SILVIA: An operational system to monitoring landslides forced by heavy precipitations at national scale in Peru

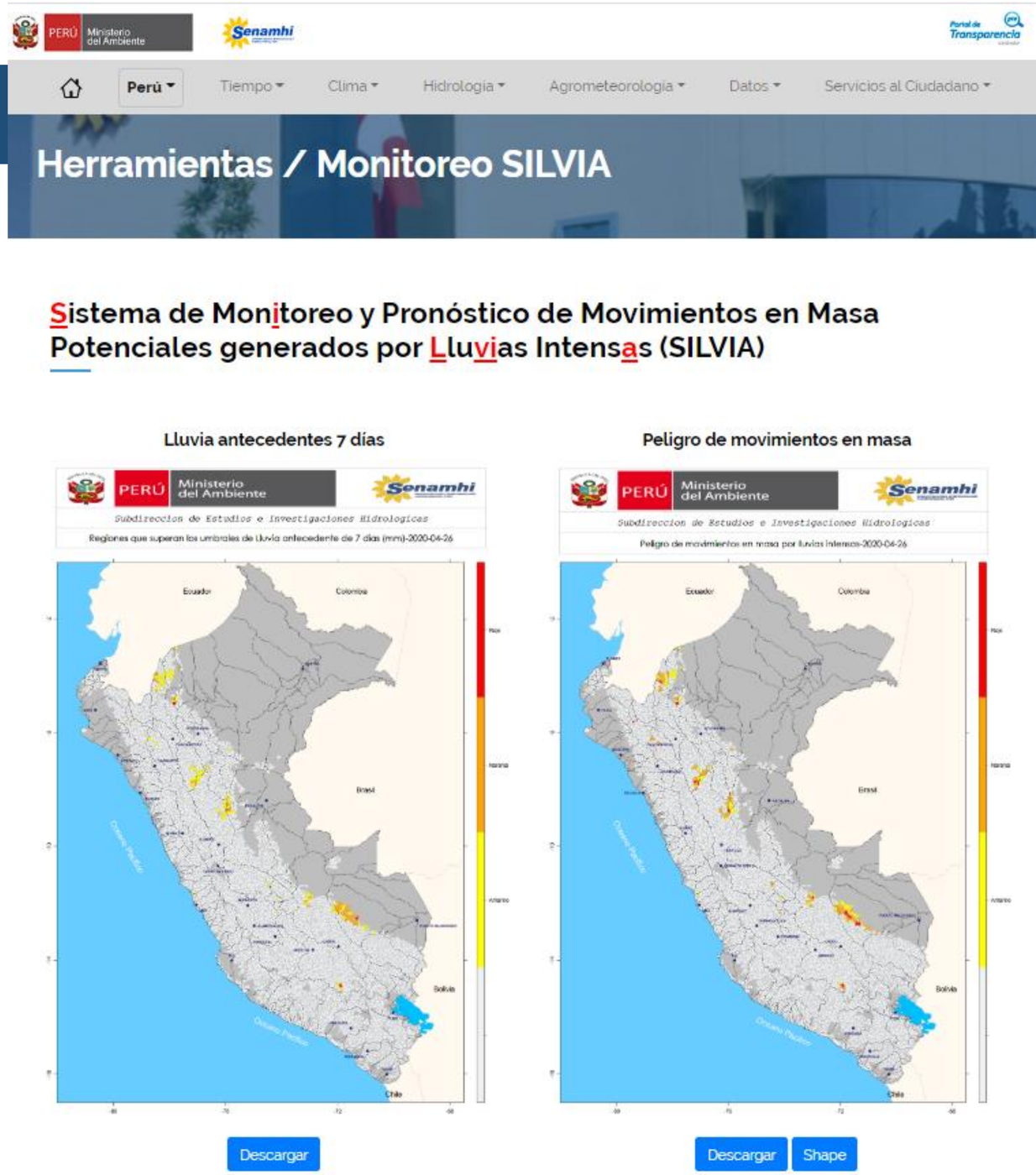
Carlos Millán [1], Waldo Lavado [1], Fiorella Vega [1], Oscar Felipe [1], Julia Acuña [1], and Ken Takahashi [1]

National Service of Meteorology and Hydrology (SENAMHI), Lima, Peru

Panoramic view of the high-risk basins of the Rímac River, Santiago de Tuna, 2019
CMA

What is SILVIA?

SILIVIA is a **system** developed at SENAHI with the aim of marking the bases **for monitoring and forecasting landslides triggered by rainfalls**



