

Tephra fallout probabilistic hazard maps for Cotopaxi and Guagua Pichincha volcanoes (Ecuador) with uncertainty quantification

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Contents of this file

Tables S1 to S3
Figures S1 to S57
Captions for Table S4 to S6

Additional Supporting Information (Files uploaded separately)

Tables S4 to S6

Introduction

This supporting information provides:

- Tables S1 and S2, which collect the raw percentiles for, respectively, eruption type probabilities (for both the next eruption and the next 100 years) and eruption source parameters as derived from the elicitation of Tadini et al. (2021);
- Table S3, which lists all the other parameters (and their uncertainty ranges) used for the simulations;
- Figure S1, which provides an example of wind directions and intensities for the whole meteorological dataset divided per month above Cotopaxi volcano at a specific pressure level;
- Figure S2, which indicates the locations of the stratigraphic sections and the calculated values of deposit density for Guagua Pichincha volcano;
- Figures S3 to S57 which collect the probabilistic maps, the isopach maps and the hazard curves related to single eruption types of, respectively, Cotopaxi (S3-S39) and Guagua Pichincha (S40-S57) volcanoes. Such maps and curves should be used in conjunction with their probability of occurrences within the next 100 years, which are reported in Fig. 2 of the main document. For each thickness value/probability value, three maps are provided (“Lower”, “Natural” and “Upper”), reflecting the model uncertainty discussed in the main document. Each contour of the maps is in % (for probabilistic maps) or in mm (for isopach maps).;
- Caption for Table S4, which reports all the exceeding probabilities for the 10 sensitive sites within Quito.

TABLES

Volcano	Variable	% - 5 th /Median/95 th		
Cotopaxi	<i>sub-Plinian Rhyolitic (NE)</i>	< 0.1	3.7	19
	<i>Plinian Rhyolitic (NE)</i>	< 0.1	2.7	15
	<i>sub-Plinian Andesitic (NE)</i>	0.4	9.5	33
	<i>Plinian Andesitic (NE)</i>	< 0.1	4.2	23
	<i>sub-Plinian Rhyolitic (N100)</i>	< 0.1	7.3	40
	<i>Plinian Rhyolitic (N100)</i>	< 0.1	6.7	41
	<i>sub-Plinian Andesitic (N100)</i>	< 0.1	28	75
	<i>Plinian Andesitic (N100)</i>	< 0.1	14	43
Guagua Pichincha	<i>sub-Plinian (NE)</i>	1.8	18	55
	<i>Plinian (NE)</i>	0.3	9.9	46
	<i>sub-Plinian (N100)</i>	2.1	25	63
	<i>Plinian (N100)</i>	1.0	17	66

Table S1. 5th, Median and 95th percentiles for eruption type occurrences for the next eruption (NE) and next 100 years (N100) time frames for all eruption types (Tadini et al., 2021).

Volcano	Variable	5th/Median/95th		
Cotopaxi	<i>Mean duration sub-Plinian Rhyolitic (minutes)</i>	15	170	6300
	<i>Total mass tephra sub-Plinian Rhyolitic (10⁹ kg)</i>	2.4	53	760
	<i>Average plume height sub-Plinian Rhyolitic (km)</i>	5.6	16	25
	<i>Mean duration Plinian Rhyolitic (minutes)</i>	27	340	13000
	<i>Total mass tephra Plinian Rhyolitic (10⁹ kg)</i>	8.8	410	7600
	<i>Average plume height Plinian Rhyolitic (km)</i>	10	24	40
	<i>Mean duration sub-Plinian Andesitic (minutes)</i>	9	75	9400
	<i>Total mass tephra sub-Plinian Andesitic (10⁹ kg)</i>	1.2	34	430
	<i>Average plume height sub-Plinian Andesitic (km)</i>	6.6	18	25
	<i>Mean duration Plinian Andesitic (minutes)</i>	11	180	19000
	<i>Total mass tephra Plinian Andesitic (10⁹ kg)</i>	11	220	4200
	<i>Average plume height Plinian Andesitic (km)</i>	13	25	35
Guagua Pichincha	<i>Mean duration sub-Plinian (minutes)</i>	9	88	6400
	<i>Total mass tephra sub-Plinian (10⁹ kg)</i>	0.4	28	660
	<i>Average plume height sub-Plinian (km)</i>	6.9	17	25
	<i>Mean duration Plinian (minutes)</i>	11	190	13000
	<i>Total mass tephra Plinian (10⁹ kg)</i>	1.6	170	3600
	<i>Average plume height Plinian (km)</i>	13	24	34

Table S2. 5th, Median and 95th percentiles for eruption source parameters (mean duration, total fallout mass and average plume height) for all eruption types (Tadini et al., 2021).

Volcano	Magma type	Parameters								
		Magma density (kg/m ³)	Magma water mass fraction (%)	Magma viscosity (Pa*s)	Particle density				Particle shape factor	Deposit density (kg/m ³)
					Φ_1	ρ_1	Φ_2	ρ_2		
Cotopaxi	<i>Rhyolitic</i>	2110	6 / 8	3.3 / 7.3	-4 / -1	440 / 500	5 / 7	2300 / 2670	0.6 / 0.7	560
	<i>Andesitic</i>	2340	5 / 6	2.8 / 7.9	-1	1000 / 1487	2 / 7	2478 / 2561	0.7 / 0.8	825
Guagua Pichincha	<i>Dacitic</i>	2220	5 / 6	4.6 / 6.9	-4 / -1	665 / 993	7	2400	0.7 / 0.8	745

Table S3. List of parameters (with their uncertainty ranges) used for the simulations for each eruption type.

Captions for Table S4 to S6

Table S4. Calculated exceeding probabilities for each thickness threshold (1, 3, 10, 30, 100 and 300 mm) for all the 10 sensitive sites within Quito and for the merged sub-Plinian and Plinian eruptions for both Cotopaxi and Guagua Pichincha volcanoes.

Table S5. Calculated exceeding probabilities for each thickness threshold (1, 3, 10, 30, 100 and 300 mm) for all the 10 sensitive sites within Quito and for all the eruption types of Cotopaxi volcano.

Table S6. Calculated exceeding probabilities for each thickness threshold (1, 3, 10, 30, 100 and 300 mm) for all the 10 sensitive sites within Quito and for all the eruption types of Guagua Pichincha volcano.

FIGURES

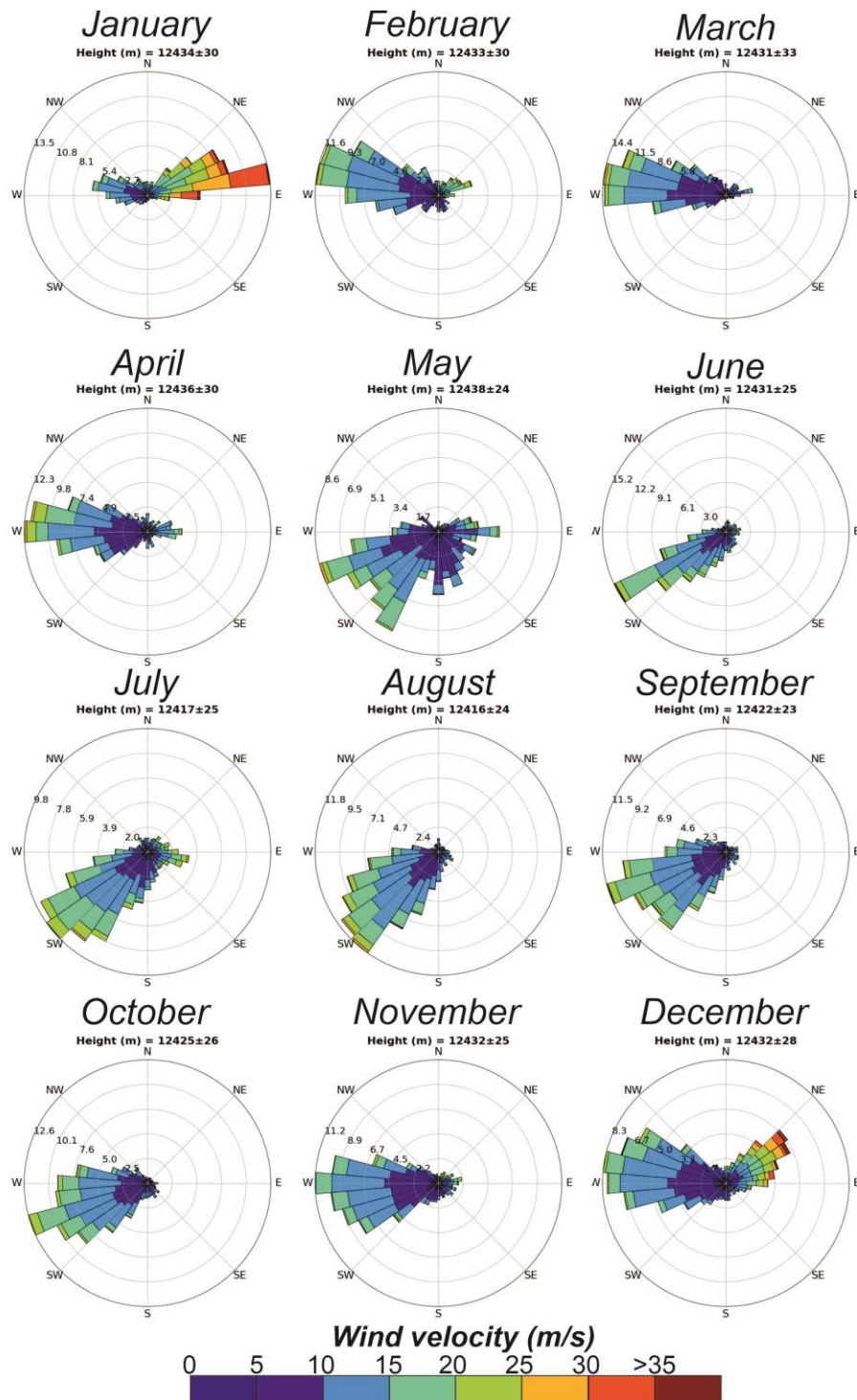


Figure S1. Wind directions and speeds for the whole GDAS dataset and for each month at the pressure level of 200 hPa (heights provided are average values \pm standard deviations) above Cotopaxi volcano. Numbers on concentric circles are percentages.

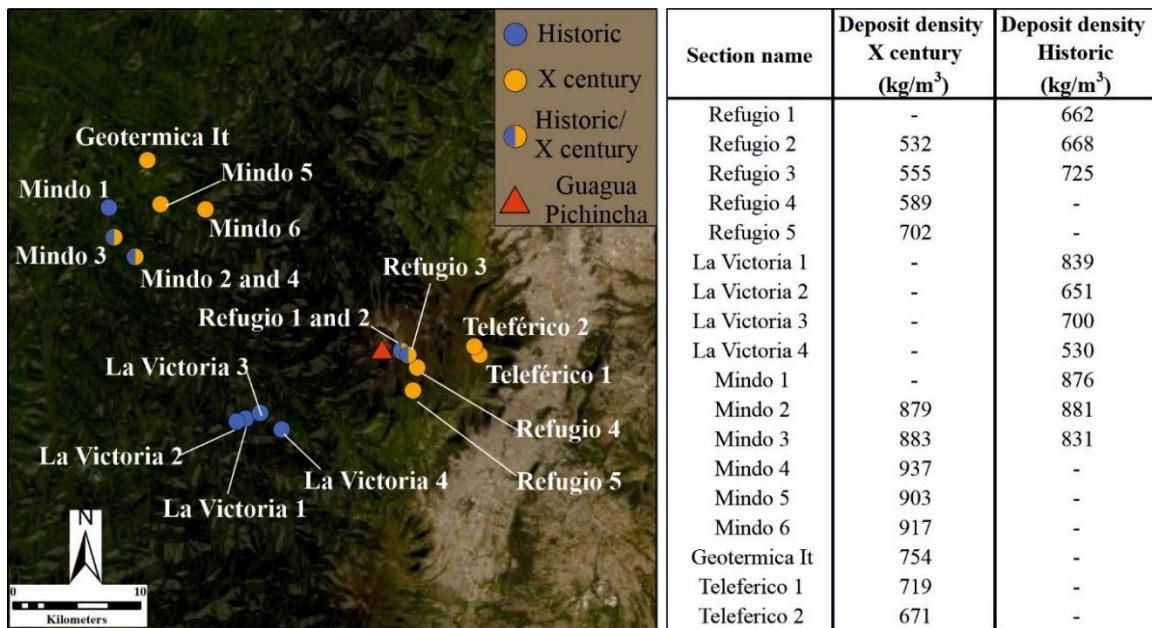


Figure S2. Sample location and calculated deposit densities for both the X century and the Historic eruption cycles of Guagua Pichincha volcano. Service Layer Credits, source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN and the GIS User Community.

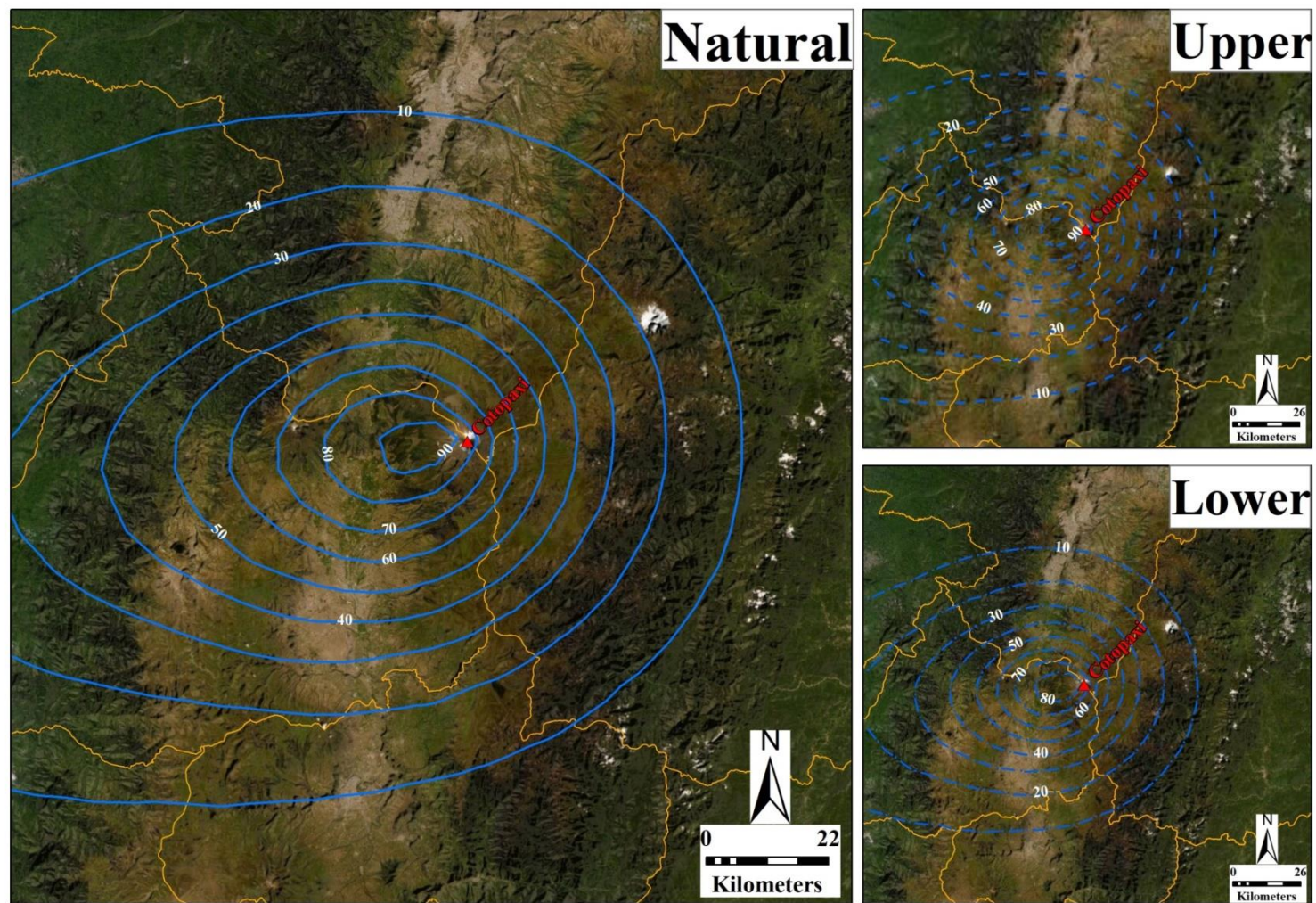


Figure S3. Cotopaxi volcano, sub-Plinian rhyolitic eruption – Probabilistic map (1 mm)

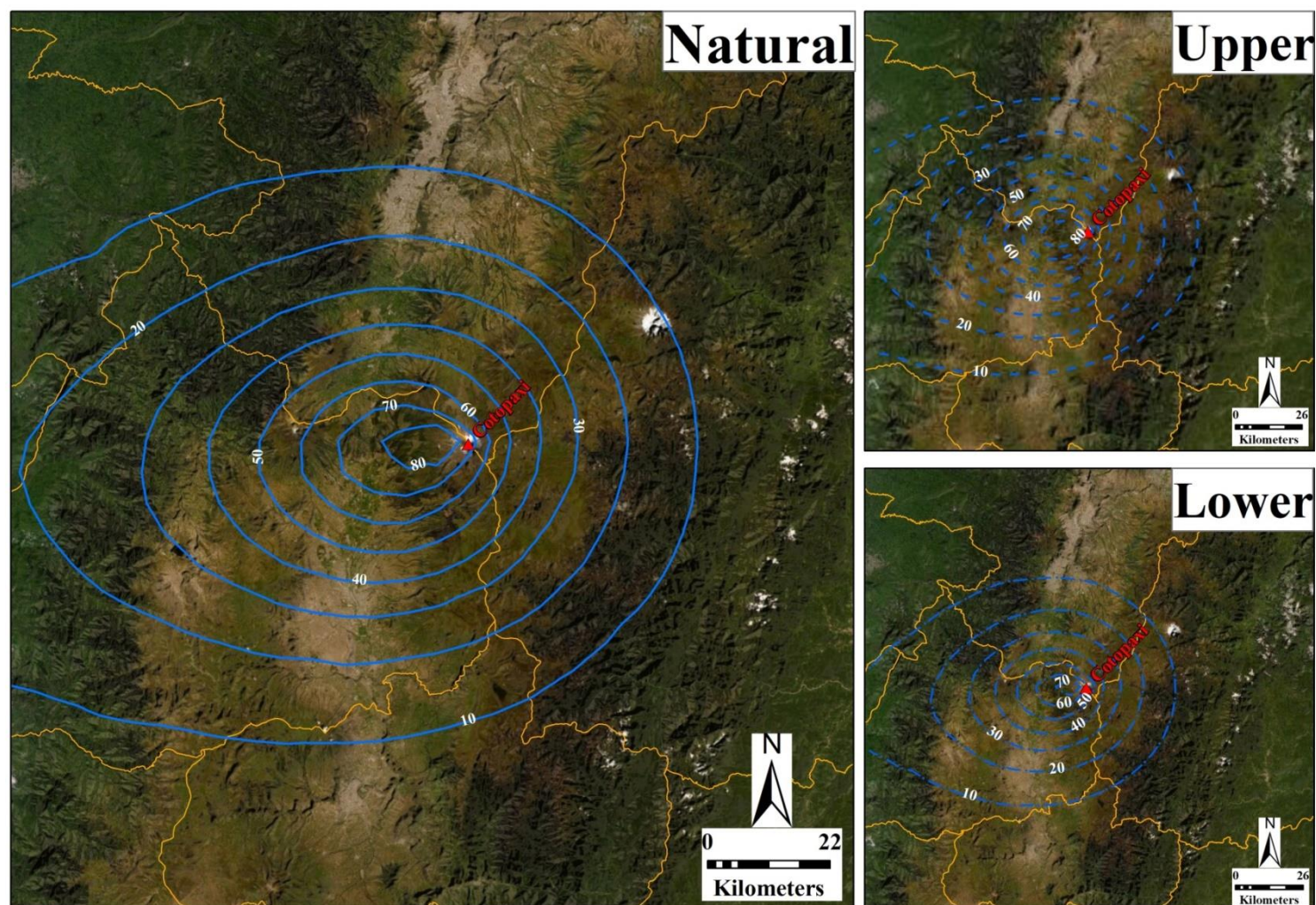


Figure S4. Cotopaxi volcano, sub-Plinian rhyolitic eruption – Probabilistic map (3 mm)

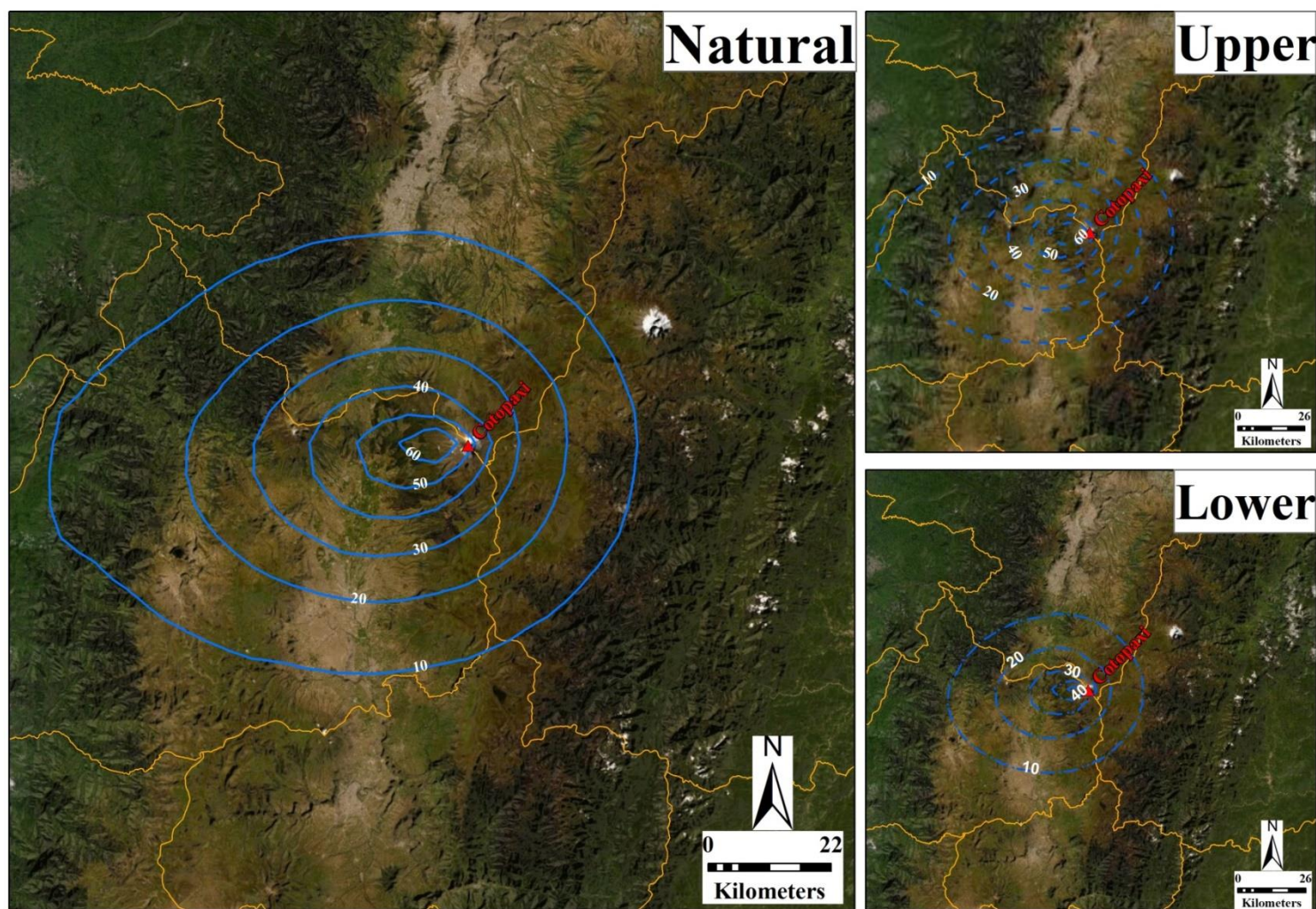


Figure S5. Cotopaxi volcano, sub-Plinian rhyolitic eruption – Probabilistic map (10 mm)

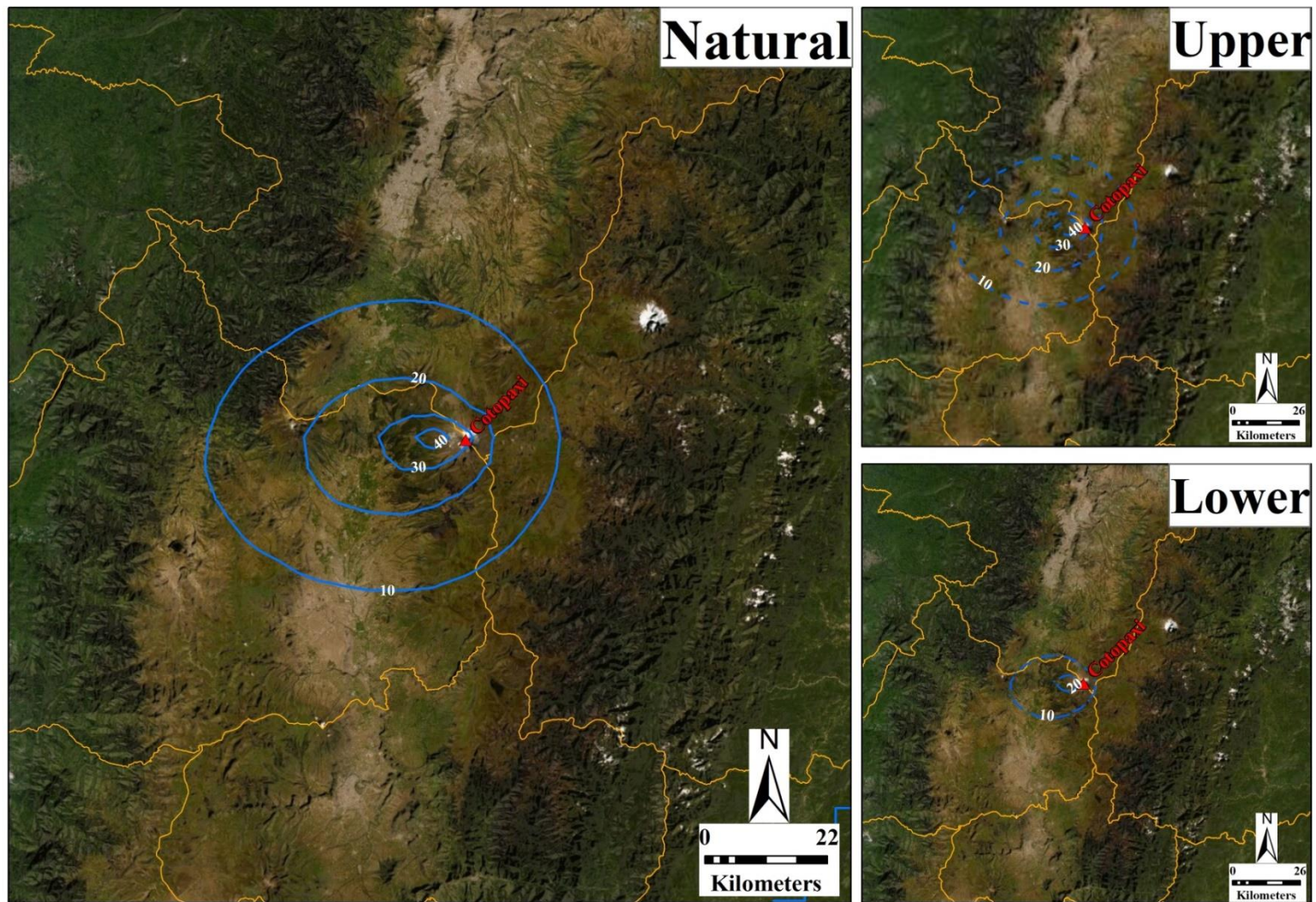


Figure S6. Cotopaxi volcano, sub-Plinian rhyolitic eruption – Probabilistic map (30 mm)

