EGU General Assembly 2022 Vienna, Austria & Online | 23–27 May 2022

NH 3.7 Towards reliable Landslide Early Warning Systems
ID: EGU22-2774ECS

DEWS: a QGIS tool pack for the automatic selection of reference rain gauges for landslide-triggering rainfall thresholds

- **Omar F. Al-Thuwaynee , Massimo Melillo, Stefano Luigi Gariano |** Research Institute for Geo-Hydrological Protection IRPI, Italian National Research Council, Perugia, Italy
- **Hyuck Jin Park, Sang-Wan Kim, IT Hwang |** Department of Energy and Mineral Resources Engineering, Sejong University, Korea
- **Luigi Lombardo |** Department of Earth Systems Analysis (ESA), University of Twente, Enschede, Netherlands
- **Paulo Hader |** Department of Civil Engineering, São Paulo State University, São Paulo, Brazil
- **Meriame Mohajane |** Department of Biology, Université Moulay Ismail, Meknès, Morocco
- **Renata Pacheco Quevedo |** Earth Observation and Geoinformatics Division, National Institute for Space Research, São José dos Campos, Brazil
- **Filippo Catani |** Department of Geosciences, University of Padova, Padova, Italy
- **Ali Aydda |** Department of Geology, University Ibn Zohr – Agadir, Agadir, Morocco

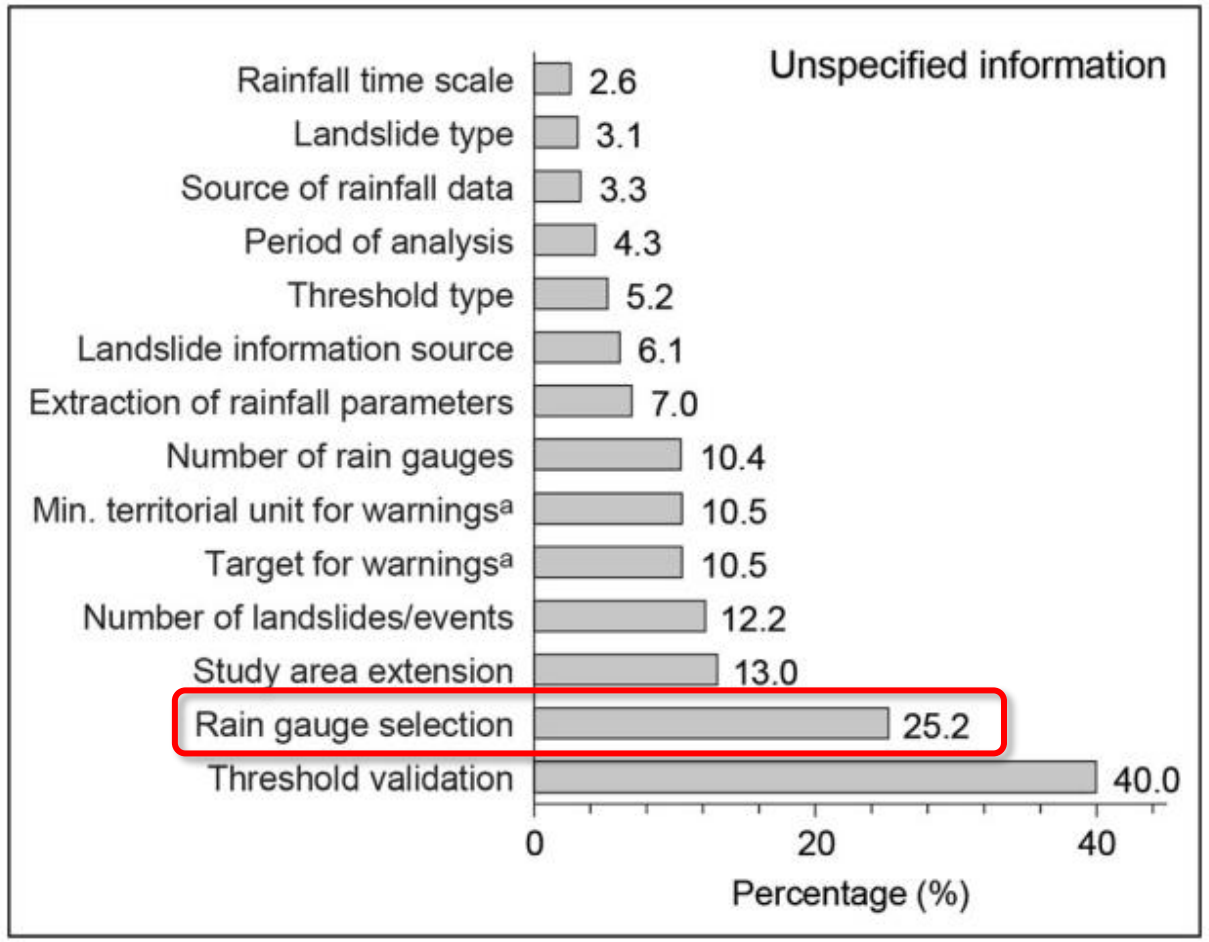


Fig. Percentage of unspecified information about threshold features. considering only the thresholds implemented in a LEWS,
(modified after Segoni et al. 2018)