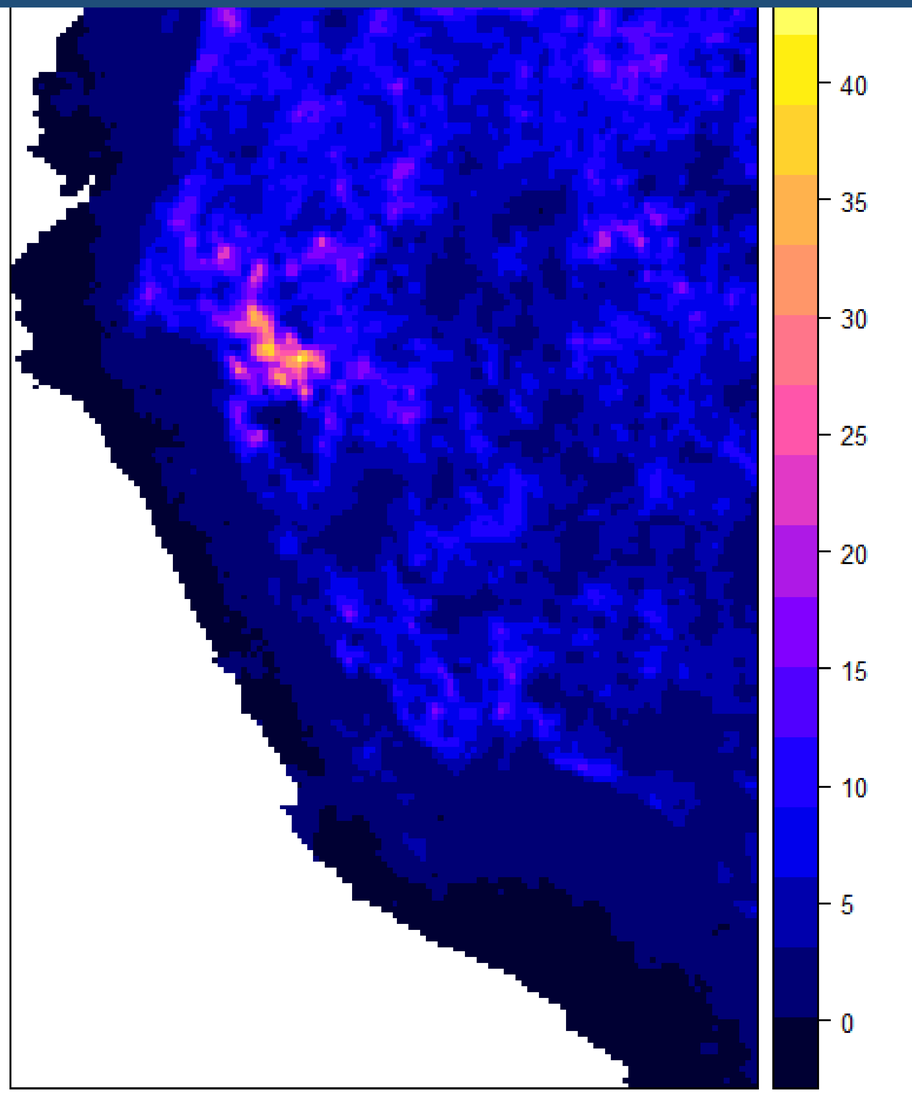
MATERIALS: Rainfall data

Peruvian Interpolated data of SENAMHI's Climatological and Hydrological Observations (**PISCO**) which has a daily operational product PISCO-prec_operativo (**PISCOop_Pp**)

Format: **Raster**

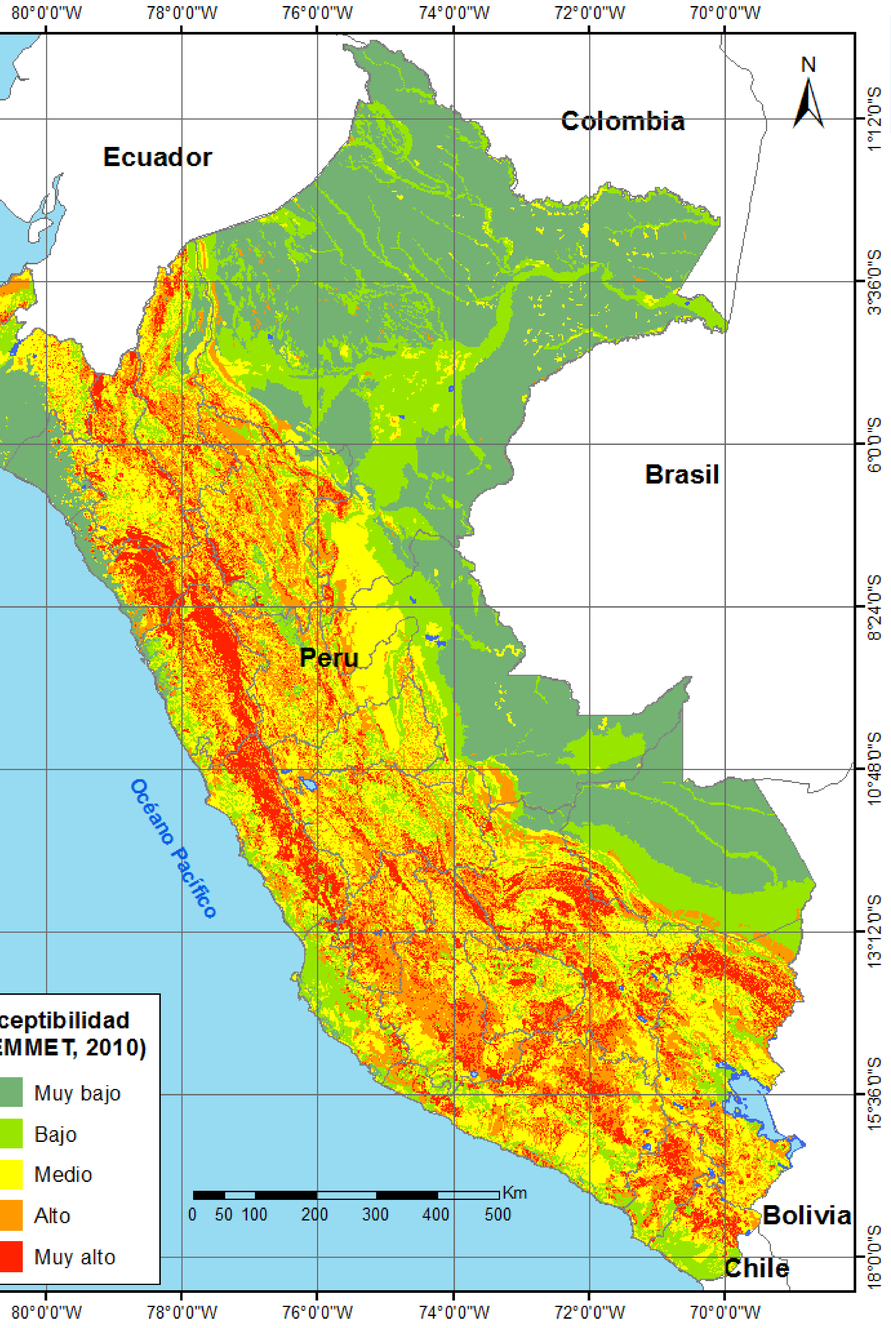
Spatial resolution: **10 km x 10 km**

Temporal resolution: **Daily**



PISCO_Op 14-09-2019 (mm)

