Hazard communication and local perception of lahar risk at Cotopaxi Volcano, Ecuador

By Olivia Cooke (UNIVBRIS), Dr J. Gottsmann (UNIVBRIS), Dr R. Christie (UNIVBRIS) and Dr P. Mothes (IGEPN)

SEVENTH FRAMEWORK PROGRAMME

THE ROYAL SOCIETY

University of BRISTOL

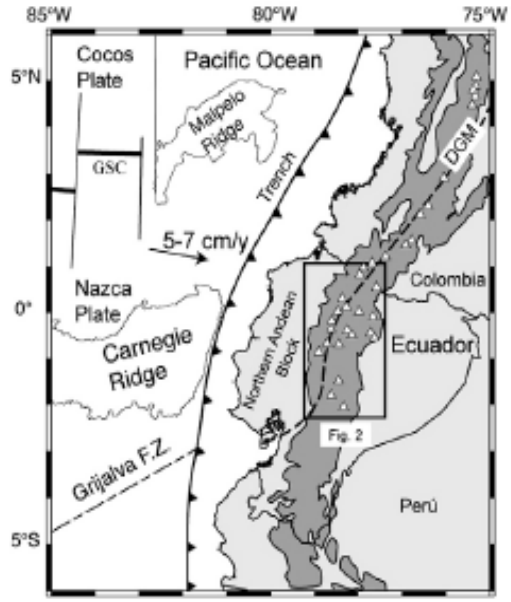
VUELCO

Background

Picture of Cotopaxi taken in July 2012 (Cooke, O., 2012)

- The tectonic of Ecuador setting has resulted in the formation of three volcanic chains in Ecuador: the Western Cordillera, the Eastern Cordillera and the Andean foothills
- Cotopaxi Volcano (5897 metres above sea level) is a stratovolcano located in the Inter-Andean Valley Depression, between the Cordilleras.
- Major explosive events occurred in 1534, 1744, 1768 and 1877 according to historic data and tephra analysis.

Top right- Location of Ecuador in South America (from CIA, 2012)



Bottom right- Tectonic setting of Ecuador (from Hall et al., 2008)

Fig. 1. Geodynamic setting of the Ecuadorian arc at the convergence of the Nazca and South American plates. The Andes are delineated by the 2000 m contour (dark grey) and the main Quaternary volcanoes by small triangles. GSC = Galapagos Spreading Center; DGM= Dolores–Guayaquil Megashear (approximate location). Area of Fig. 2 shown as box.

Hazards from Cotopaxi

TABLE 1. Synthesis of the last 2000 years of Cotopaxi's eruptions, broken down into major periods and the phenomena produced.

Age	Principal Eruptions	Sub-plinian to Plinian Tephra Falls	Pyroclastic Flows	Lahars	Lava Flows	VEI
1880 AD	1	1				2-3
1877	2	1	Yes	many	Yes	4
1853-1854	2	1	Yes	many	1	3-4
1768	1	1	Yes	many	1 ?	4
1766	1	1	Yes	many		3
1744	1	1	Yes	many		4
1743	1	1	Yes	many		3-4
1742	3	2	Yes	2 grps		4
1532-34 AD	2	2	Yes	2 grps	1	3-4
~900 yr. BP	4	3	Yes	many		3-4
1000 yr. BP	2	2	Yes	2 grps		> 4
1180 yr. BP	1	1	Yes	many		3-4
1210 yr. BP	1	1	Yes	2 grps	1	4
1770 yr. BP	1	1	?	many	several	4
1880 yr. BP	1	1	Yes	2 grps	1	> 4
1880 - 2000	1	1	Yes	many		4
~2000 yr. BP	1	1	Yes	?		4
TOTAL	26	22 times	>14 times	>20 times	>7	

A table showing the most recent activity of Cotopaxi (from Mothes et al., 2004)

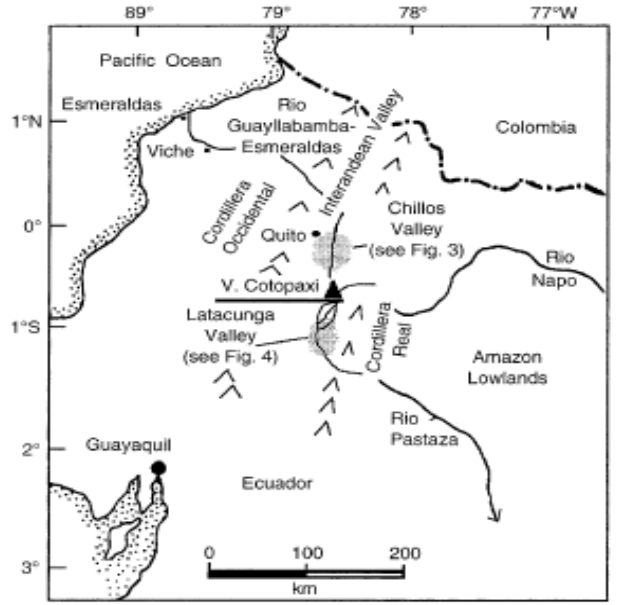


Fig. 2 Partial map of Ecuador showing the Inter-Andean Valley, bordered by the Cordillera Occidental and the Cordillera Oriental, and occupied by Cotopaxi Volcano and the adjacent Chillos and Latacunga valleys. The Río Pita-San Pedro-Guayllabamba-Esmeraldas river system enters the Pacific Ocean near the city of Esmeraldas. The Ríos Napo and Pastaza join the Amazon River downstream

