METEOR

Modelling Exposure Through Earth Observation Routines

INTRODUCTION TO VOLCANOES AND VOLCANIC HAZARD ASSESSMENT IN METEOR

https://meteor-project.org

Outline

- Introduction to Volcanoes
  - Types of volcano
  - Style and Size of eruptions
  - Volcanic Hazards: PDCs, Tephra, Lahar
  - Volcanic Hazard Management
- Modelling volcanic hazards – METEOR
  - Volcanic hazards in Tanzania
  - Tephra2 Simulations
  - Lahar and PDC basin modelling

Introduction to volcanoes

- 10% of the world’s population live within 100 km of a volcano active in the last 10,000 years
- The explosive potential of a volcano is linked to magma viscosity and gas content.
- Low viscosity magmas have effusive eruptions
- High viscosity magmas *tend* to have more explosive eruptions.

Fig… anism
Program and CIESIN gridded population data
Image credit: Pu'u O'o vent, Hawaii USGS.

Types of Volcanoes

Broadly 2 types of volcanoes:

Shield Volcano: Low viscosity lavas, forming gentle slopes. Hawaiian type volcanoes

Stratovolcano: Higher viscosity lavas, forming steep slopes as lavas build up around the vent of the volcano. More likely to produce explosive eruptions due to gas build up.

Other: Fissure, Cinder cones, Domes, Caldera

Caldera's are formed in very large, highly explosive eruptions.

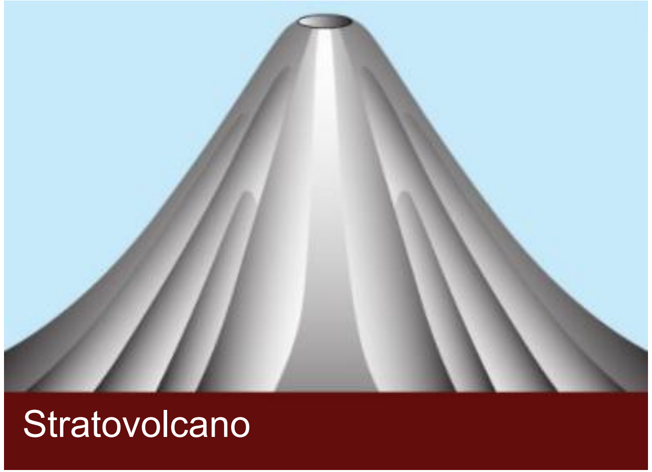

Image Source: BGS, UKRI

Styles of eruption

- Hawaiian / Strombolian: Least violent – lava flows and fire fountains. Lava fragments.
- Vulcanian: Small to moderate eruptions. Can generate ash columns up to 20km high.
- Plinian eruptions: Form large ash columns (20 -35km tall), which may collapse.

Image credit: USGS

Image credit: ESA Earth Online

Image credit: USGS

Image credit: BGS

The size of eruptions

Volcanic Explosivity Index

- 0 – 8 Scale
- Logarithmic.
- Assess: eruption volume, plume height, frequency, tropospheric and stratospheric injection.

