de Jarpa - town "Puquio" where the March 18, 2010 a mudflow occurred (Figure 2).

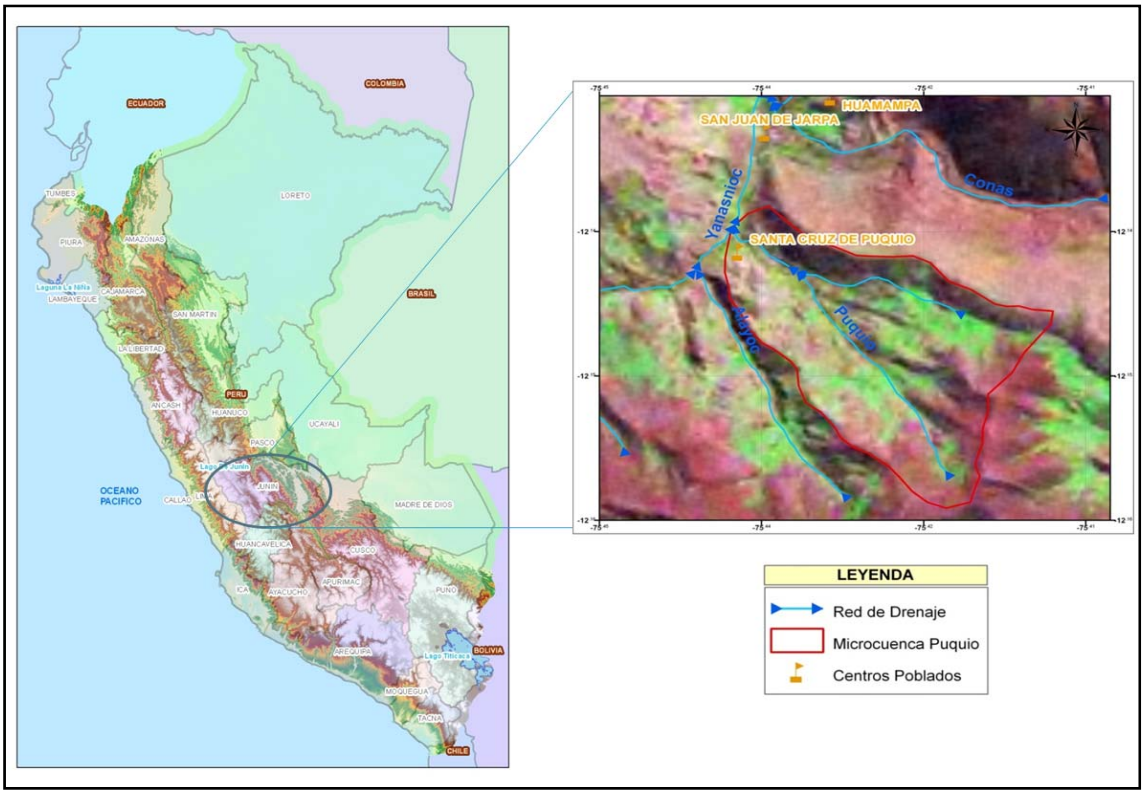

Figure 1: Location map of the Puquio Microbasin.
Prepared by: M. Moreno.

Figure 2: Shows how the avalanche occurred on March 18, 2010, destroyed a communication channel (Bridge).

The Puquio microbasin is exposed to huaycos and floods events of mild to moderate magnitudes. These events are often recorded in different watersheds of Peru, usually during the rainy season, one of these records was in March 2010 (Figure 3), which was the motivation of this study. Mila (2000) indicates that the geodynamic phenomena occurring in Peru (mudflows, mudslides, landslides and floods), the mudflows constitute 91% and and the floods 1%.

Desbordes de tres ríos causan inundaciones

19 de Marzo del 2010

DESASTRE. FUERTE GRANIZADA PROVOCÓ QUE AGUAS DE RÍOS SE INCREMENTARAN

Ayer, al promediar la 17:00 horas, el cielo se oscureció y cayó durante 60 minutos una tremenda granizada, que superaba los dos centímetros de diámetro, en las alturas del distrito de San Juan de Jarpa, Los cerros se cubrieron de blanco con 30 centímetros de grosor de granizo, luego le siguió una tormenta con un aguacero intenso y vientos huracanados.

Figure 3: Journalist of the event happened in Puquio.
Source: Correo Huancayo newspaper - March 19, 2010

There are government agencies like the National Service of Meteorology and Hydrology (SENAMHI – Servicio Nacional de Meteorología e Hidrología) that predicts the occurrence of heavy rainfall events, but not necessarily as localized, motivating preparedness and prevention alerted communities (Figure 4).

SENAMHI pronostica huaycos e inundaciones

Los fuertes chaparrones y lluvias provocarán inundaciones de viviendas, huaycos en las carreteras aniego de los cultivos agrícolas durante todo el presente mes de enero.

Así señaló ayer el Ing. Manuel Gutarra Pomalaza, jefe del Centro Regional de Meteorología e Hidrología al ser consultado por CORREO sobre los pronósticos del tiempo en esta época de lluvias.

Explicó que enero se caracteriza en la sierra central por la presencia de tormentas con precipitaciones pluviales mayores de 20 mm. en las 24 horas, acompañada de chaparrones, granizadas aisladas y fuertes vientos.

Para contrarrestar los daños; Gutarra sugirió realizar drenaje de viviendas con zanjas de desagüe; limpiar los buzones pluviales; adecuar las cunetas en las carreteras y hacer zanjas de drenaje en los cultivos.

El jefe del SENAMHI — Regional Junín agregó que durante el día habrán temperaturas agradables; en algunas horas sensiblemente frías debido al proceso de evaporación.

