

## Supplementary Information

### **Drivers of crop impacts from tephra fallout: insights from interviews with farming communities around Tungurahua volcano, Ecuador**

Noa Ligo<sup>1</sup>, Alicia Guevara Caiquetan<sup>2</sup>, Pierre Delmelle<sup>1,\*</sup>

<sup>1</sup>Environmental Sciences, Earth and Life Institute, UCLouvain, Croix du sud 2, bte L7.05.10, B-1348 Louvain-la-Neuve, Belgium

<sup>2</sup>Departamento de Metalurgia Extractiva (DEMEX), Escuela Politécnica Nacional, Ladrón de Guevara E11-253, O·Box 17-01-2759, Quito, Ecuador

\*corresponding author

Email: pierre.delmelle@uclouvain.be

Tel.: +32 (0)10 473 686

ORCID ID: 0000-0001-8606-829X

## Spanish version of the structured questionnaire

Encuesta No.:

Encuestador nombre:

Sector:

Coordenadas (GPS):

Nombre del entrevistado:

Edad del entrevistado:

Años dedicados a la agricultura:

Teléfono o referencia:

1. ¿Qué cultivos cultiva actualmente? (Marcar con una X):

Maíz		Manzanas		Otros cultivos (especificar)
Fréjol		Tomate de árbol		
Habas		Mora		
Papas		Duraznos		
Cebolla blanca		Claudia		
Zanahoria		Pastos		

2. ¿En qué meses siembra y en qué meses cosecha los cultivos? ¿Cuánto tiempo (semanas, meses) después de la siembra son más vulnerables los cultivos a la ceniza del volcán Tungurahua?

Cultivo	Meses de siembra	Meses de cosecha	Cuánto tiempo después de la siembra es más vulnerable el cultivo a la ceniza

3. ¿En qué meses aparecen los frutos? ¿En qué meses se cosechan?, ¿En qué meses son más vulnerables los frutos a la ceniza?

Cultivo	Meses en que aparece fruto	Meses en el que se cosecha	En qué meses es más vulnerable el fruto a la acción de la ceniza

4. ¿Cuáles son los cultivos, entre los que usted cultiva, que son más vulnerables a la acción de la ceniza?

5. Antes de las primeras caídas de ceniza (antes de 1999), ¿usted cultivaba otros cultivos?

SI NO

6. ¿En caso afirmativo, cuáles cultivos cultivaba?

7. ¿Qué pasa con los cultivos o con los productos cuando cae la ceniza del volcán Tungurahua?

Cultivo	¿Qué pasa en los cultivos o los productos cuando cae ceniza (hojas, flores, frutos, raíces, etc.)?

8. ¿Qué es lo que usted hace para disminuir los problemas en los cultivos o los productos luego de la caída de ceniza?

Cultivo	Acciones para salvar el cultivo o los productos cuando cae la ceniza

9. Después de la caída de ceniza, ¿usted cree que disminuye la cantidad (quintales) de productos que logra cosechar?

SI NO

10. En caso afirmativo, ¿en cuánto se reduce?

la cuarta parte      la mitad      tres cuartas partes      todo

11. El volcán Tungurahua expulsa ceniza de diferentes tipos:      SI      NO

12. En caso afirmativo, ¿cuáles son las diferencias que ha observado en la ceniza?

el color      el tamaño      la forma

otra diferencia (especificar):

13. La ceniza que afecta más a los cultivos y a los productos es:

la más fina      la más gruesa      la más blanca      la más negra

otro tipo (especificar):

## English version of the structured questionnaire

Interview No. Interviewer name:  
 Village: UTM coordinates (GPS):  
 Interviewee name:  
 Interviewee age: Years in agriculture  
 Phone number or contact details:

1. Which crops do you currently grow? Mark with a X):

Corn		Apple		Other crop (name it)
Frijole		Tamarillo		
Fava bean		Blackberry		
Potato		Pear		
White onion		Greengage		
Carrot		Pasture		

2. Which months do you sow and harvest crops? How long (weeks, months) after sowing are crops most vulnerable to tephra fall from Tungurahua volcano?

Crop	Sowing months	Harvest months	How long after sowing is the crop most vulnerable to tephra?

3. In which months do tree fruits appear? In which months are they harvested? In which months are tree fruits most vulnerable to tephra fall?

Crop	Tree fruit appearance months	Harvest months	Months of greatest vulnerability to tephra

4. Which crops are most vulnerable to tephra fall?

5. Before the first tephra fall event (before 1999), did you grow other crops?

YES NO

6. If yes, which crops did you grow? .....

7. What happens to crops or products after they have received tephra?

Crop	What happens to crops or products after they have received tephra (leaves, flowers, fruits, roots, etc.)?