In 107 papers, Segoni et al. (2018) stated that, “Surprisingly, in about 25% of the analyzed thresholds, a clear description of the method adopted for the rain gauge selection is missing.”

- In LEWS, Landslide threshold used to identify the rainfall condition associated with high probability of landslide occurrence.
- Rain gauge (more than radar or satellite data) used to construct the rainfall events that might be responsible in landslide occurrence (Althuwaynee et al. 2018).

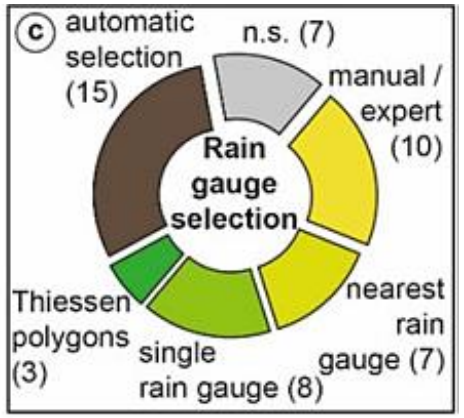
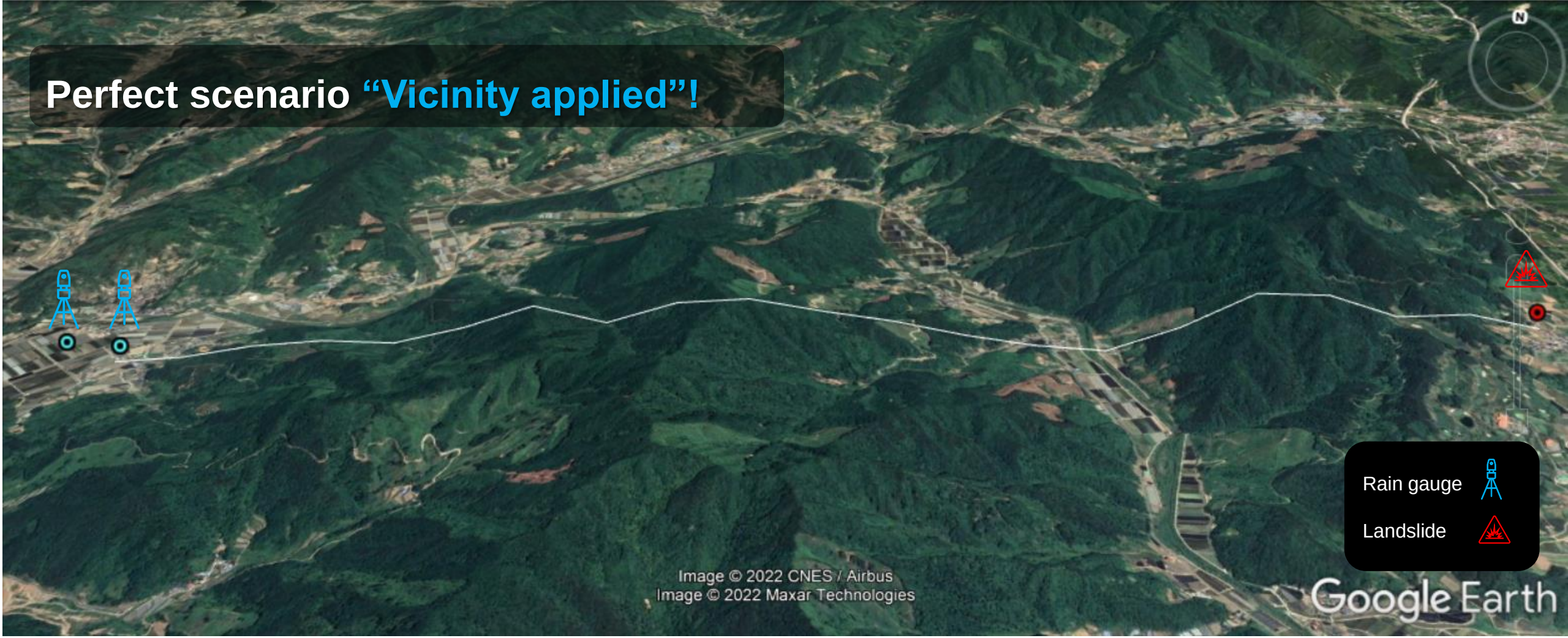