Figure 4: Newspaper clipping that is intended to alert the population.
Source: Correo Huancayo newspaper

Methods

For this study we have evaluated three criteria: The evaluation of the geomorphic and hydrometeorological parameters of the microbasin (the microbasin characterization), statistical analysis of rainfall antecedent to the event in 3, 5 and 10 days, and the estimation of risks proposed by the Civil defense Institute (INDECI – Instituto Nacional de Defensa Civil).

- To characterize the microbasin are detailed parameters such as rainfall in the microbasin (considering the record presented by the meteorological San Juan de Jarpa's station that is closest to the microbasin located 2 km. away). This characterization takes into account data such as slope, shape coefficients and time of concentration by the methods of Kirpich, Giandotti and method of the U.S. Corps of Engineers.

- For the evaluation of historical rainfall and / or history, it has records of rainfall intensity (mm / day) from 1964 to 2010 from the San Juan de Jarpa's station, which were grouped into 3 , 5 and 10 days respectively, for the calculation of the accumulated precipitation each day to assess, thus obtaining the behavior of the accumulated rainfall in these time intervals

- Finally, we make the risk assessment following the methodology of the basic manual of risk estimation (INDECI, 2006). Which establishes values and estimates the level of risk and vulnerability to the danger to be assessed, should be taken into account that was considered 8 types of vulnerabilities proposed by INDECI, ultimately leading to the assessment of the risk level matrix.

Findings and Discussions

1) Physical and Geomorphologic characteristics of the zone of Study

The microbasin Puquio has a total area of 4.69 Km ² or 469 hectares approximately and a perimeter of 9.54 km. He presents a length and approximate width of 3.56 km and 1.32 km respectively. The morphology of the microbasin is defined by the following parameters:

- **Evaluation of the physical parameters of the microbasin**

  These parameters have reference to the form of the microbasin; they determine the distribution of the water unloads along the principal course and he is largely the person in charge of the characteristics of the increasing ones of water. The indexes more employees to represent these characteristics are:

  - Parameters of form

    It allows to know the possibility of increasing of water from the existing relation between the area of the microbasin and the length of the same one, also he estimates the possibility of trend to have an intense simultaneous rain in the whole microbasin. There has been calculated the value of 0.37 of the shape factor of the Puquio microbasin.

  - Gravelius's index

    The index of compactness of a basin, defined by Gravelius, it expresses the relation between the perimeter of the basin, and the equivalent perimeter of a circumference, which has the same area of the basin. There has been calculated the value of Gravelius's coefficient for Puquio's microbasin, being this 1.23. (If the resultant coefficient tends to 1, the form of the basin tends to be a circular letter, for this reason, the time of concentration would be minimal).

  - Equivalent rectangle

    It expresses the hydrological behavior of a basin of an analogous way to a rectangle that had the same area and perimeter, therefore, the same Gravelius's index (Villón, 2002). For the microbasin Puquio, there was obtained a major length of 3.36 km and a minor length of 1.4 km. The values to the right of the rectangle indicate the altitude of the microbasin, while the percentages, inside the rectangle they indicate the area that represents the microbasin between the differences of altitudes (Figure 5).

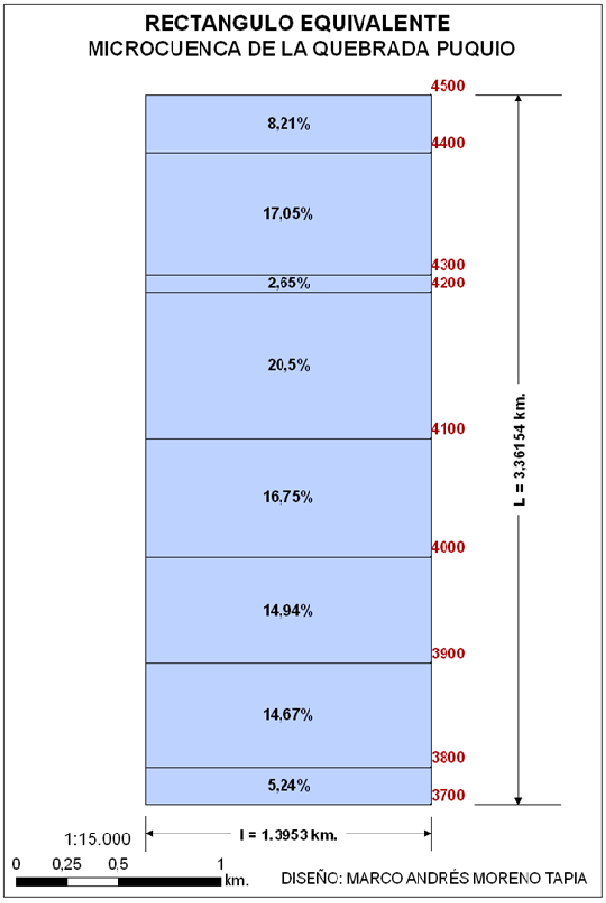

Figure 5: Equivalent Rectangle of the Puquio microbasin

Source: Moreno. 2011

- **Parameters relative to the Hydrographic Network**

  - Length of the longest Riverbed

    Later there appear the dimensions of the rivers of the microbasin of the gully Puquio (Figure 6).