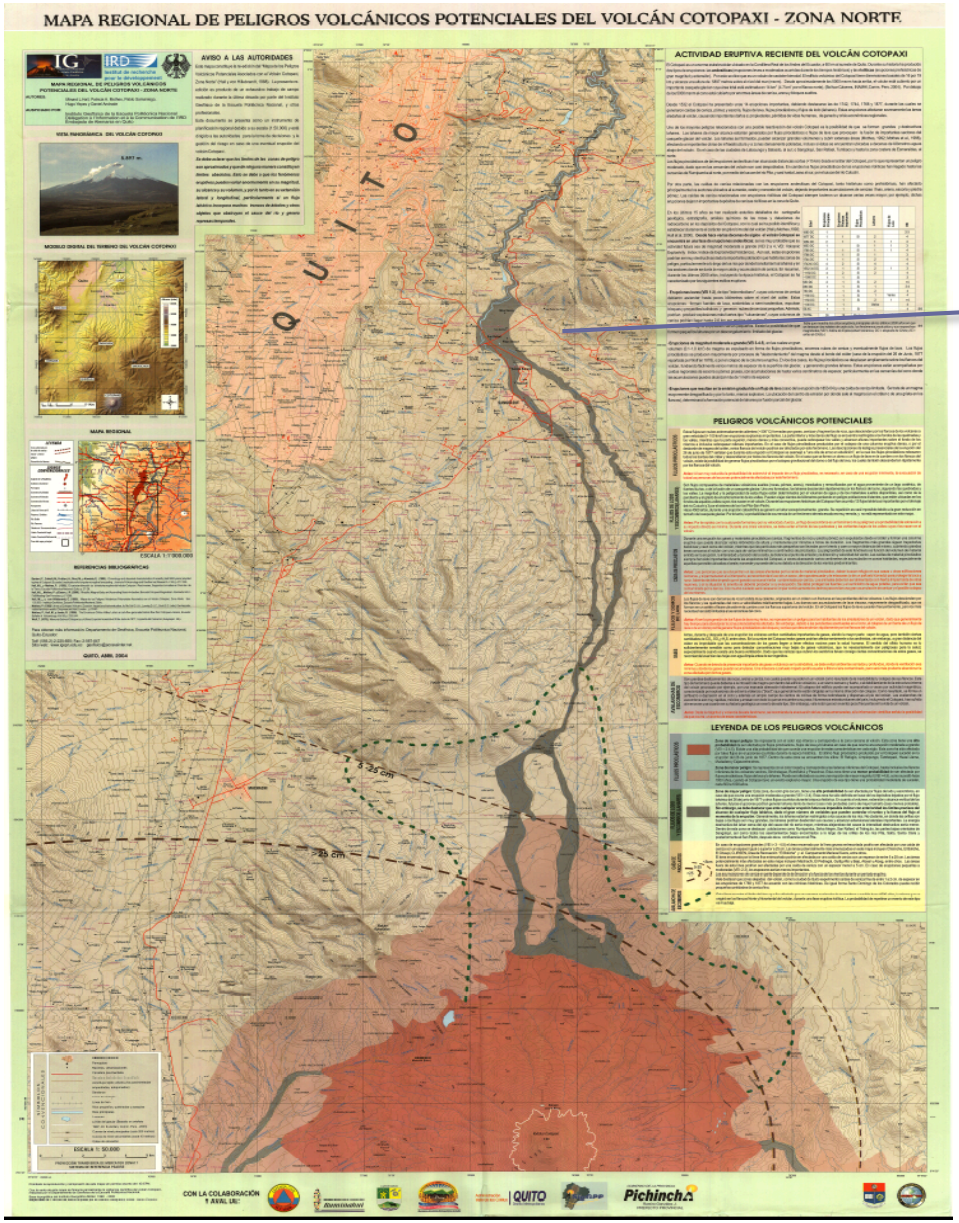
Map of Cotopaxi's drainage system (from Mothes et al., 1998).

- Lahars are a hot or cold mixture of water, unconsolidated volcanic debris and rock fragments
- They can vary in size, from a few to hundreds of metres wide, from several centimetres to tens of metres deep, and speeds up to tens of kilometres per hour
- Lahars are one of the main eruptive and non-eruptive volcanic hazards from glacier-clad Cotopaxi.

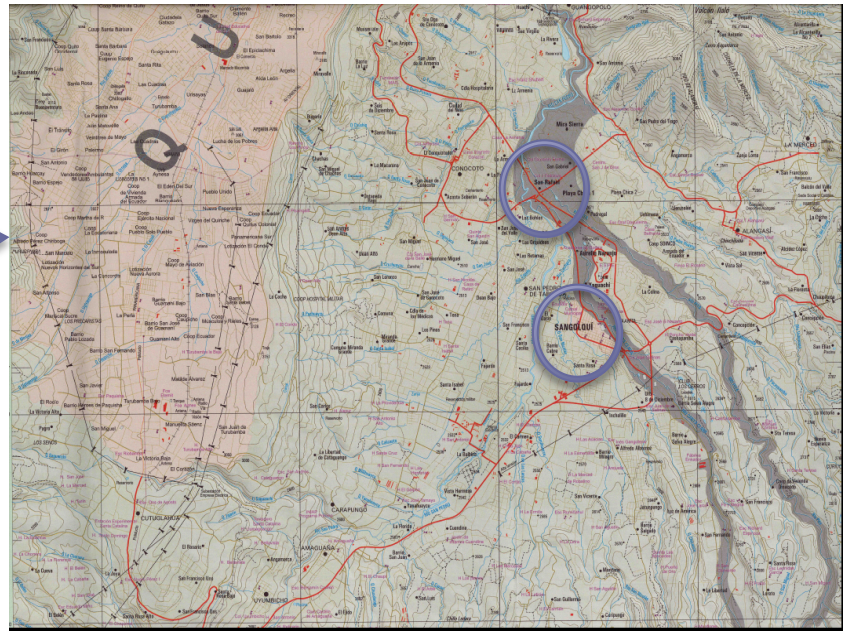
Risk Perception and Hazard Communication