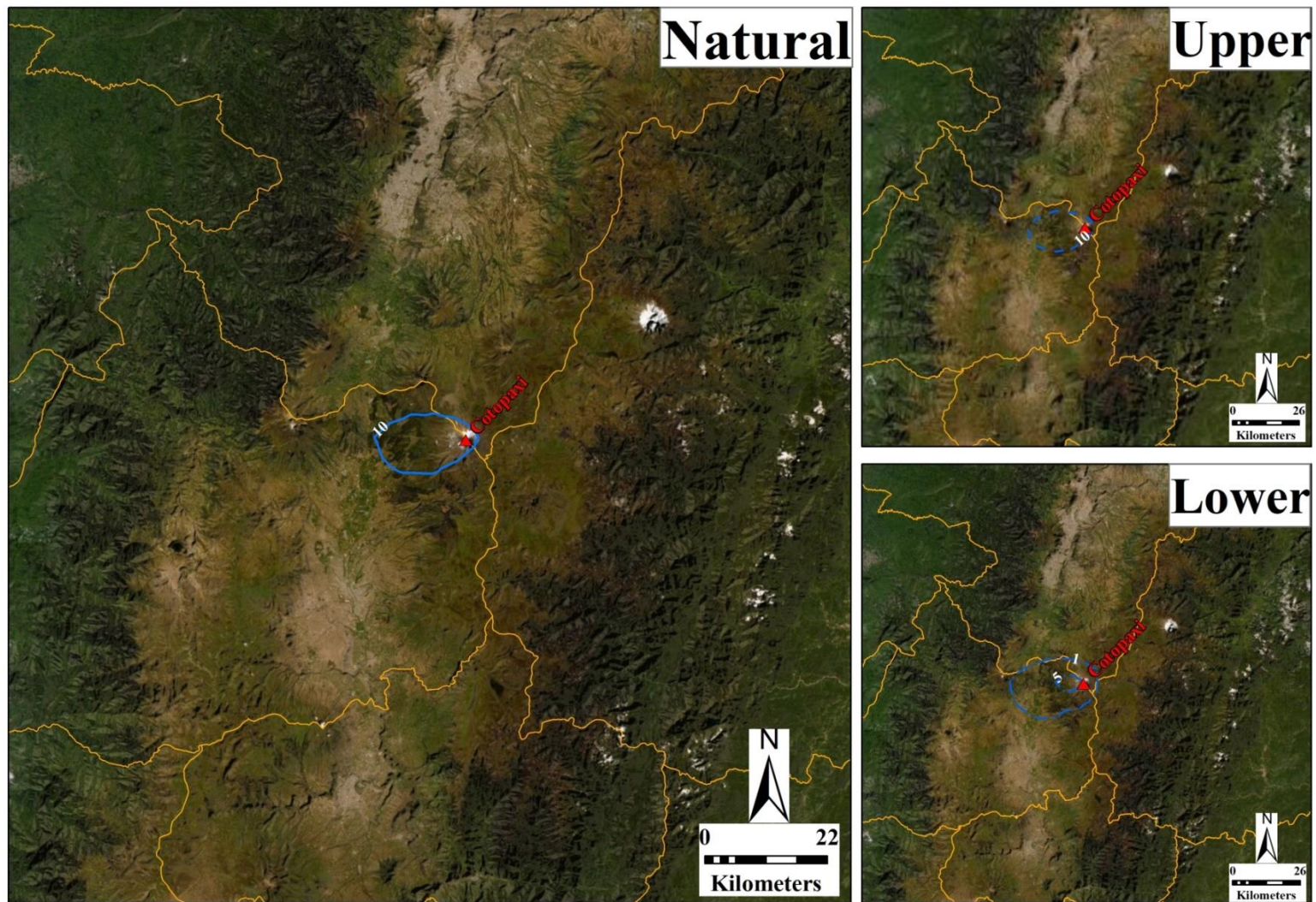


Figure S7. Cotopaxi volcano, sub-Plinian rhyolitic eruption – Probabilistic map (100 mm)

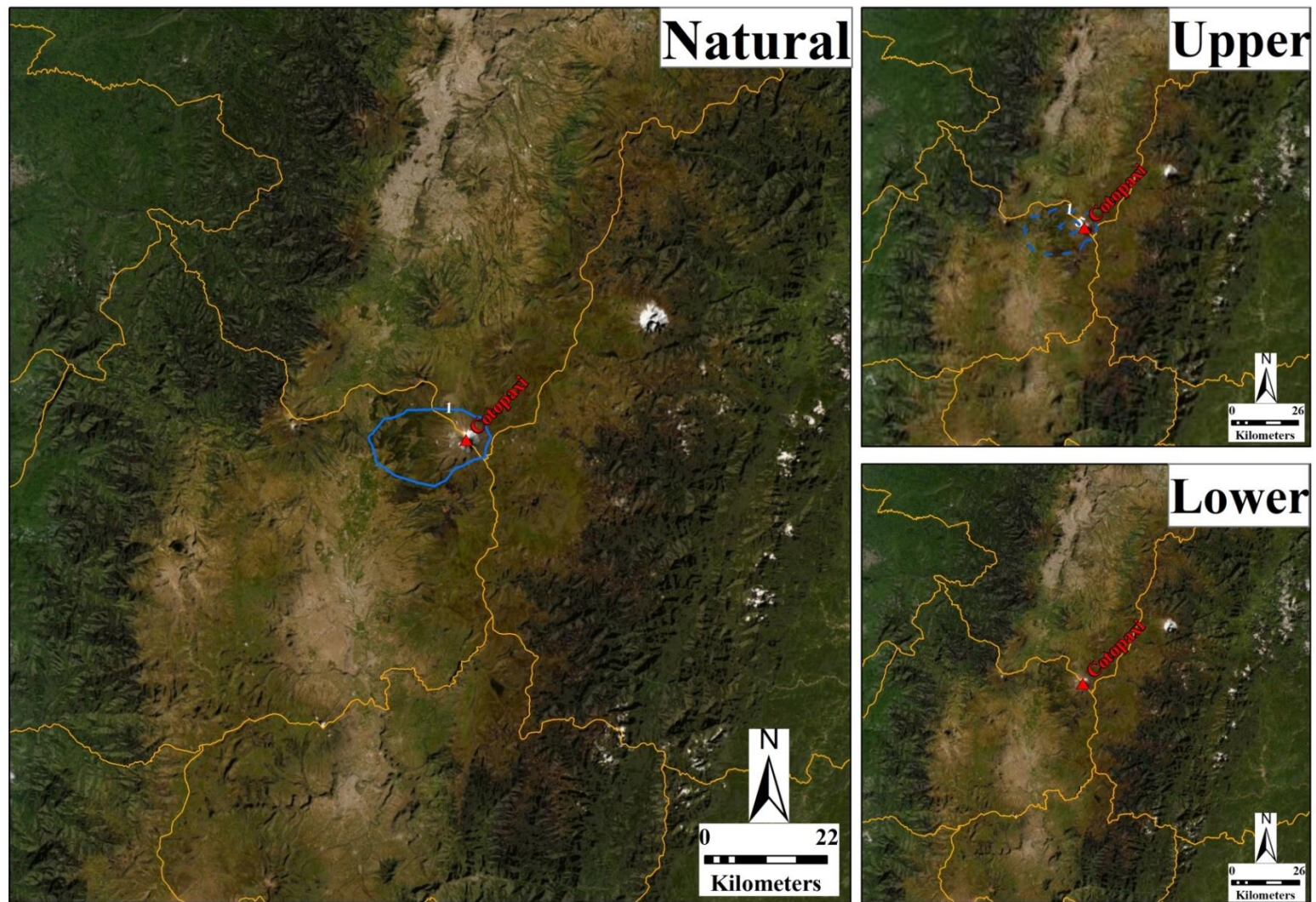


Figure S8. Cotopaxi volcano, sub-Plinian rhyolitic eruption – Probabilistic map (300 mm)

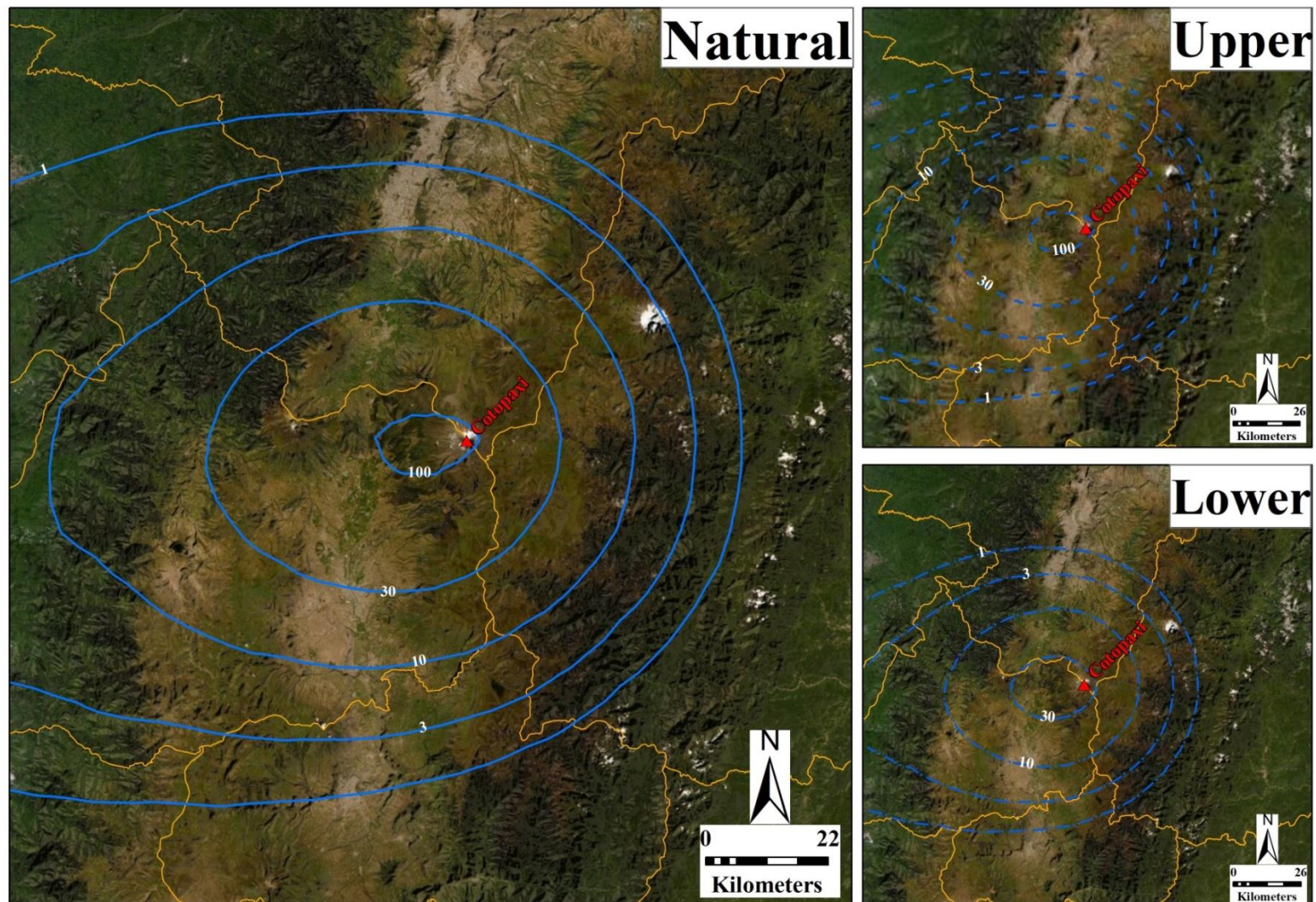


Figure S9. Cotopaxi volcano, sub-Plinian rhyolitic eruption – Isopach map (10 %)

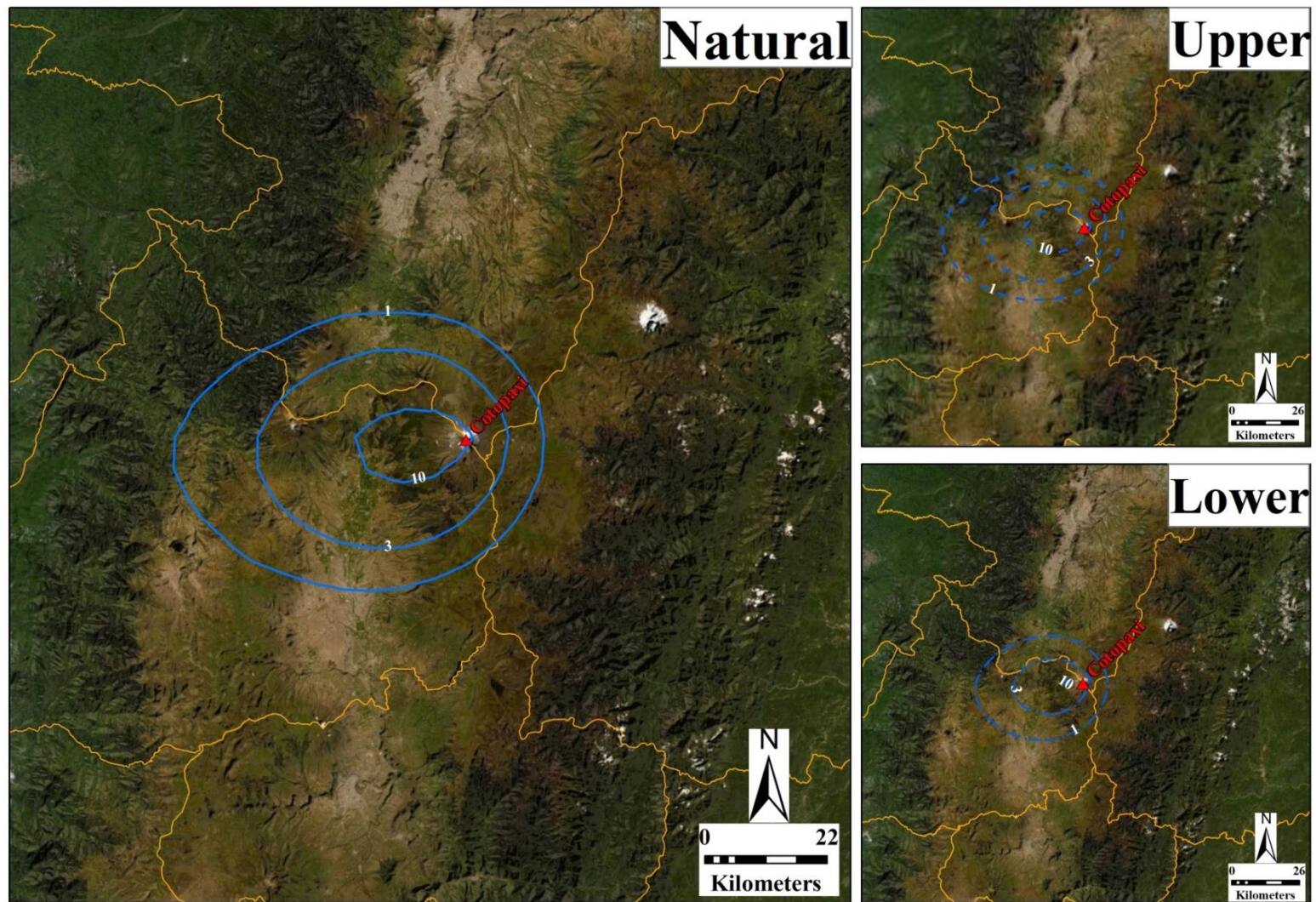


Figure S10. Cotopaxi volcano, sub-Plinian rhyolitic eruption – Isopach map (50 %)

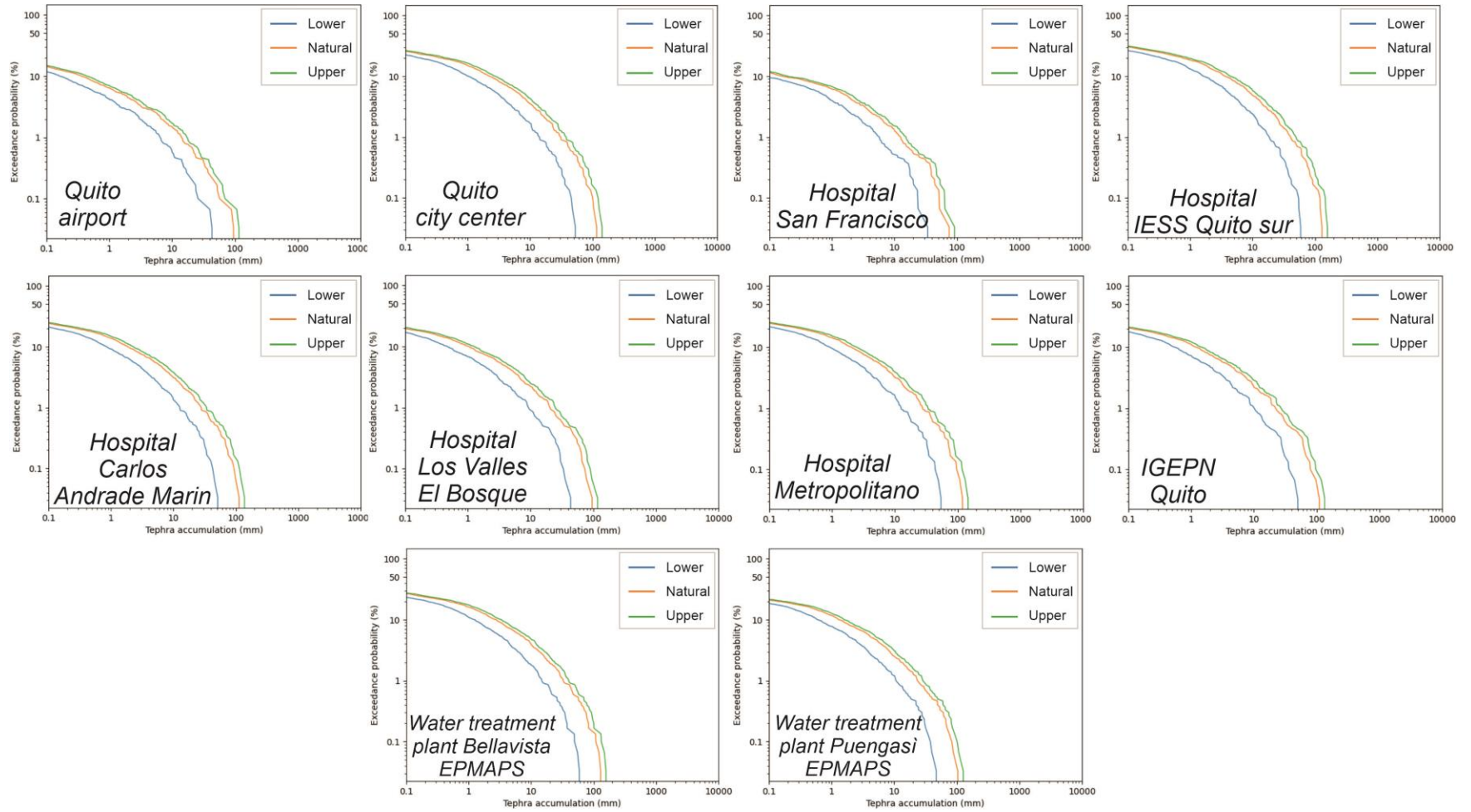


Figure S11. Cotopaxi volcano, sub-Plinian rhyolitic eruption – Hazard curves

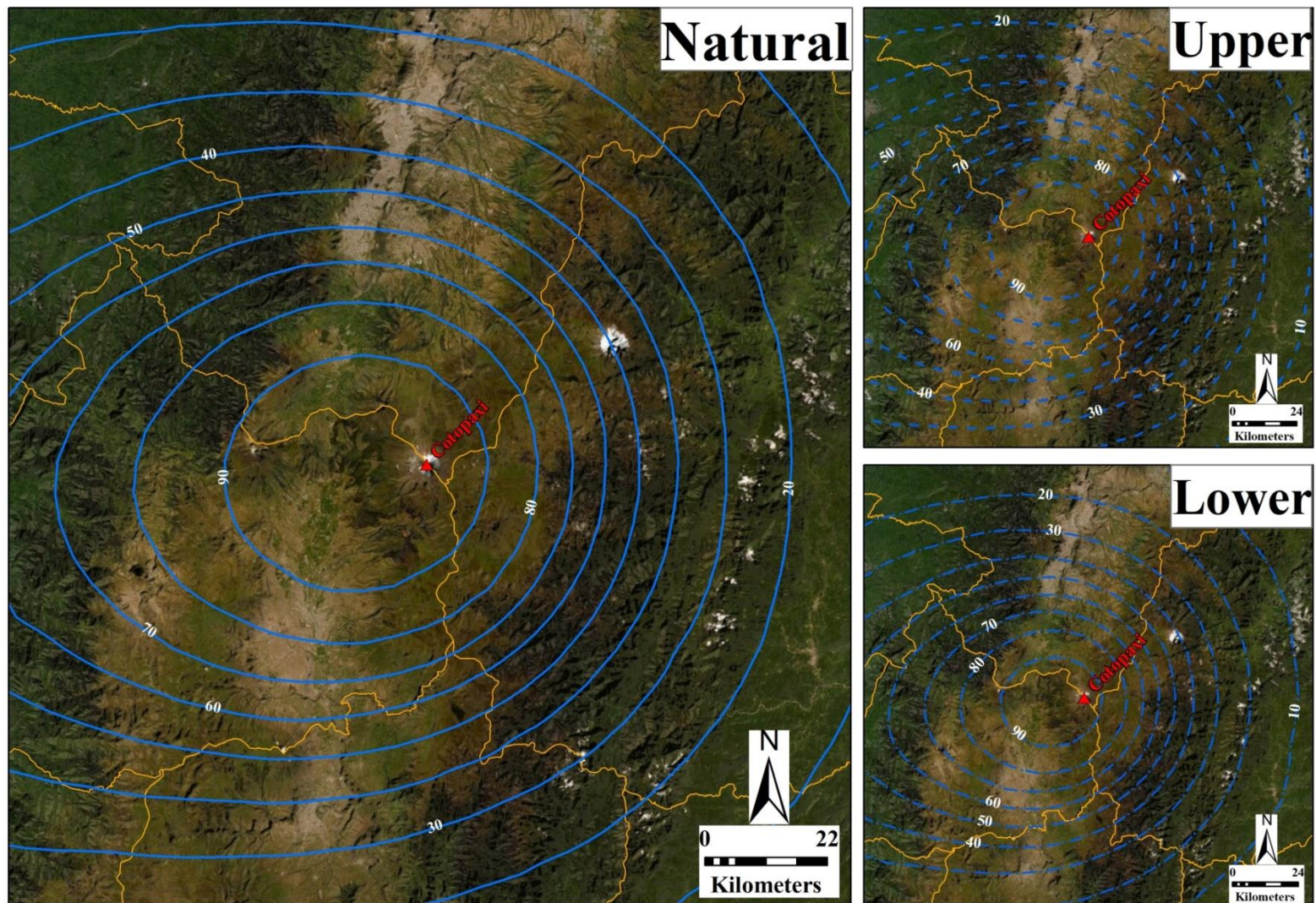


Figure S12. Cotopaxi volcano, Plinian rhyolitic eruption – Probabilistic map (1 mm)

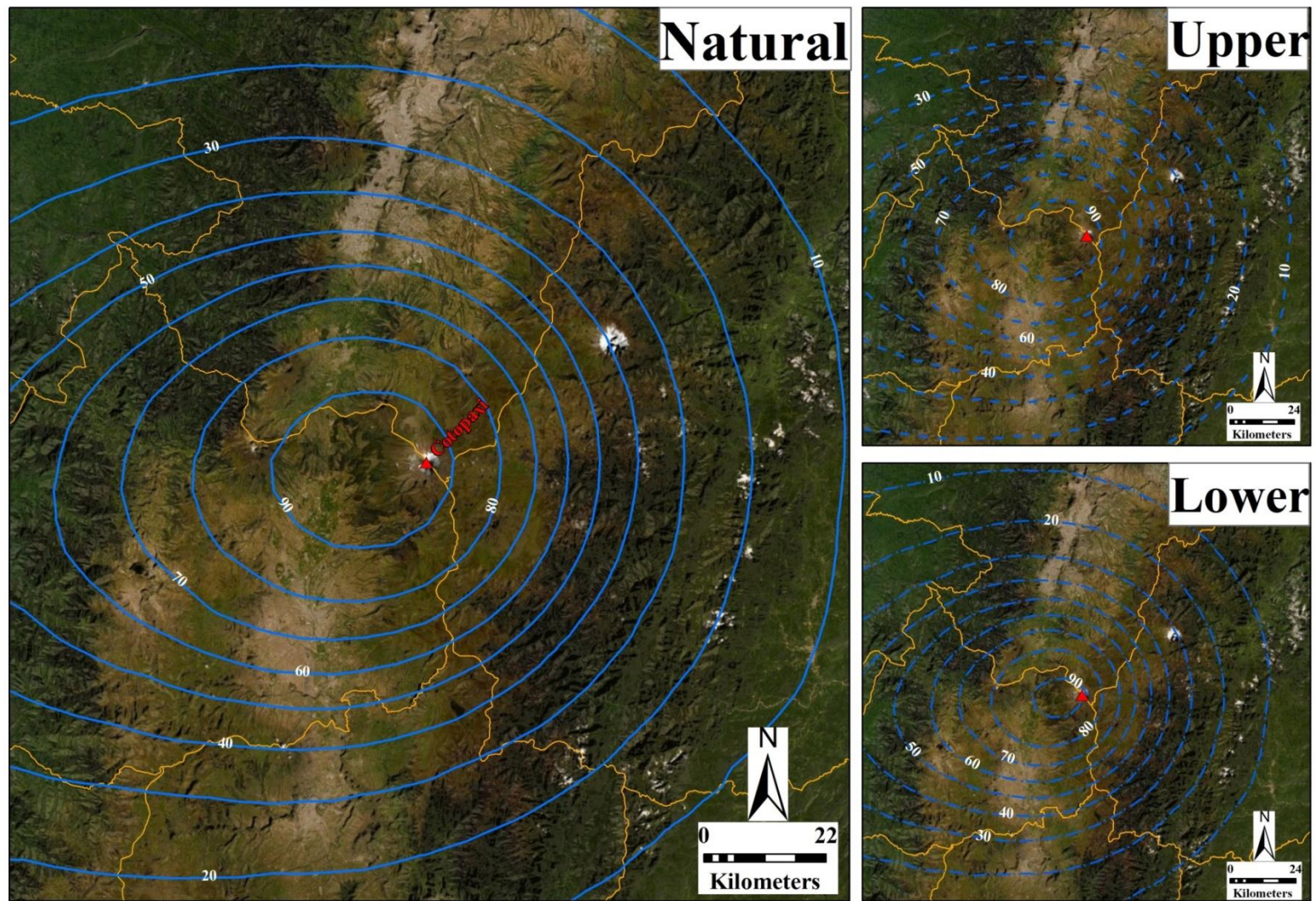


Figure S13. Cotopaxi volcano, Plinian rhyolitic eruption – Probabilistic map (3 mm)