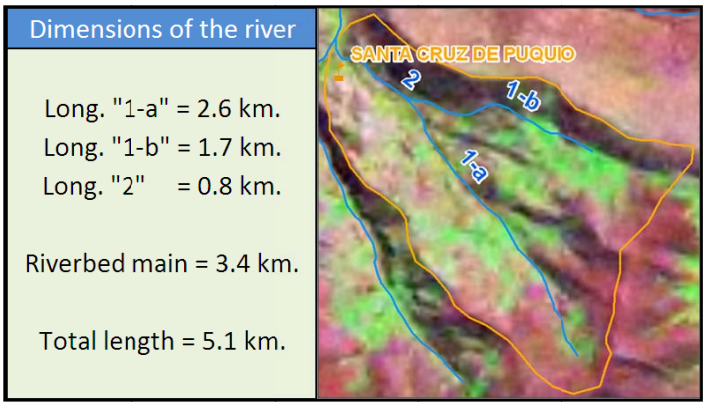

Figure 6: Dimensions of the rivers of the microbasin of the gully Puquio.
Prepared by: M. Moreno.

- Average slope of the riverbed

  The lowest topographic point of the riverbed is the river mouth of the gully Puquio in the river Yanasnioc (Black river) that has an approximate altitude of 3760 m.s.n.m., while the highest point of the riverbed is 4420 m.s.n.m. The difference of heights is of 660 mts. The length of the principal river is of 3424 mts., which provides an average slope of 19.27 %

- **Hydrological parameters**

  The zone of study is in Junín's department (left Margin of the valley of the Mantaro), and the total ones of annual rains of meteorological stations more near the zone of study, they indicate values between 647.6 and 943.8 mm that represent the quantity of average rain for this station.

ESTACION	X	Y	Z	PP ANUAL (mm).
San Juan de Jarpa	-75,42333	-12,11686	3600	943,8
Laive	-75,35527	-12,25022	3860	671,3
Viques	-75,23722	-12,15222	3186	682,8
Huayao	-75,338888	-12,03361	3360	647,6

Table 1: It shows the zone of study and the nearby meteorological stations, as average of his annual rainfalls (measured since the year 1964 to 2010).
Source: Own Production

a. Determination of the Run-off:

- Method of the Regional Hydrology:

  From the Equation of the Hydrological Regionalization of the Study of the Hydrology of Peru in function to the average rainfall of the basin, the Run-off is obtained in the microbasin of study.

$$E = 0.00025(P^{2.0564})$$

Where:
E = Run off
P = Average Precipitation on the microbasin (mm).

For the information of rainfall, is necessary know the average of annual precipitation (Table 1).

Using the method of Regional Hydrology, and the average of the annual rainfalls on the station San Juan de Jarpa, a run-off of 327.71 is obtained.

b. Determination of time of concentration:

- Method 1 (Giandotti).

According to Giandotti, the time of concentration is depending on the length of the principal riverbed, the area and the average elevation of the basin. For the calculation of this one he proposes the following formula.

$$TC = \frac{4\sqrt{S} + 1.5L}{0.8\sqrt{H}}$$

Where:
TC = Time of concentration in hours
S = Area of the basin in km²
L = Length of the principal riverbed
H = Average elevation of the basin in mts.

S	L	H
4.69	3.42	4120.2

Using Giandotti's method for the calculation of the time of concentration, considering the parameters S, L and H of the zone of study, one determined that the time of concentration of the microbasin Puquio is 0.26 hours, equivalent to 15 minutes.

- Method 2 (U.S. Corps of Engineers)

According to the U.S. Corps of Engineers the time of concentration decides of the following way:

$$TC = 0.3\left(\frac{L}{J^{1/4}}\right)^{0.76}$$

Where:
TC = Time of concentration in hours.
L = Length of the principal riverbed in km.
H = average slope of the main riverbed.

Being the values of the parameters, the following ones:

L	J
3.42	19.27

Determining the time of concentration of Puquio's microbasin is 0.44 hours, equivalent to 26 minutes.

- Method 3 (Kirpich - California Highway Service)

According to the California Highway Service, the time of concentration is determined as follows:

$$TC = \left(\frac{0.870L^3}{H}\right)^{0.385}$$

Where:
TC = Time of concentration in hours.
L = Length of main riverbed in km.
H = Difference in elevation between the basin outlet and hydraulically farthest point in meters.

L	H
3.42	695

Using Kirpich's method, for the calculation of the time of concentration, one determined that the time of concentration of the microbasin Puquio is 0.32 hours, equivalent to 19 minutes.

With the above results, it can present a summary table of the Time of Concentration calculations determined by methods Giandotti, U.S. corps of Engineers and Kirpich, in order to determine the average values of concentration time.

Method	Formula	Parameters					Tc (Hours)
		Lenght of the riverbed (km)	Average high (mts)	Area (Km²)	Diference of the level (m)	Average slope of the riverbed (%)	
Giandotti	$TC = \frac{4\sqrt{S} + 1.5L}{0.8\sqrt{H}}$	3.42	4120.2	4.69			0.26
U.S. corps of Engineers	$TC = 0.3\left(\frac{L}{J^{1/4}}\right)^{0.76}$	3.42				19.27	0.44
Kirpich	$TC = \left(\frac{0.870L^3}{H}\right)^{0.385}$	3.42			695		0.32
Time of concentration estimate = 0.34 hours ≈ 20 minutes							

Table 2: Table they summarize of the determination of the time of concentration according to diverse methods.

Source: Own Production

2) Statistical analysis the rainfalls precedents to the event of March 18, 2010.

The rainfalls were evaluated precedents to the event of March 18, 2010 by intervals of 3, 5 and 10 days respectively, with the purpose of comparing the quantity of rainfall accumulated by every interval of days. The quantity of rainfall was evaluated from the year 1964 until the year 2010 understood between the periods On October 03 to March 27 (considering to the spring station and summer where there are registered the events of intense rains), to determine the trend of the behavior of the accumulated rains.