- Hawaiian = VEI 0 - 1
- Plinian = VEI 5 - 6

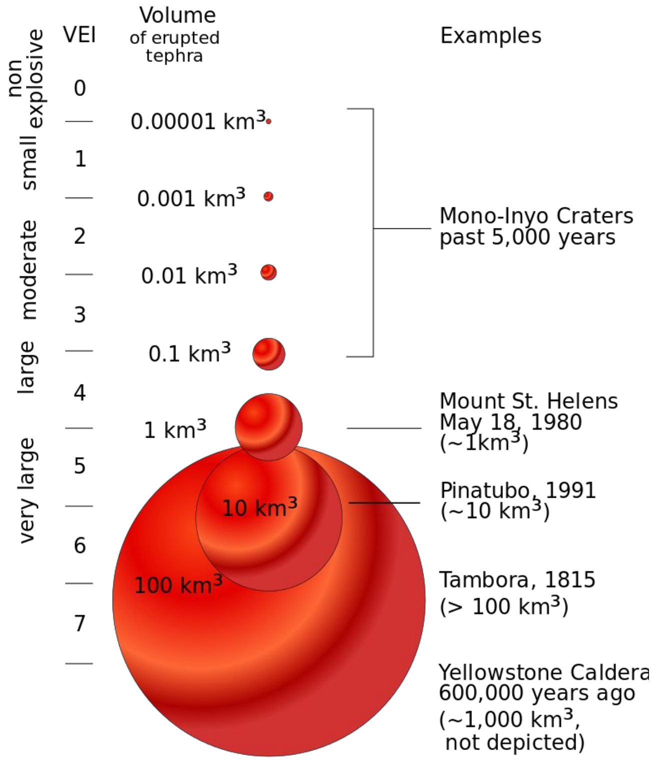

Image credit: USGS

Volcanic Hazards

There are 2 kinds of volcanic hazard: **Primary and Secondary**.

- Primary hazards are produced during eruption by the volcano.
- Secondary hazards occur as a result of the primary hazard.
- Both can affect populations at distances of less then a kilometer (volcanic bombs) from the volcano up to several 100 kilometers away (ash fall / tsunami).

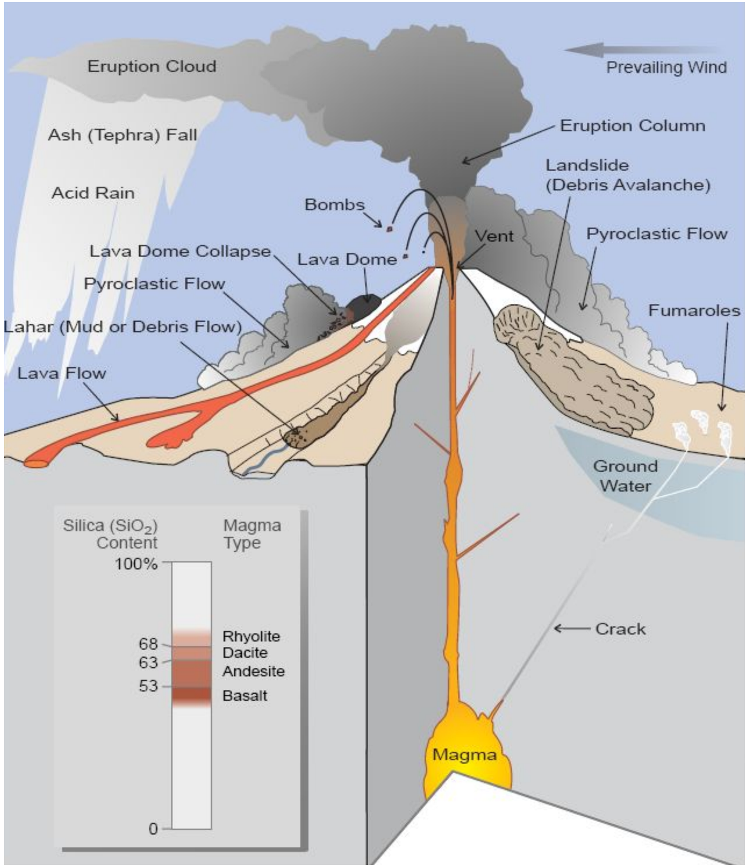

Image credit: USGS ‘ Geologic hazards at volcanoes’ poster.