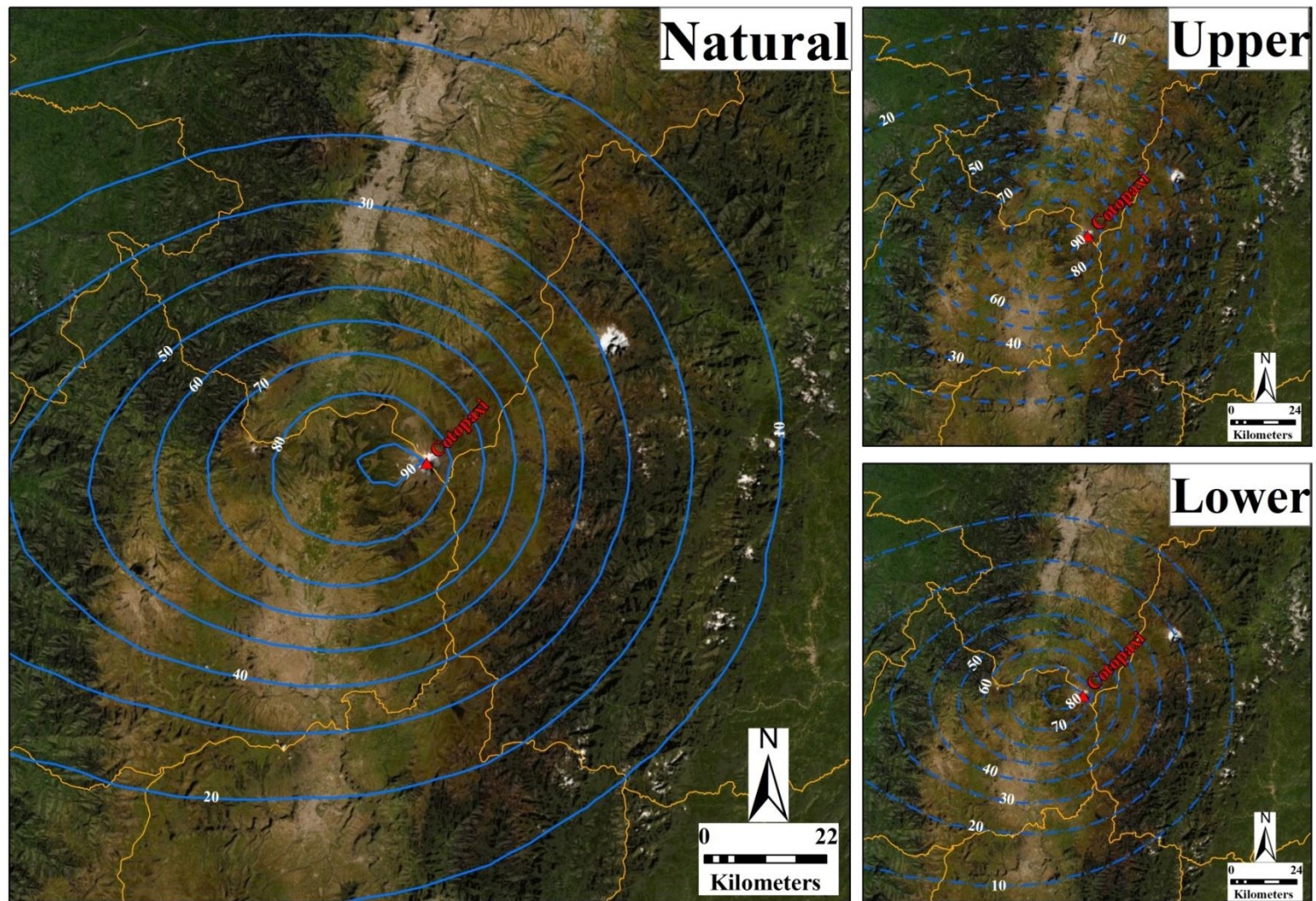


Figure S14. Cotopaxi volcano, Plinian rhyolitic eruption – Probabilistic map (10 mm)

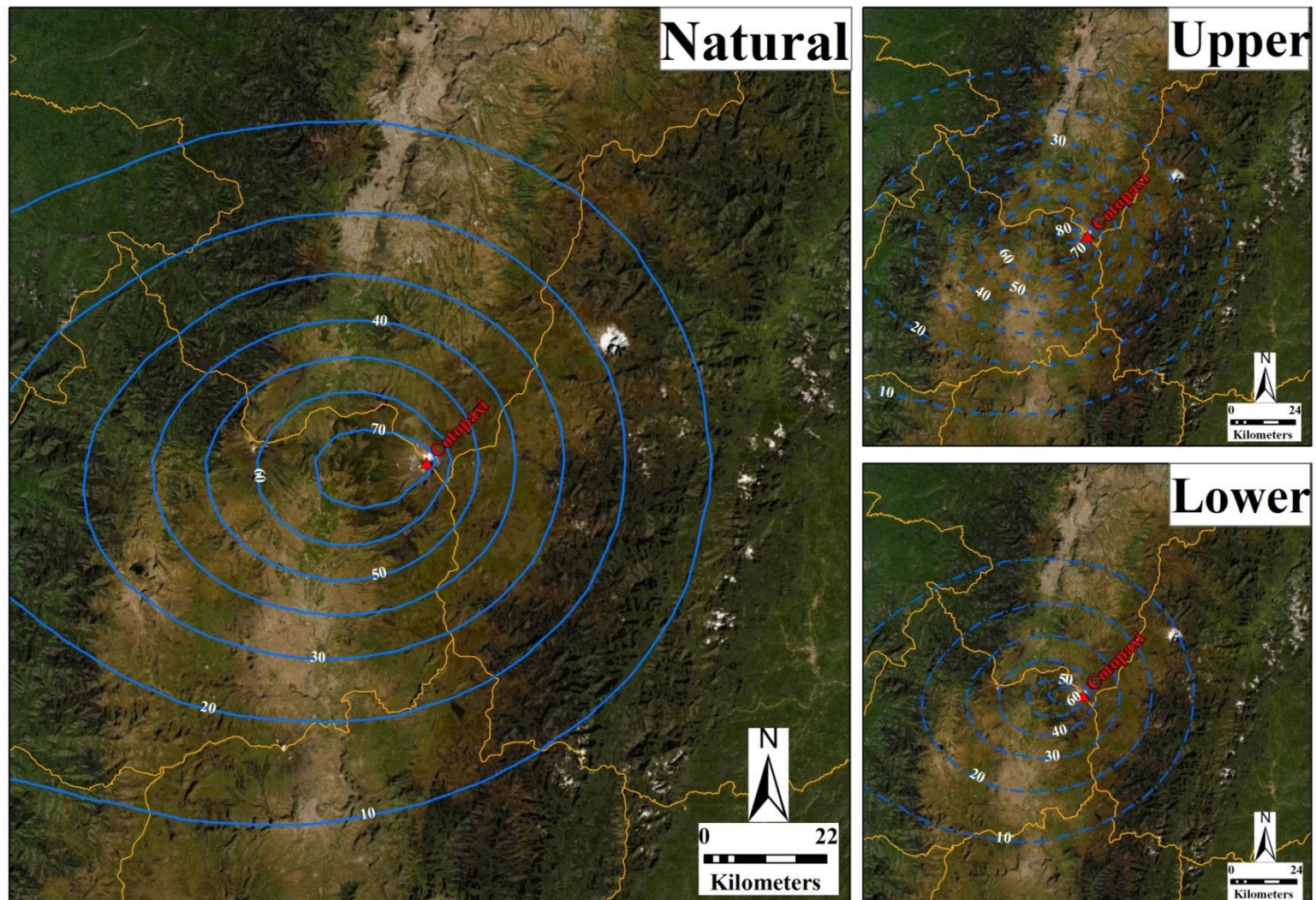


Figure S15. Cotopaxi volcano, Plinian rhyolitic eruption – Probabilistic map (30 mm)

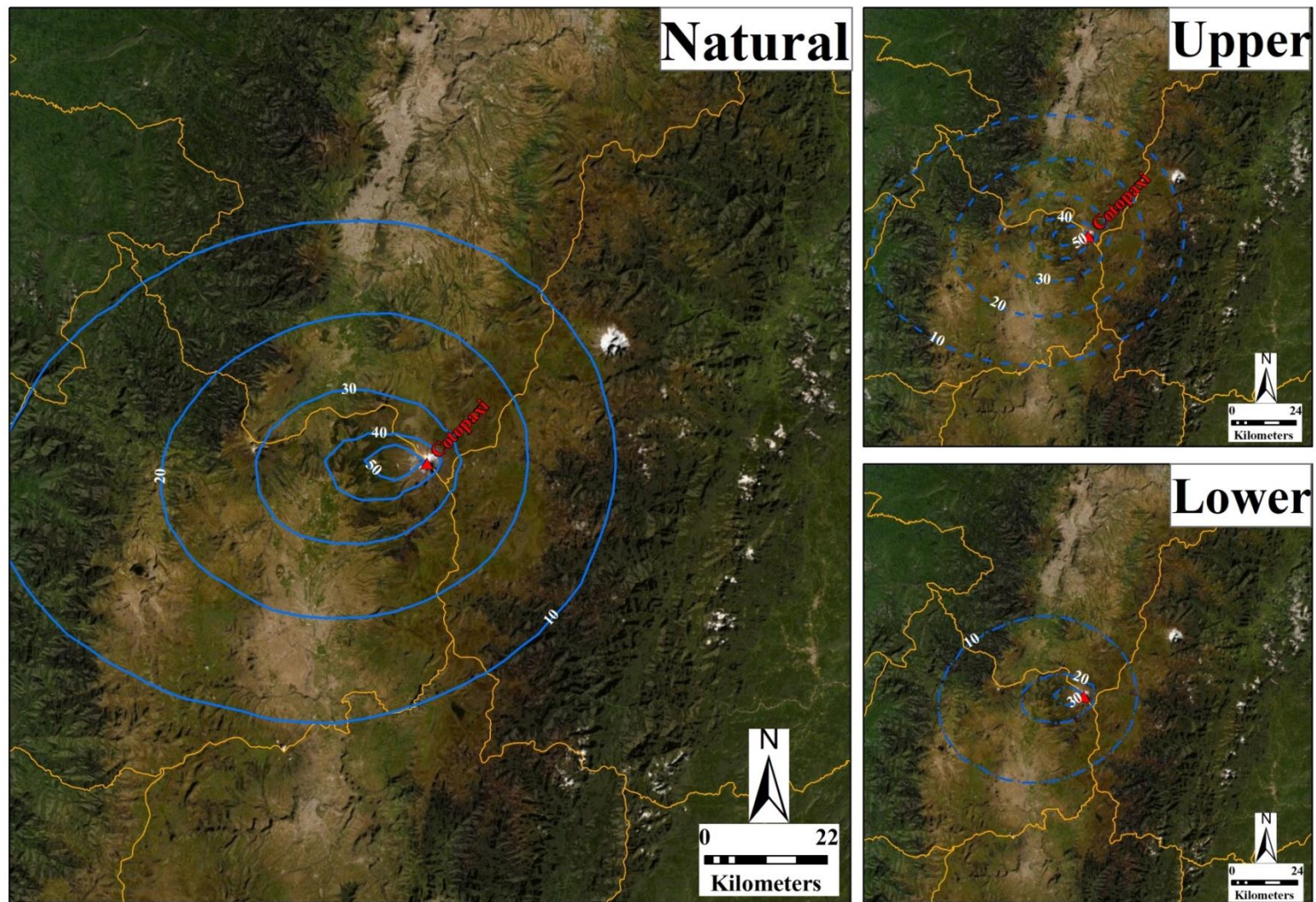


Figure S16. Cotopaxi volcano, Plinian rhyolitic eruption – Probabilistic map (100 mm)

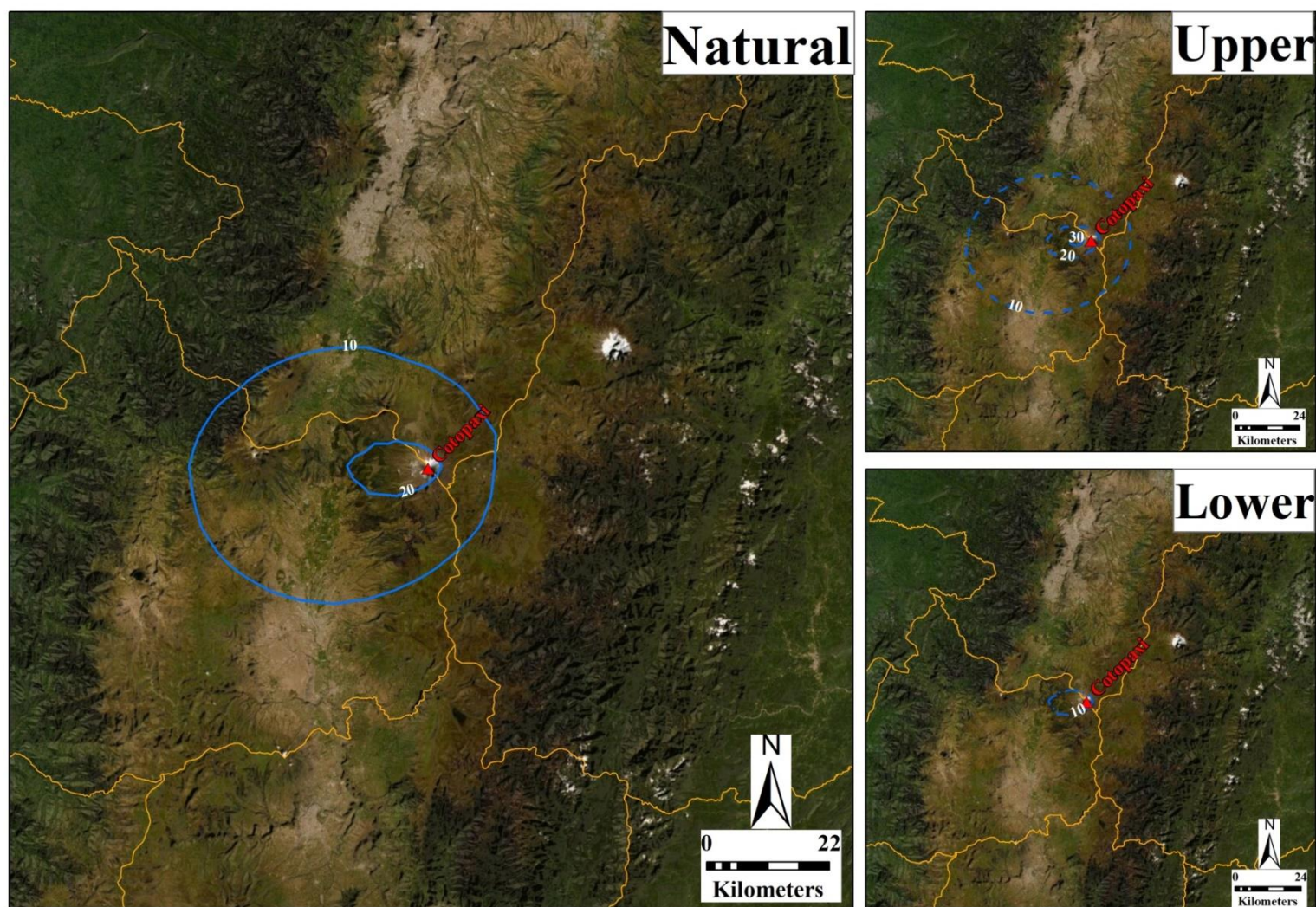


Figure S17. Cotopaxi volcano, Plinian rhyolitic eruption – Probabilistic map (300 mm)

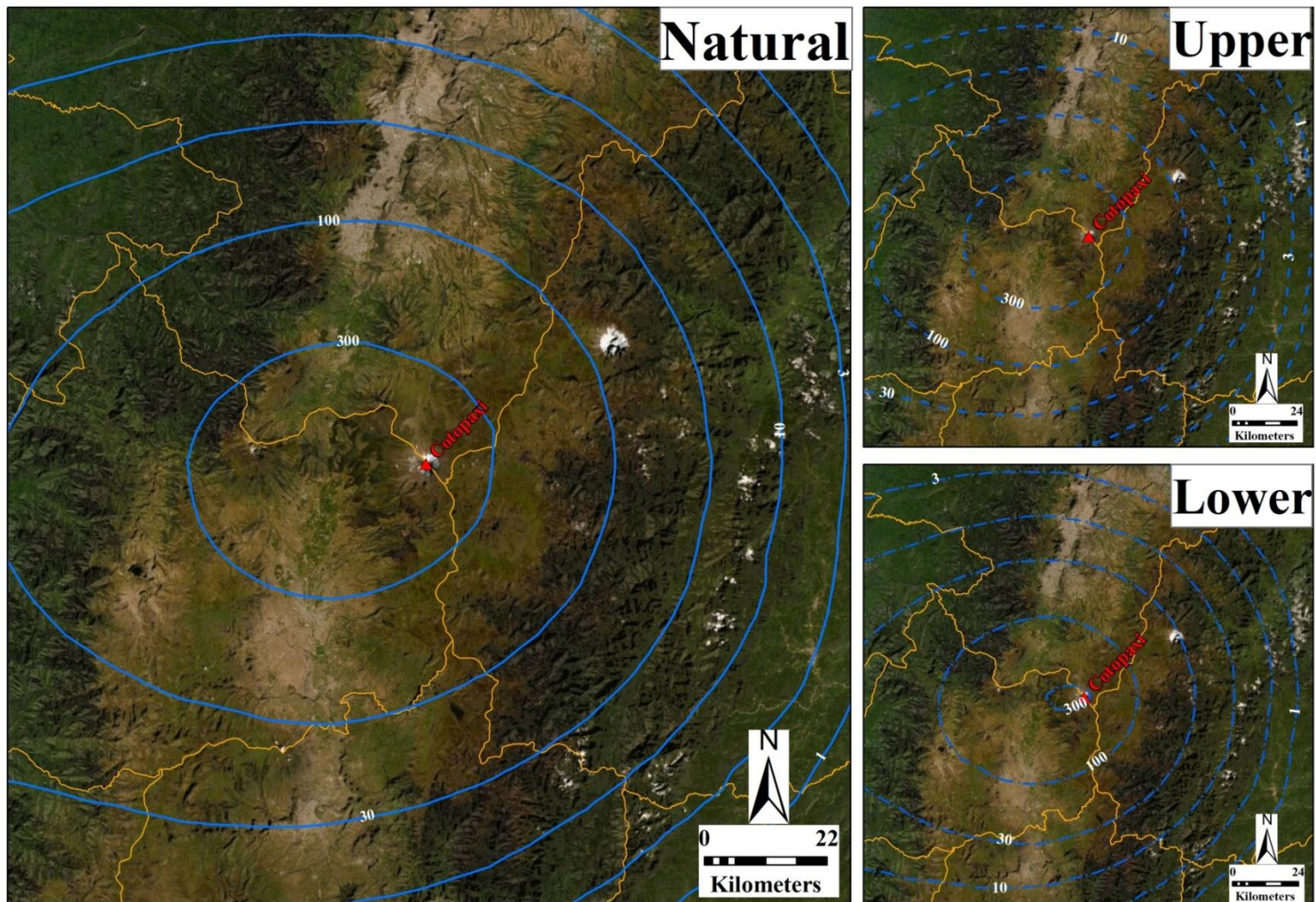


Figure S18. Cotopaxi volcano, Plinian rhyolitic eruption – Isopach map (10 %)

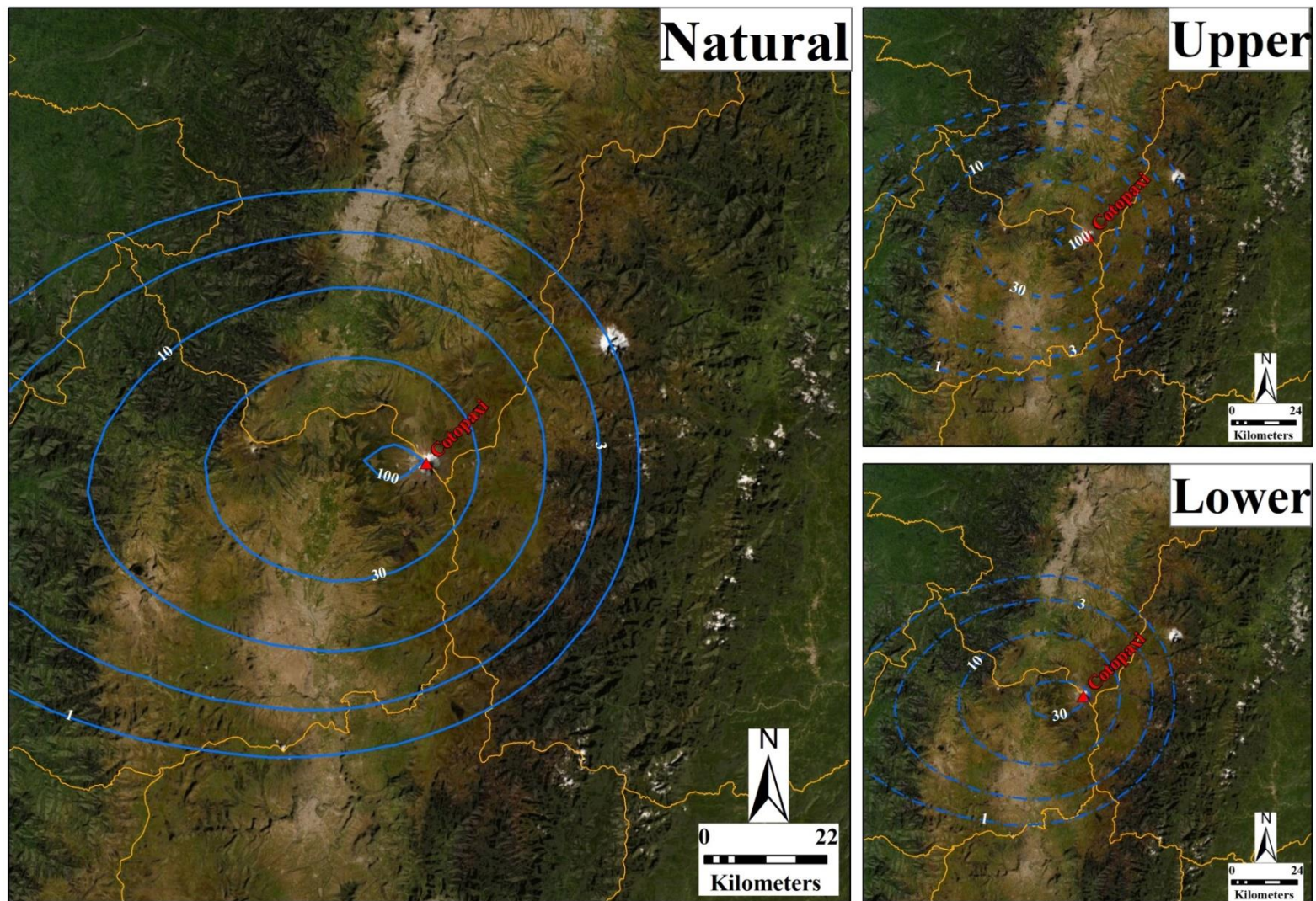


Figure S19. Cotopaxi volcano, Plinian rhyolitic eruption – Probabilistic map (50 %)

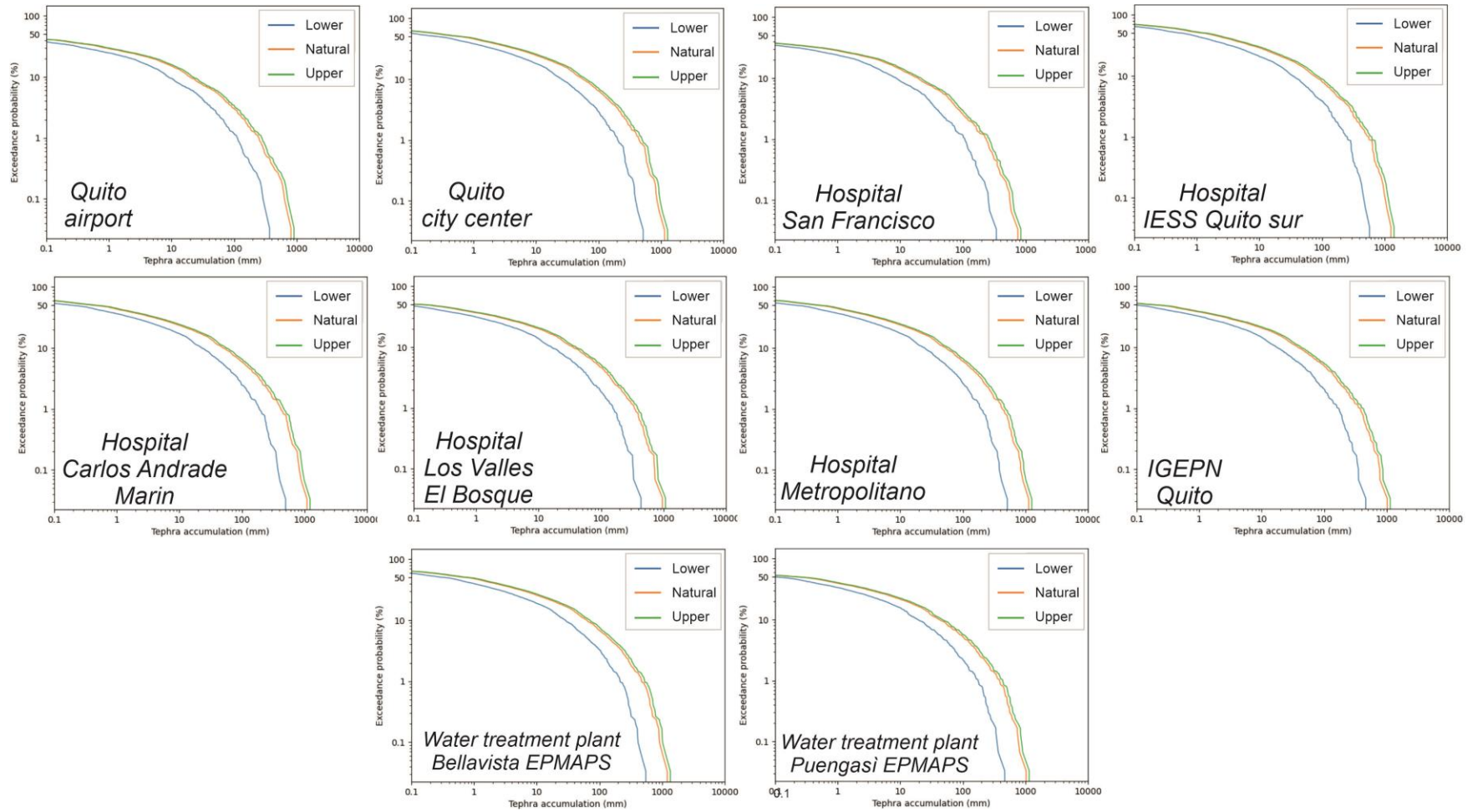


Figure S20. Cotopaxi volcano, Plinian rhyolitic eruption – Hazard curves

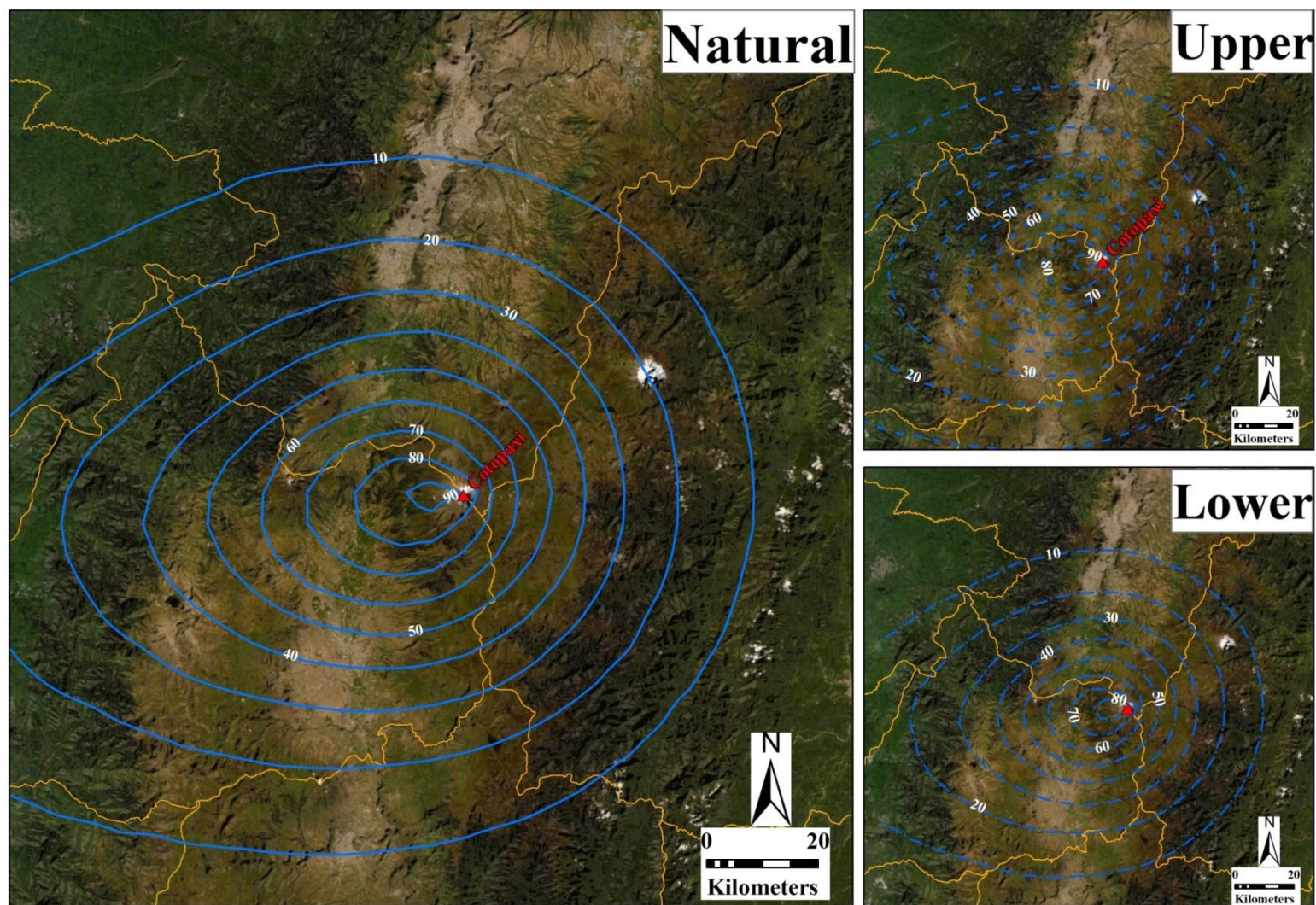


Figure S21. Cotopaxi volcano, sub-Plinian andesitic eruption – Probabilistic map (1 mm)