MATERIALS: Susceptibility map



Susceptibility map (INGEMMET, 2010)

The **factors correlated** with their respective weights are:

- Vegetation cover (0.05)
- Hydrogeology (0.1)
- Geomorphology (0.25)
- Slope (0.2)
- Lithology (0.4)

METHODOLOGY: Rainfall thresholds

Kirschbaum and Stanley (2018) determined an **Antecedent Rainfall Index (ARI global)**, based on the weighted average of the last 7 days of rain. This methodology was adapted to establish the thresholds used in SILVIA.

ARI calculates a weighted average of the last 7 rainy days. The function to determine ARI is presented in equation 1:

$$ARI = \frac{\sum_{t=0}^{6} p_t w_t}{\sum_{t=0}^{6} w_t} \qquad (1)$$

where ***t*** is the number of days before the present, ***pt*** is the precipitation at time ***t***, and ***wt = (t +1)*** $^{-2}$.

- The ARI of the rains of the last 7 days were determined as a **moving window**.
- ARI it was determinate for **wet periods** of each year between the months of **November to April**
- It was considering as a reference **climatological period 1981 -2010**
- From ARI, three thresholds were established based on the **percentiles of 90% (P90), 95% (P95) and 99% (P99)**
- Three levels of precipitation incidence were defined:

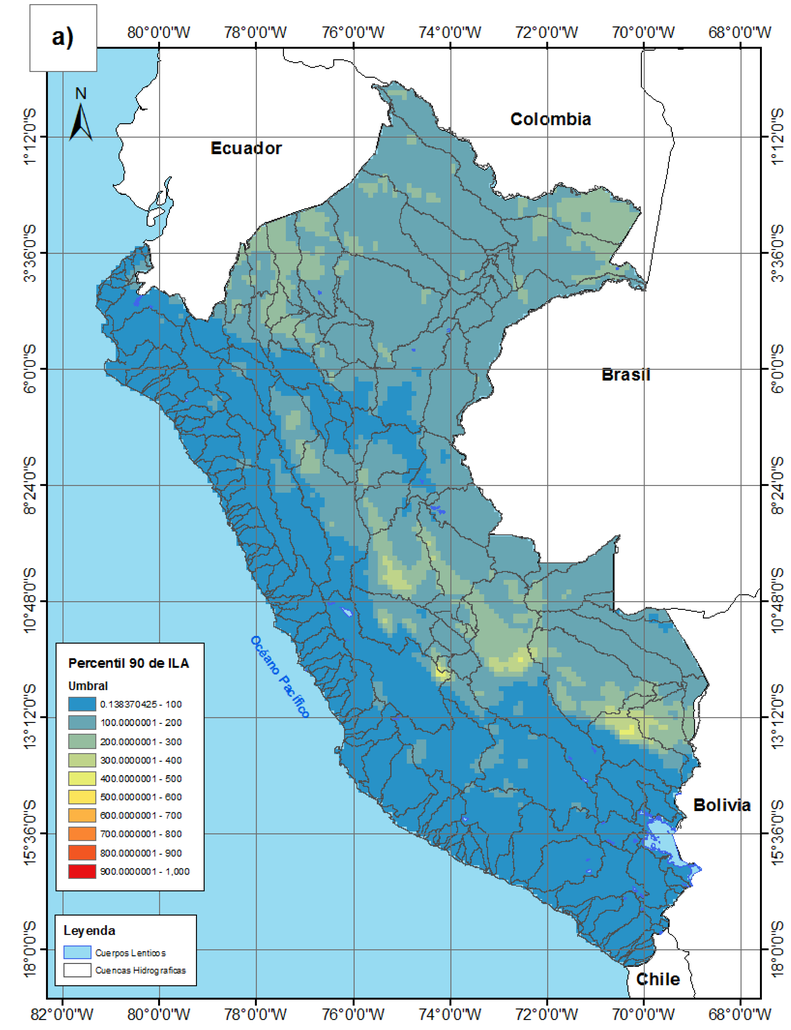
  Low Incidence (L1 - ILA between P90 and P95)