Fig. Doughnut charts (c) methods employed for rain gauge selection Key: n.s. not specified
(Modified after Gariano et al. 2020)

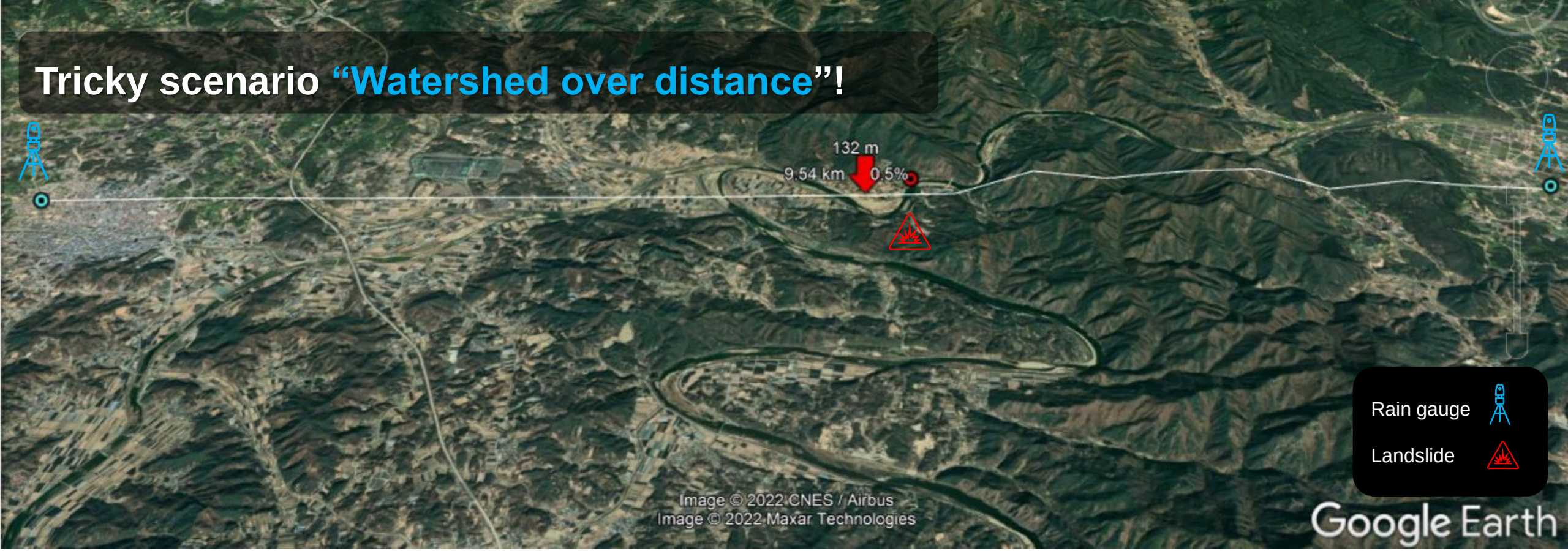
no consensus on which selection technique is the most suitable approach (Gariano et al. 2020). Mostly distance dependent!

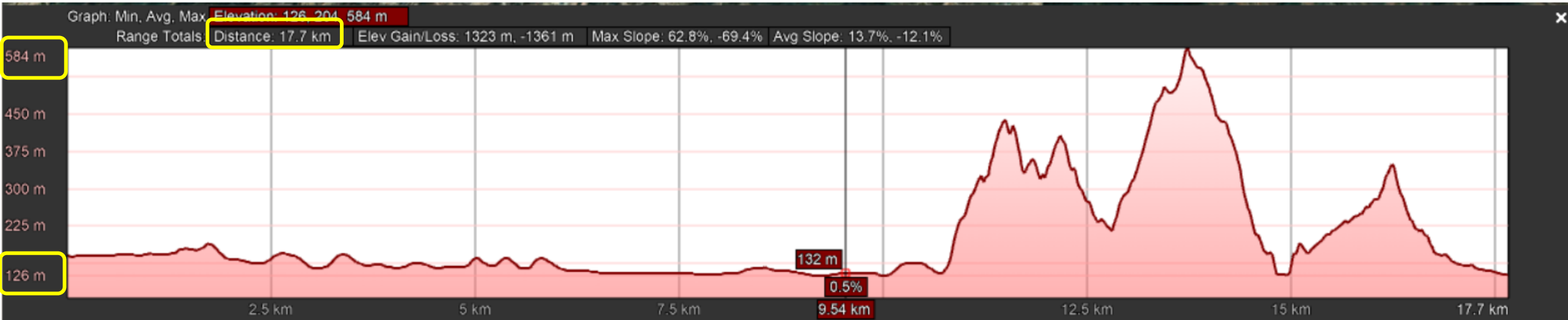
Perfect scenario “Vicinity applied”!