Volcanic Hazards

Primary Hazards

- Lava Flows
- Pyroclastic Flows (Pyroclastic density currents)
- Ash (Tephra) Fall
- Bombs and ejecta
- Landslides (Debris Avalanches)

Secondary Hazards

- Lahars / mudflows
- Floods
- Fires
- Tsunamis

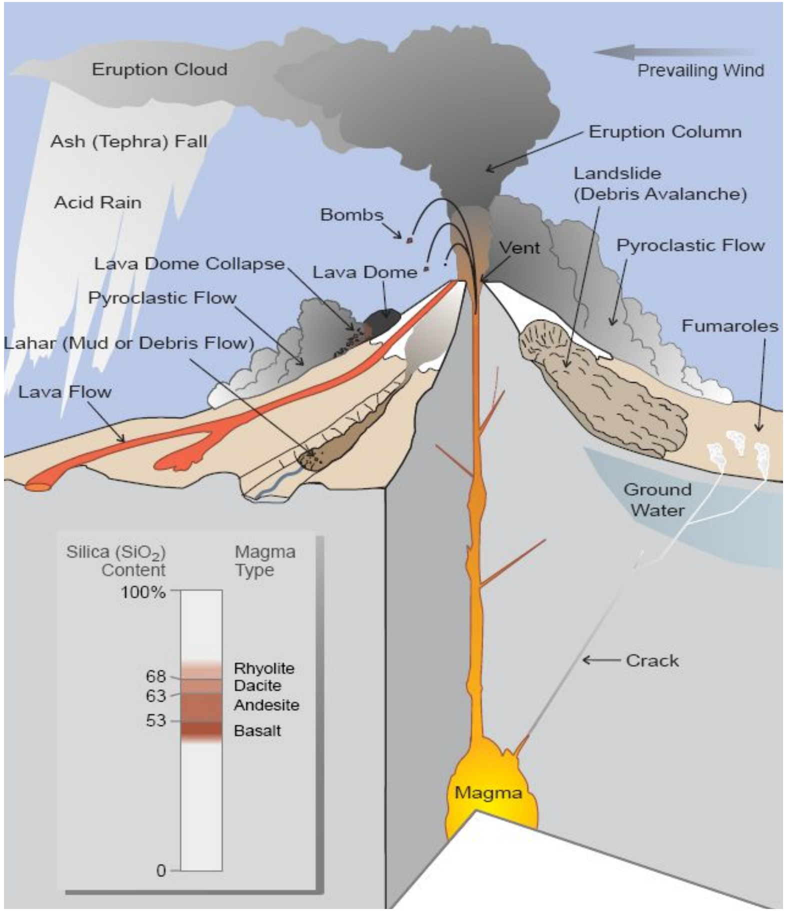

Image credit: USGS ' Geologic hazards at volcanoes' poster.

Pyroclastic Density Currents

- Flow of fast-moving currents of hot gas and rock
- Travel at speeds higher than 80 km per hour
- Typically reach temperatures between 200 and 700 degrees.
- They are caused by:
  - **Eruption column collapse**
  - **Lava dome Collapse**
  - **'Boiling over' from an eruptive vent**

Photo Credit: CVGHM eruption of Sinabung

Tephra / ash hazards

All pieces or fragments of rock ejected into the air by an erupting volcano.

- >64mm = bombs, <2mm = ash
- Can be transported far from the summit of the volcano.
- Travel depends on: height of the column, temperature of the air, wind direction and wind speed.
- Can damage buildings (collapse roofs), impact health, interact with airplanes.

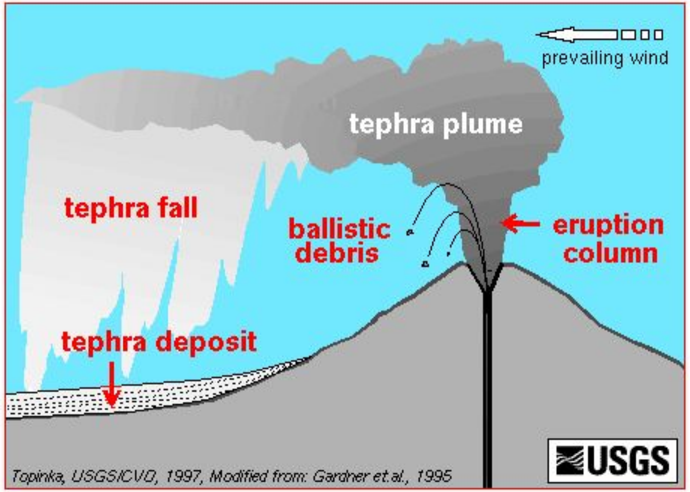

Photo: USGS

Lahars

- May be formed by:
  - eruption onto snow or ice field
  - breaching of a crater lake
  - precipitation onto unconsolidated ash & PDC deposits
- Can increase by 10x the original size.
- Velocities 10s km/h, Travel for 10s km
- Deposits may be metres to 10s m thick
- Hazard may continue for years