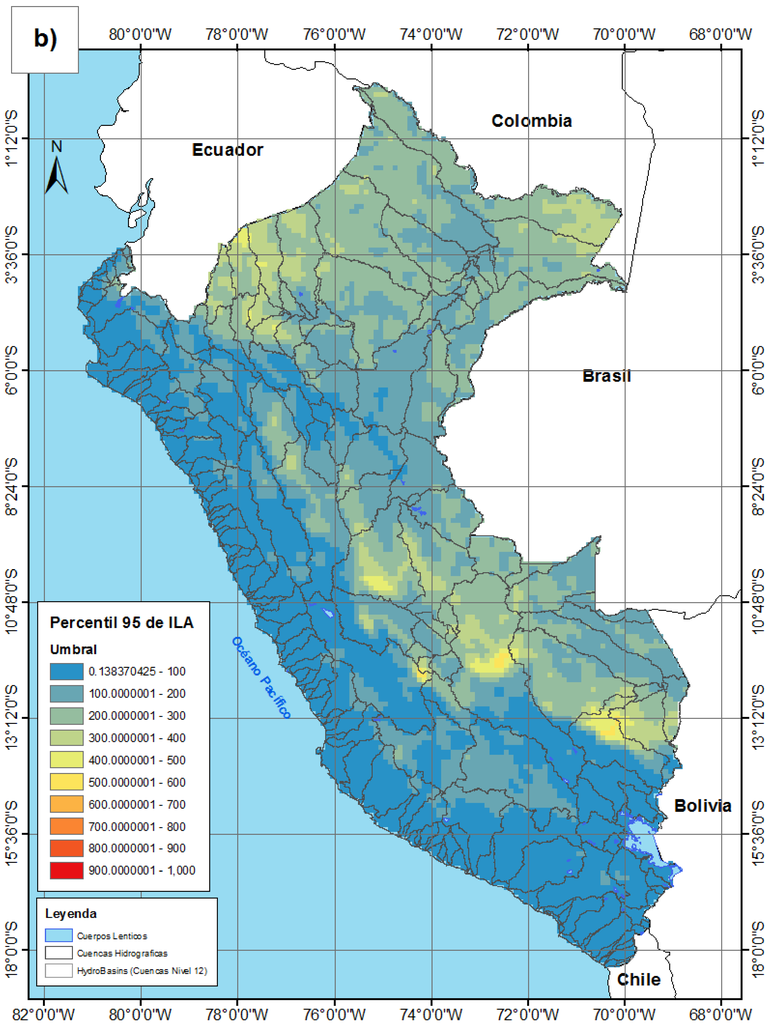
  Medium Incidence (L2 - ILA between P95 and P99)

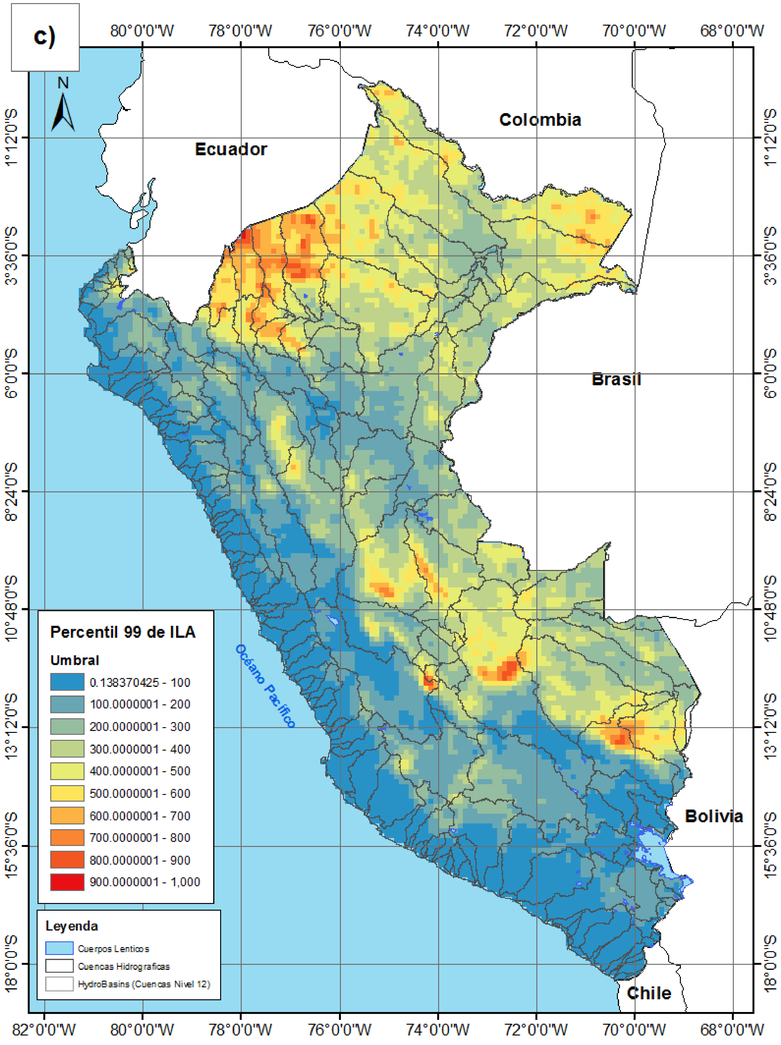
  High Incidence (L3 - ILA greater than P99)

METHODOLOGY: Rainfall thresholds

Rainfall Index Thresholds Weighted at the 90th (a), 95 (b) and 99 (c) percentiles







METHODOLOGY: Analysis scope

Analysis area for issuing alerts: Level 12 basins (Pfastetter method, HydroBASINS v1.0)