- ‘Risk= Hazard x vulnerability’

- Risk perception can enable the understanding of how a population views officials, and how they will respond to them.
- Communication is vital to peoples perception of the volcanic hazards they face, a lack of understanding can lead to mistrust.
- Communication is important in regards to mitigation of a hazard.



Risk map from IGEPN, 2010



Map showing the location of the study sites, and the lahar risk zones (Hall et al., 2004, IGEPN)

- San Rafael in Municipio del Distrito Metropolitano de Quito
- Sangolqui in Municipal de Rumiñahui.

Aim

To investigate perceptions of lahar risk in the Valle de los Chillos to inform mitigation and communication strategies.

The objectives of this study were to:

- Establish risk of volcanic activity
- Establish the populations perception of risk
- Examine the potential influences on people's perceptions of volcanic risk, in particular, of lahars.
- Investigate the mitigation and communication strategies in place
- Compare and contrast risk, risk perception and the mitigation strategies in place, and examine the subsequent vulnerability.

Methodology

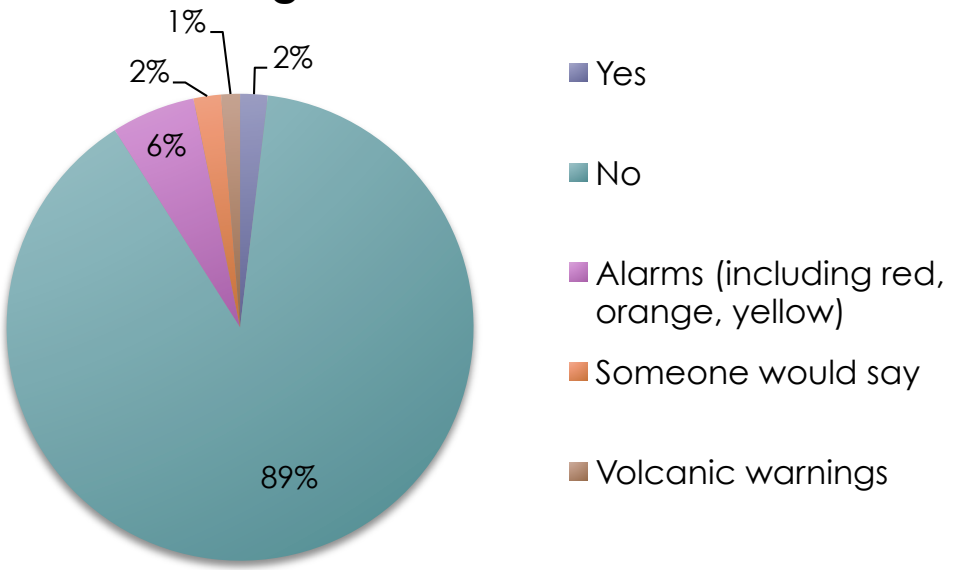
Examples of Questions:

- How likely do you think it is that this village will be affected by a lahar?
- Who would you listen to if they tell you to evacuate? IGEPN or ESPE?
- Have you received any information or been to any workshops on the volcano?
- **158 people were interviewed.** 65.2% of the participants were female, with a mean age of all respondents being 36 years old.