Images from: Eruption of Mount Pinatubo (Image credit: USGS)

Volcanic Hazard Management

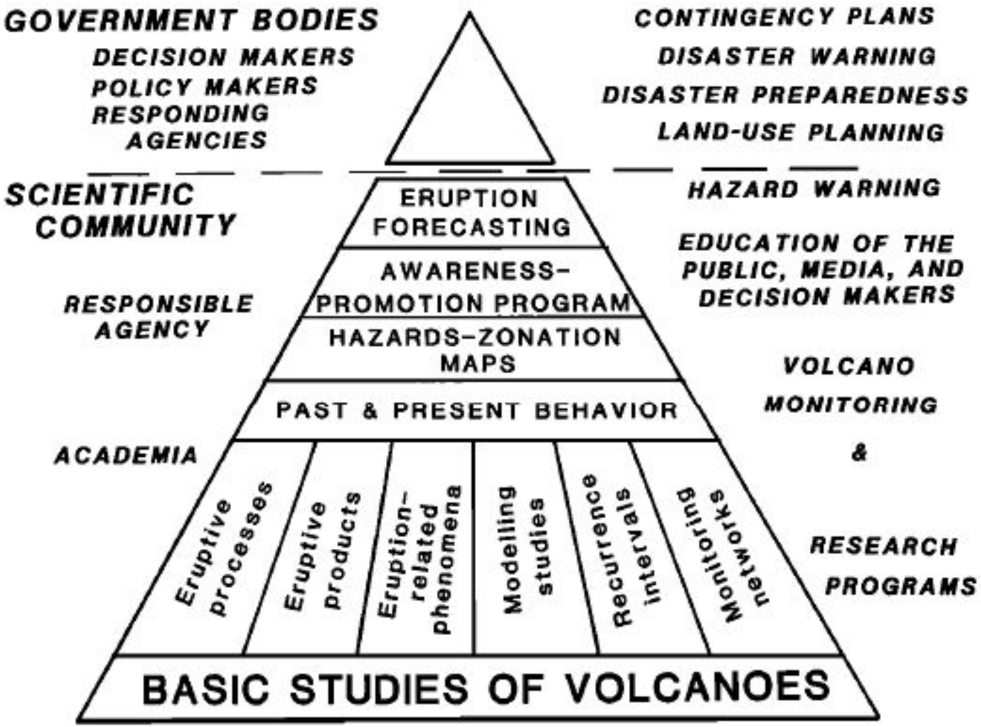

Figure 1.2 Volcano hazard mitigation (Tilling, 1989, p.242)

MODELLING VOLCANIC HAZARDS - METEOR

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Volcanic Hazards in Tanzania