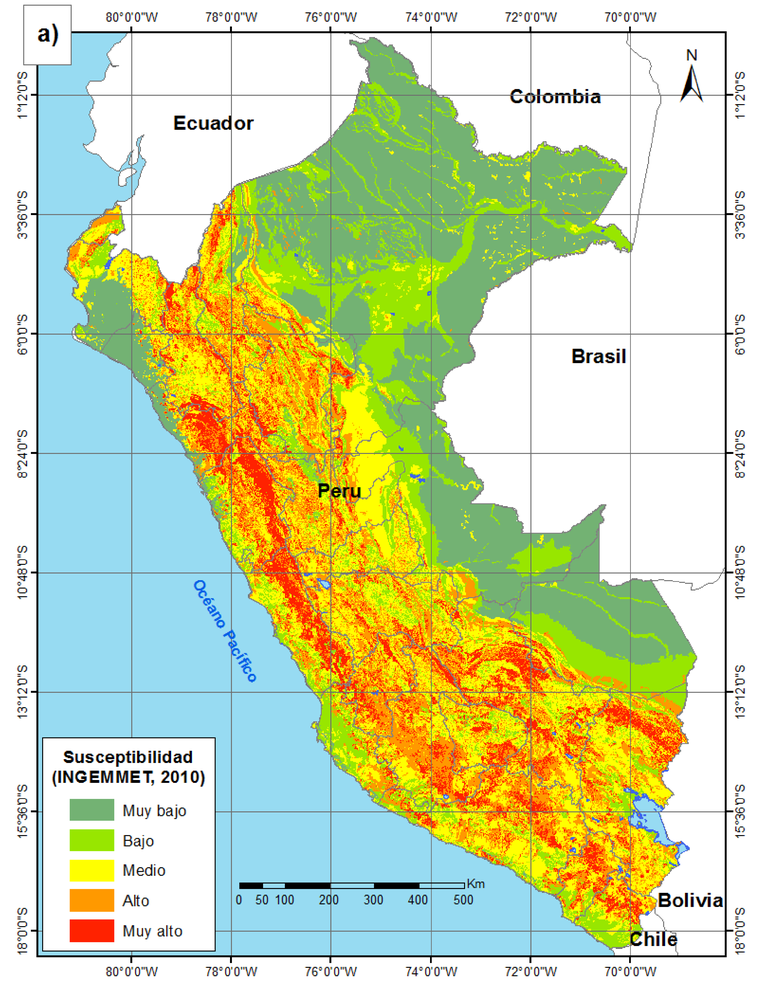
Peru include a total of **10849 basins**

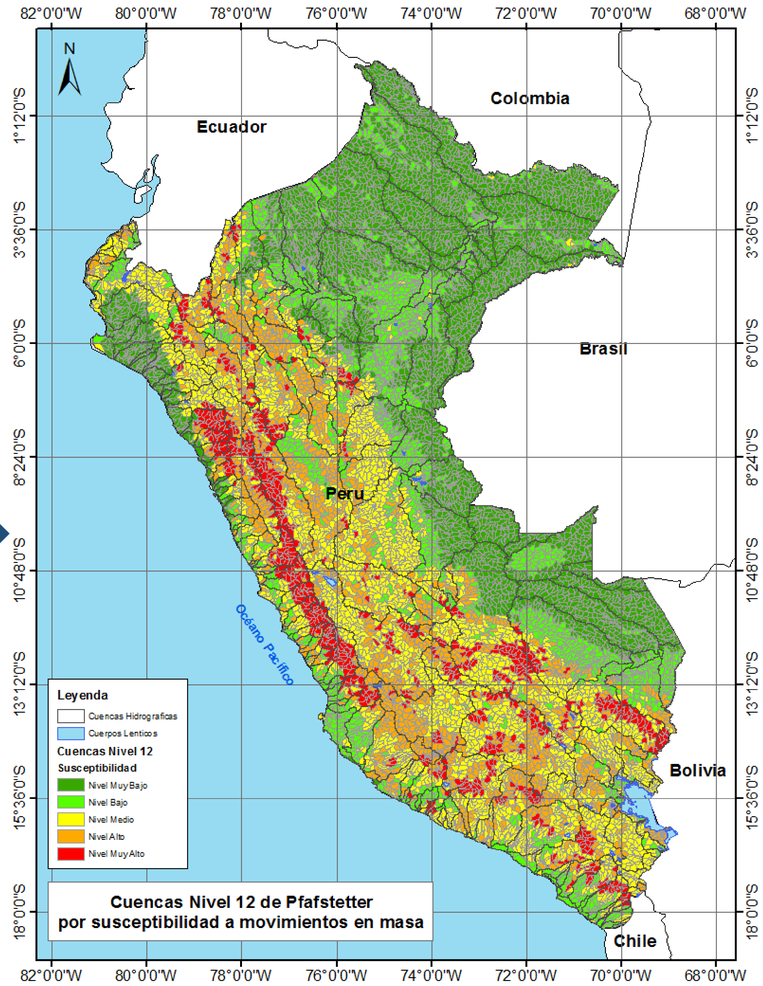
Average area: **118.57 km2**

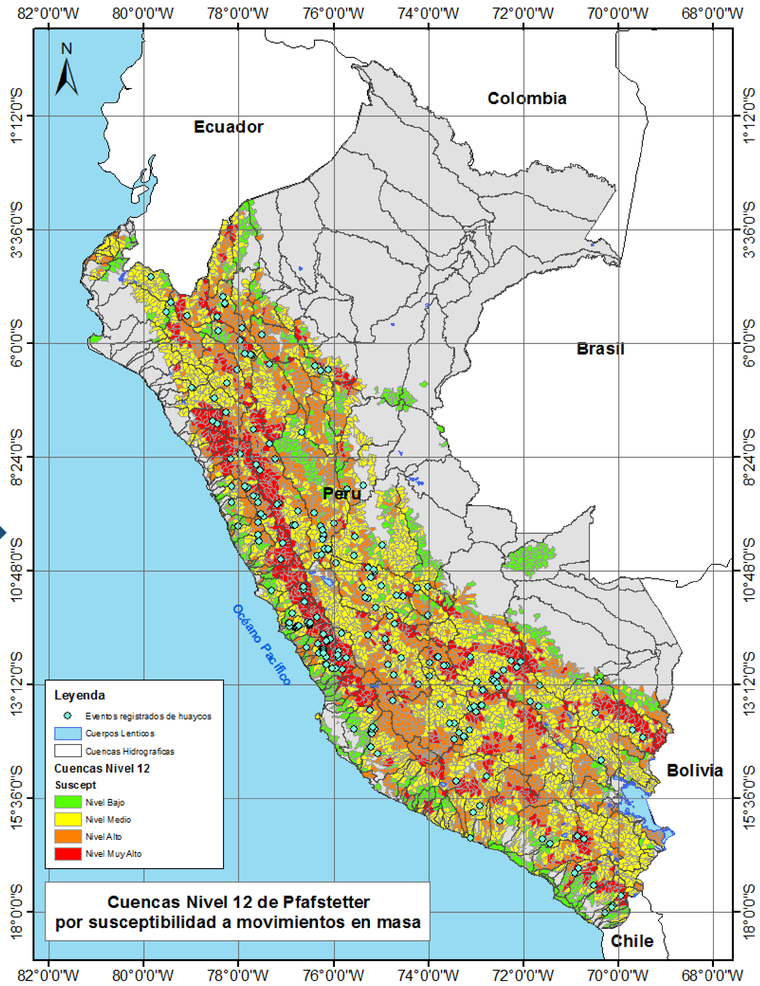
The following methodology was applied:

- **Overlapping** basins with the adapted susceptibility map.
- Determination of susceptibility level, considering the mode of the susceptibility categories within its extension area.
- Included **two restrictions**: i) the first is that the areas categorized with Very Low susceptibility were not considered. ii) level 12 basins with a slope less than 4.1 ° are not being considered

METHODOLOGY: Analysis scope







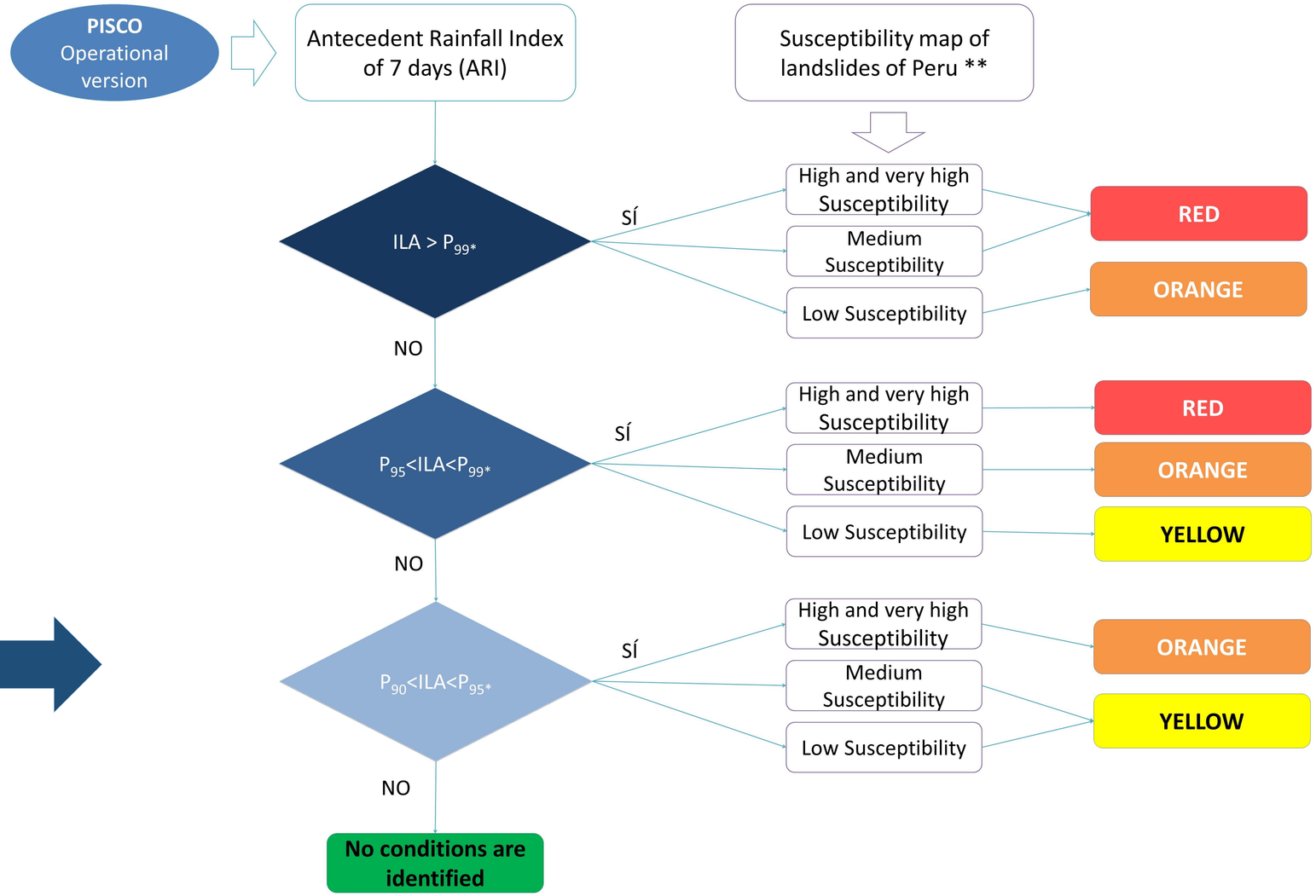
METHODOLOGY: Hazard classification

Hazard matrix based on:

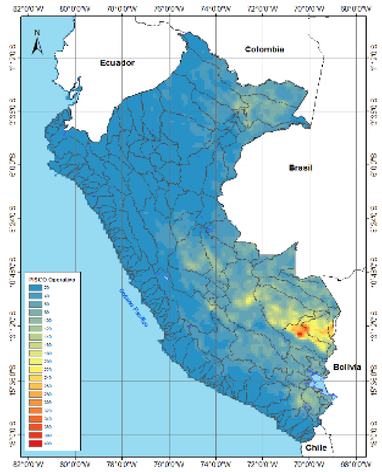
Susceptibility classes (S1, low susceptibility; S2, medium susceptibility; S3, high and very high susceptibility) and,

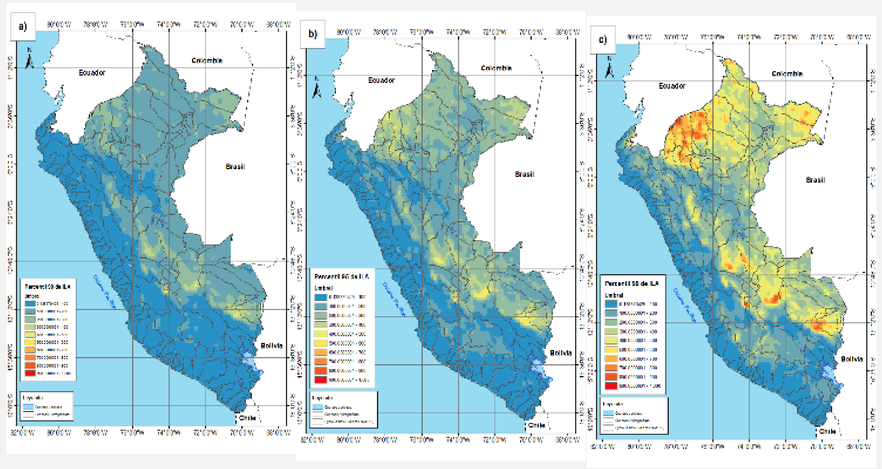
Rainfall index classes (L1, low precipitation; L2, medium precipitation; L3, high precipitation), defines three hazard classes from P1 (moderate danger), P2 (strong danger) and P3 (extreme danger).

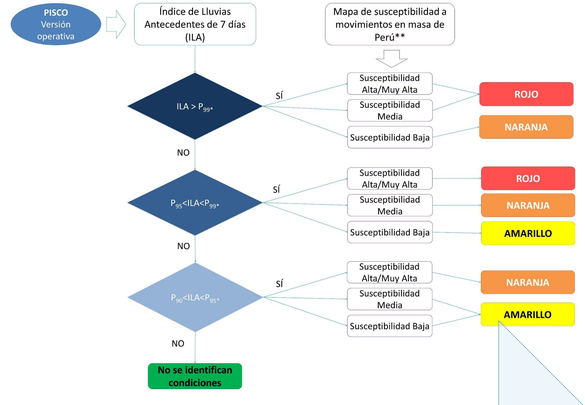
	S1 SB	S2 SM	S3 SA
L1 P90-95	P1	P2	P3
L2 P95-99	P2	P2	P3
L3 >P99	P3	P3	P3



Algorithm to define the hazard of landslides forced by heavy precipitations







* P99%, P95% Y P90%: Percentiles de ILA sobre la época de lluvia (NDEFMA)
**Mapa de susceptibilidad del INGEMMET (2010)

PISCO Operational

Grid precipitation data

LANDSLIDE SUSCEPTIBILITY

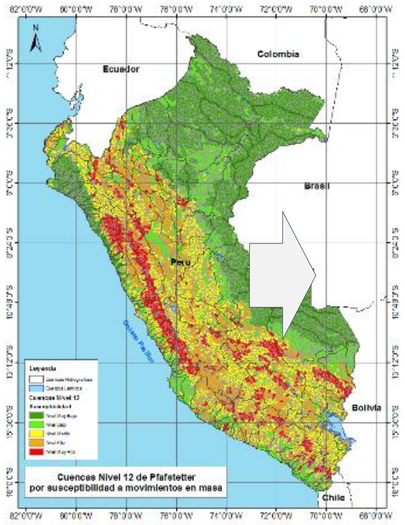
RAINFALL THRESHOLDS

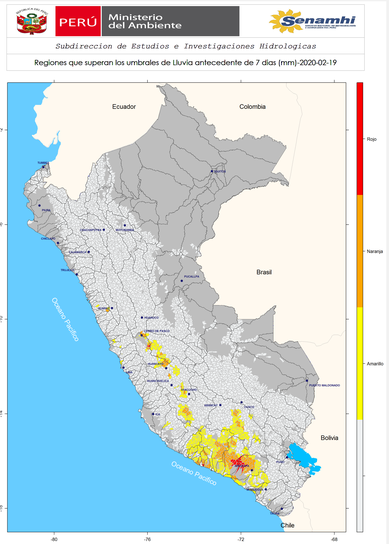
RAINFALL MONITORING

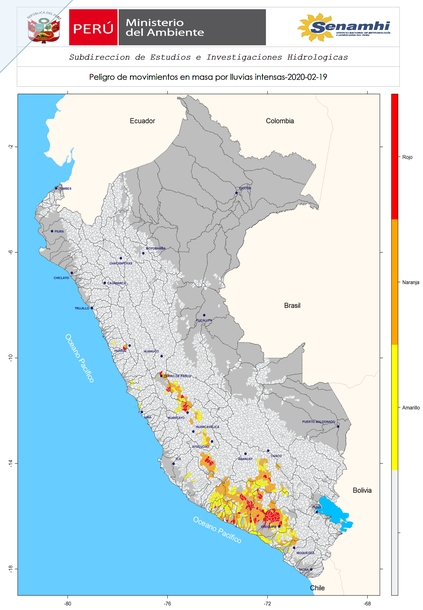
(ARI)

HAZARD CLASSIFICATION

SILVIA







RESULTS: Platform for the Monitoring and Forecasting System of Potential Mass Movements generated by Heavy Rainfall (SILVIA)

This work is showed at the web of SENAMHI, as a tool to monitoring the favourable conditions for landslides triggered by antecedent rainfall, at the next link: https://www.senamhi.gob.pe/?p=monitoreo-silvia

SILVIA was improved using precipitation daily forecasting and was implemented as a warning system generating a daily-time system to cope with streams activation in subbasins (*"Activación de quebradas"*, https://www.senamhi.gob.pe/?p=aviso-activacion-quebrada).