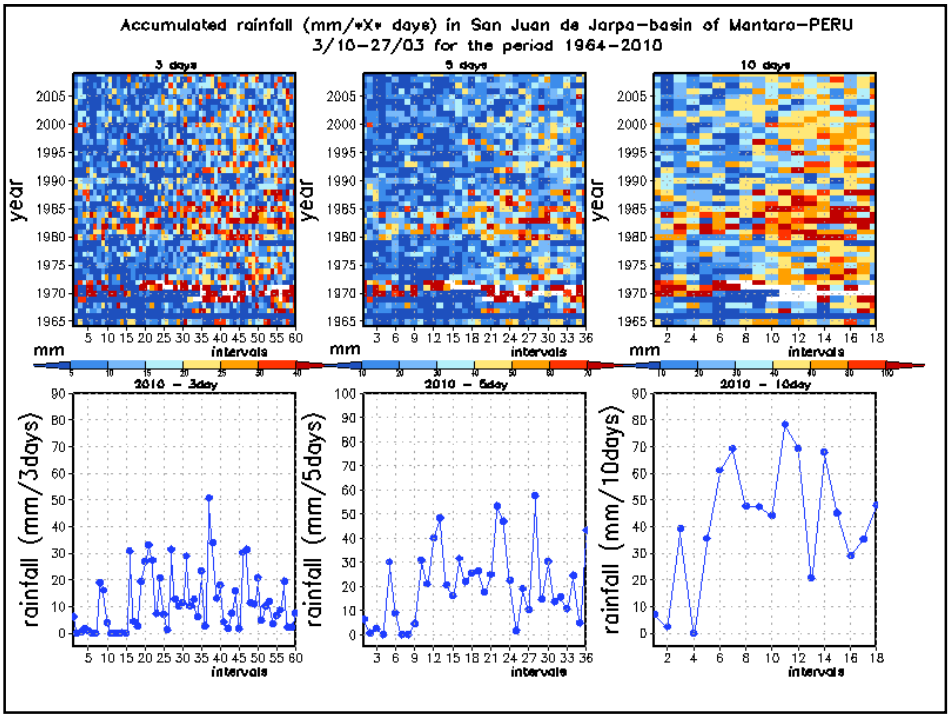

Figure 7: There appears the intensity of rain (palette of colors) for the 3, 5, and 10 days precedents of the event from the period 1964 - 2010 (top Part). One shows the quantities of rain accumulated for 3, 5 and 10 days precedents to the event (low Part).

Prepared by: J. Sulca and M. Moreno.

In the figure 7, it is possible to estimate that the trend of the rainfalls of 3, 5 and 10 days precedents in the day of the event (March 18, 2010), it is positive (with regard to the previous interval).

It was possible to determine that for the rains accumulated of 3 days, considering the date of the event, he presents the major intensity (19 mm / 3 days) for the group of intervals to evaluating (Figure 8).

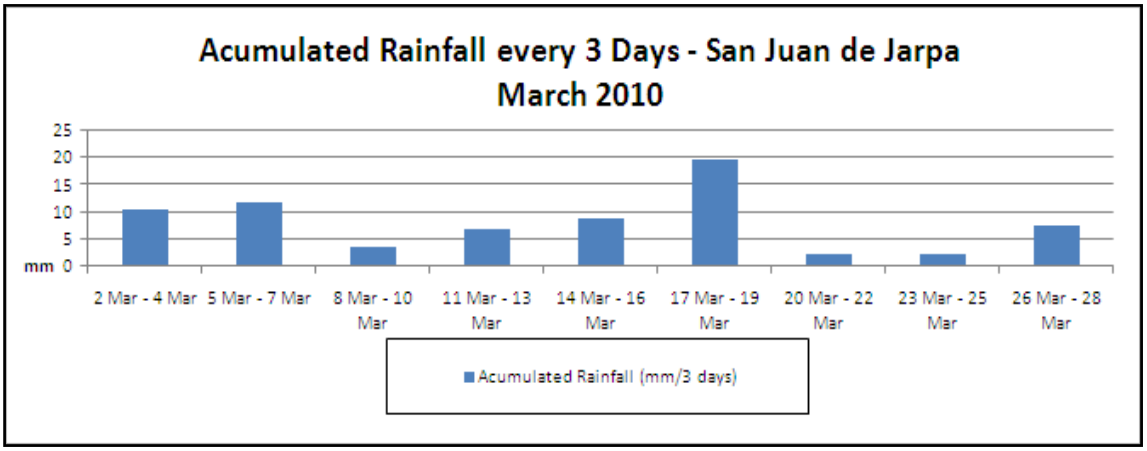

Figure 8: Shows the quantity of accumulated rain (19mm), for the March 17 on March 19.

Prepared by: M. Moreno.

3) Risk Estimation of mudflows due to the intense rains.

a) Threat Assessment

There were evaluated the natural and technological threats of the zone of study. The threats identified in the place, associated with strong rains are: mudflows and floods.

There are technological hazards further consideration, unless the dumping of household waste in the streets and the Cunas river.

To assign threat levels to the events of huaycos, was used as proposed by the Basic Manual for estimating risks of INDECI (2006) (Table 3).