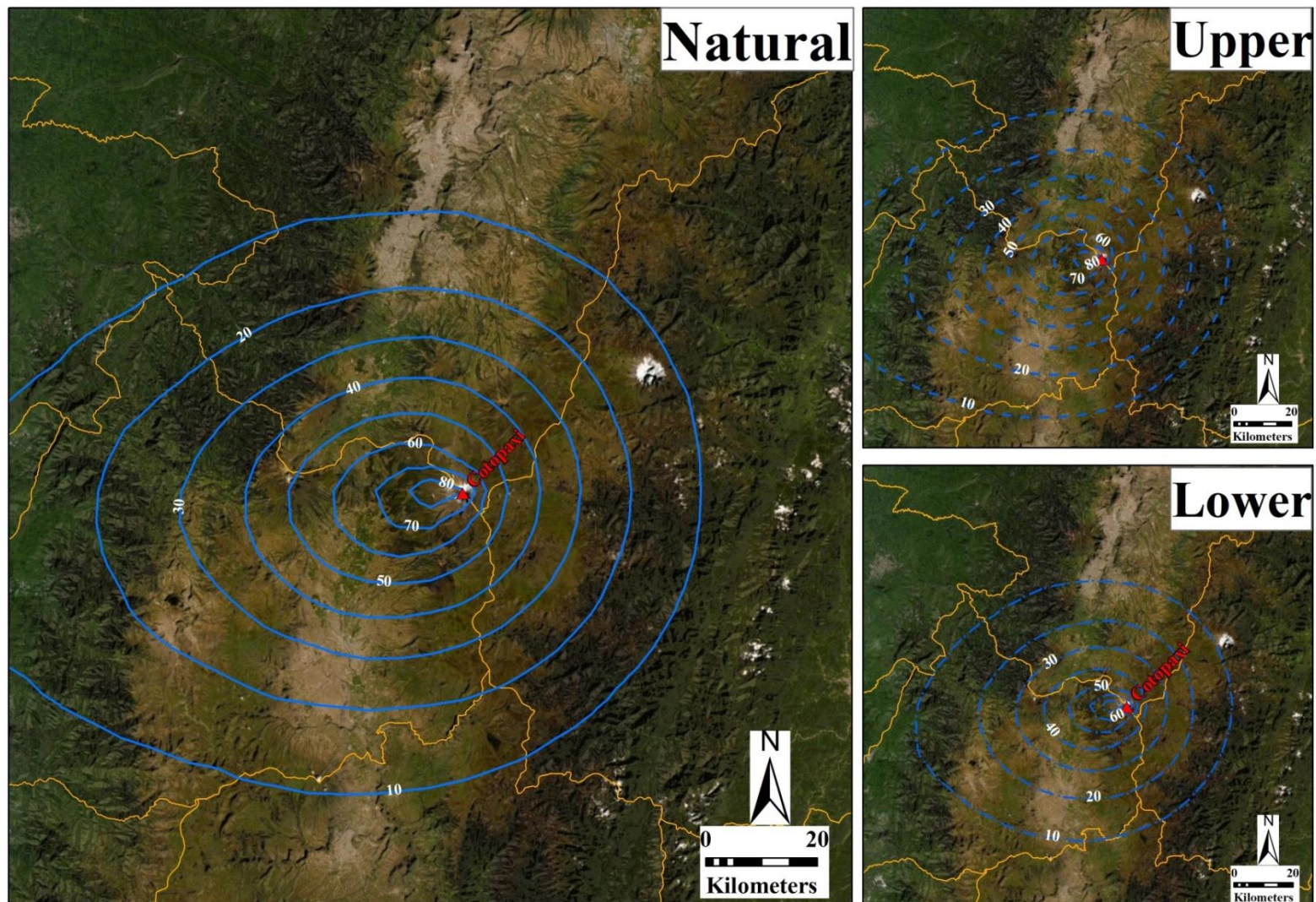


Figure S22. Cotopaxi volcano, sub-Plinian andesitic eruption – Probabilistic map (3 mm)

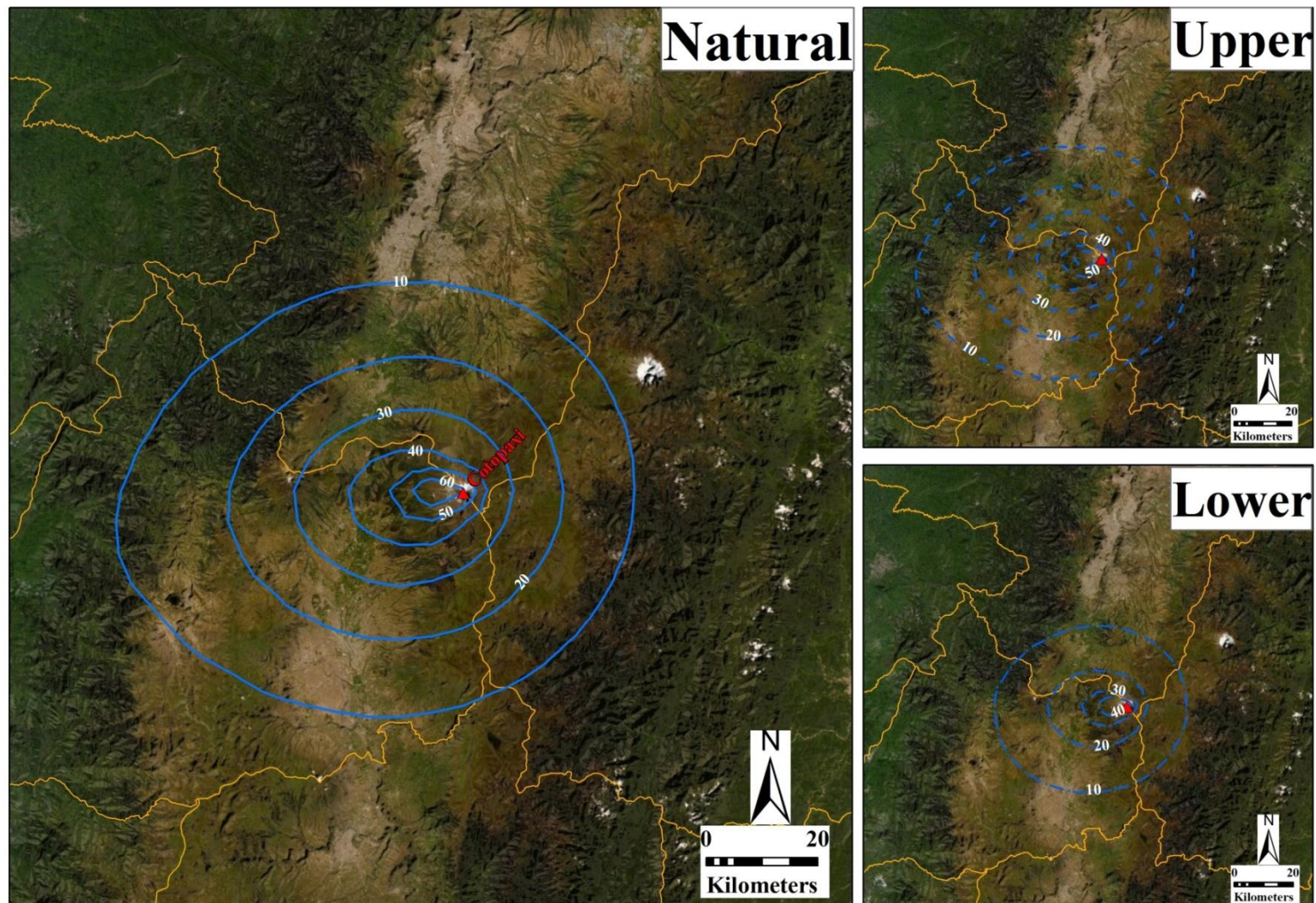


Figure S23. Cotopaxi volcano, sub-Plinian andesitic eruption – Probabilistic map (10 mm)

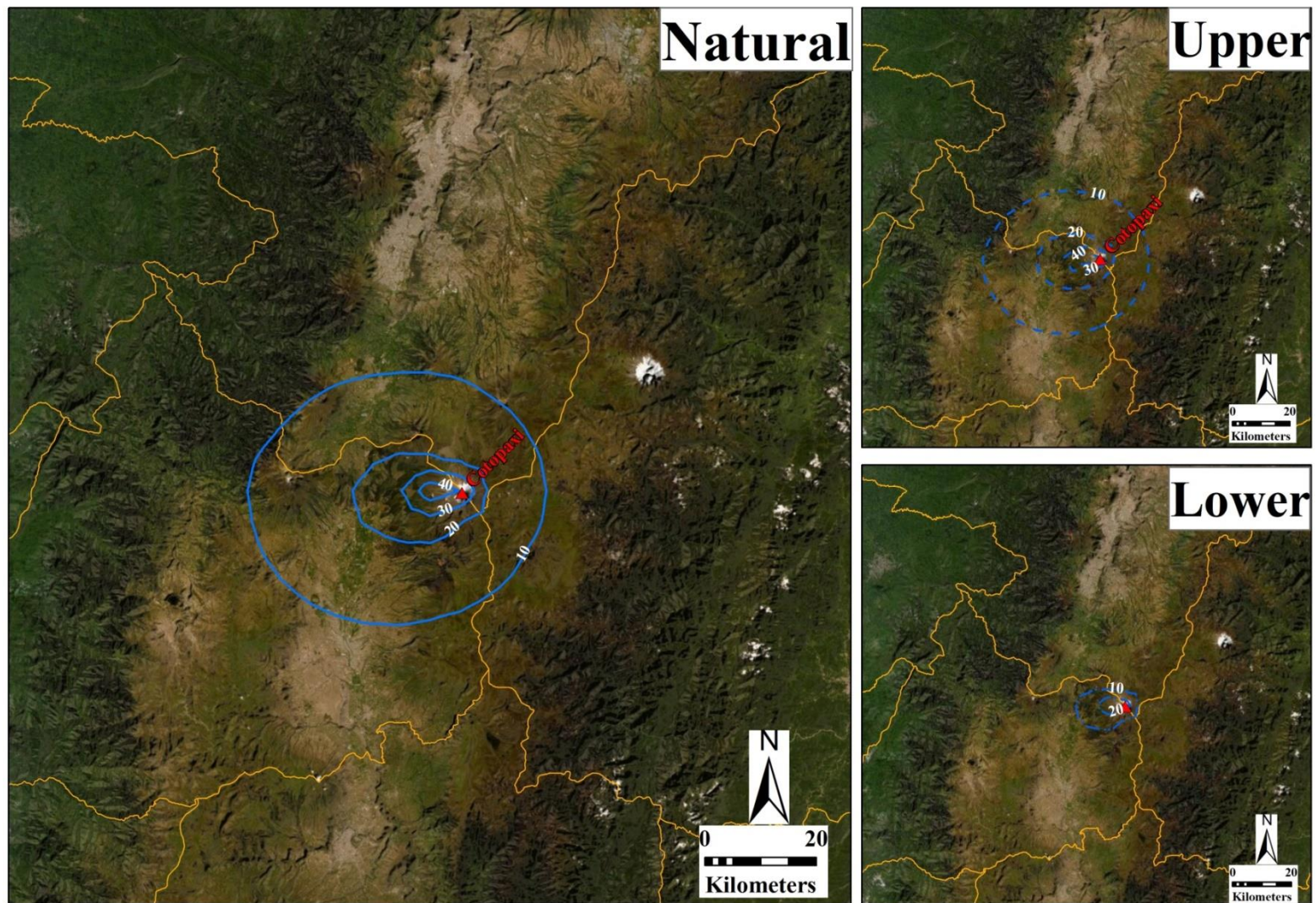


Figure S24. Cotopaxi volcano, sub-Plinian andesitic eruption – Probabilistic map (30 mm)

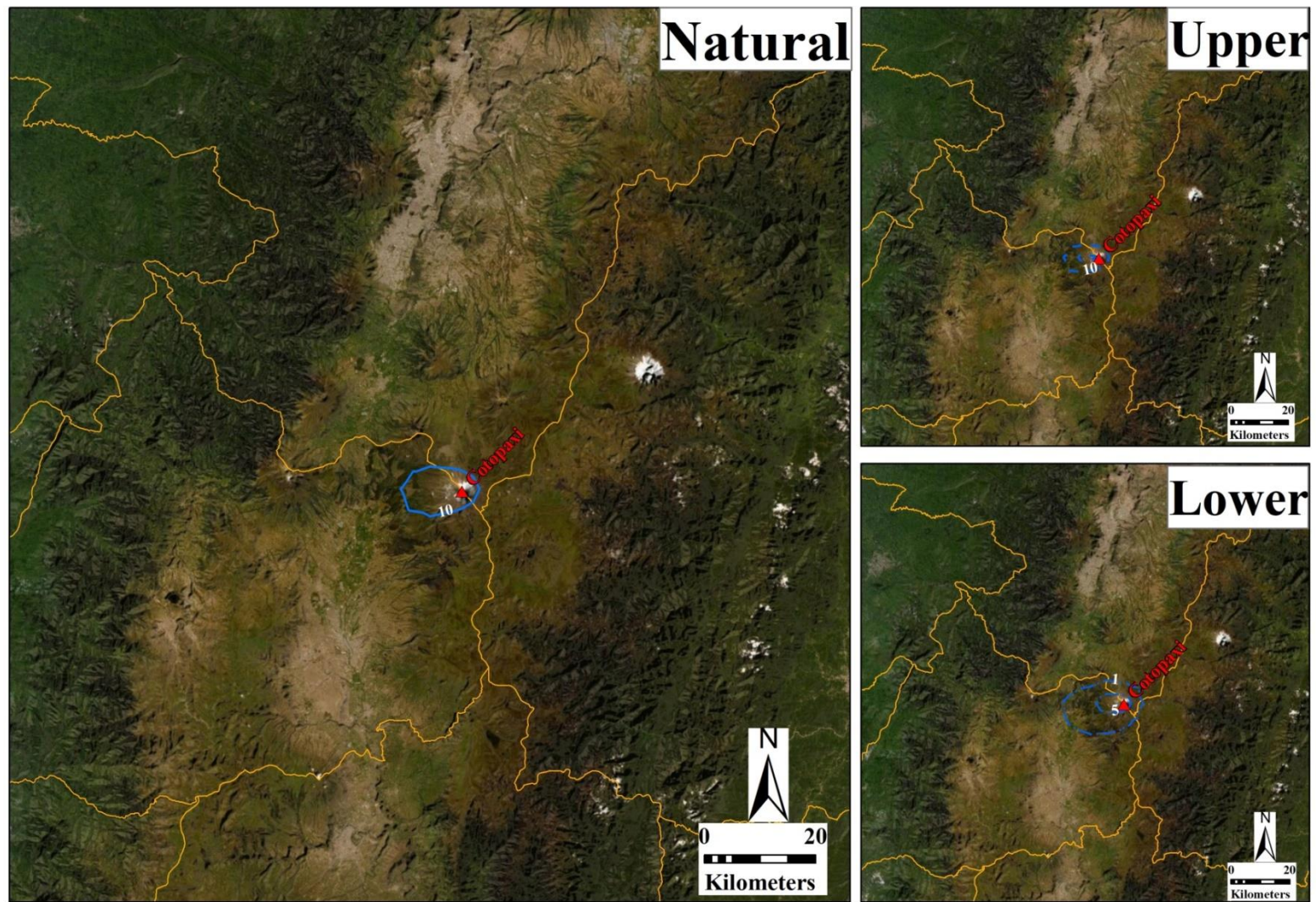


Figure S25. Cotopaxi volcano, sub-Plinian andesitic eruption – Probabilistic map (100 mm)

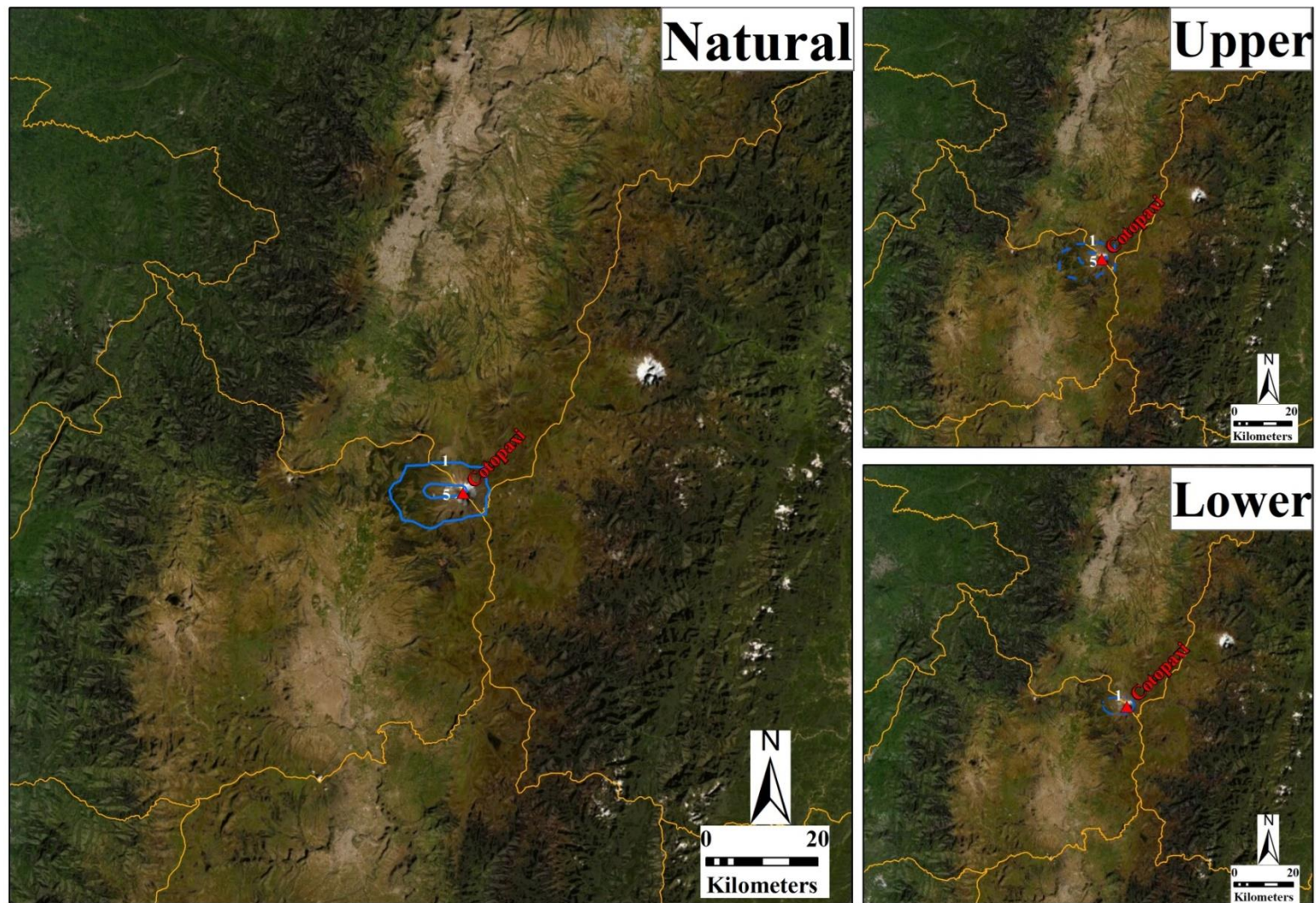


Figure S26. Cotopaxi volcano, sub-Plinian andesitic eruption – Probabilistic map (300 mm)

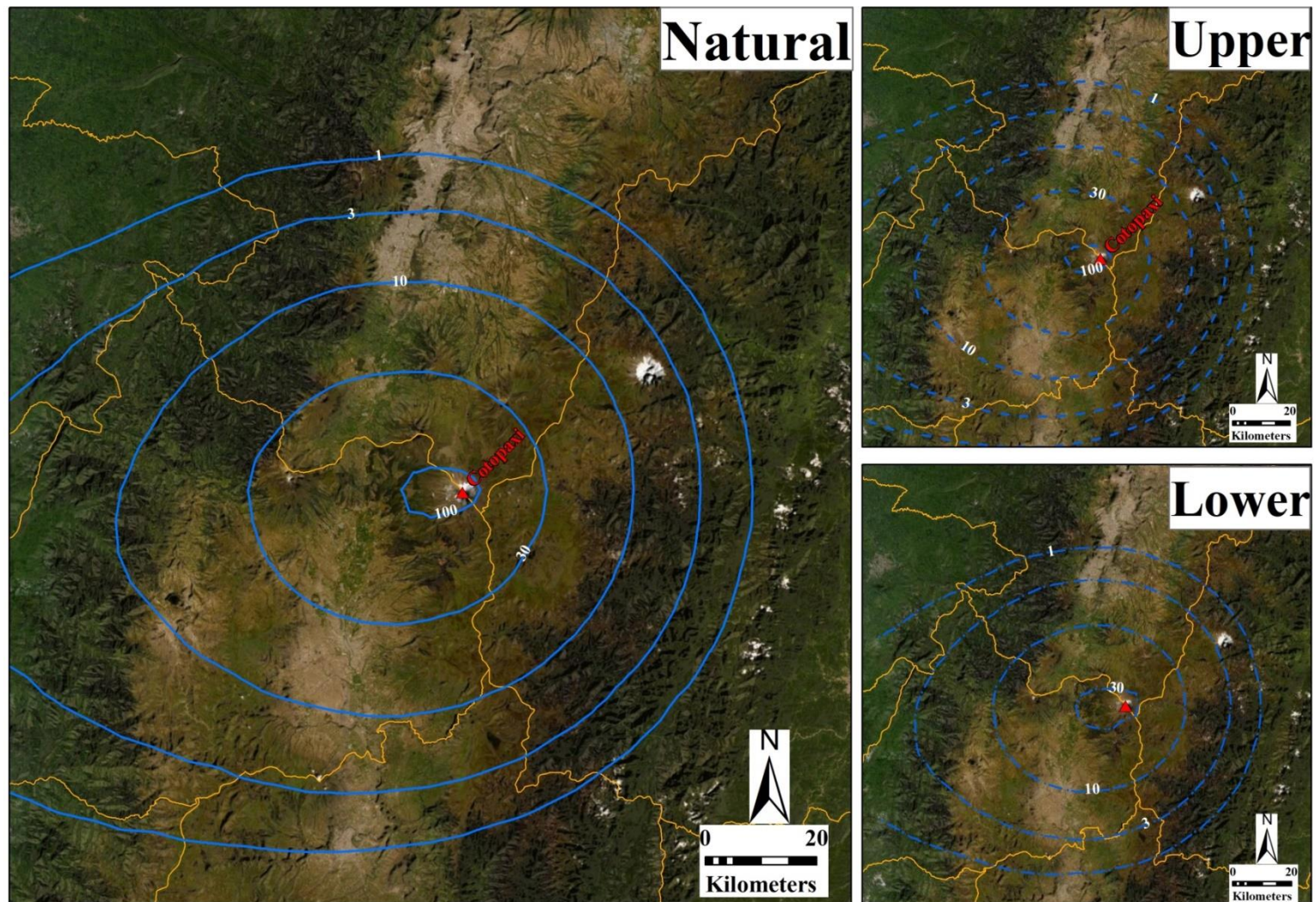


Figure S28. Cotopaxi volcano, sub-Plinian andesitic eruption – Isopach map (10 %)