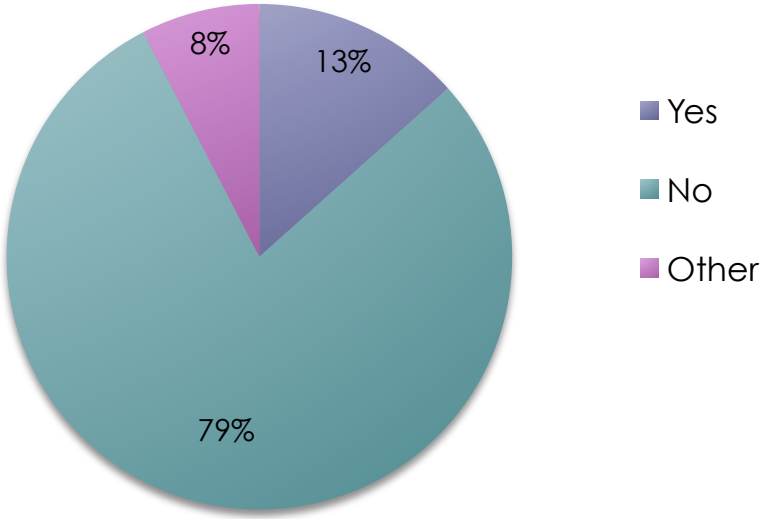
Results

1) Communication Protocols

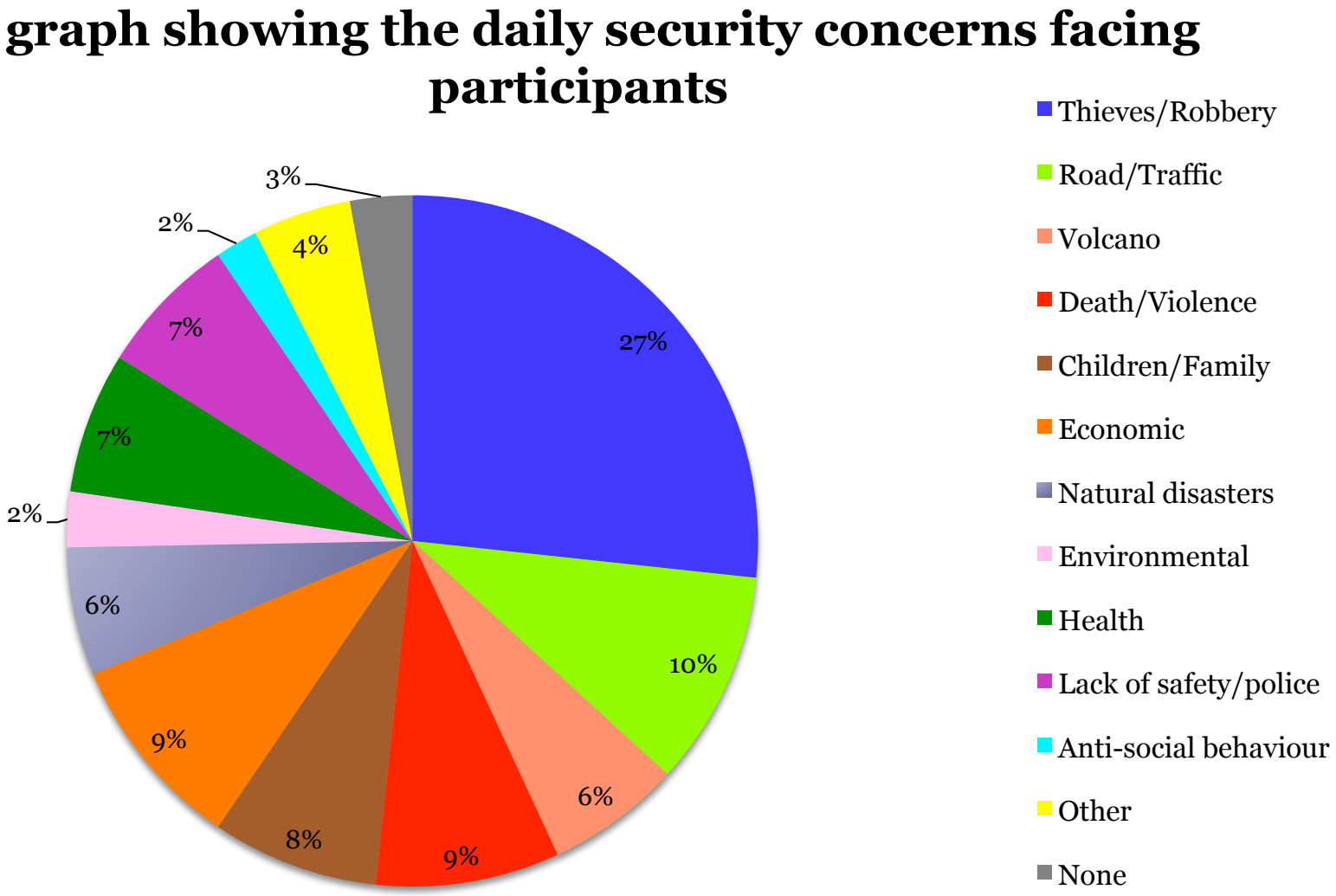
A graph showing the percentage of participants who know the warning signal for a lahar