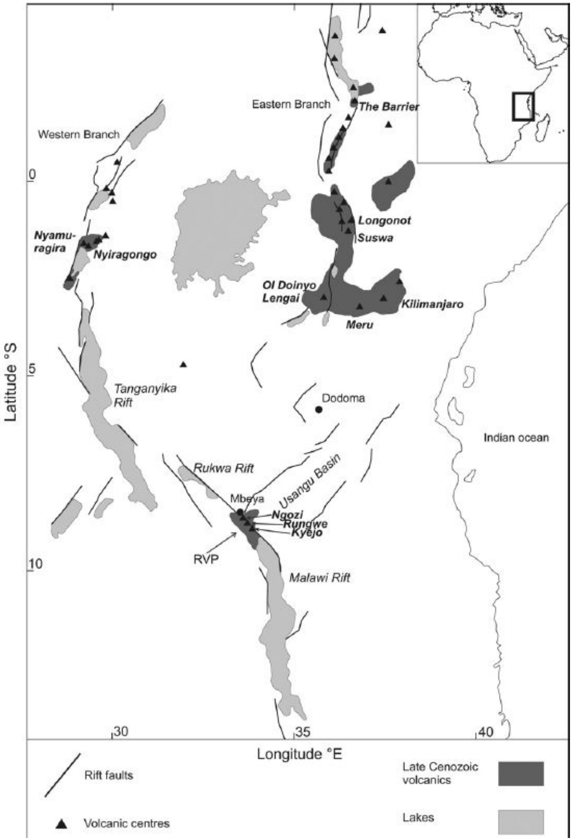
6 volcanoes active in the Holocene – Ol Doinyo Lengai, Meru, Igwisi Hills, Ngozi, Kyejo, Rungwe

Main Hazards:

Pyroclastic flows

Ash fall

Lahars



Fontijn et al (2010) JVGR

Inputs:

- Eruption history
- Volumes of deposits
- DEM (10 or 30m)
- Particle size distribution
- Plume height
- Wind speed / direction
- Duration of column

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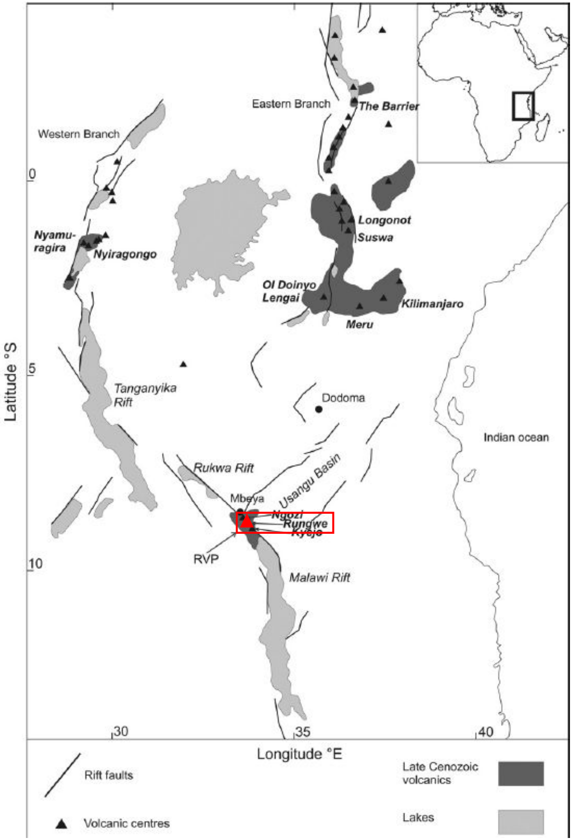
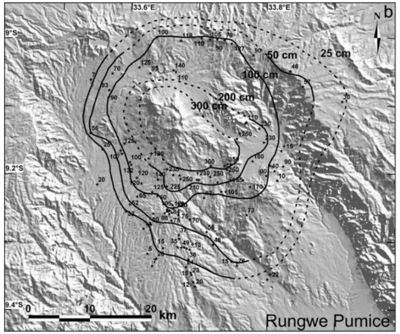
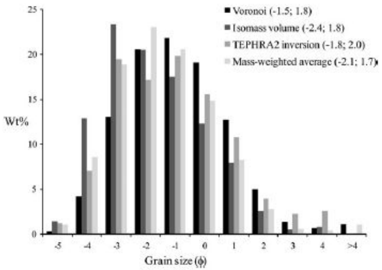


Fontijn et al (2010) JVGR

Rungwe – Tephra 2 simulations

Tephra 2: advection diffusion model to calculate tephra accumulation given a pre-defined set of eruptive conditions.