DISCUSSION

The level of representativeness, resolution and reliability of the variables: susceptibility to landslides and rain, are important for the reliability of SILVIA.

SILVIA only considers antecedent rain as a triggering factor, and although rain has been determined to be the most important factor in causing mass movements, there are other temporal hydrometeorological variables that provide insight into how conditions develop. activation reviews.

SILVIA considers rainfall thresholds that exceed the 90th, 95th and 99th percentiles of the accumulated series, according a global threshold, which must be updated and adjusted to regional thresholds estimated from monitored events.

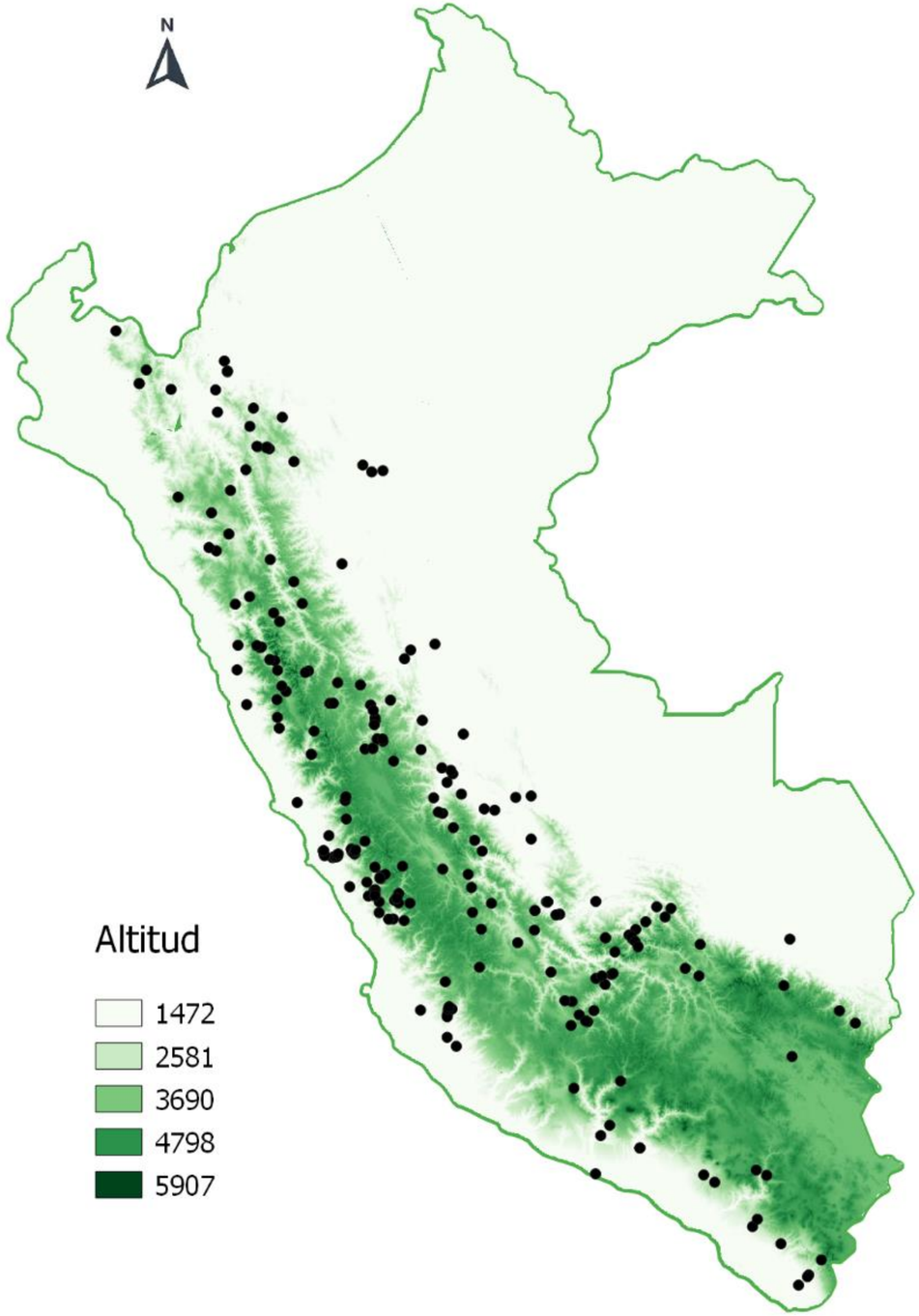
PERSPECTIVES AND FUTURE WORKS

SENAMHI implemented a landslides registration system to get a landslide triggered by rainfall database, with a relevant information.

This database, will be use to:

- adjust and generate new thresholds at regional scale
- calibrate and validate SILVIA

229 events registered to date:
63 events during 2017
42 events during 2018
124 events during 2019



Landslides and huaycos spatial distribution

GRACIAS

DANKE

THANKS

Questions and suggestions are welcome:
cmillan@senamhi.gob.pe