STRATUM, DESCRIPTION AND VALUE OF THE DANGER ZONE		
STRATUM LEVEL	**DESCRIPTION /FEATURES**	**VALUE**
PB Low Hazard	Flat or low slope, rock and compacted soil, dry, high bearing capacity. Non-flooded uplands, ravines and hills away from contemptible. Not threatened by hazards such as volcanic activity, tsunamis, etc. Distance greater than 500 m. from the place of technological risk.	**1** < 25%
PM Medium Hazard	Soil of medium quality, with moderate seismic accelerations. Very sporadic flooding, low speed and tight. From 300 to 500 m. from the place of technological risk.	**2** 26% to 50%
PA High Hazard	Sectors where high seismic accelerations expected for their geotechnical characteristics. Areas that are inundated at low speed and remain under water for several days. Occurrence of partial liquefaction and expansive soils. From 150 to 300 m. from the place of technological risk.	**3** 51% to 75%
PMA Very High Hazard	Areas threatened by avalanches and alud-alluvion flows of stone and mudflows ("lloclla"). Areas threatened by pyroclastic flows or lava. Funds arising from the broken top of active volcanoes and areas of deposition affectible by mudflows. Sectors threatened by landslides or floods at high speed with great strength and power hydrodynamic erosion. Other sectors threatened by hazards: earthquake, frost, and so on. Soils with high probability of widespread liquefaction or collapsible soils in large proportions. Less than 150 m. from the place of technological risk.	**4** 76% to 100%

Table 3: Stratum, description and value of the danger zones
Source: INDECI. 2006

Whereas the study area is within the catchment area of failure Huaytapallana (has potential for seismicity in the Mantaro Valley) and is exposed to floods, mudslides and heavy rains in the summer period was estimated a danger of "High", with 55% for stratification present problems of mudflows and floods.

b) Vulnerability Assessment

To assign the levels of vulnerability will be used as proposed by INDECI (2006) in Table 4:

STRATUM, DESCRIPTION AND VALUE OF THE VULNERABILITY		
STRATUM LEVEL	**DESCRIPTION /FEATURES**	**VALUE**
VB Low Vulnerability	Housings seated in sure areas, with noble material or resistant earthquake, in good condition of conservation, population with a level of average and high revenue, in good condition of conservation, population with a level of average and high revenue, with studies and culture of prevention, with coverage of the basic services, with good level of organization, total participation and joint between them with good level of organization, Total participation and joint between the institutions and existing organizations.	**1** < 25%
VM Medium Vulnerability	Housing settled on land of intermediate quality, with moderate seismic accelerations. Very sporadic flooding, low speed and tight. With noble material, in fair to good condition, a population with average economic income level, culture of prevention in development, with partial coverage of basic services, with easy access to emergency care. Population organized with the participation of most, moderately related and partial integration between institutions and organizations.	**2** 26% to 50%
VA High Vulnerability	Housing settled in areas where high seismic accelerations are expected by their geotechnical characteristics, with poor material, in poor and fair condition of construction, with overcrowding and urban blight processes running. Population with low income, without knowledge and culture of prevention, partial coverage of basic services, limited accessibility to emergency care as well as with a little organization, minimum participation, weak relationship and low integration between institutions and organizations.	**3** 51% to 75%
VMA Very High Vulnerability	Housing settled in areas of soils with high probability of widespread liquefaction or collapsible soils in large proportions, durable material of construction in poor condition, with accelerated processes of crowding and overcrowding. Low-income population, no culture of prevention, lack of basic services and limited accessibility for emergency as well as a no organization, participation and relationships between institutions and organizations.	**4** 76% to 100%

Table 4: Stratum, Description and value of the vulnerability

Source: INDECI. 2006

According to the basic manual for estimating risk, there are 8 different vulnerabilities:

1) Natural and ecological vulnerability

For the analysis of this type of vulnerability it was considered the Table 5:

VULNERABILITY ENVIROMENTAL AND ECOLOGICAL				
VARIABLE	LEVEL OF VULNERABILITIES			
	VB	VM	VA	VMA
	< 25 %	26 to 50 %	51 to 75 %	76 to 100 %
Weather Conditions	Levels of temperature to the average normal	Levels of temperature lightly superior to the normal average	Levels of temperature superior to the normal average	Levels of temperature superior to the normal average
Composition and quality of the air and the water	Without any degree of pollution	With a moderate level of pollution	High degree of pollution	Not suitable level of pollution
Ecological conditions	Conservation of the natural resources, population planned growth, the deforestation and pollution is not practiced	Moderate level of exploitation of the natural resources; light growth of the population and of the level of pollution	High level of exploitation of the natural resources, increase of the population and of the level of pollution.	Indiscriminate exploitation of natural resources; increase of the population out of the planning, deforestation and pollution

Table 5: Environmental and ecological Vulnerability

Source: INDECI. 2006

The levels of vulnerability for each variable are:

- Atmospheric Conditions: (VB = 05 %), it presents few changes of temperature due to the climatic variability of the zone but one does not register sudden changes of temperature. (Figure 9).

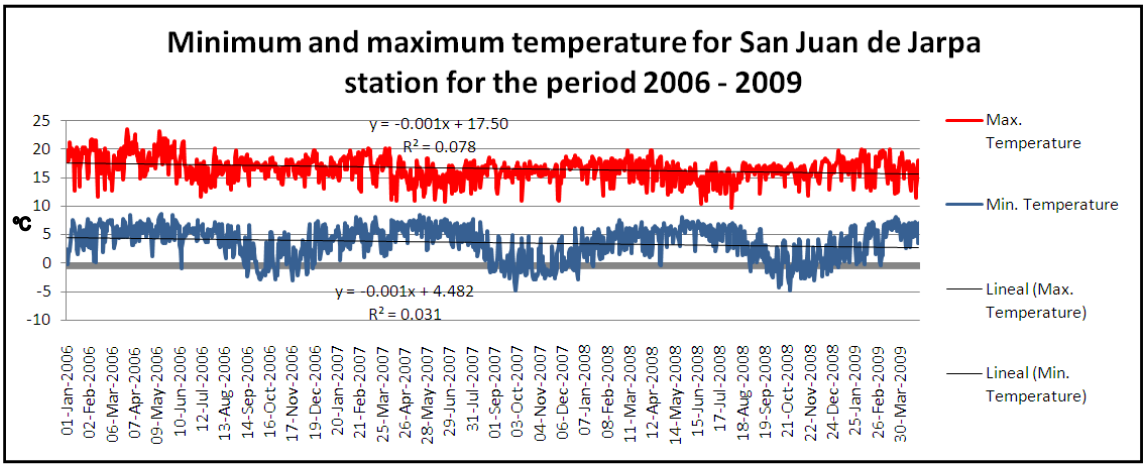

Figure 9: Shows Itself the behavior of the maximum and minimal temperature (Celsius degree) for the station San Juan de Jarpa in the period 2006-2009

Prepared by: M. Moreno.