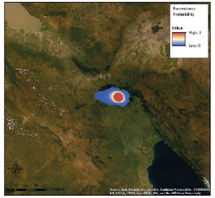
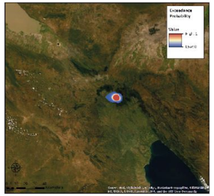
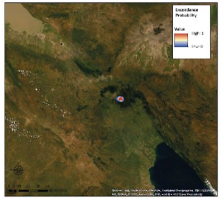
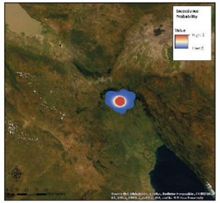
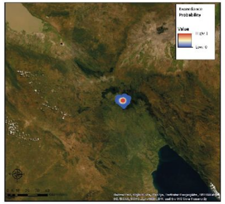
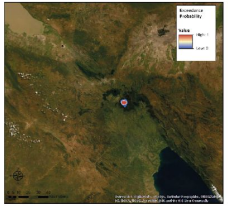
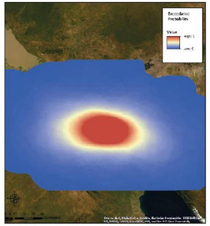
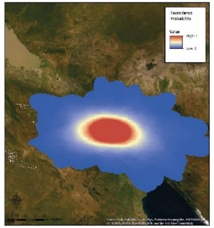
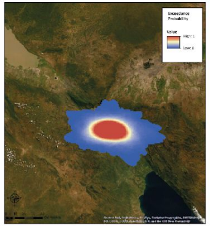
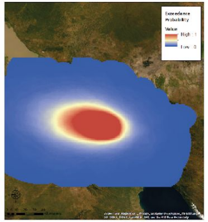
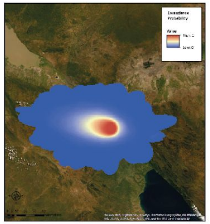
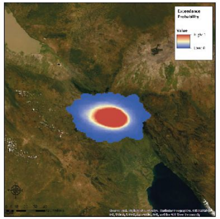
Grain size distributions described by Fontjin et al (2011) and 2012

- Eruptive parameters: volume and plume height defined by the VEI of eruption. Particle size distribution
- Particle parameters: Fall time threshold (of particles) defined by properties (density and diameter), lithic and pumice densities etc – from Fontjin et al.
- Atmospheric parameters – 10 year wind data from NOAA. Gives speed, height and 2 atmospheric levels

2 eruption types – based on eruption history and previous elicitation.

1. VEI 2: >$10^6 m^3$ <$10^7 m^3$ ejected volume. Plume height 1 – 5km
2. VEI 4: >$0.1 km^3$ <$1 km^3$ ejected volume. Plume height 10km

Rungwe – Tephra 2 simulations: Results

		1 kg/m^2	10 kg/m^2	100 kg/m^2
VEI 2	Apr - Nov			
	Dec - Mar			
VEI 4	Apr - Nov			
	Dec - Mar			

Rungwe – Tephra 2 simulations: Uncertainties

- Eruption history is not complete.
- Future source parameters and wind conditions are likely to vary
- Tephra 2 makes an assumption that the input parameters are representative of the average conditions over the peak eruption duration and that most of the tephra is ejected in a short duration explosive event.

Lahar and Pyroclastic basin modelling

DTM Preparation

- Resample SRTM DTMs to 450m
- Create buffer zones around each volcano (3 km and 30 km for PDC hazard; 10 km and 100 km for lahar hazard)
- Clip raster to outer buffers (30 km and 100 km) – Extract by Mask