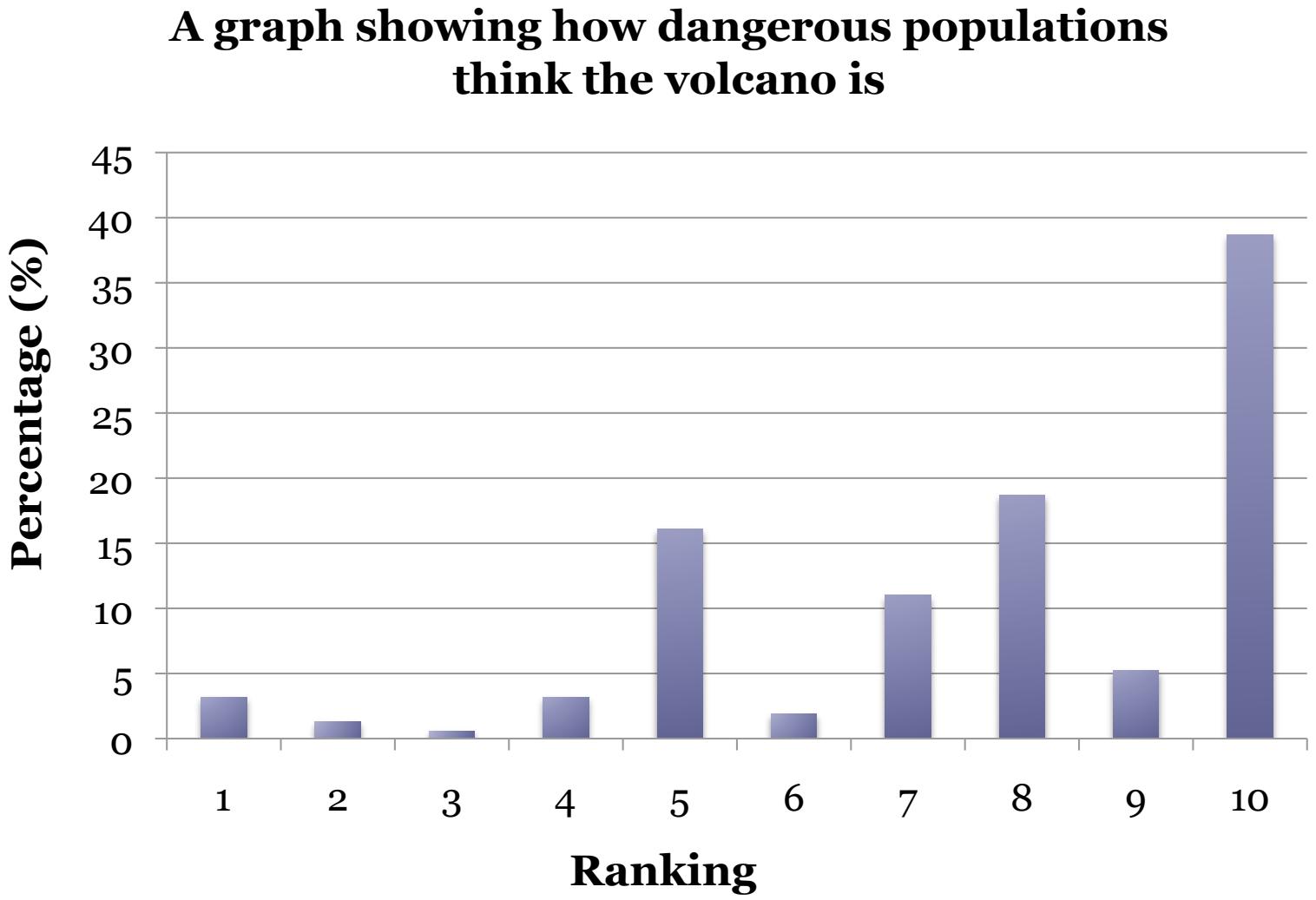


A graph showing whether populations have received information or been to workshops about the volcano