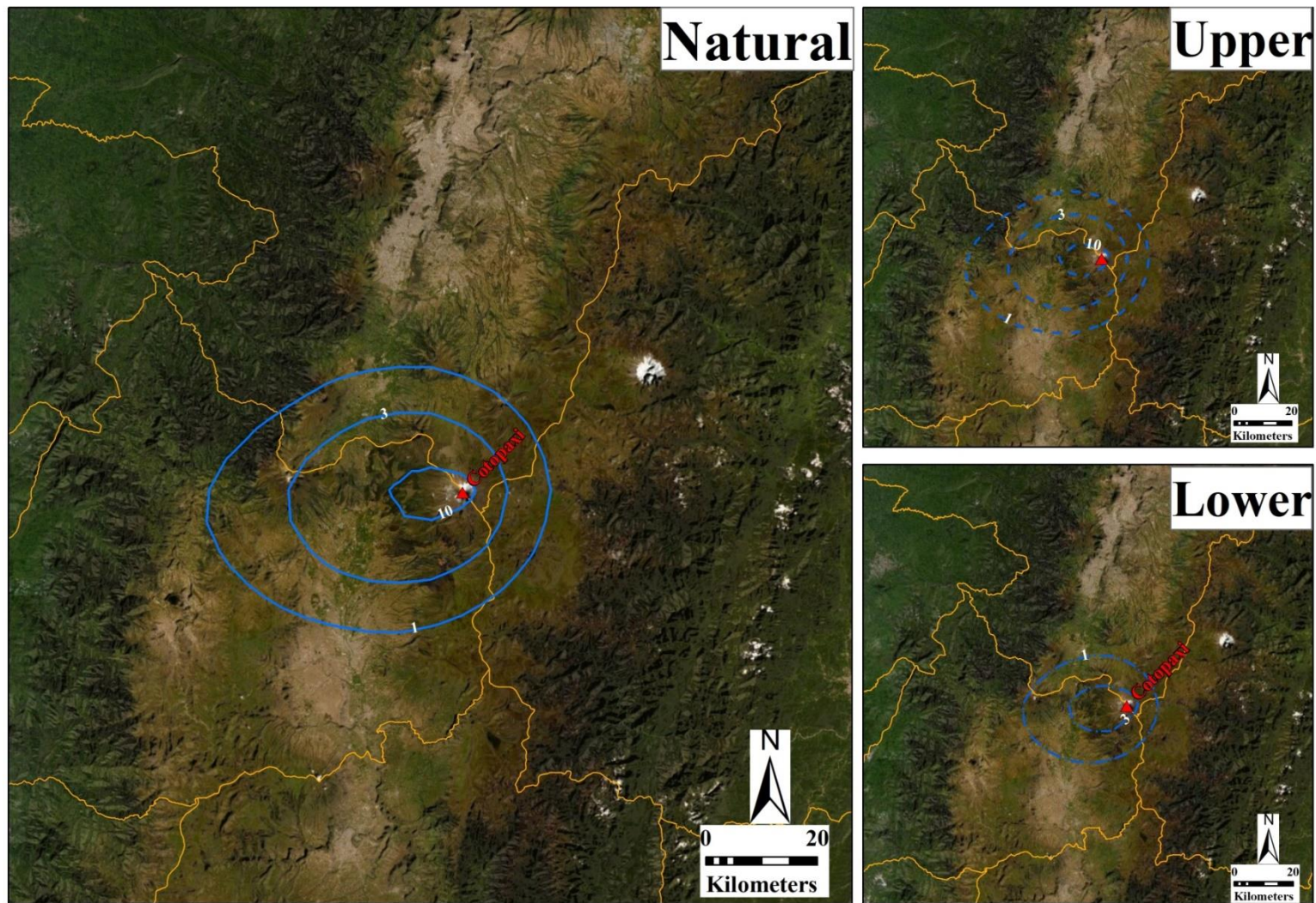


Figure S29. Cotopaxi volcano, sub-Plinian andesitic eruption – Probabilistic map (50 %)

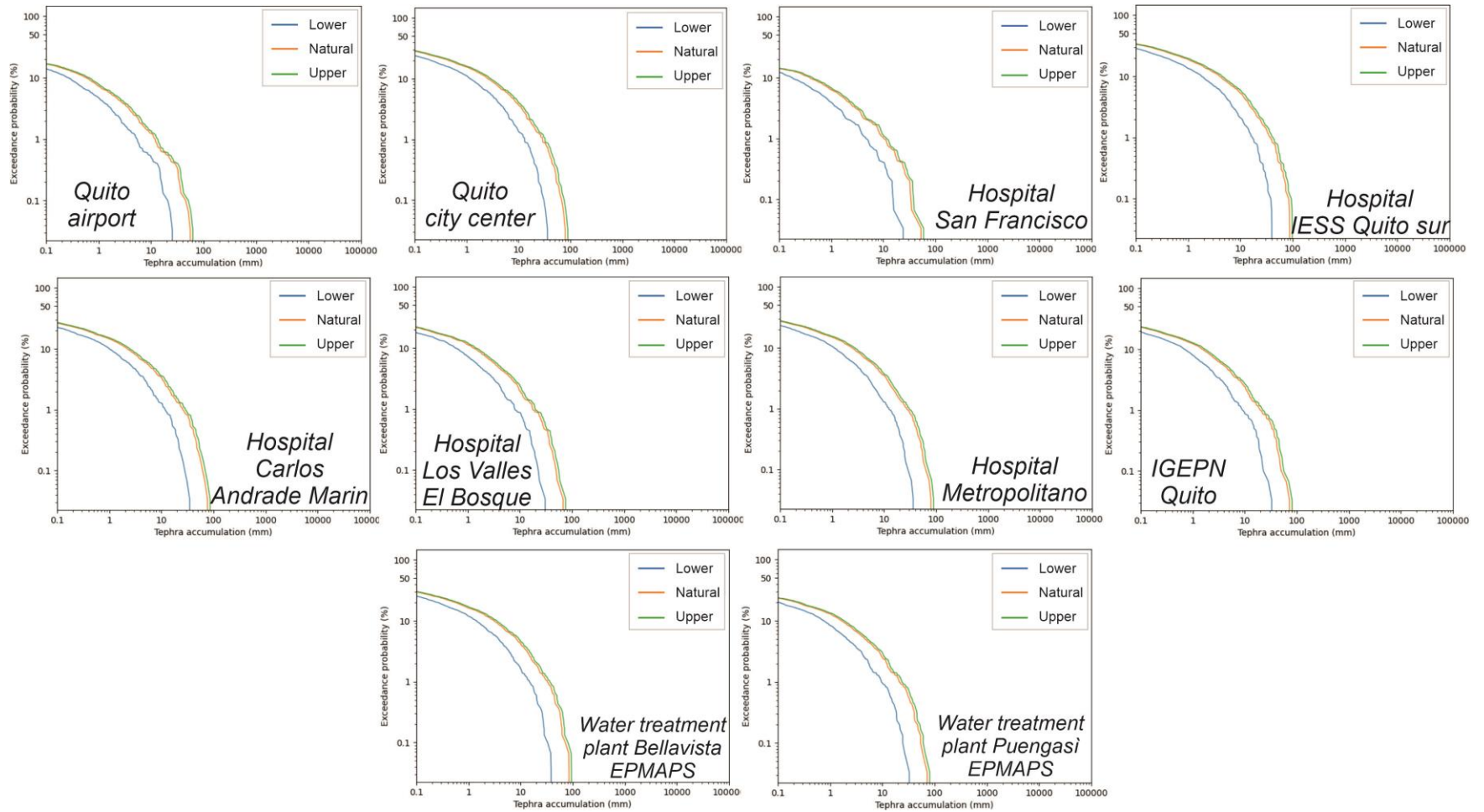


Figure S30. Cotopaxi eruption, sub-Plinian andesitic eruption – Hazard curves

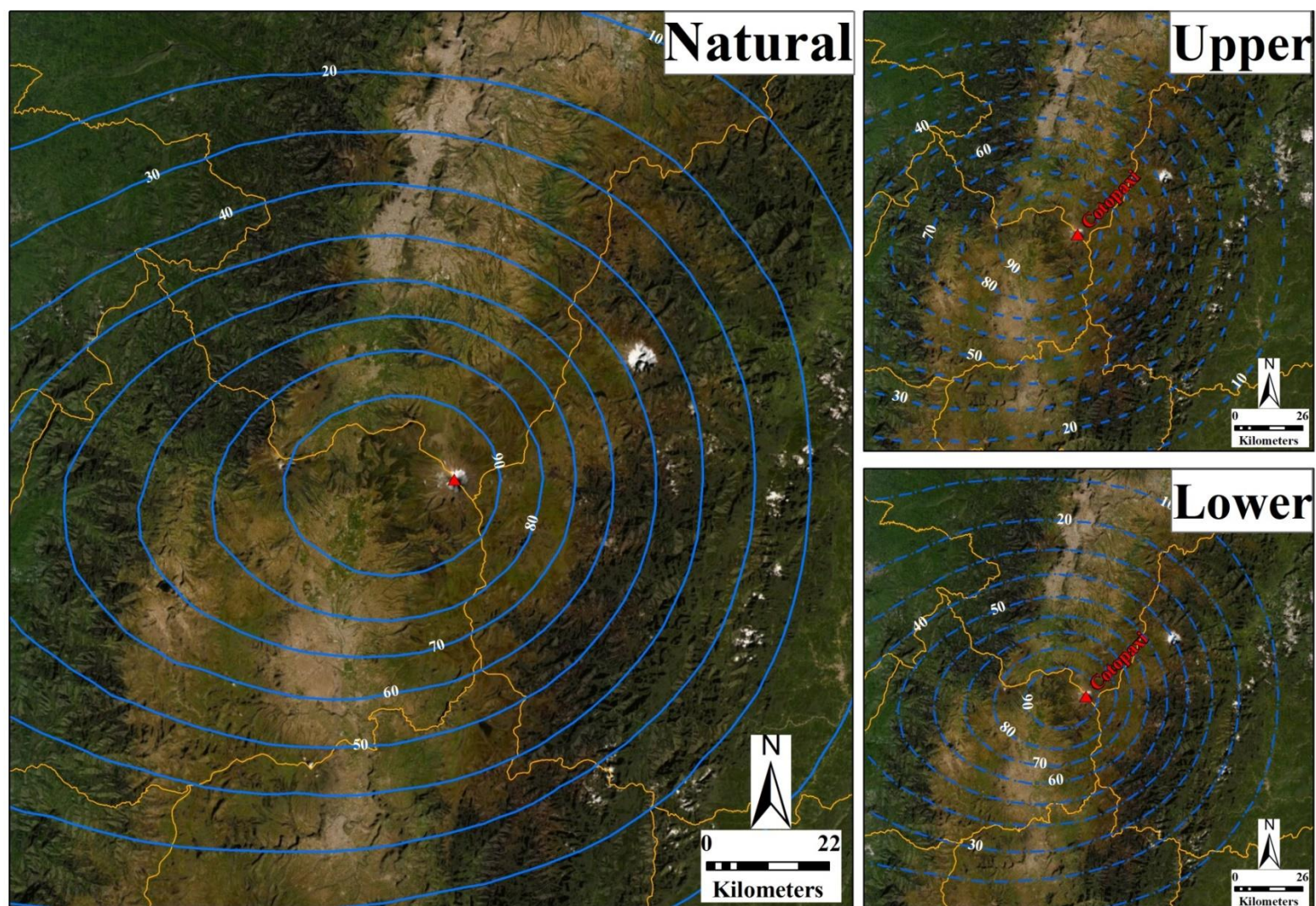


Figure S31. Cotopaxi volcano, Plinian andesitic eruption – Probabilistic map (1 mm)

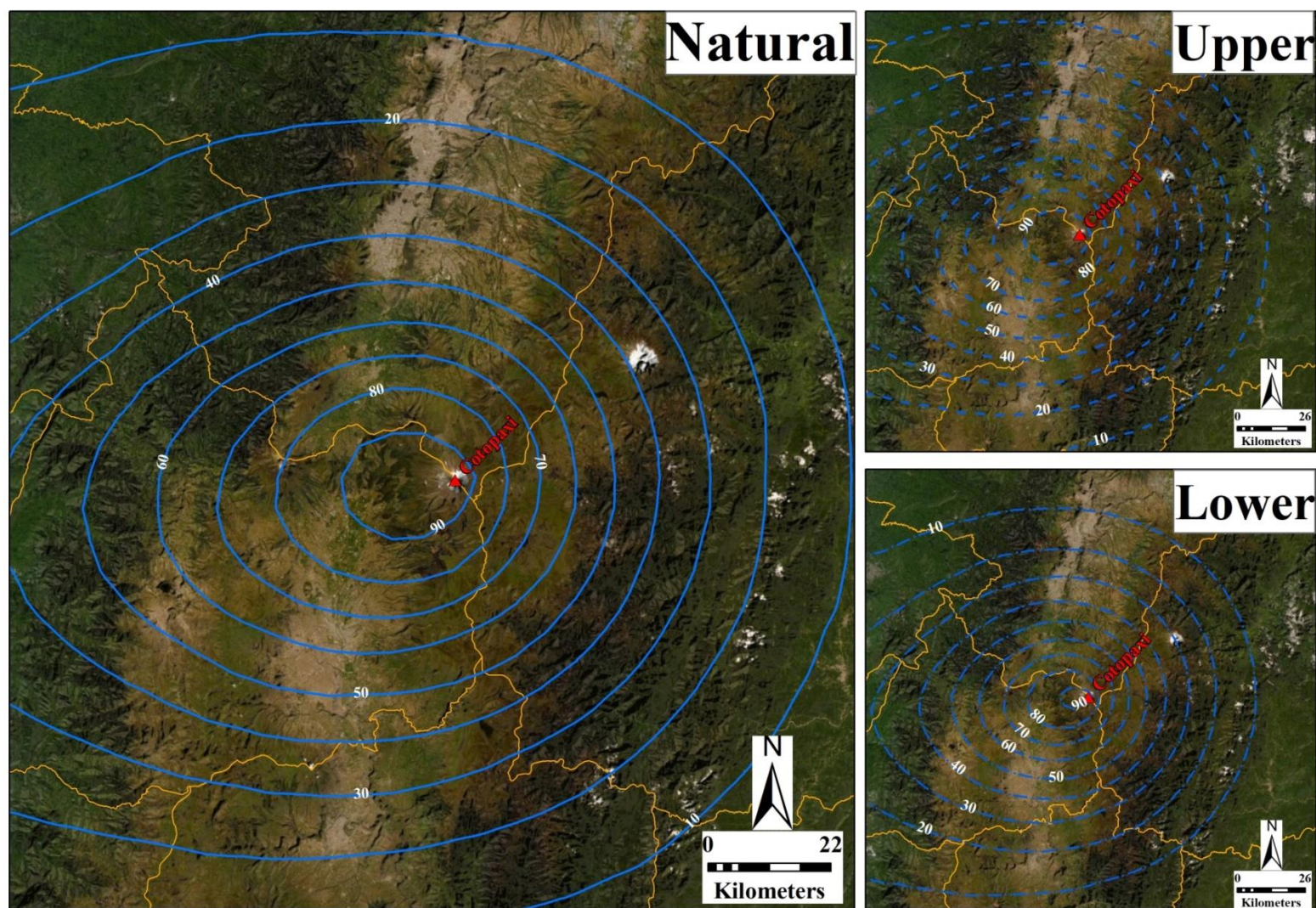


Figure S32. Cotopaxi volcano, Plinian andesitic eruption – Probabilistic map (3 mm)

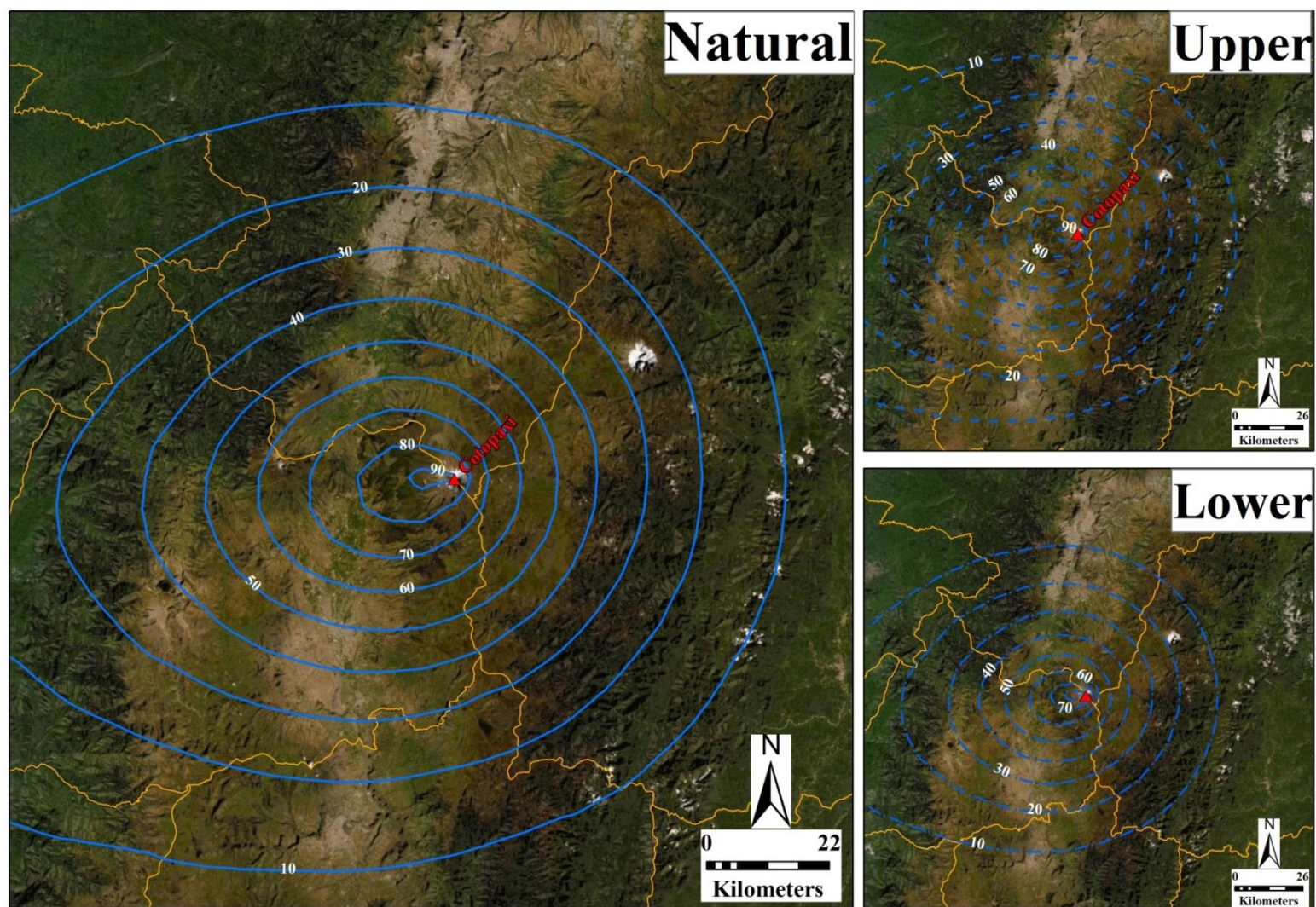


Figure S33. Cotopaxi volcano, Plinian andesitic eruption – Probabilistic map (10 mm)

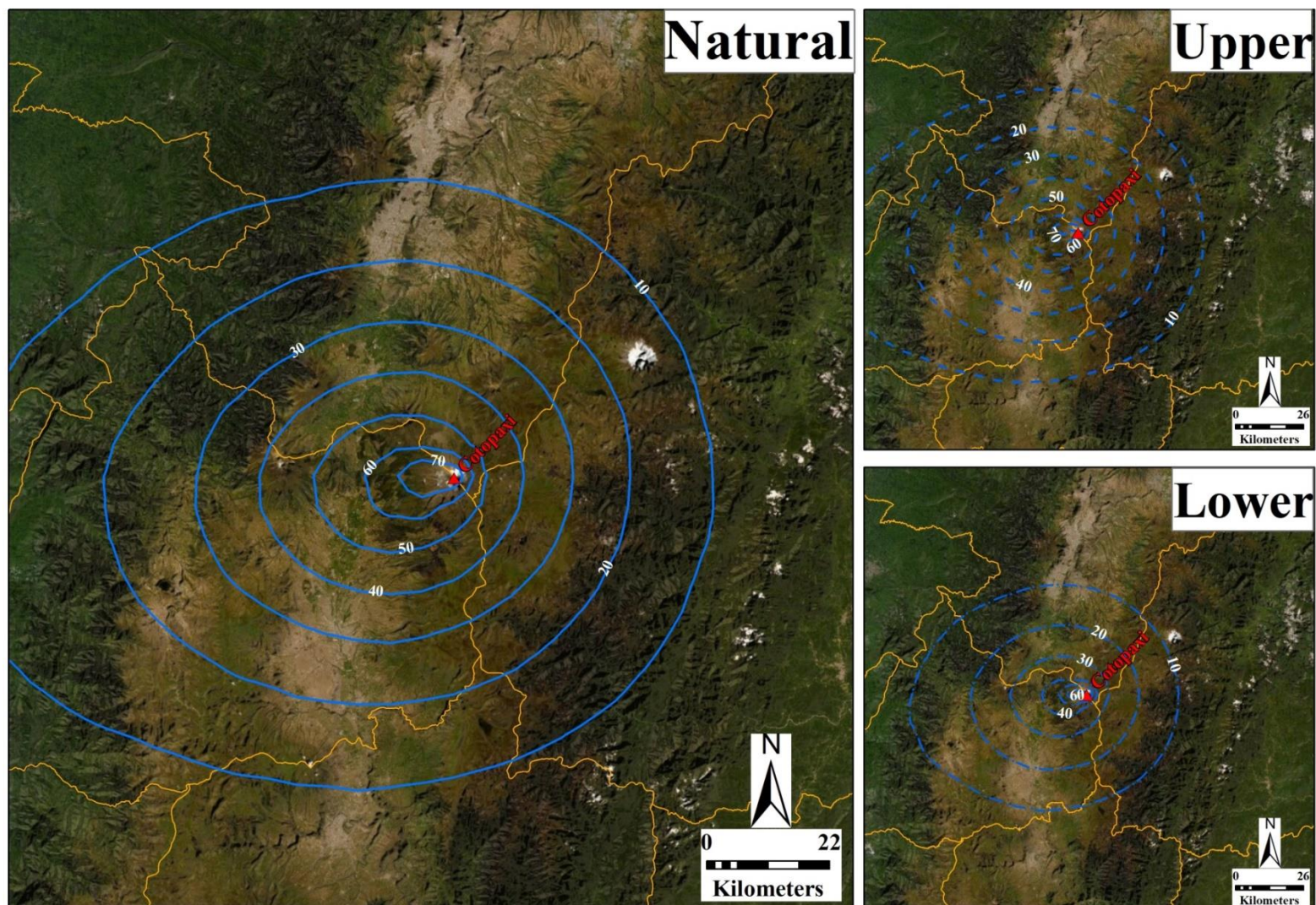


Figure S34. Cotopaxi volcano, Plinian andesitic eruption – Probabilistic map (30 mm)

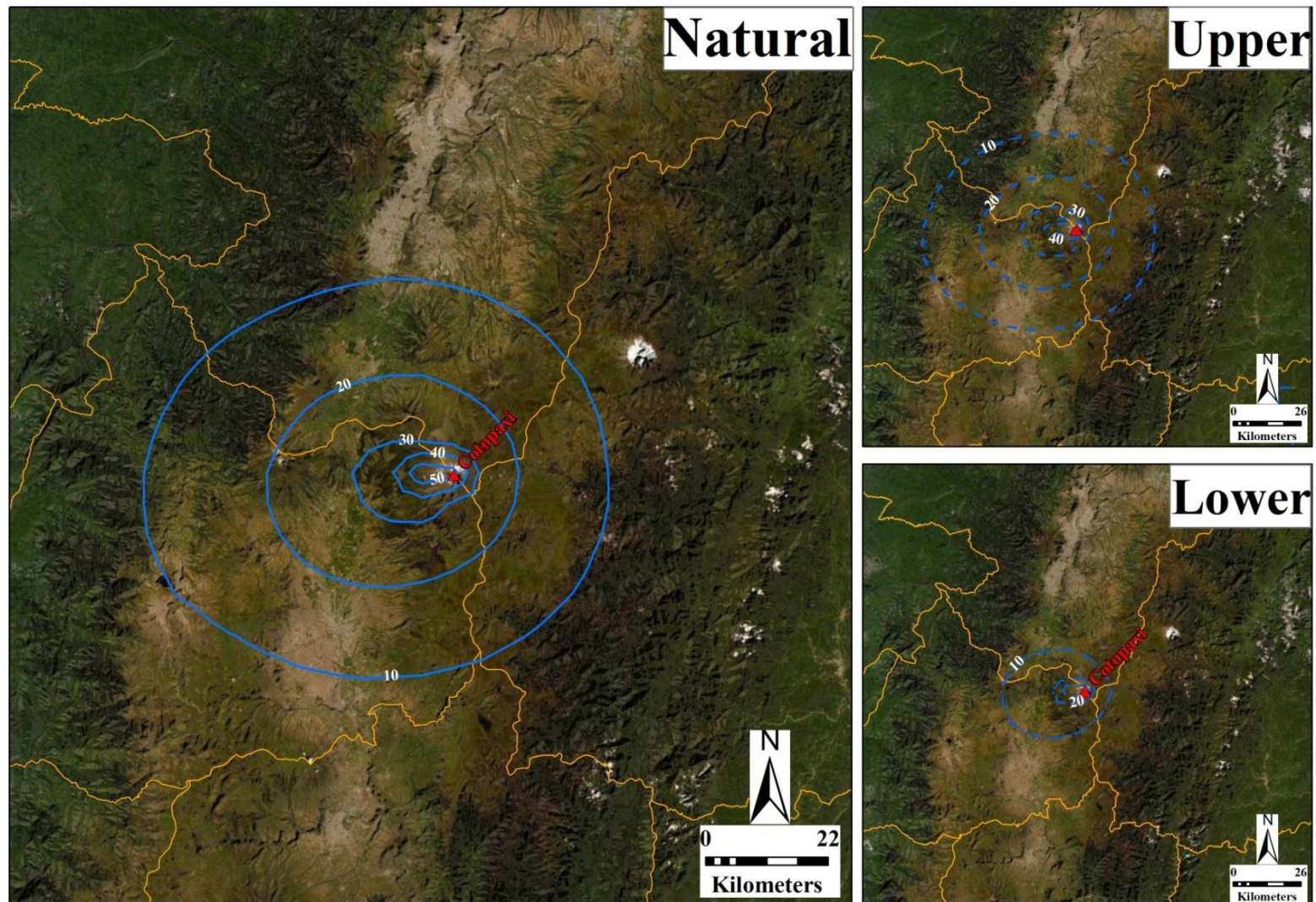


Figure S35. Cotopaxi volcano, Plinian andesitic eruption – Probabilistic map (100 mm)

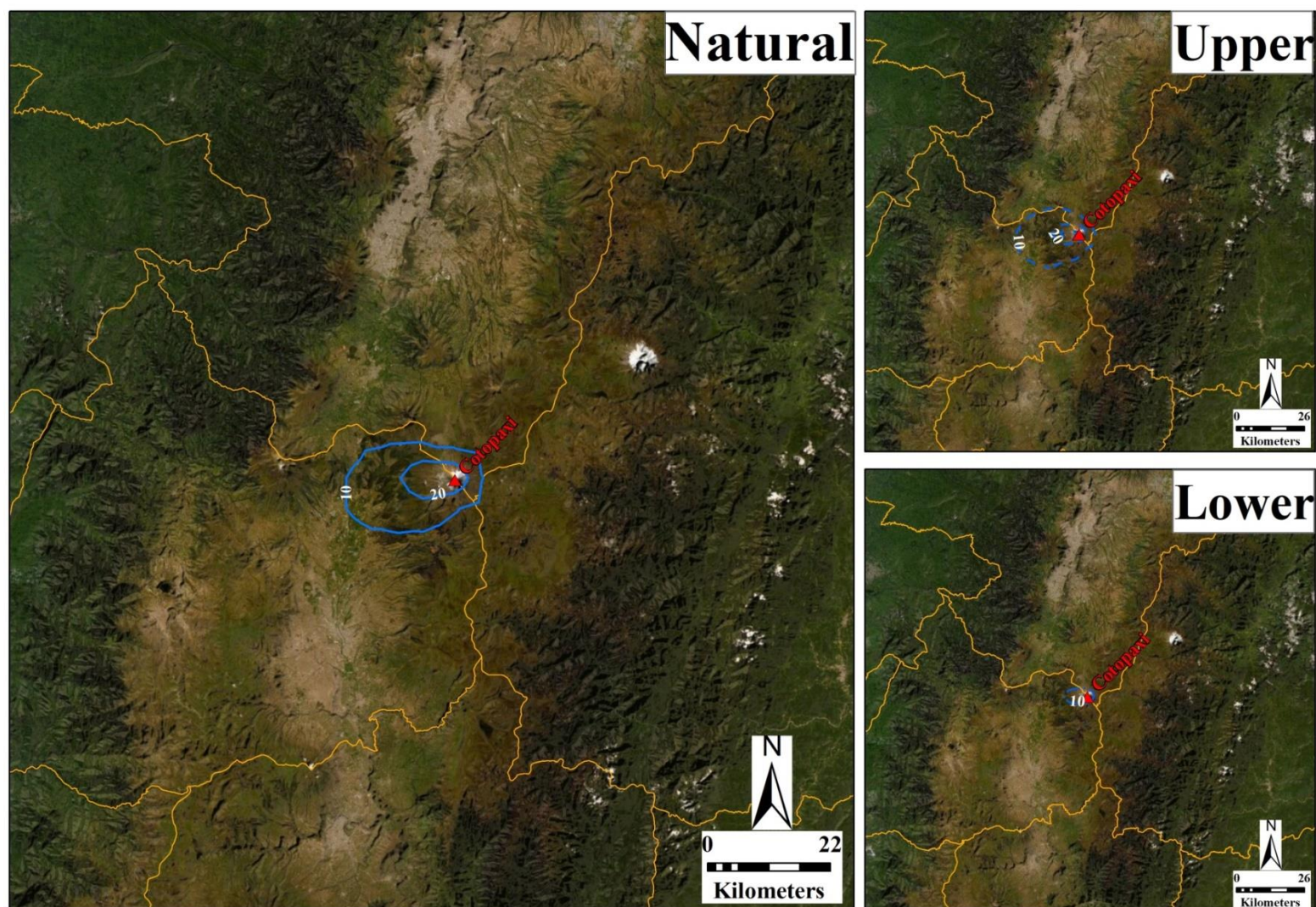


Figure S36. Cotopaxi volcano, Plinian andesitic eruption – Probabilistic map (300 mm)