- Composition and quality of the air and the water. (VB = 05 %), he does not present a significant degree of pollution.

- Ecological Conditions (VB = 05 %), due to the fact that the zone of study has a population moderate growth and it did not appreciate practices of deforestation.

Therefore, it thinks that the environmental and ecological vulnerability presents a value of 05 % ((05+05+05)/3); of which it corresponds to a low vulnerability.

2) Physical vulnerability

For the analysis of this type of vulnerability it was considered the Table 6:

PHYSICAL VULNERABILITY				
VARIABLE	**LEVEL OF VULNERABILITY**			
	VB	**VM**	**VA**	**VMA**
	< 25 %	**26 to 50 %**	**51 to 75 %**	**76 to 100 %**
Material of construction used in housings	Earthquake resistant structure with appropriate building techniques (concrete or steel).	Structure of concrete, steel or wood, without proper building technique.	Structures of adobe, stone or wood, without structural reinforcements.	Structures of adobe, stone or wood, without structural reinforcements.
Location of housings	Very remote > 5 Km	Moderately well nearby 1 - 5 Km	Near 0.2 – 1 Km	Very near 0.2 – 0 Km
Geological characteristics, quality and type of soil	Zones without faults or fractures, soils with good geotechnical characteristics	Zone lightly fractured, soils of medium capacity amble	Zone lightly fractured, soils of medium capacity amble	Area very fractured, failed, collapsible soils (fill, high water table in peat, inorganic material, etc.).
Existing laws	With strictly fulfilled laws	With laws fairly enforced	Compliance with laws without	Without law

Table 6: Physical Vulnerability
Source: INDECI. 2006

The levels of vulnerability for each variable are:

- Material of construction used in housings: (VA = 70 %), since the majority of the houses in 95 % approximately are of wall and adobe and present cracks in his walls for the antiquity of his construction. (Figure 10).

Figure 10: Type of material of predominant construction and accession of the housings.
Source: Céspedes. 2011

- Location of housings (VA = 60 %). A considerable percentage of the population is seated on vulnerable zones to floods by possible overflows both of the Black river and of the river Cradles. Also there exist other housings that are seated on humid zones, where the phreatic napa is to scanty meters of the surface.
- Geological Characteristics, quality and type of soil (VM = 50 %), for being nearby to the channels of the rivers and having the existence of gullies in the whole relief of the community, they originate infiltrations of water and the existence of humid zones in his environment, on which the population is based. On these zones it is possible to deduce that the capacity amble is low for the presence of dampness in the soil.
- Existing Laws. (VA = 60 %). A lack of studies exists in rural areas that they indicate in that places it is possible to construct and the absence of regulations of territorial classification; on the other hand one possesses the national regulation of buildings (norm G - 050), which is necessary what way has to construct the housings him, nevertheless, the rural population constructs in agreement to his experience and not chord to the regulation was recommending.

For this, it thinks that the physical vulnerability presents a value of 60 % ((70+60+50+60)/4); of which it corresponds to a high vulnerability.

3) Economic vulnerability

For the analysis of this type of vulnerability the following table is born in mind:

ECONOMIC VULNERABILITY				
VARIABLE	**NIVEL DE VULNERABILIDAD**			
	VB	**VM**	**VA**	**VMA**
	< 25 %	**26 to 50 %**	**51 to 75 %**	**76 to 100 %**
Economic Activity	High productivity and distributed well Resources. Products for the exterior trade or out of the locality	Moderately productive and regular distribution of the resources. Products for the domestic trade, to local level.	Scantily productive and deficient distribution of the resources. Products for the self-consumption.	Without productivity and void distribution of resources.
Labour market access	Labor offer> Demands	Labor offer = Demands	Labor offer < Demands	There is no Labor Offer.
Level of income	High level of income	Sufficient level of income	Level of income that covers basic needs	Low income to cover basic needs.
Situation of Poverty or Human Development	Population without poverty	Population with minor percentage poverty	Population with medium poverty	Population with total or extreme poverty

Table 7: Economic Vulnerability
Source: INDECI. 2006

The levels of vulnerability for each variable are:

- Economic Activity: (VA = 55 %), due to the fact that the products that the population obtains are mainly for his self-consumption.
- Access to the labor market. (VMA = 80 %), due to the fact that the majority of the population is employed at activities of agricultural, shepherding and other labors out of the community.
- Level of income. (VA = 75 %). The population covers with great effort the expenses of the basic familiar basket.
- Situation of poverty or human development (VA = 80 %), this rural this community considered in condition of extreme poverty.

Therefore, it thinks that the Economic vulnerability presents a value of 72.5 % ((55+80+75+80)/4); which corresponds to a high vulnerability.