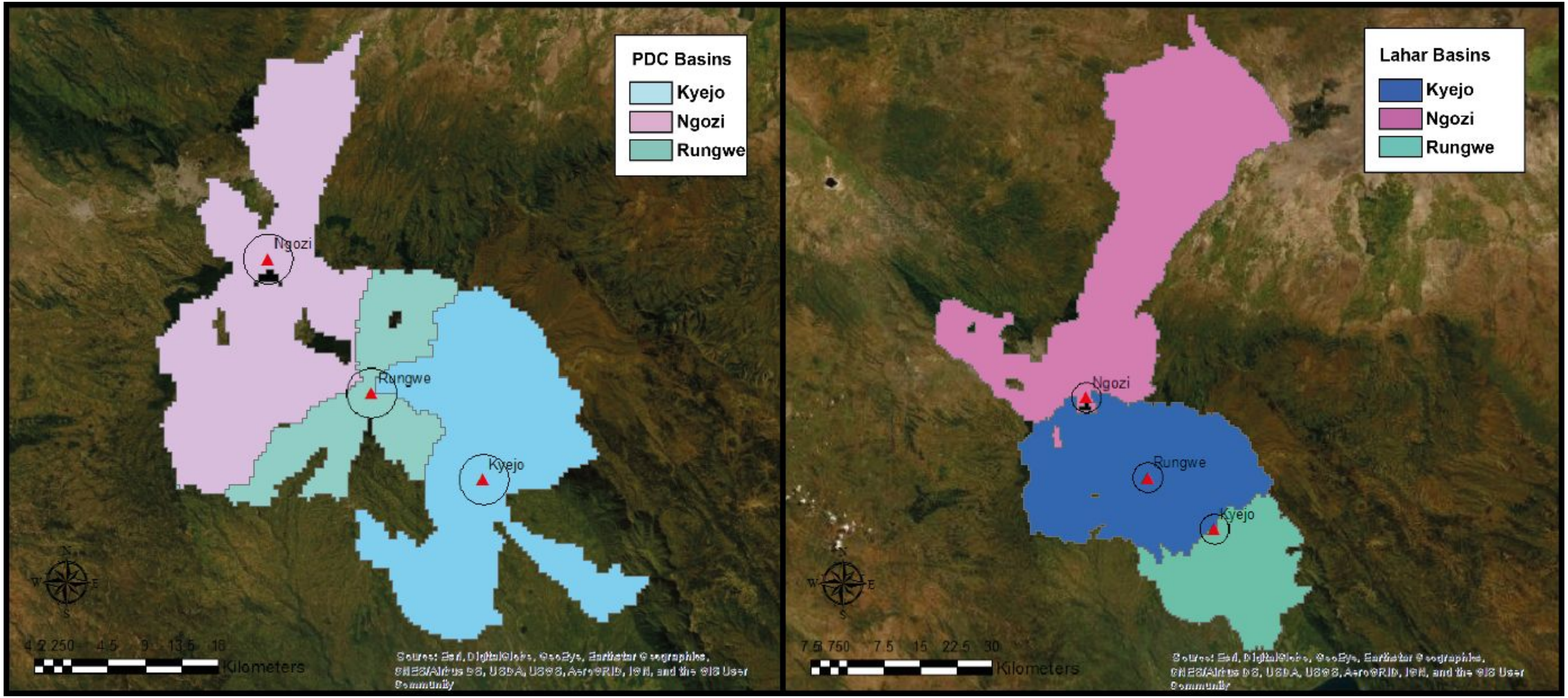
Pyroclastic

- *Clip 'final' DTM to 30 km buffer*
- Calculate flow direction on 'final' DTM
- Calculate basins from flow direction
- Select all basin polygons that intersect with the inner hazard buffer
- Dissolve/merge polygons to give one footprint of potential hazard zones.

Lahar

- Calculate 'Slope' (Spatial analyst > Surface) from clipped raster
- Reclassify into 0 and >0. Use Properties > Unique values to determine lowest value that is > 0 (e.g. 0.002) and use this as the threshold for reclassifying.
- Convert to integer type and pass integer grid through the majority filter.
- Remove lakes and identify sinks, remove if necessary.
- Multiply filled DTM (sinks removed) with lakes removed DTM to give final raster for basin analysis

Lahar and Pyroclastic basin modelling - results



https://maps.meteor-project.org/map/vol-basins-tza/#6/-4.903/32.293

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