Perfect scenario “Vicinity applied”!



Tricky scenario “Watershed over distance”!





Hypothesis | rain gauges selection criteria

Slope units

- smallest homogenous surfaces that are highly relevant when addressing any hydrological and morphological differences within the surface),
- represent actual slope shapes within predefined slope aspect directional angle, relate to physiographic elements that partition any terrain into half sub-catchments.

Improving the threshold reliability by optimizing the topographical and hydrological settings of landslide events and rain gauges (macro to micro) is recommended

Grouping type	Variables
Environmental	Anthropogenic parameters
	Position within catchment
	Rainfall
	Land use/land cover
Geotechnical	Soil texture
	Soil thickness
	Other geotechnical parameters
Topographical	Drainage
	Surface roughness
	Topographic indices
	Elevation
	Slope aspect
	Slope length
	Slope angle
	Slope curvature
Geological	Strata-slope interaction
	Lineaments/faults
	Geology/lithology

Table. Typical variables affecting landslide hazard or susceptibility grouped into four major types. From Suzen and Kaya (2011) (modified after Budimir et al. - 2015)

Problem

How to decide the best rain gauges, to construct rainfall events that might induced landslides?

Selecting more rain gauges is better?

OR

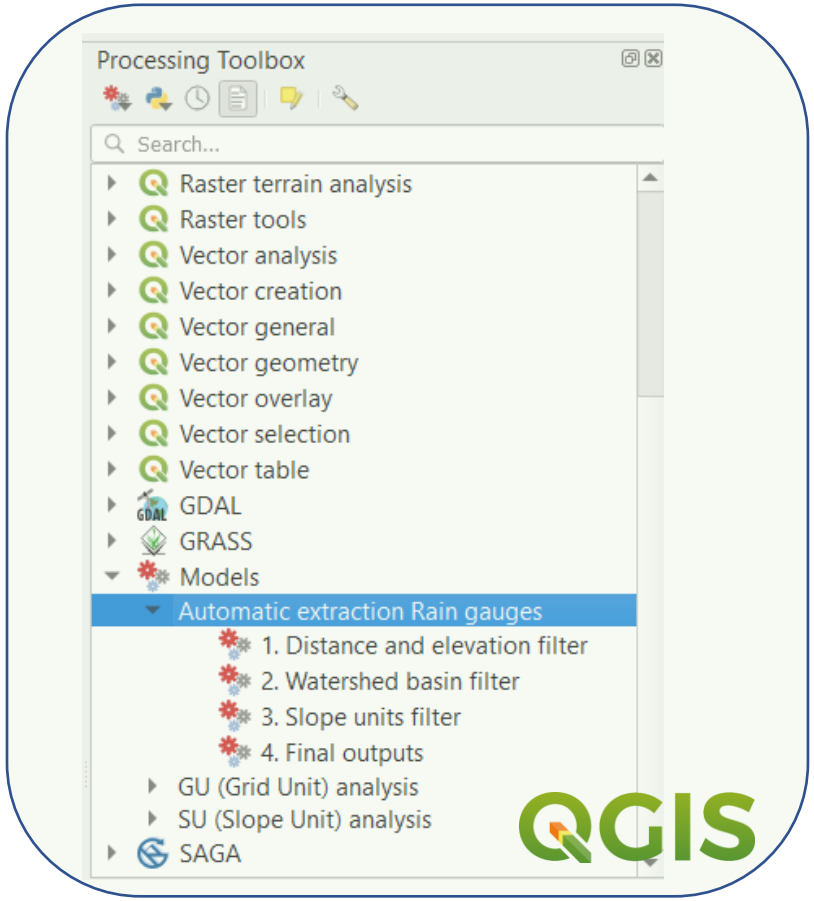
Selecting less rain gauges distributed based on topographical relationship with landslide events?