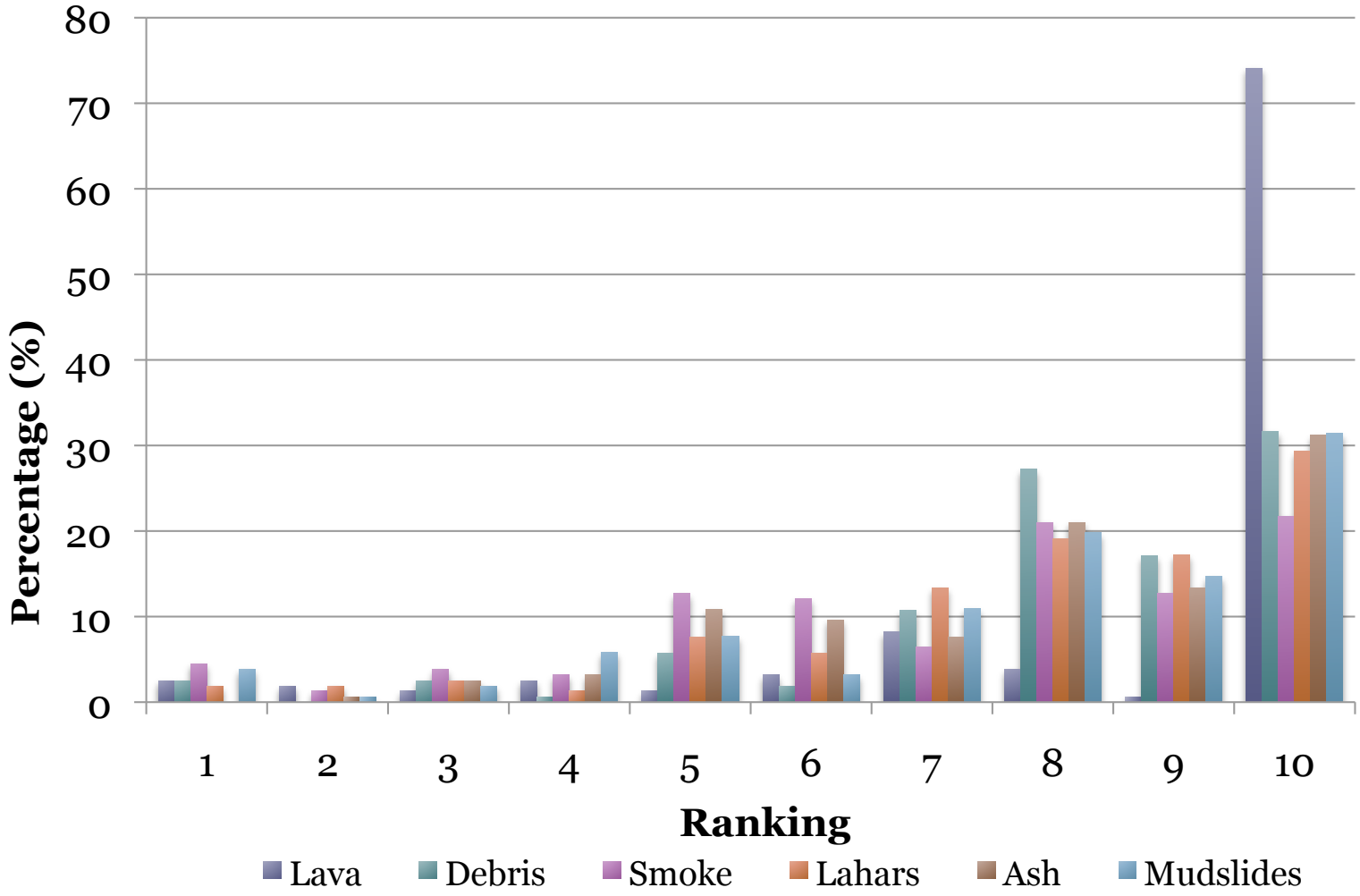


2) Volcanic risk perception in the context of other daily risks

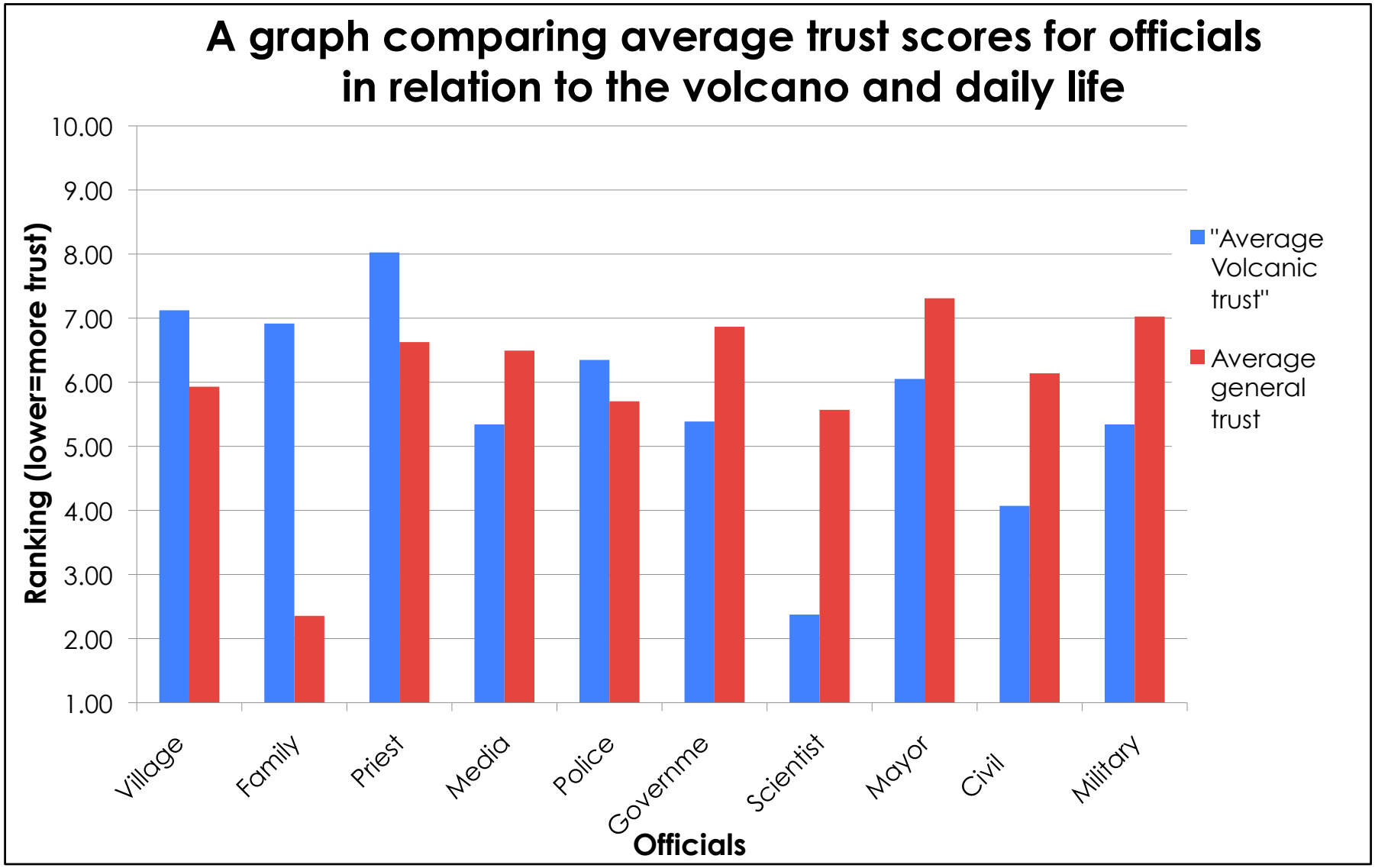



A graph showing how dangerous populations think the volcano is
Percentage (%)
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
Ranking