8. What do you do to reduce tephra impact on crops or products after they have received tephra?

Crop	Actions to salvage crops or product after they have been exposed to tephra

9. After crops were exposed to tephra, do you think the amount (quintals) of product you harvested decreased?

YES                  NO

10. If yes, by how much is it reduced?

one-quarter                  one-half                  three-quarters                  all

11. Tungurahua volcano emits different types of tephra:

YES                  NO

12. If yes, what differences have you observed?

colour                  size                  shape

other difference (specify):

13. Tephra that affects crops and products the most is:

the finest                  the coarsest                  the whitest                  the blackest

other type (specify):

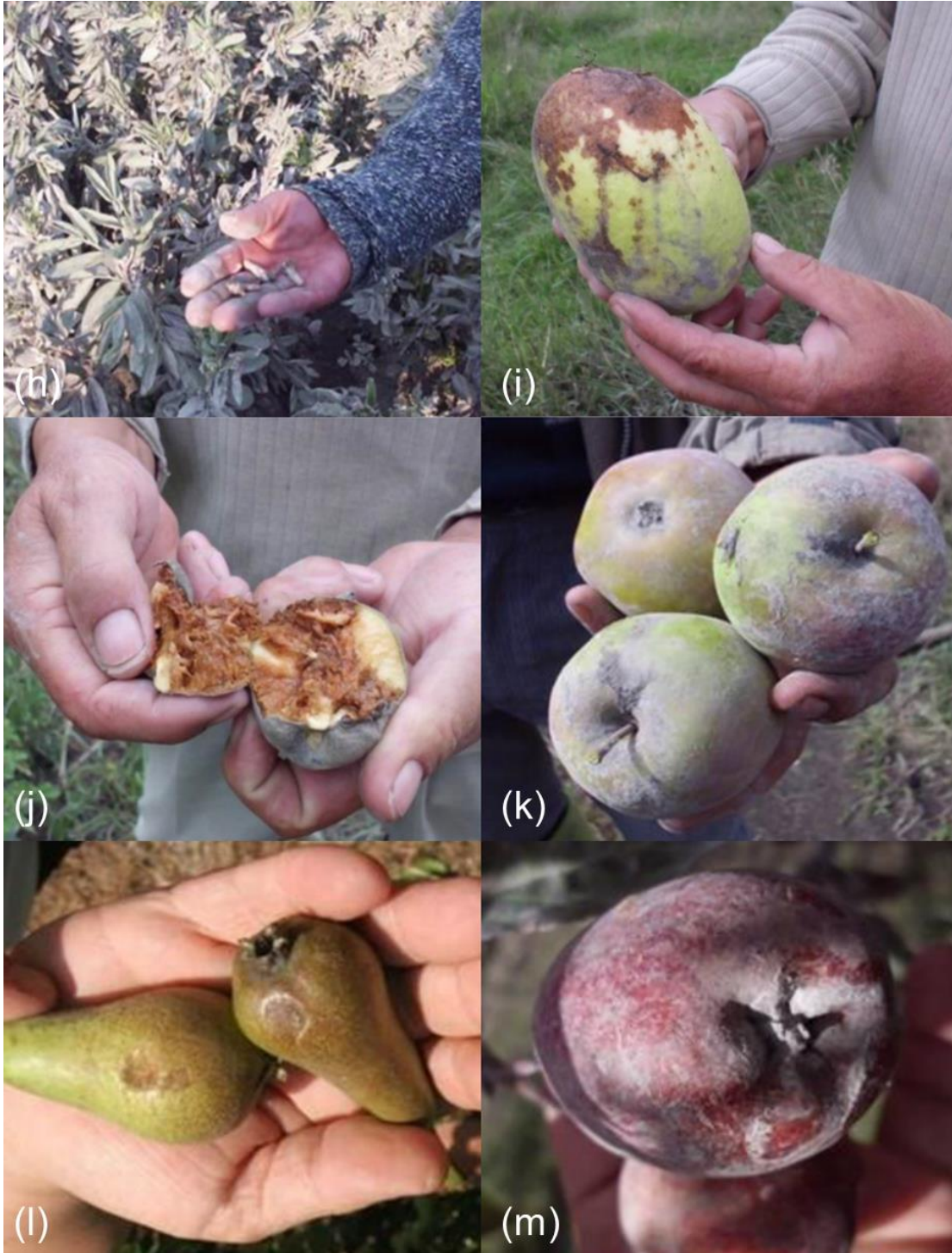
**Table S1** Names, altitudes, geographical coordinates and distances from Tungurahua volcano of the 15 villages surveyed. *N* and *n* are the number of households and farmers interviewed, respectively, in each village.