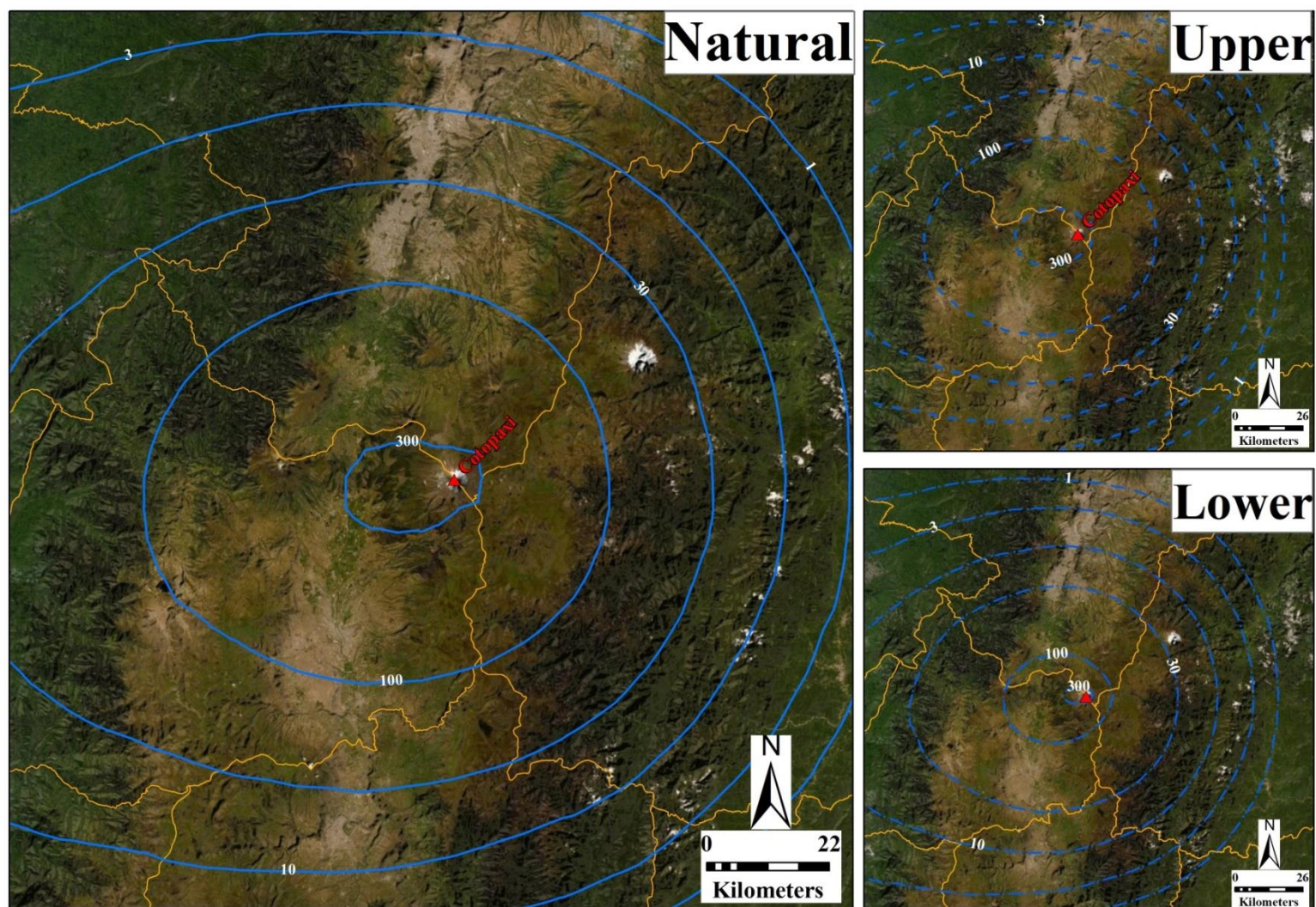


Figure S37. Cotopaxi volcano, Plinian andesitic eruption – Isopach map (10 %)

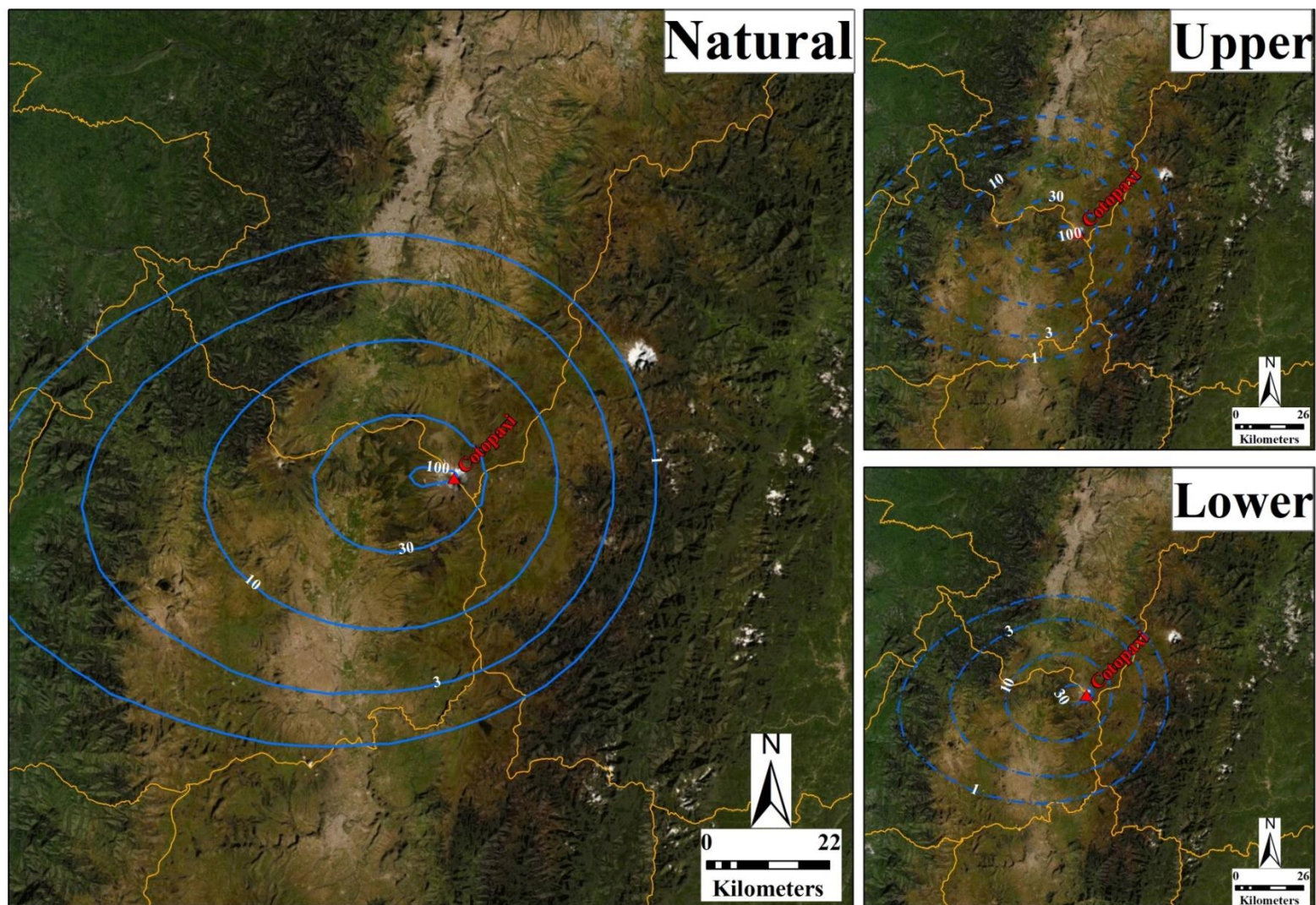


Figure S38. Cotopaxi volcano, Plinian andesitic eruption – Probabilistic map (50 %)

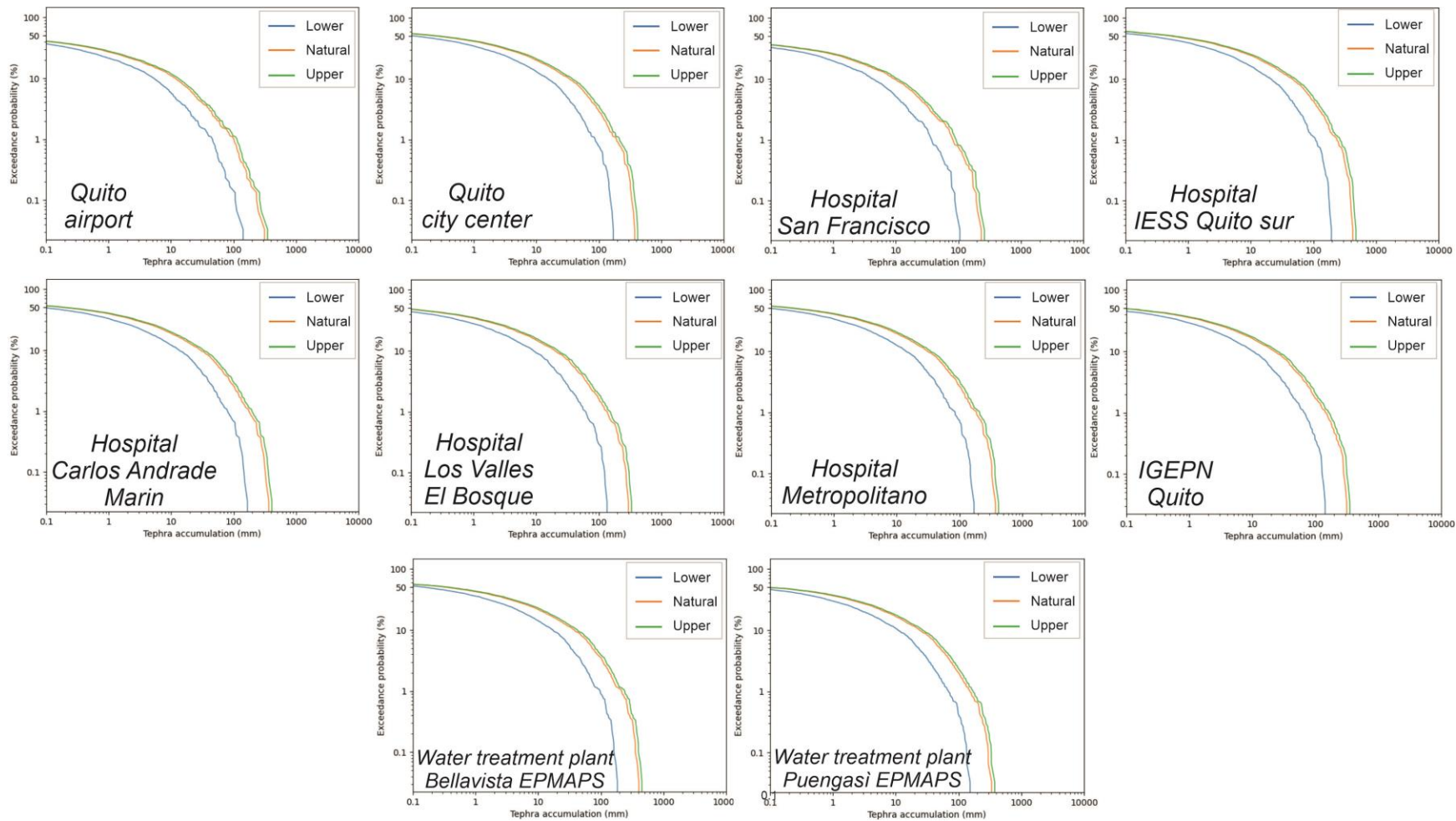


Figure S39. Cotopaxi volcano, Plinian andesitic eruption – Hazard curves

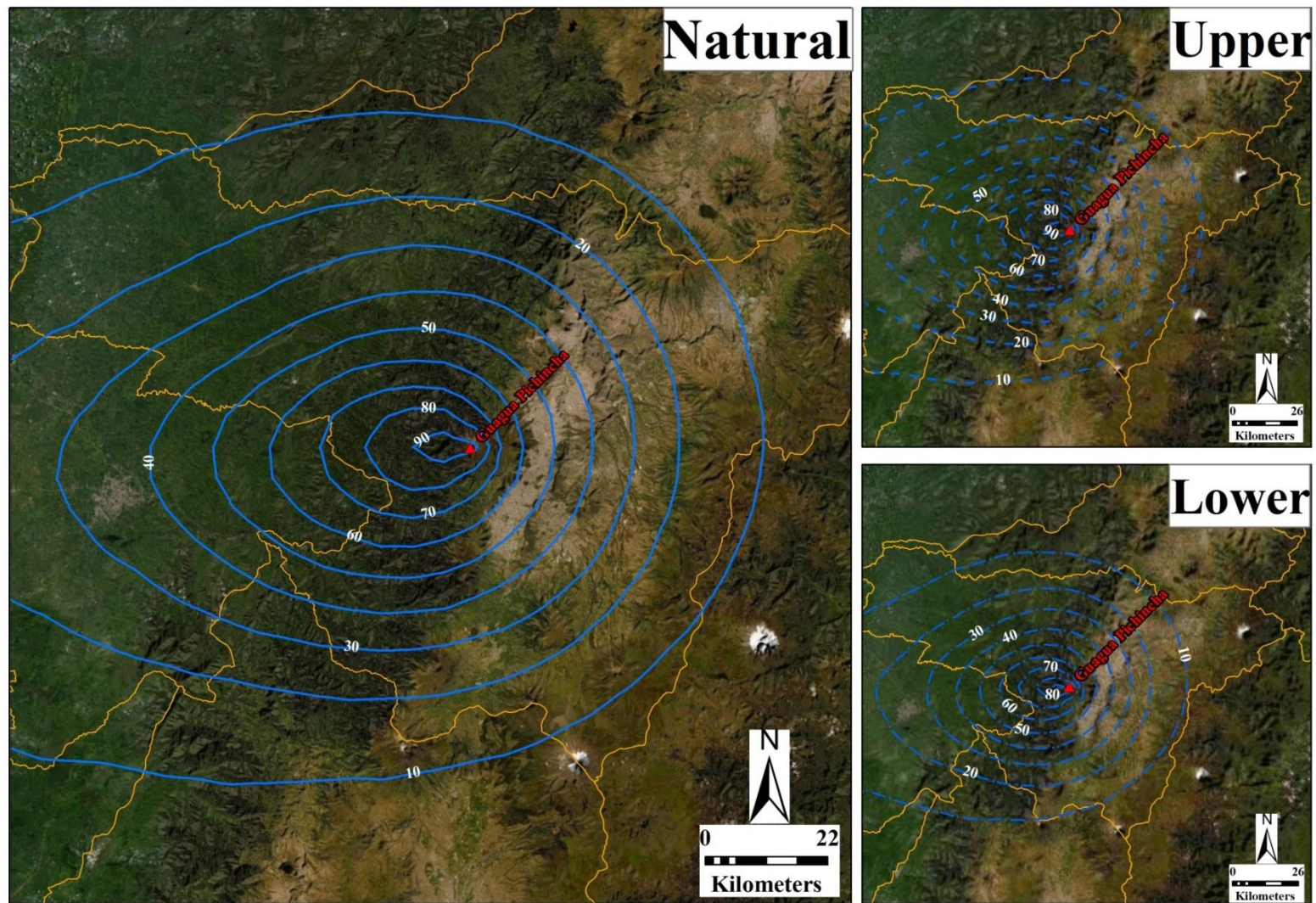


Figure S40. Guagua Pichincha volcano, sub-Plinian eruption – Probabilistic map (1 mm)

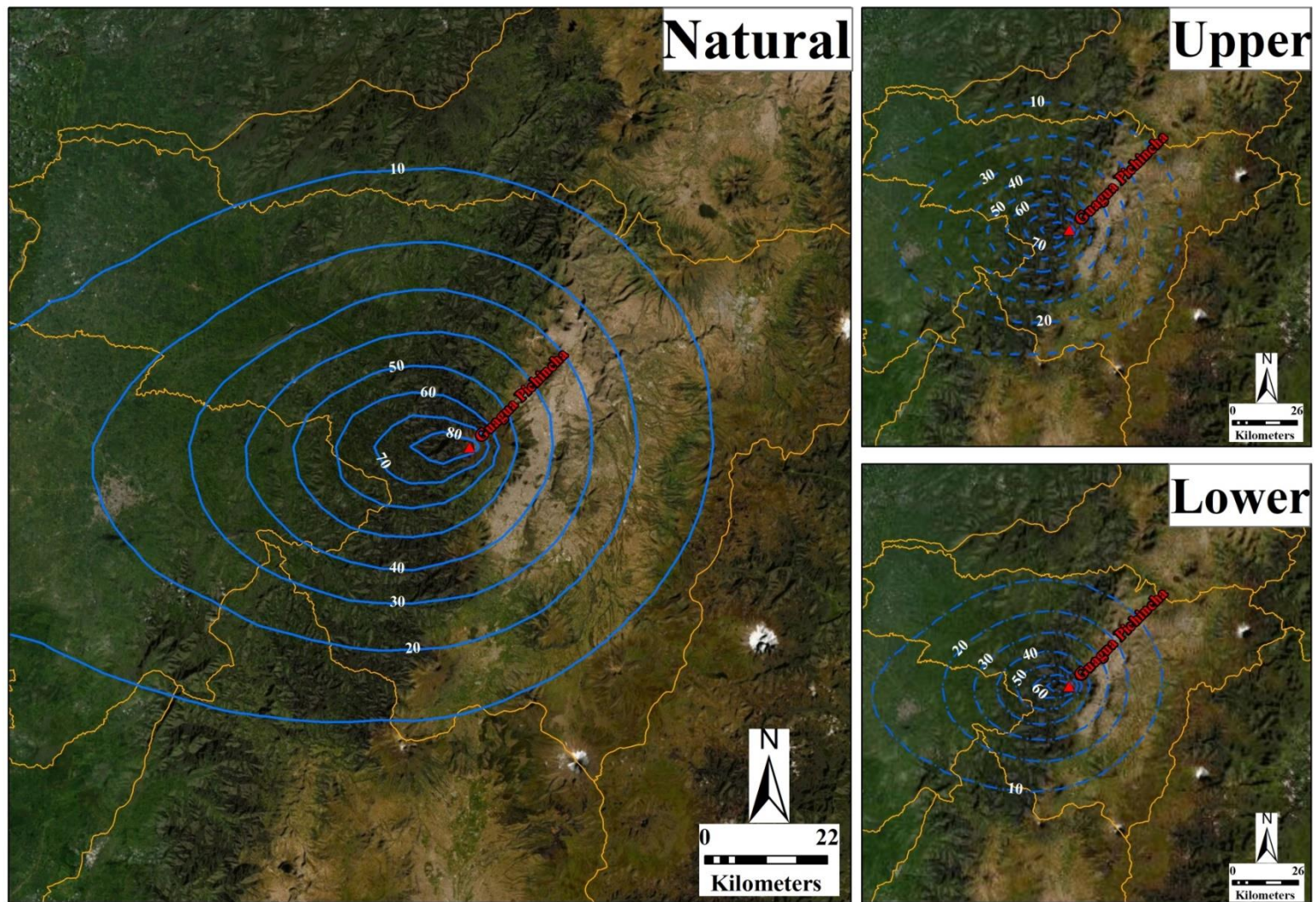


Figure S41. Guagua Pichincha volcano, sub-Plinian eruption – Probabilistic map (3 mm)

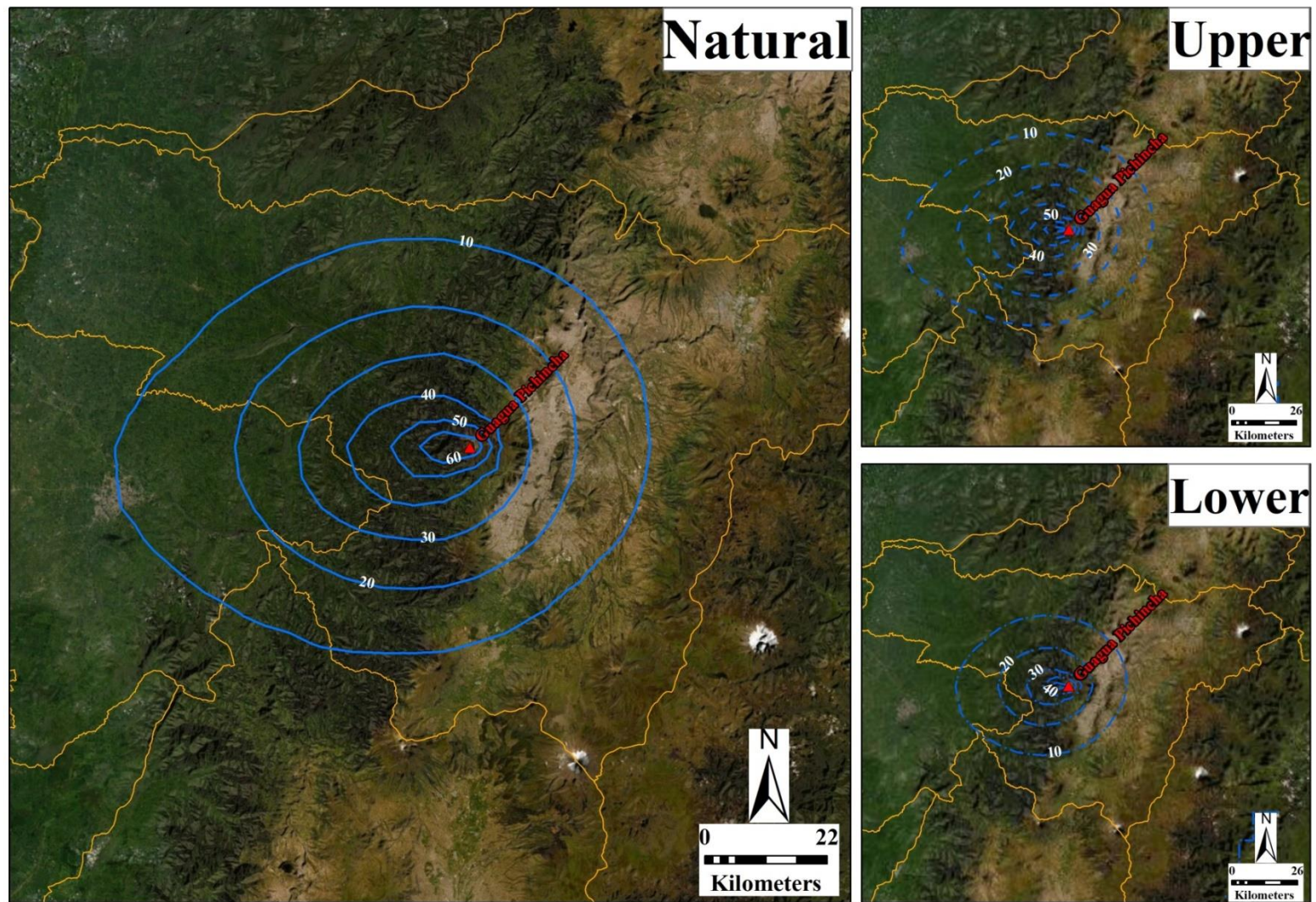


Figure S42. Guagua Pichincha volcano, sub-Plinian eruption – Probabilistic map (10 mm)

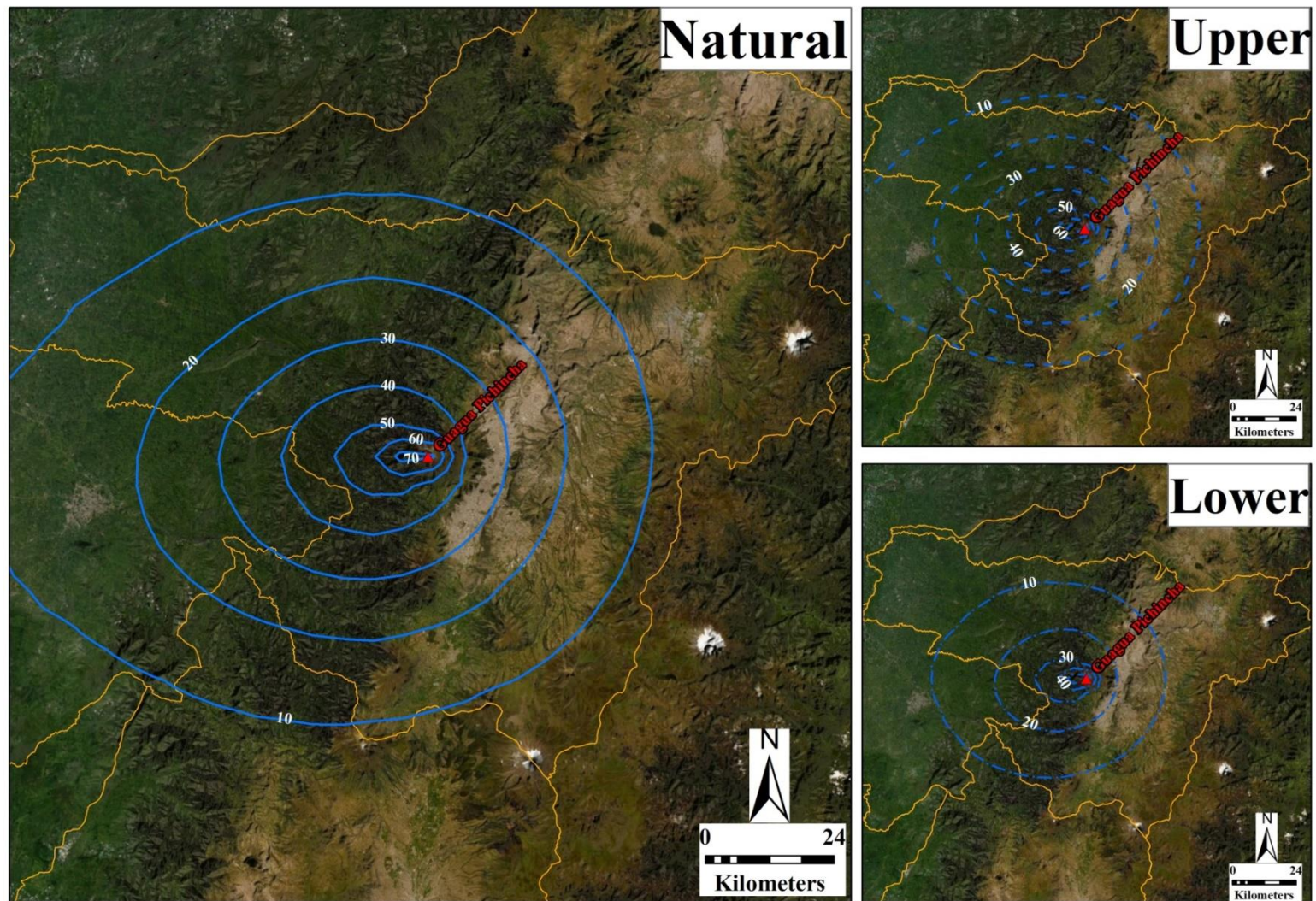


Figure S43. Guagua Pichincha volcano, sub-Plinian eruption – Probabilistic map (30 mm)