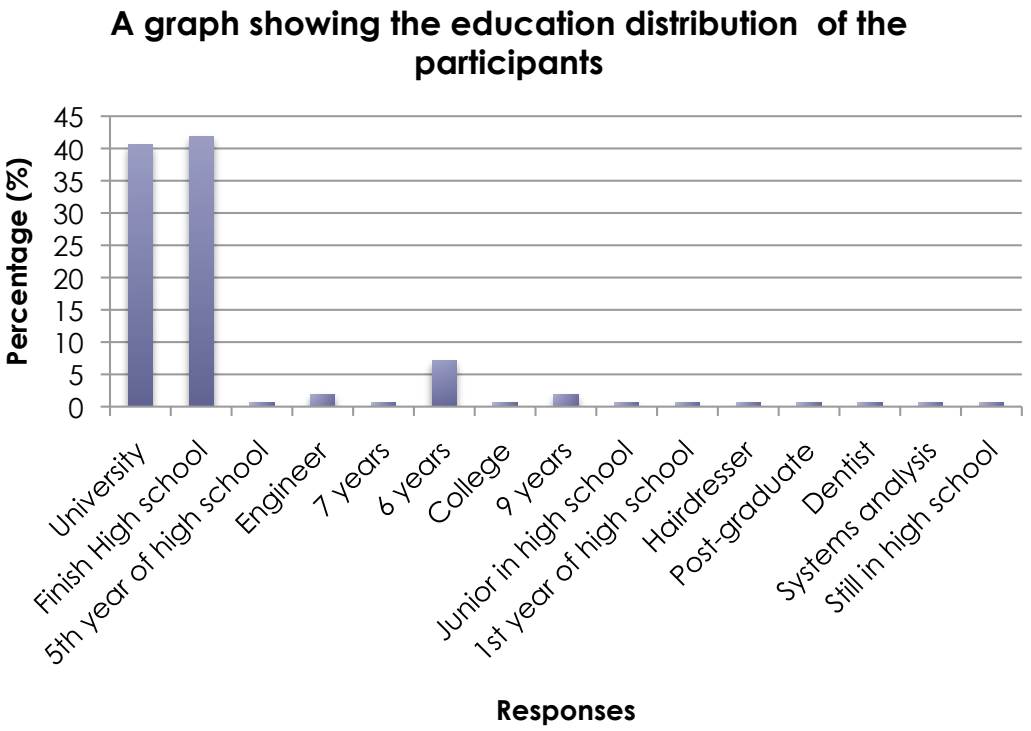
A graph showing how dangerous populations find different volcanic products



3) Trust in scientists vs implementers



4) Effects of demographics



Findings from this study echo previous studies (D'Ercole,1989) that indicated that the wealthier and more educated populations in the Valle de los Chillos were least aware of the lahar risk.

	Frequency	Percentage	Valid Percentage	Cumulative Percentage
Administrator	7	3.7	4	4
Cleaner	3	1.6	1.7	5.7
Cook	2	1.1	1.1	6.8
Driver	3	1.6	1.7	8.5
Business (owner)	50	26.7	28.4	36.9
Housewife	7	3.7	4	40.9
Dressmaker	5	2.7	2.8	43.8
Engineer	4	2.1	2.3	46
Student	9	4.8	5.1	51.1
Secretary	3	1.6	1.7	52.8
Builder	2	1.1	1.1	54
Hairdresser	11	5.9	6.3	60.2
Teacher	3	1.6	1.7	61.9
Shopkeeper	2	1.1	1.1	63.1
Clerk	10	5.3	5.7	68.8
Works in laboratory	1	0.5	0.6	69.3
Works in a shop	6	3.2	3.4	72.7
Operates machinery	1	0.5	0.6	73.3
Chemical engineer	1	0.5	0.6	73.9
Helps priest	1	0.5	0.6	74.4
Retired	1	0.5	0.6	75
Security	2	1.1	1.1	76.1
Maid	1	0.5	0.6	76.7
Salesperson	15	8	0.5	85.2
Unemployed	1	0.5	0.6	85.8
Catholic Priest	1	0.5	0.6	86.4
Musician	1	0.5	0.6	86.9
Owner of spa	1	0.5	0.6	87.5
Bakery	3	1.6	1.7	89.2
Dentist	1	0.5	0.6	89.8
Electromechanics	1	0.5	0.6	90.3
Mechanical Technician	2	1.1	1.1	91.5
Beautician	1	0.5	0.6	92
Designer	1	0.5	0.6	92.6
Fixes watches	1	0.5	0.6	93.2
Makes bags	1	0.5	0.6	93.8
Cosmotology	1	0.5	0.6	94.3
Journalist	1	0.5	0.6	94.9
Travel agent	2	1.1	1.1	96
Plane technician	1	0.5	0.6	96.6
Makes clothes	1	0.5	0.6	97.2
Manicurist	1	0.5	0.6	97.7
Commercial sector	1	0.5	0.6	98.3
Real estate	1	0.5	0.6	98.9
Physiotherapist	1	0.5	0.6	99.4
Military	1	0.5	0.6	100

Discussion

- Risk perception of Cotopaxi in the Valle de los Chillos is relatively low, and the perception of the risk that lahars pose is even lower.

- Need for better information and education on volcanic hazards from Cotopaxi and improved warning mechanisms.

- Trust is important in hazard communication and risk perception.