<b>Village name</b>	<b>Altitude</b> (m a.s.l.)	<b>UTM coordinates<sup>a</sup></b> (Easting) (Northing)		<b>Distance from the volcano</b> (km)	<i>N</i>	<i>n</i>
Juive Grande	1990	782391	9843649	6.0	70	19
Cusúa	2262	779662	9842312	6.3	44	16
Bilbao	2296	777996	9840446	6.6	50	17
Yuibug	2440	777513	9836515	6.8	3	3
El Altar	2469	777292	9830813	9.9	395	24
Puela	2492	777275	9832424	8.8	151	22
Choglontus	2586	777824	9835032	7.0	12	8
El Manzano	2586	777567	9834273	7.7	52	17
Cotaló	2599	776871	9841701	8.2	46	16
Pillate	2680	776014	9839088	8.2	39	15
San José del Chazo	2939	772304	9830659	13.9	38	15
Sabañag	3489	769449	9835570	14.9	42	16
Hualcanga	3496	767847	9838817	16.3	22	12
El Santuario	3507	771367	9839551	12.9	73	19
Santa Fe de Galán	3591	770909	9834940	13.9	166	22
				<i>total</i>	<i>1203</i>	<i>241</i>

a: UTM coordinates (17S) correspond to the centre of the village.



**Figure S1** Photos illustrating tephra-induced damage to various crops in the region affected repeatedly by the explosive eruptions of Tungurahua volcano (1999-2014). potato: tephra retention on foliage (a); frijole: leaf yellowing and drying following exposure to tephra (b); corn: dying plants with dried, yellowy-brown leaves that received tephra during the flowering stage (c); tamarillo: tephra adhering to immature (d) and mature (e) fruits; blackberry: young fruits covered with tephra (f); peach: “burnt” leaves and fruits coated with tephra (g)



**Figure S1 continued** fava bean: plants covered by tephra have pods with a smaller-than normal size (h); black seed sputephra: contact with tephra-covered soil induces putrefaction of the fruit (i); peach: fruit rotting from the inside after exposure to tephra (j); apple: tephra adhering to the fruit skin (k); pear: cleaning with water of the fruits reveals soft brown rotting areas due to exposure to tephra (l); plum: softening of the fruit skin in areas where tephra adheres (m)

**Table S2** Location (village name), distance from Tungurahua volcano and sampling date for the 43 tephra samples analysed for their fine (< 63  $\mu\text{m}$ ) particle content. The measurements were used to create six classes of tephra that differed by their content in fine particles, i.e. < 5, 5-10, 10-20, 20-30, 30-40 and > 40 wt.%. Each tephra class was photographed in order to assemble the chart shown in Figure 4.

Village name	Distance from the volcano (km)	Sampling date
Bilbao	7.4	6 October 1999
Bilbao	7.4	21 July 2000
Bilbao	7.4	10 August 2001
Pillate	8.6	16 September 2001
Chacauco	8.5	17 May 2002
Pillate	8.6	2 October 2002
Pillate	8.6	7 October 2003
Vazcún	8.4	8 November 2003
Pillate	8.6	17 July 2004
El Manzano	8.5	20 April 2006
Mirador	15.3	26 May 2006
Mirador	15.3	24 August 2006
Choglontus	6.6	27 July 2007
Choglontus	6.6	5 August 2007
Santa Fe de	13.2	9 December 2007
Choglontus	6.6	5 February 2008
El Manzano	8.5	6 February 2008
El Manzano	8.5	7 February 2008
Choglontus	6.6	10 February 2008
Santa Fe de Galán	13.2	21 June 2009
Cahuají	9.5	17 February 2010
Cahuají	9.5	28 May 2010
Cahuají	9.5	23 December 2011
Choglontus	6.6	27 December 2011
Retu	3.2	4 February 2012
El Santuario	13.1	10 February 2012
El Manzano	8.5	23 February 2012
El Manzano	8.5	17 May 2012
El Manzano	8.5	23 May 2012
Choglontus	6.6	10 August 2012
Choglontus	6.6	13 August 2012
El Santuario	13.1	23 August 2012
Choglontus	6.6	23 August 2012
Pillate	8.6	24 August 2012
Choglontus	6.6	31 August 2012
Río Verde	25	16 December 2012
Vazcún	8.4	17 December 2012
El Manzano	8.5	20 December 2012
El Manzano	8.5	21 December 2012
El Manzano	8.5	23 December 2012
El Manzano	8.5	17 March 2013
El Manzano	8.5	24 April 2013
El Manzano	8.5	10 May 2013



**Figure S2** Photos illustrating the mitigation measures for tephra impacts on crops deployed by farmers in the region affected repeatedly by the explosive eruptions of Tungurahua volcano (1999-2014). potato: cleaning of tephra-covered foliage with water (a); corn: manual shaking of individual plants to shed off tephra (b); fava bean: manual removal of tephra from individual plants (c); white onion: inspection and manual cleaning of the harvested produce (d); tamarillo: manual shaking with a stick of the tephra-covered leaves (e); pasture: dusting off of tephra deposited on grass by swirling a around a stick (f).