Objectives

Free automatic rain gauges selection tool

Novel criteria (built in QGIS software) to build multiple spatial filters ;

1. distance,
2. elevation,
3. watershed,
4. **Slope unit (SU) using LaGriSU tool (AlThuwaynee et al.2022:Submitted)**



Basic inputs of model data and minimum parameters

Data:

1. DEM,
2. landslide inventory,
3. rain gauge locations

Parameters (with defaults):

1. raster resolution,
2. search radius,
3. altitude difference,
4. minimum area of single basin and exterior watershed

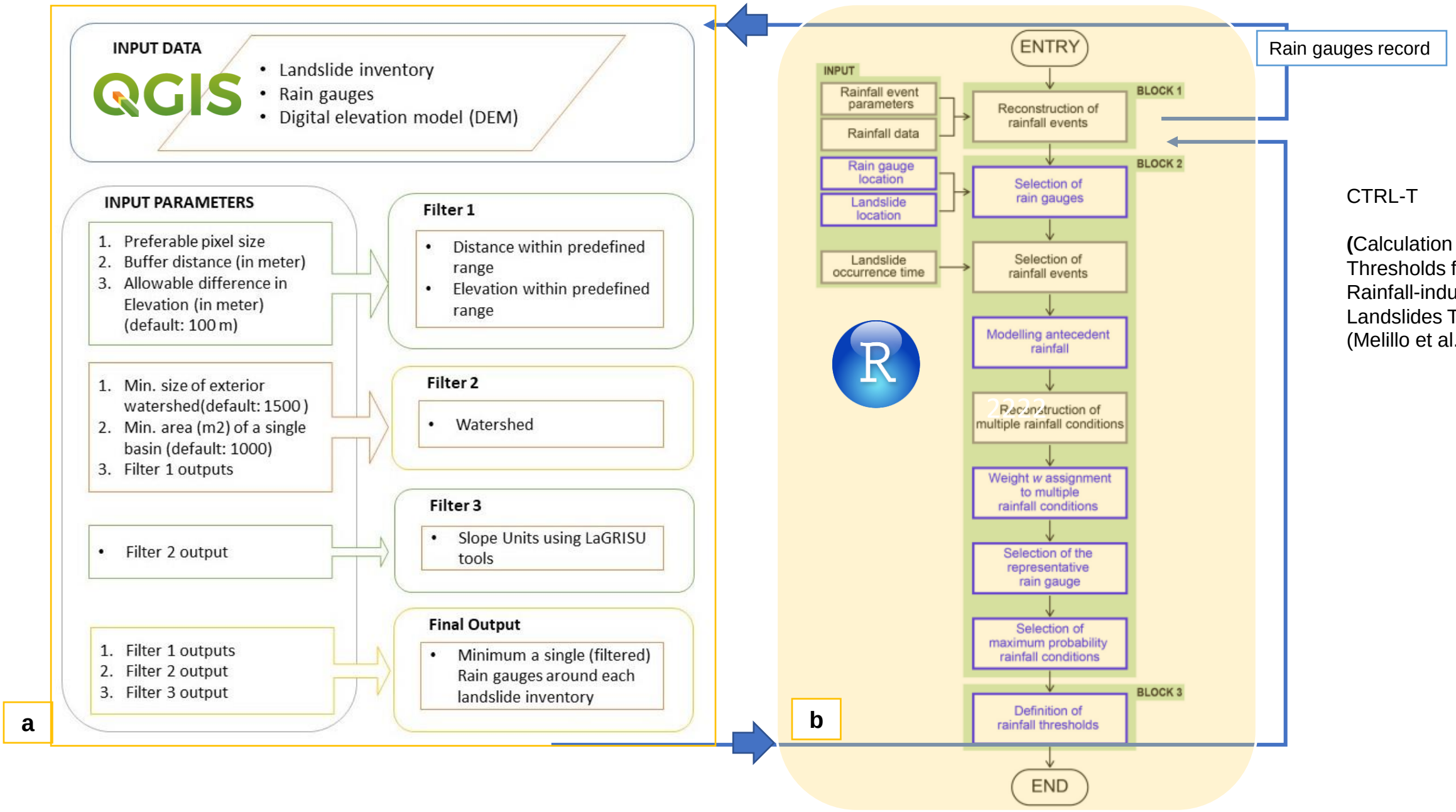


Fig. framework of the Free- tool pack of (a) DEWS and its Integration with (b) CTRL-T

| F1: R ∩ (**distance** to L) ≈ R within buffer zone=R1, If R1 ⊊R then terminate

| F2: ({R1 ∈ F1} ≈ [{abs(R1**elevation** ∈ F1 – Lelevation) : check if its within allowable limits}])= R2, If R2 ⊊R1 then R1

| F3: ({R2 ∈ F2} ∩ (**watershed** ∪ L) ≈ R within watersheds of L=R3 , If R3 ⊊R2 then R2, If R2 ⊊R1 then R1,

| F4: ({R3 ∈ F3 } ∩ (**Slope units** ∪ L) ≈ R within Slope units of L=R4, if R4 ⊊ R3 then R3, and if R3 ⊊ R2 then R2, If R2 ⊊R1 then R1

| {R1 ∪ R2 ∪ R3 ∪ R4 } ≈ Rhat (check if Rhat ∩ (distance to L) ≈ minimum of a single rain gauge related to each landslide incident within specific distance: then : OK! *Else check log for errors*.