Conclusions

- The current level of knowledge of lahar risk is inadequate in relation to the actual lahar risk
- This lack of knowledge, hazard communication and education, serves to increase the risk the populations face, and hence endanger lives.
- Scientists need to be more integrated into risk communication.
- Additional education schemes alongside the current ones need to be implemented.

Future work

Interview everyone in San Rafael and Sangolqui to get a better view of risk perception and communication in the area.

To expand the research to other drainage systems around Cotopaxi.

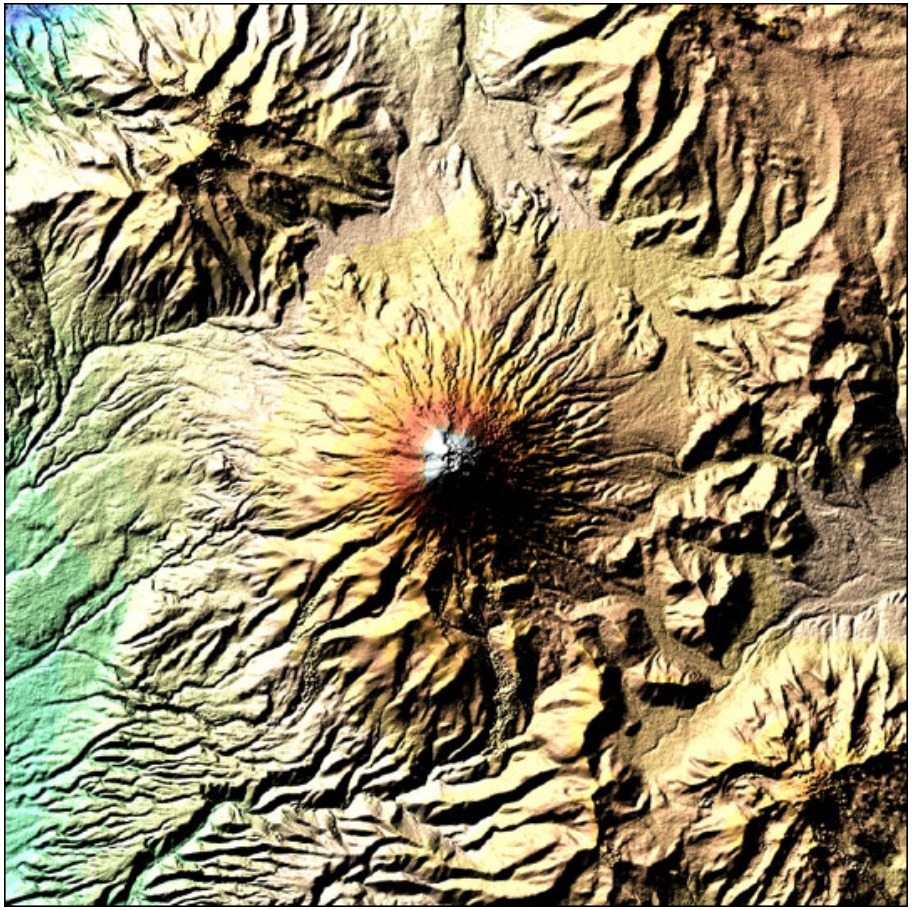
To extend this project to other countries to compare the results

A new risk map should be developed to take account the new infrastructure which has been developed since the previous maps were completed.

Further studies need to be carried out to determine whether the education and mitigation starting to be implemented now is effective.

Hazard communication signs in San Rafael and Sangolqui (Cooke, O., 2012)

Thank you



Left- Lahar channel on the slope at the base of Cotopaxi (Cooke, O., 2012)
Above- Satellite image of Cotopaxi (NASA Earth Observatory, 2000)

References

- CIA (2012) Ecuador. Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/ec.html [Accessed: 1st May 2012]
- D'Ercole R. (1996) – Représentations cartographiques des facteurs de vulnérabilité des populations exposées à une menace volcanique. Application à la région du volcan Cotopaxi (Équateur). *Bulletin de l'Institut Français d'Etudes Andines*, **25** (3) pp.479-507
- Hall, M., Mothes, P, Samaniego, P., Yepes, H. and Andrade, D. (2004) Mapa Regional de Peligros Volcánicos Potenciales del Volcán Cotopaxi-Zona Norte. Escala 1: 50,000 Instituto Geofisico de la Escuela Politécnica Nacional: Quito
- Hall, M. and Mothes, P. (2008) The rhyolitic–andesitic eruptive history of Cotopaxi volcano, Ecuador. *Bulletin of Volcanology* **70** pp.675-702
- IGEPN (2010) Cotopaxi. Mapa de Peligros. Available at: http://www.igepn.edu.ec/index.php/mapas/cotopaxi.html# [Accessed: 26th January 2012]
- Mothes, P., Hall, M. and Janda, R. (1998) The enormous Chillos Valley Lahar: an ash-flow-generated debris flow from Cotopaxi Volcano, Ecuador. *Bulletin of Volcanology* **59** pp. 233–244
- Mothes, P., Hall, M., Andrade, D., Samaniego, P., Pierson, T., Ruiz, A. and Yepes, H. (2004) Character, Stratigraphy and Magnitude of Historical Lahars-Cotopaxi Volcano, Ecuador. *Acta Vulcanologica* **16** (1-2) pp.85-108
- NASA Earth Observatory (2000) Image of Mount Cotopaxi. Available at: http://earthobservatory.nasa.gov/IOTD/view.php?id=1816 [Accessed: 3rd March 2013]