4) Social Vulnerability

For the analysis of this type of vulnerability it was considered the Table 8:

SOCIAL VULNERABILITY				
VARIABLE	**LEVEL OF VULNERABILITY**			
	VB	**VM**	**VA**	**VMA**
	< 25 %	**26 to 50 %**	**51 to 75 %**	**76 to 100 %**
Level of Organization	Totally organized population	Organized population	Scantily organized population	Not organized population
Participation of the population in the communal works	Total equity	Participation of the majority	Minimal participation	Void participation
Degree of relation between the institutions and local organizations	Strong Relation	Moderately related	Weak relation	Doesn't exist
Type of integration between the organizations and Institutional places.	Total integration	Partial integration	Low Integration	Doesn't exist integration

Table 8: Social Vulnerability
Source: INDECI. 2006

The levels of vulnerability for each variable are:

- Level of organization: (VA = 55 %), the community they do not have an organization adapted between the own settlers and his authority representatives.
- Participation of the population in the communal works (VA = 50 %), support exists between the population, but not quite it can help with the same way, this carries to the inequality of efforts that generates complaints and reluctance between the population.
- Degree of relation between the institutions and local organizations (VA = 75 %), does not exist a good relation between institutions (as the municipality) with the local organizations. The population does not feel very well represented by his authorities.
- Type of integration between the organizations and local institutions. (VMA = 85 %), one has not seen an integration of this type in the zone.

For this, it thinks that the Social vulnerability presents a value of 66.25 % ((55+50+75+85)/4); of which it corresponds to a high vulnerability.

5) Educational vulnerability

For the analysis of this type of vulnerability it was considered the Table 9:

EDUCATIONAL VULNERABILITY				
VARIABLE	**LEVEL OF VULNERABILITY**			
	VB	**VM**	**VA**	**VMA**
	< 25 %	**26 to 50 %**	**51 to 75 %**	**76 to 100 %**
Educational formal programs (Prevention and Attention of disasters - PAD)	Permanent development of topics related to prevention of disasters	I develop with regular permanency on topics of prevention of disasters	Insufficient development of topics on prevention of disasters	PAD's topics are not included in the development of educational programs
Programs of Training (not formal education) of the population in PAD	The totality of the this population qualified and prepared before a disaster	The majority of the population is qualified and prepared	The this scantily qualified and prepared population	Not qualified this one not prepared the totality of the population
Campaigns of diffusion (TV, radio and press) on PAD	Massive and frequent diffusion	Massive diffusion and frequent little	Scanty diffusion	There is no diffusion
Scope of education programs on strategic groups majority	Coverage	Coverage Coverage	Insufficient coverage less than half of the target	No coverage

Table N ° 9: Educational Vulnerability
Source: INDECI. 2006

The levels of vulnerability for each variable are:

- Educational formal Programs (VA = 75 %), insufficient development of topics exists on prevention of disasters, to sorrow that the municipality has notion on the subject matter of prevention.
- Programs of training (VMA = 80 %), great part of the population is not prepared not qualified in case of a disaster happens.
- Campaigns of diffusion (VMA = 95 %), one does not rely on persuasive diffusion that it should come to the settler to be aware and to take the actions to his scope, small diffusion that exists is between the communication of the neighbors (advices).
- Scope of educational programs on strategic groups (VMA = 95 %), there becomes small mention of this activity in the educational programs in the community.

For this, it thinks that the educational vulnerability presents a value of 86.25 % ((75+80+95+95)/4); of which it corresponds to a very high vulnerability.

6) Cultural and ideological vulnerability

For the analysis of this type of vulnerability it was considered the table 10:

VULNERABILIDAD CULTURAL E IDEOLOGICA				
VARIABLE	**NIVEL DE VULNERABILIDAD**			
	VB	**VM**	**VA**	**VMA**
	< 25 %	**26 to 50 %**	**51 to 75 %**	**76 to 100 %**
Knowledge on the occurrence of disasters	Total knowledge of the population on the reasons and consequences of the disasters	The majority of the population has knowledge on the reasons and consequences of the disasters	Scanty knowledge of the population on the reasons and consequences of the disasters	Total ignorance of the population on the reasons and consequences of the disasters
Perception of the population on the disasters	The totality of the population has a royal perception on the occurrence of disasters	The majority of the population has a royal perception of the occurrence of the disasters	The minority of the population has a realistic perception and more mystical and religious	Totally unreal perception - mystical – religious
Attitude opposite to the occurrence of disasters	Highly proactive attitude	Partially sighted attitude	Poorly sighted attitude	Fatalistic attitude, conformist and with laziness

Table 10: Cultural and Ideological Vulnerability
Source: INDECI. 2006

The levels of vulnerability for each variable are:

- Knowledge on the occurrence of disasters. (VM = 30 %). The population is conscious of the occurrence of the phenomena of natural origin that happens in the community.
- Perception of the population on disasters. (VM = 50 %). The population has a royal perception and of the occurrence of the disasters.
- Attitude opposite to the occurrence of disasters. (VA = 75 %). The population does not establish measures of prevention largely of the area of the community.

For this, it thinks that the cultural and ideological vulnerability presents a value of 51.7 % ((30+50+75)/3); of which it corresponds to a high vulnerability

7) Political and institutional vulnerability

For the analysis of this type of vulnerability it was considered the table 11:

POLITICAL INSTITUTIONAL VULNERABILITY				
VARIABLE	**LEVEL OF VULNERABILITY**			
	VB	**VM**	**VA**	**VMA**
	< 25 %	**26 to 50 %**	**51 to 75 %**	**76 to 100 %**
Local autonomy	Total autonomy	Partial Autonomy	Low Autonomy	There is no autonomy
Political leadership	Total acceptance and support	Acceptance and partial support	Minority acceptance and support	No acceptance or endorsement
Civil participation	total participation	participation majority	participation minority	No involvement
Coordination of actions between local authorities and functioning of the CDC	Permanent coordination and activation of the CDC	Sporadic coordinations	Scanty coordination	There is no coordination CDC does not exist

Table 11: Political and Institutional Vulnerability
Source: INDECI. 2006

The levels of vulnerability for each variable are:

- Local Autonomy (VM = 30 %). Since the population they depend on the municipalities distritales, provincial and regional.
- Political Leadership. (VB =50 %). The population recognizes his mayor distrital but a partial support exists on the part of the total population.
- Civil Participation (VA = 70 %). Not the whole population is participative to the meetings that could be summoned.
- Coordination of actions between local authorities and functioning of the CDC. (VMA = 100 %). A committee does not exist prepared adequately to be able to take the functions that it must have according to the " Manual of basic Knowledge for committees of civil defense and offices of civil defense ".