***R** (Rain gauges inventory);*

***R1,R2,R3,R4** (Filtered Rain gauges);*

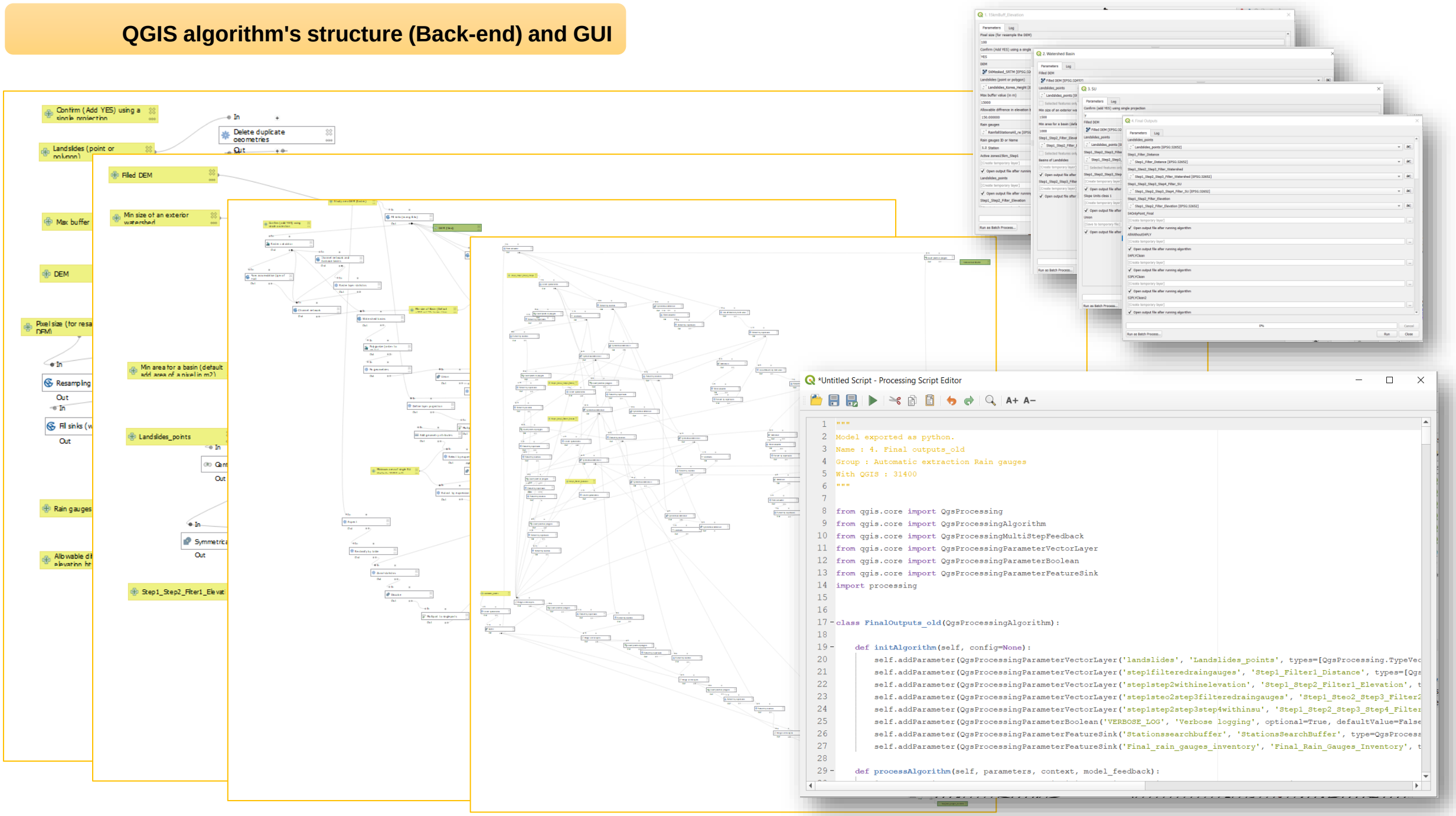
***L** (Landslide inventory);*

***F1,F2,F3,F4** (spatial filters)*

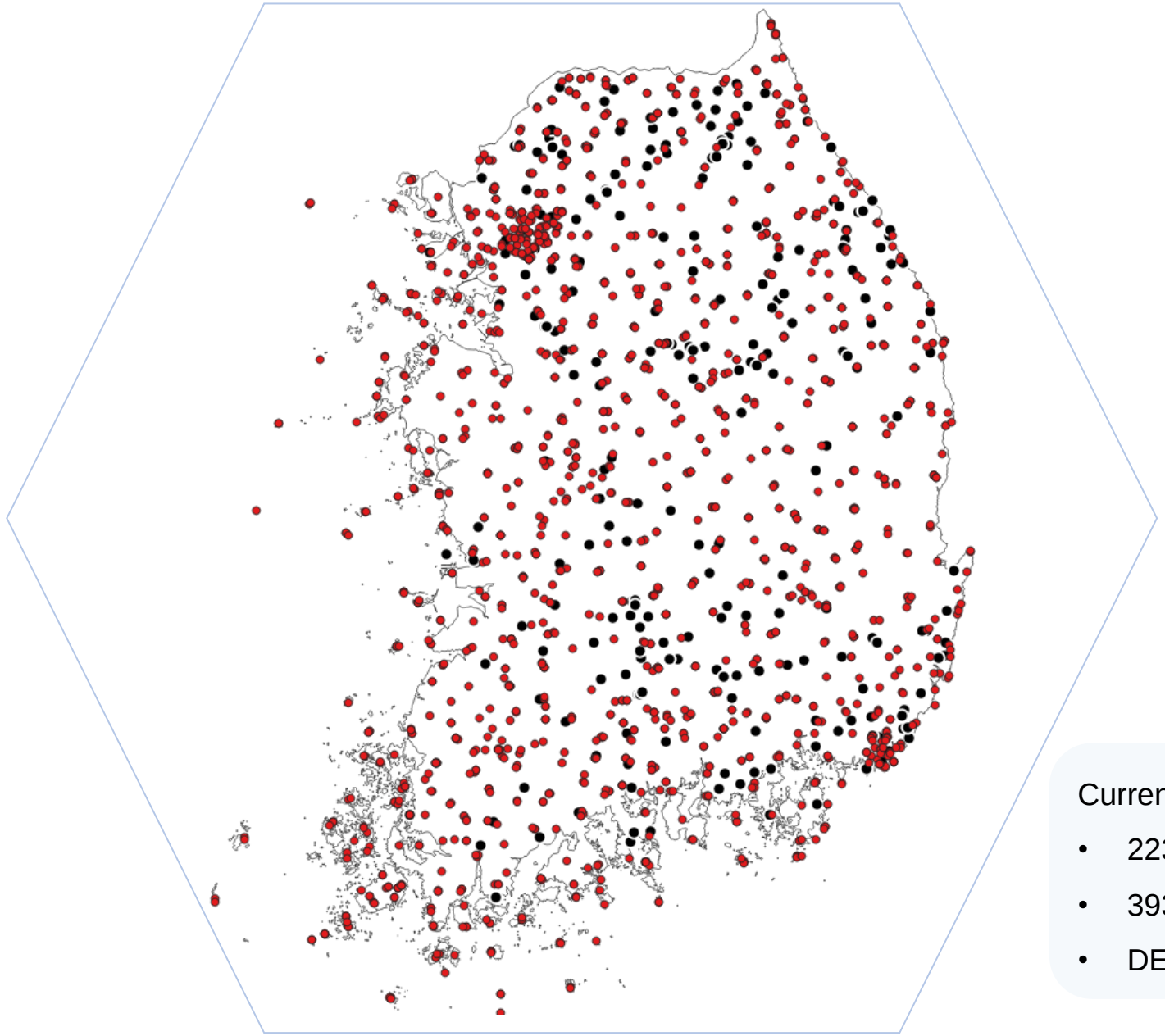
To have the minimum **One** rain gauge related to each landslide event

Priority to **Distance** (to select the default extent), then **SU** (to start with smallest), then **Watershed** and **Elevation**

QGIS algorithm's structure (Back-end) and GUI



Study area



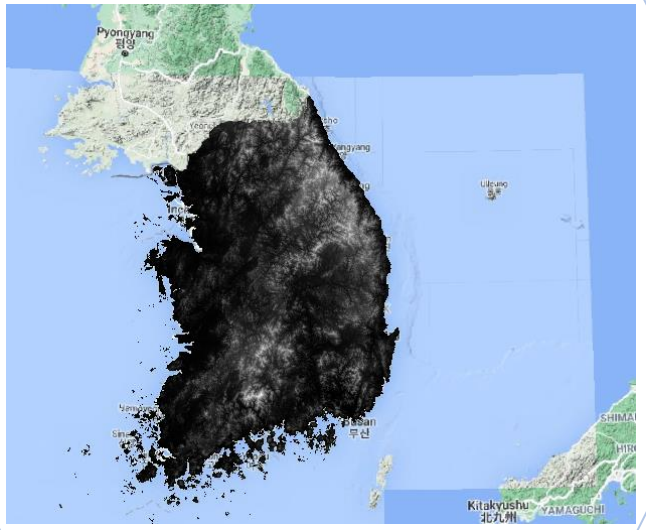


Fig. Study area South Korea (national scale),

Current Data

- 223 shallow Landslide inventory (hourly) (1999-2011) (black dots)
- 393 Rain gauges (ASOS & AWS) (red dots)
- DEM using SRTM 30 m