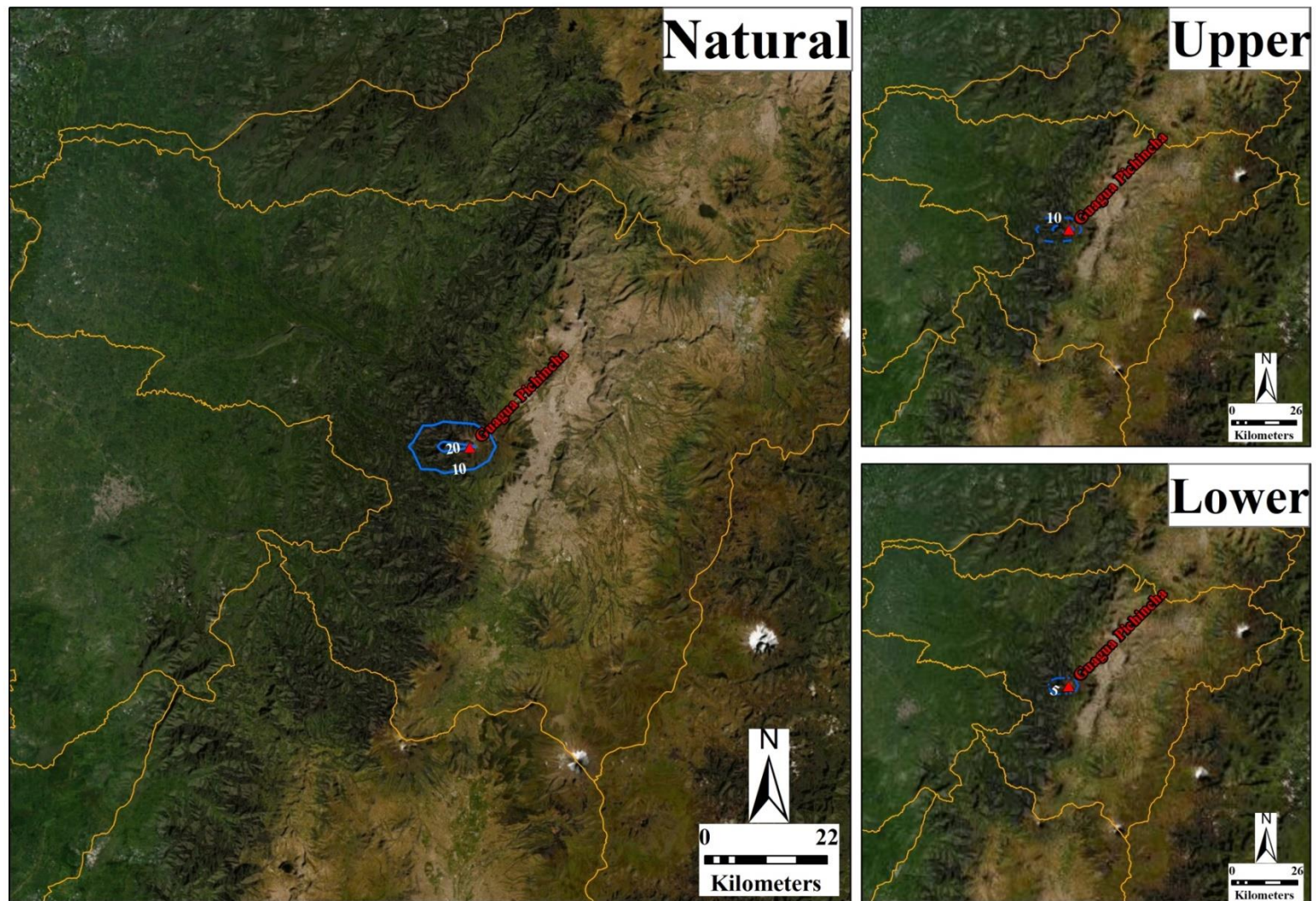


Figure S44. Guagua Pichincha volcano, sub-Plinian eruption – Probabilistic map (100 mm)

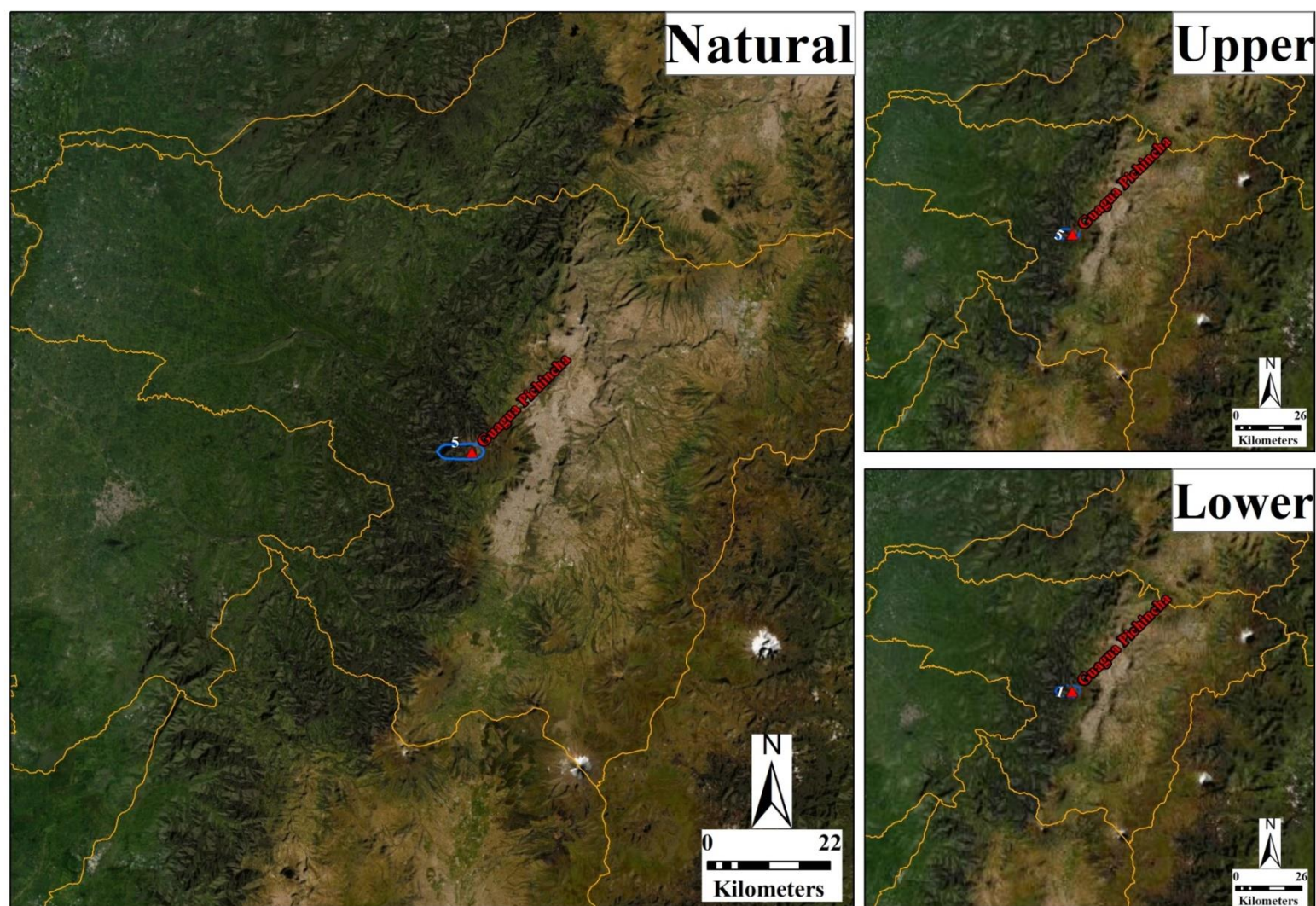


Figure S45. Guagua Pichincha volcano, sub-Plinian eruption – Probabilistic map (300 mm)

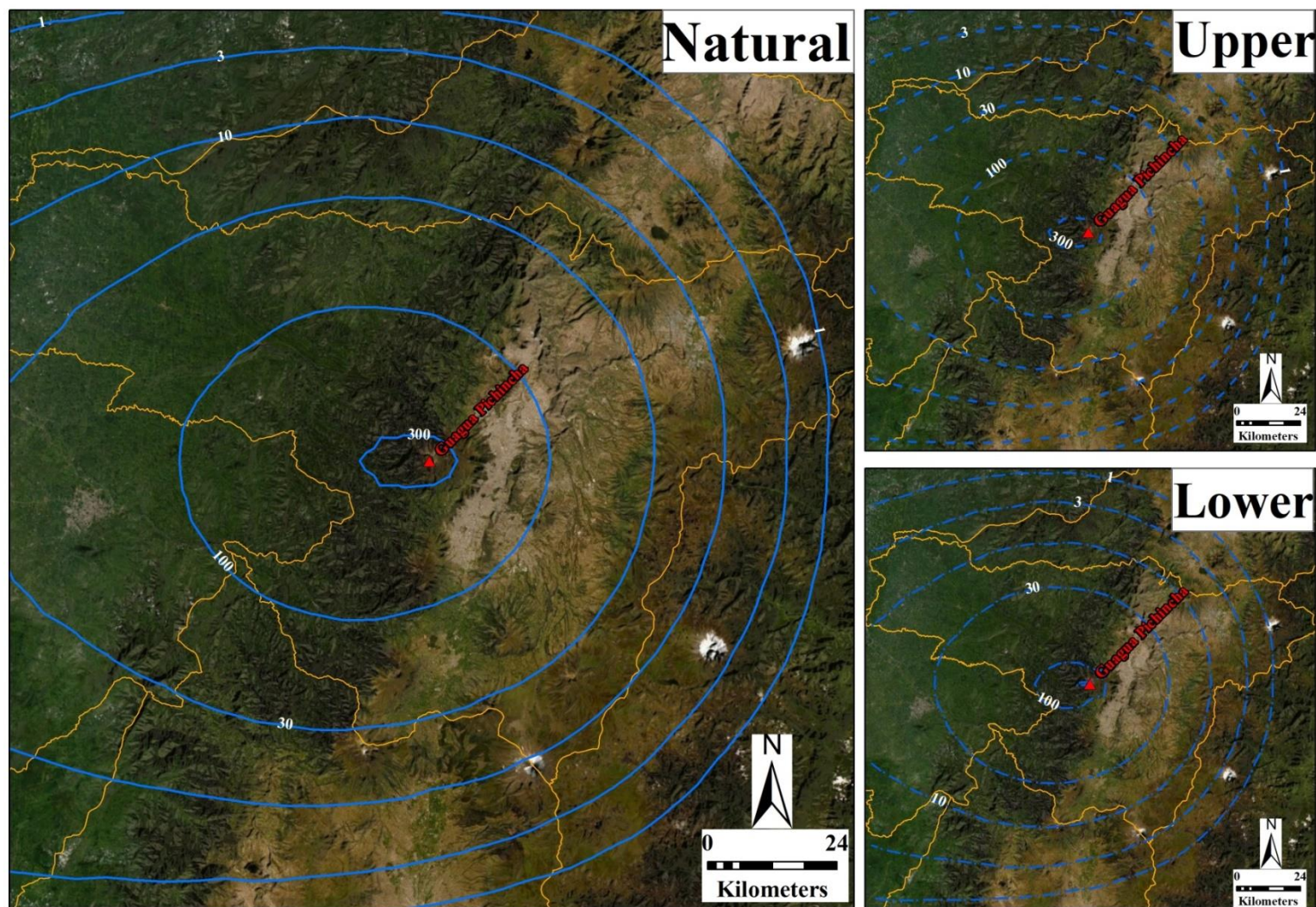


Figure S46. Guagua Pichincha volcano, sub-Plinian eruption – Isopach map (10 %)

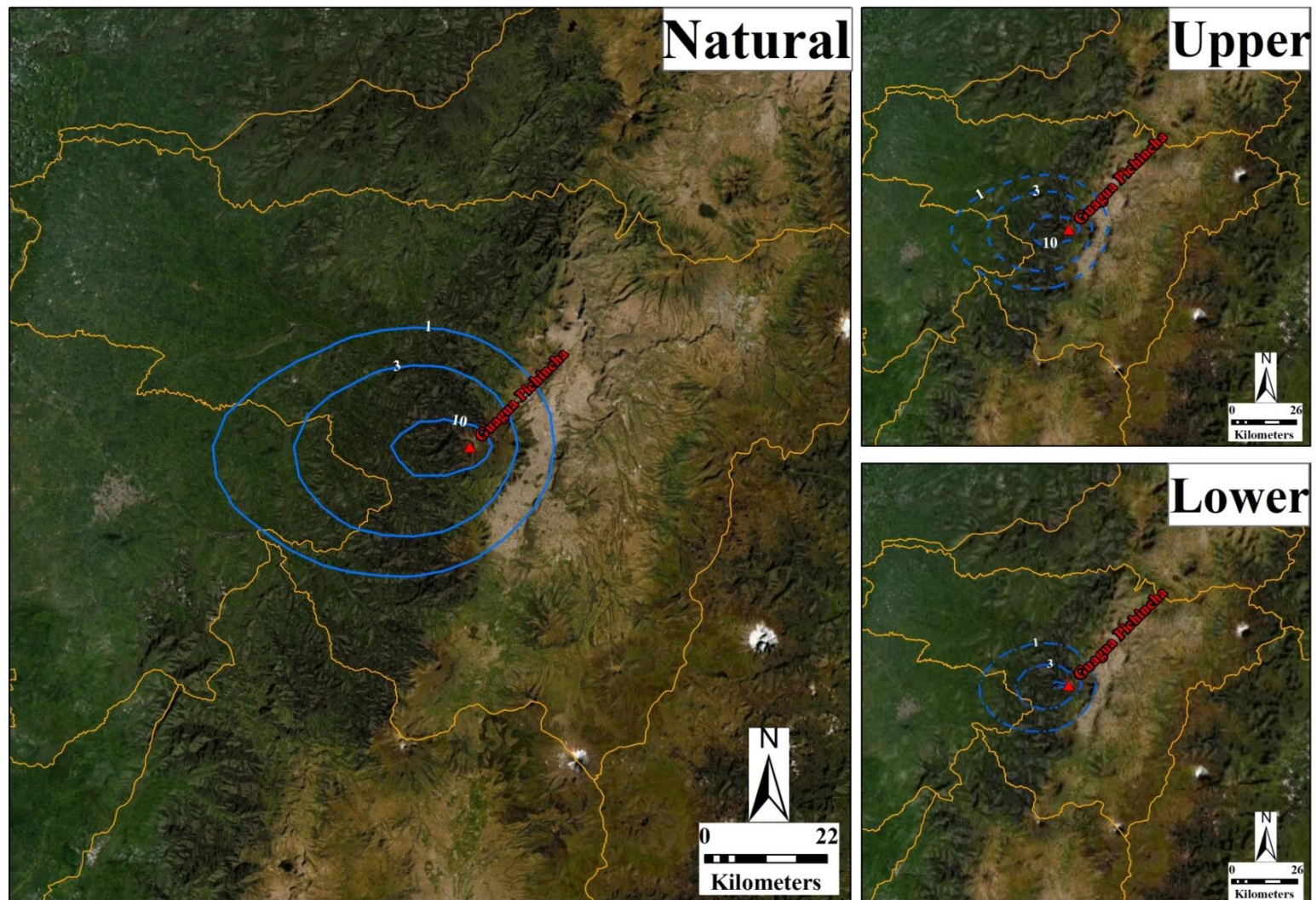


Figure S47. Guagua Pichincha volcano, sub-Plinian eruption – Isopach map (50 %)

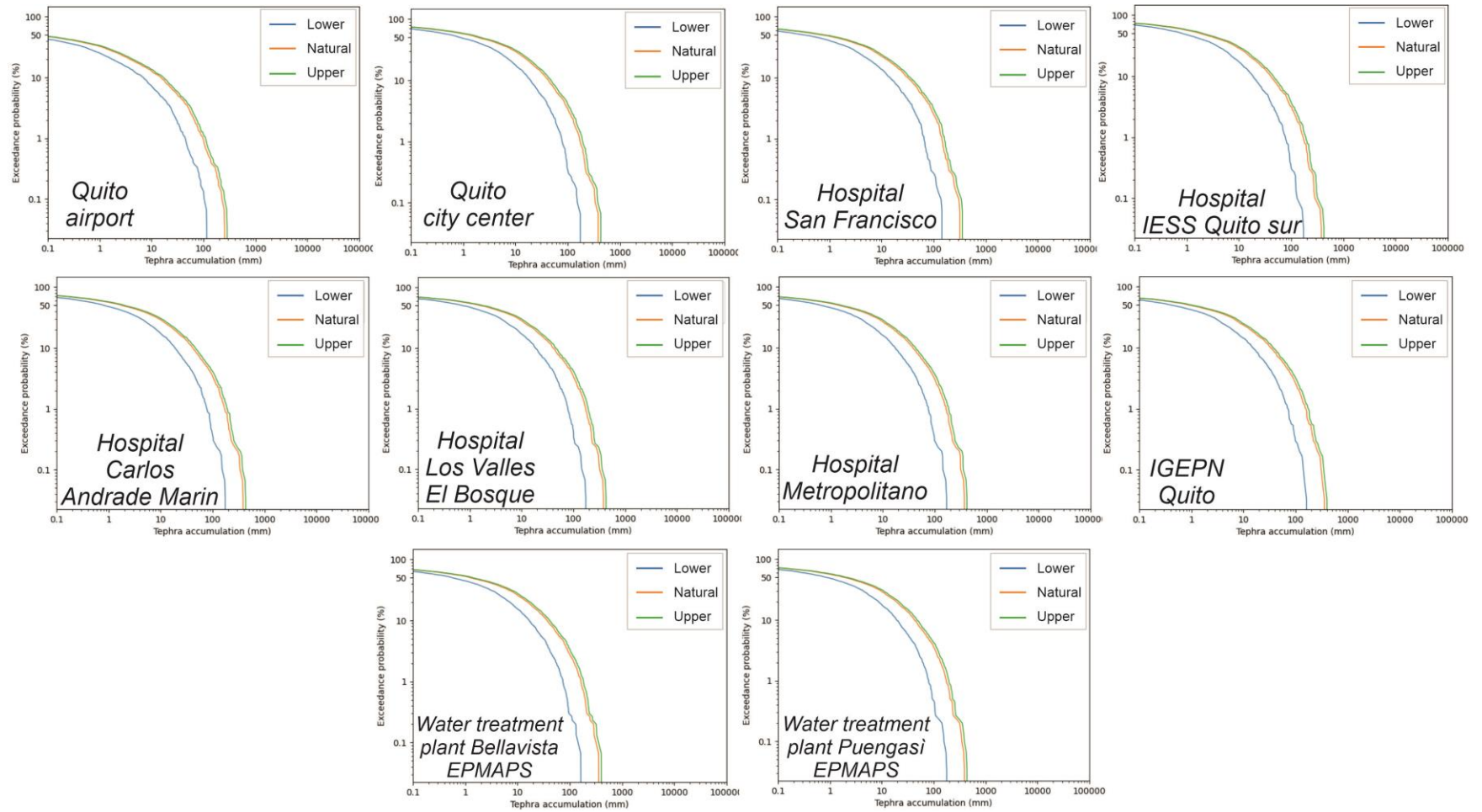


Figure S48. Guagua Pichincha volcano, sub-Plinian eruption – Hazard curves

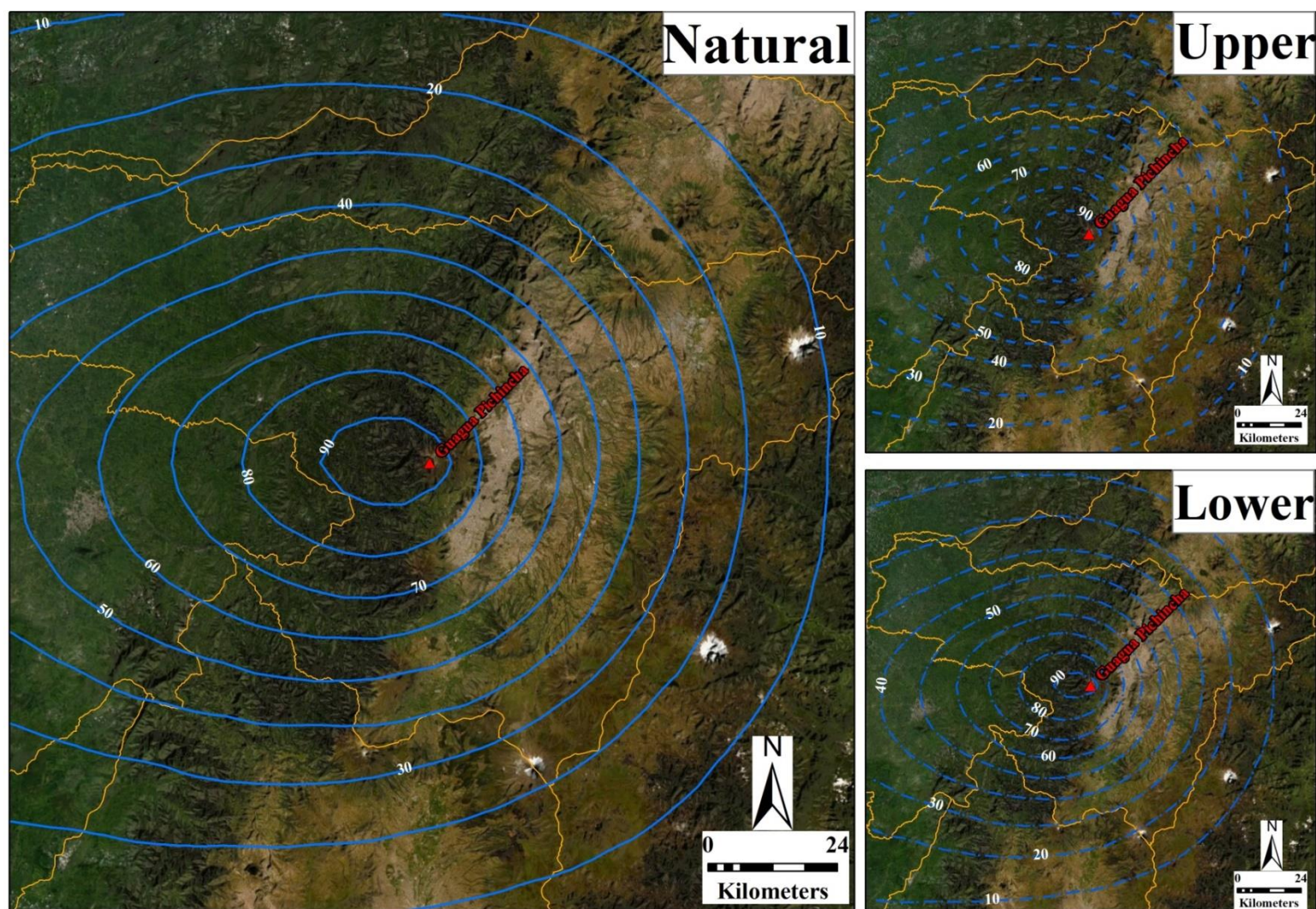


Figure S49. Guagua Pichincha volcano, Plinian eruption – Probabilistic map (1 mm)

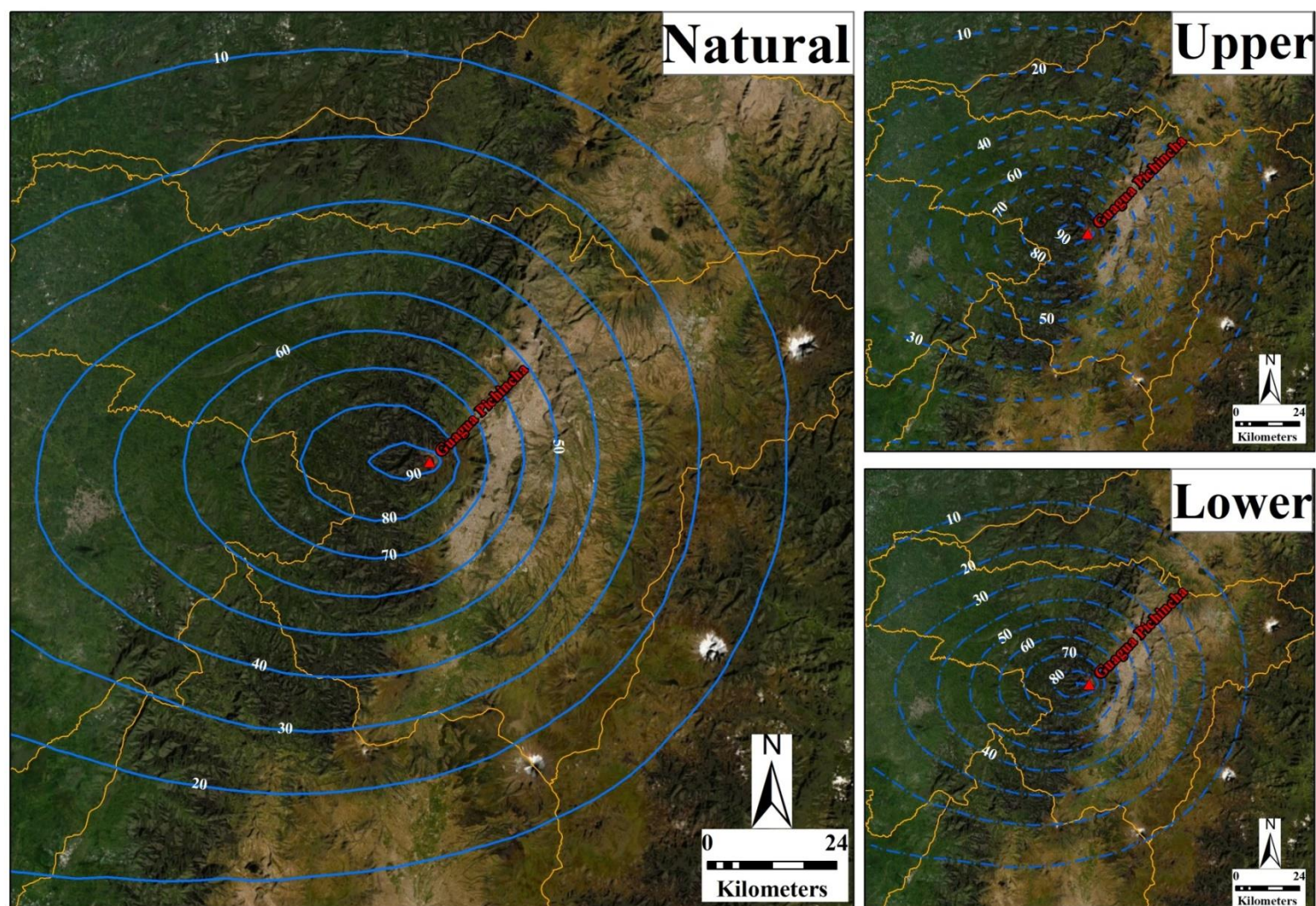


Figure S50. Guagua Pichincha volcano, Plinian eruption – Probabilistic map (3 mm)