For this, it thinks that the political institutional vulnerability presents a value of 62.5 % ((30+50+70+100)/4); of which it corresponds to a high vulnerability.

8) Scientific and technical vulnerability

For the analysis of this type of vulnerability it was considered the table 12:

VULNERABILITY CIENTIFIC Y TECHNOLOGICAL				
VARIABLE	**LEVEL OF VULNERABILITY**			
	VB	**VM**	**VA**	**VMA**
	< 25 %	**26 to 50 %**	**51 to 75 %**	**76 to 100 %**
Existence of research on natural disasters in the locality	All of the natural hazards were studied	Most natural hazards were studied	There are few studies of natural hazards	There do not exist studies of any type of the dangers
Existence of instruments for meaures of complete fenomena	Totally orchestrated population	Partially orchestrated population	Population limited ofinstruments	Population without instruments
Knowledge about the existence of studies	Full knowledge of existing studies	Partial knowledge of the studies	Minimal knowledge of the existing studies	They do not have knowledge of the studies
The Population fulfills the conclusions and recommendations	La totalidad de la población cumplen las conclusiones y recomendaciones	The totality of the population they fulfill the conclusions and recommendations	The conclusions and recommendations are fulfilled in minimal proportion	They do not fulfill the conclusions and recommendations

Table 12: Scientific and technological Vulnerability
Source: INDECI. 2006

The levels of vulnerability for each variable are:

- Existence of works of investigation on natural disasters in the locality (VM = 40 %). There exist projects that realize studies in the area of study.
- Existence of instruments for measurement of complete phenomena. (VM = 30 %). There exists a meteorological station (meteorological Station San Juan of Jarpa - SENAMHI) in the community to 2 km from the microbasin in study, wherefrom one takes information of rainfall, temperature, atmospheric pressure, etc.
- Knowledge on the existence of studies. (VM = 40 %). The population has knowledge of the studies that was realized in the community across informative chats and across the communication between neighbors.
- The population fulfills the conclusions and recommendations. (VM = 70 %), there are not fulfilled in its entirety the recommendations offered to other investigations.

For this, it thinks that the scientific and technological vulnerability presents a value of 45 % ((40+30+40+70)/4); of which it corresponds to an average vulnerability.

Finally, calculation the average vulnerability, which appears in the following table:

TIPE	LEVEL OF VULNERABILITY				TOTAL
	VB	VM	VA	VMA	
	< 25 %	26 to 50 %	51 % to 75%	75 % to 100 %	
NATURAL AND ECOLOGIC	5%				05%
FÍSICAL			60%		60%
ECONOMIC				72.50%	72.5%
SOCIAL			66.25%		66.25%
EDUCATIVE				86.25%	86.25%
CULTURAL AND IDIOLOGIC		51.7%			51.70%
INSTITUTIONAL AND POLITICAL			62.50%		62.50%
CIENTIFIC AND TECHNIQUE		45%			45.00%
				Total	449.2%
				Average	56.15%

Table 13: I square summary of the levels of vulnerability
Source. INDECI. 2006

Of the previous picture it appreciates that the average vulnerability is 56.15 %, that is to say, he presents a high vulnerability.

c) Risk Estimation for huaycos caused by intense rains in the microbasin.

For the determination of the level of risk, it was considered the table 14:

Very high risk	High risk	High risk	Very High Risk	Very High Risk
High risk	Medium risk	Medium risk	High risk	Very High Risk
Medium risk	Low Risk	Medium risk	Medium risk	High risk
Low risk	Low Risk	Low Risk	Medium risk	High risk
Hazard/ Vulnerability	Low Vulnerability	Medium Vulnerability	High Vulnerability	Very High Vulnerability

LEYENDA:

Low Risk (< de 25 %)

Medium Risk (26 % al 50 %)

High Risk (51% al 75%)

Very high risk (76 % al 100%)

Table 14: Levels of Risk
Source: INDECI. 2006

To determine the level of risk the following thing is had in consideration:

Level am I in danger = 55 % (High level)

Level of average Vulnerability = 56.15 % (High level)

From these values it is possible to think that the level of the risk is High, with a value of 55.6 % approximately.

Conclusions and recommendations

• Villagers who are located in the watershed of the creek Puquio have high vulnerability and high risk to recurrent exposure to threats of mudflows due to heavy rain.

• It was found very high education vulnerability in the Puquio's Town, for which the authorities should strengthen activities related to education in prevention of natural disasters to reduce this level of vulnerability.

• Other important vulnerabilities found were the vulnerable social, economic and political institutions, so the authorities and the population should have more closely and to facilitate decision making and immediate actions mediated through community organizations in If there is a natural disaster in the town center.

• It is necessary enforce current regulations regarding earthquake resistant structures and to establish appropriate parameters to the reality of the population. (It considers the help they can provide social programs).

• The river must have a proper cleaning and maintenance on a regular period, the occurrence of new events dragged event new material, which shall be deposited in the riverbed, and this would worsen the old deposits that lie by the last event.

• It must take into account the need to select measures of protection such as coastal defenses that can be built on the site. The construction of a defensive wall in the Puquio river will reduces significantly the level of risk that exists in the area, which would prevent the mudflow damage significantly to the community and its activities. It could opt for this method of mitigation due the total length of river channels is 5 km (a short length), and it would be feasible to do in the area.

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