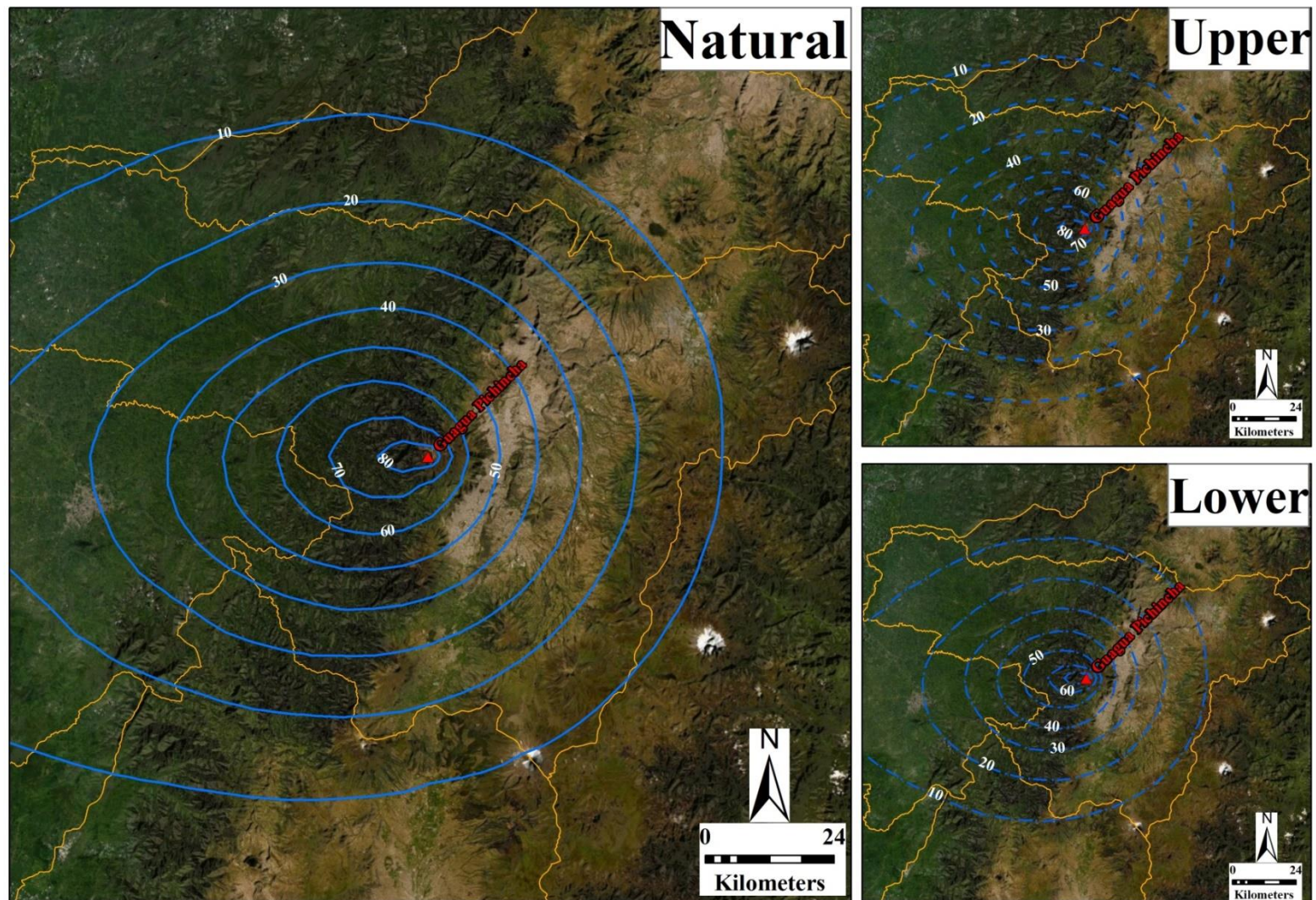


Figure S51. Guagua Pichincha volcano, Plinian eruption – Probabilistic map (10 mm)

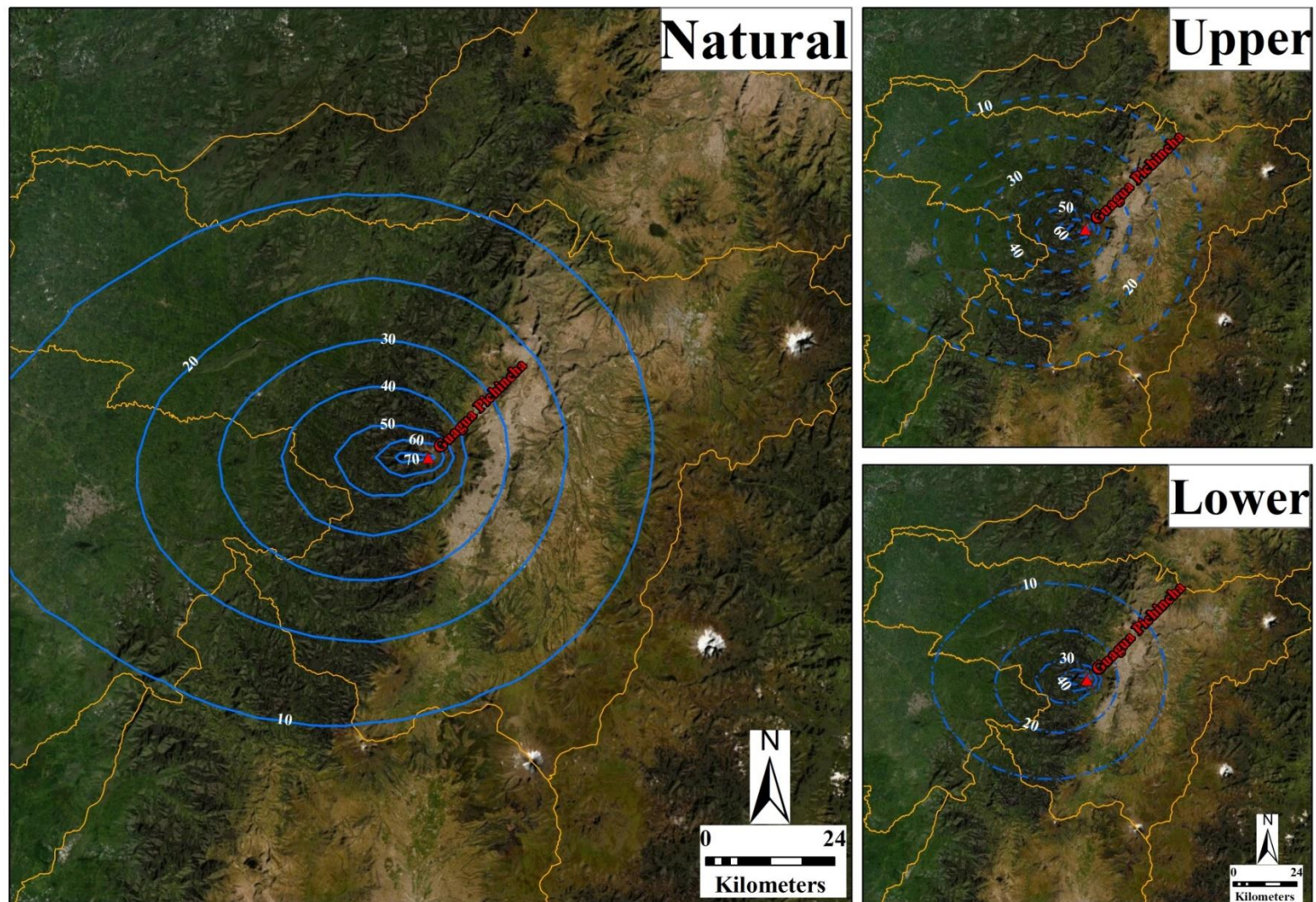


Figure S52. Guagua Pichincha volcano, Plinian eruption – Probabilistic map (30 mm)

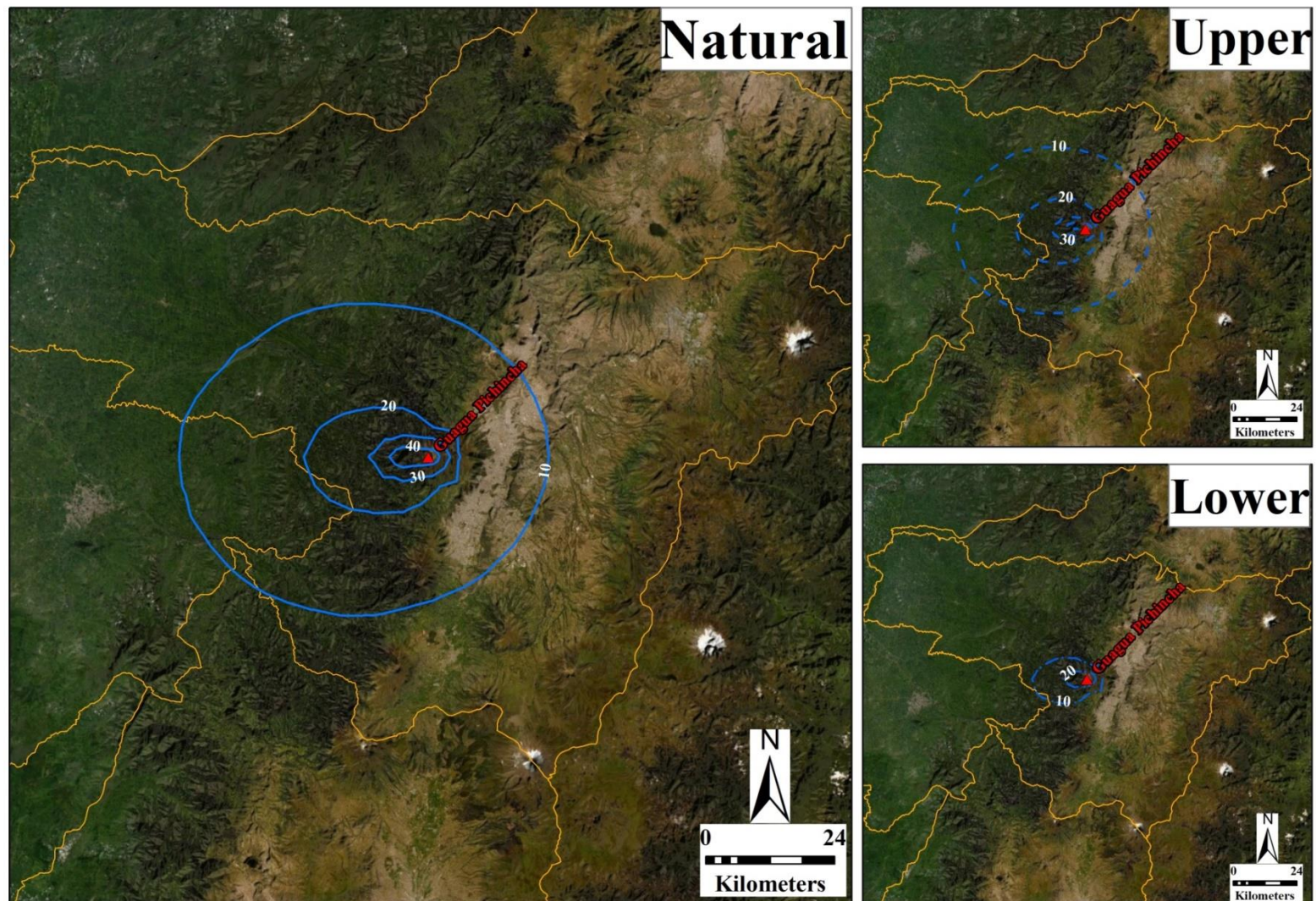


Figure S53. Guagua Pichincha volcano, Plinian eruption – Probabilistic map (100 mm)

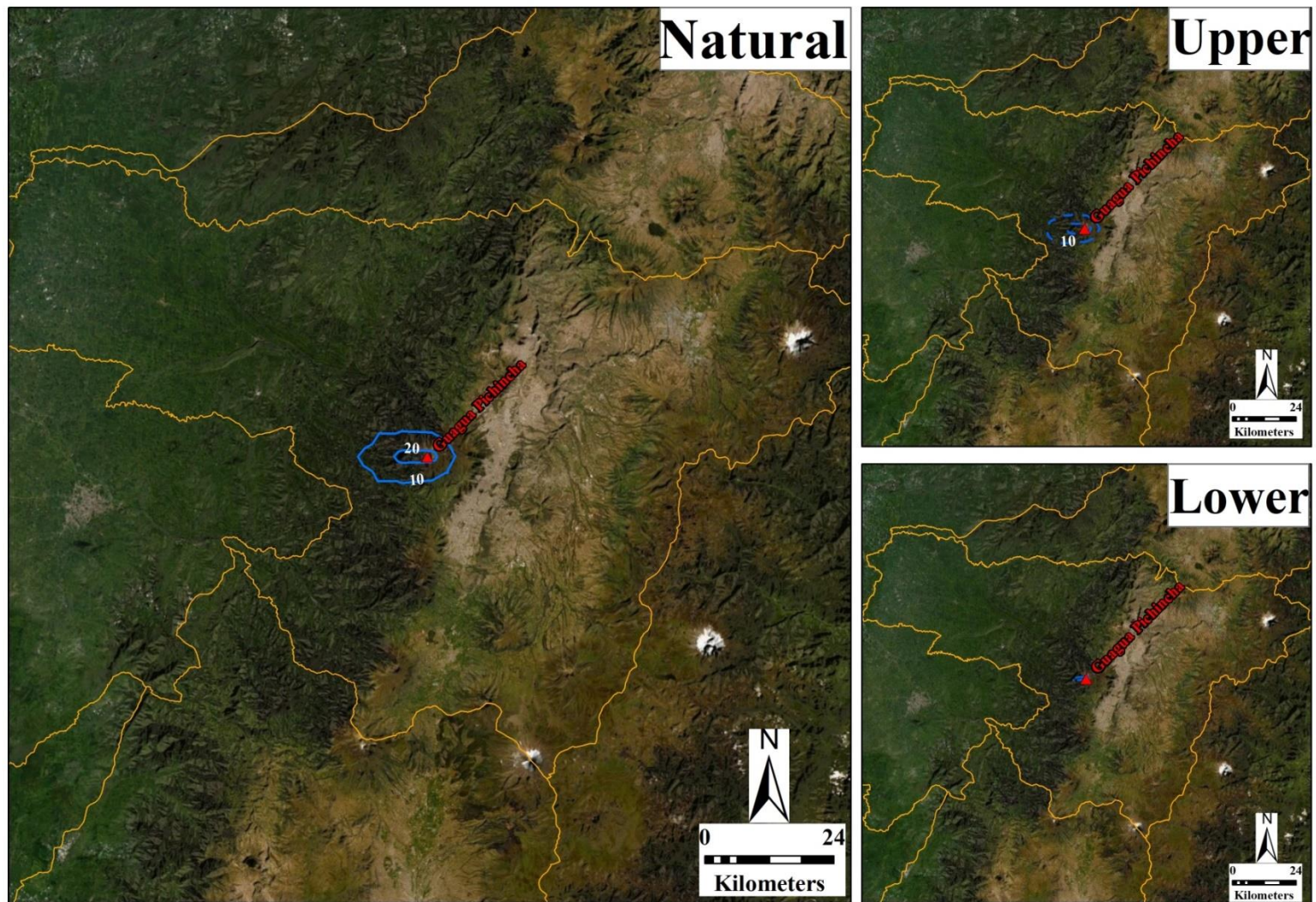


Figure S54. Guagua Pichincha volcano, Plinian eruption – Probabilistic map (300 mm)

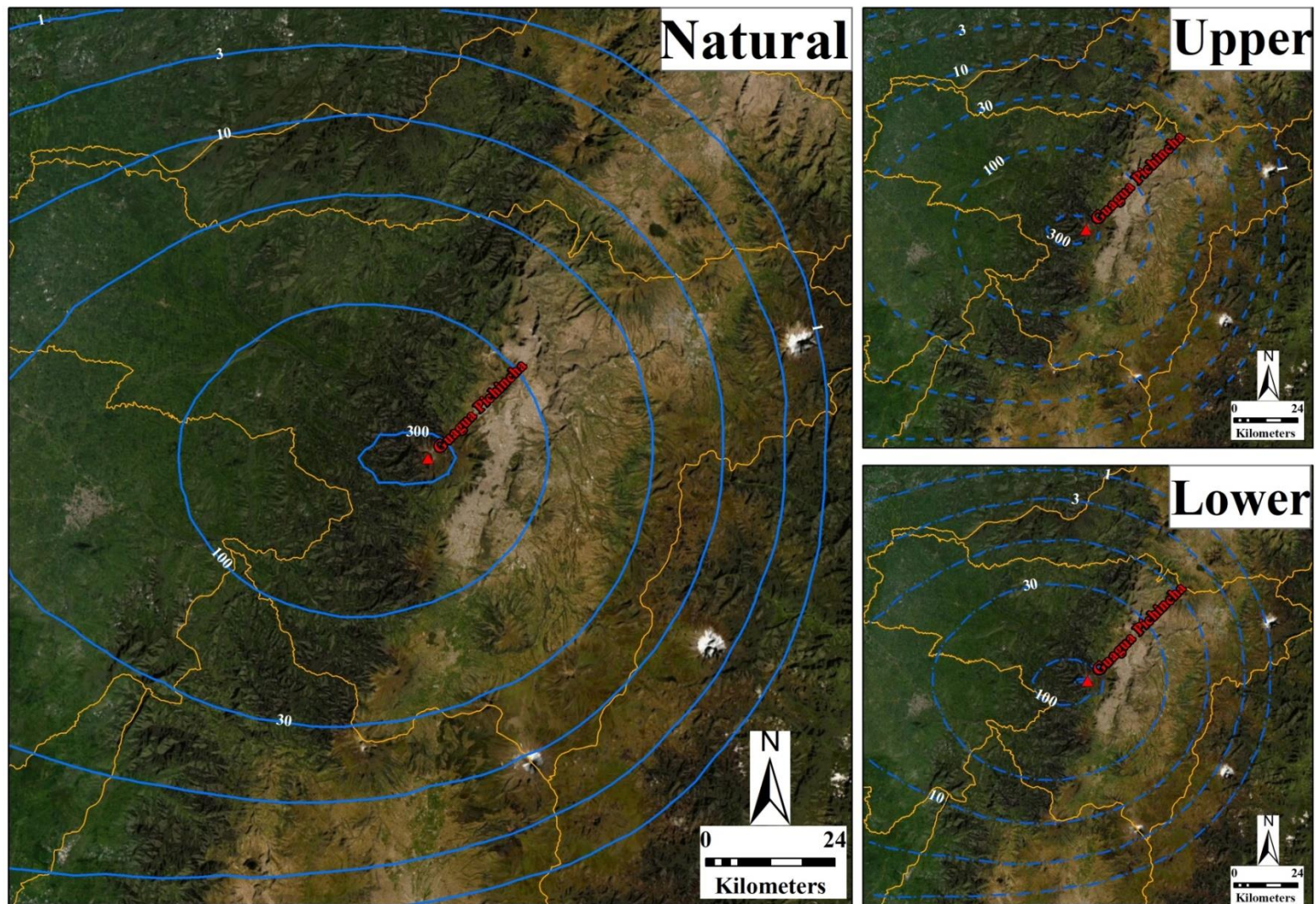


Figure S55. Guagua Pichincha volcano, Plinian eruption – Isopach map (10 %)

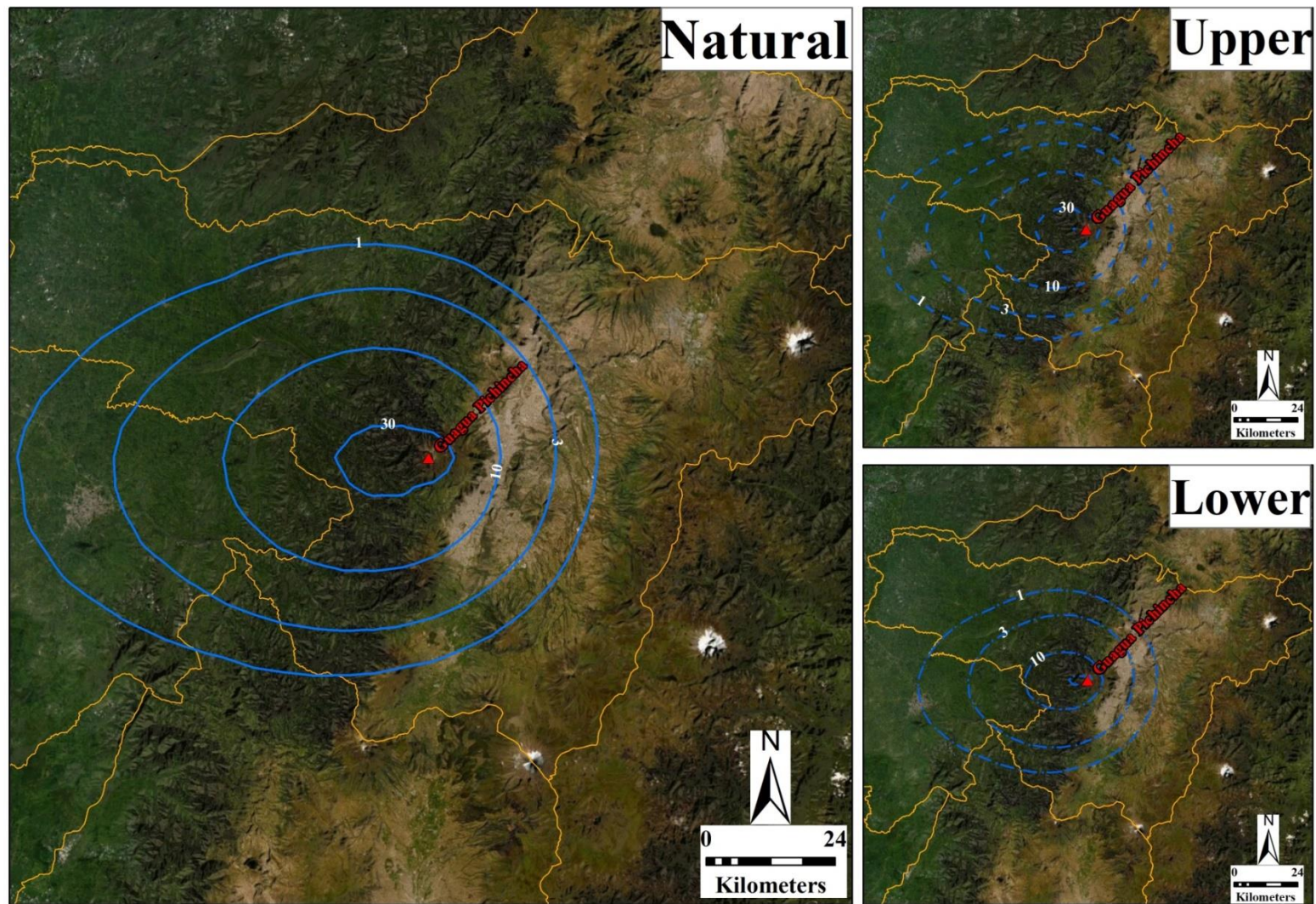


Figure S56. Guagua Pichincha volcano, Plinian eruption – Isopach map (50 %)

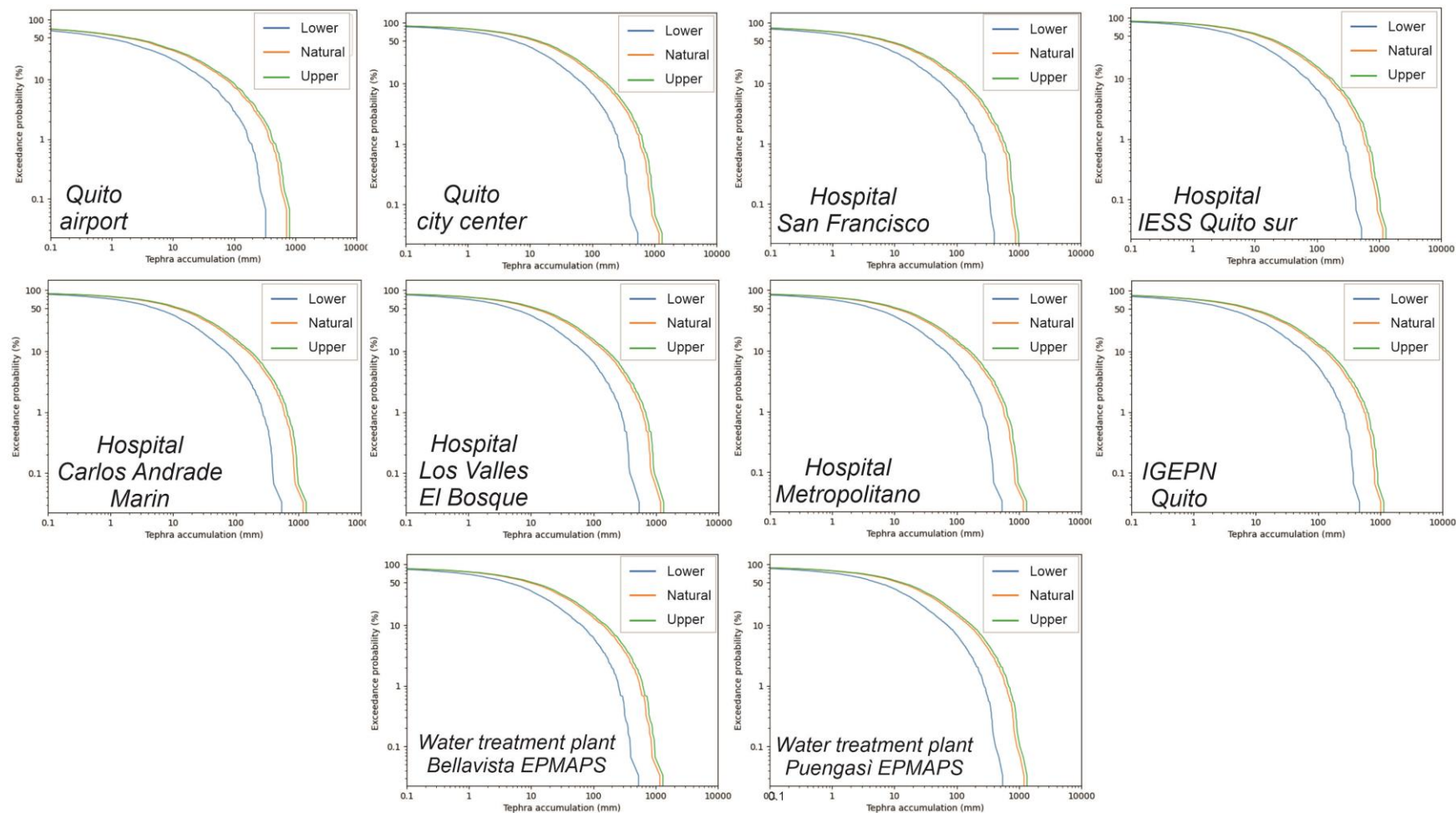


Figure S57. Guagua Pichincha volcano, Plinian eruption – Hazard curves