Primarily Results: DEWS Tool

Fig. Output of Filter 1 (Distance) and Filter 2 (Elevation), Landslides (black dots), Step1 after 15km distance (red dots) and Step2 within 150 m elevation (green dots).

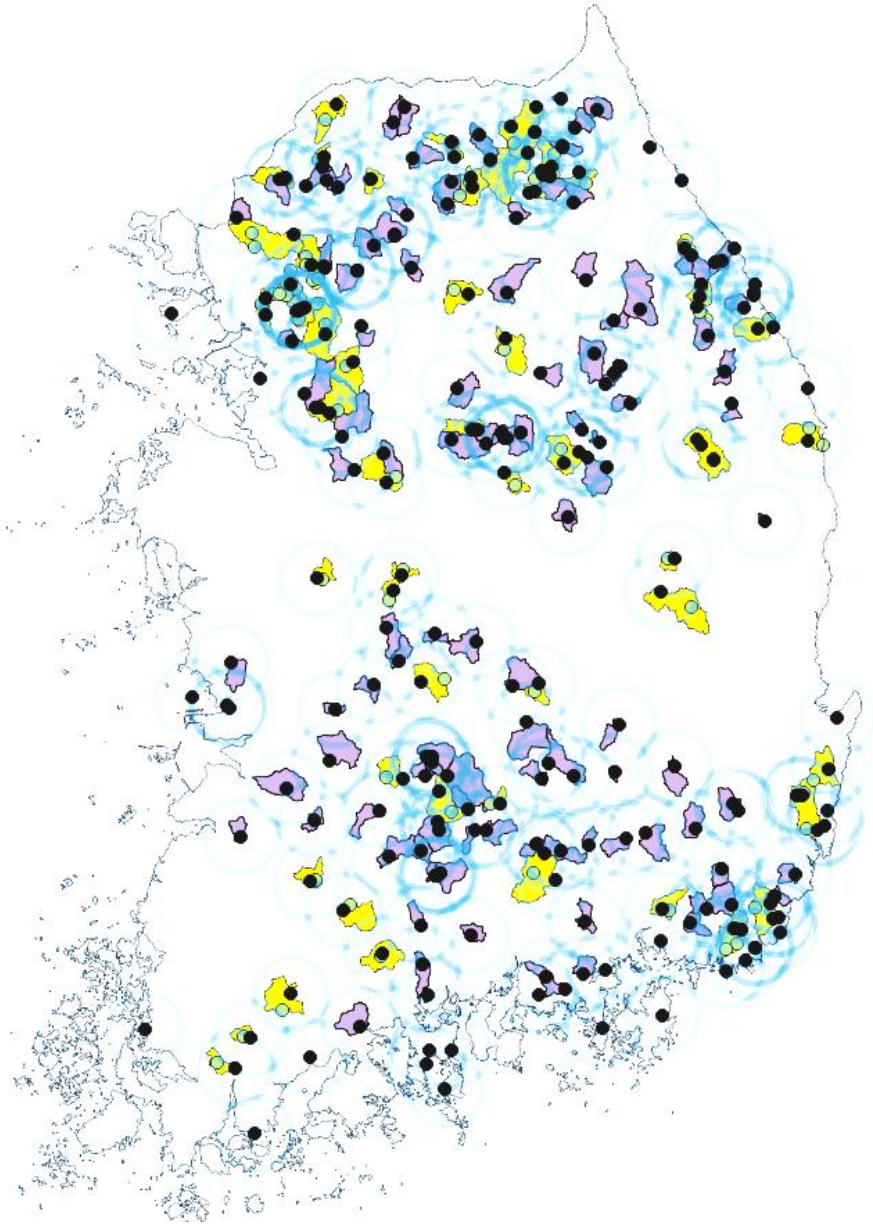


Fig. Filter 3 (watershed) , Landslides (black dots), resultant Rain gauges (green dots) Watershed with rain gauges and landslide (yellow areas).

Primarily Results: DEWS

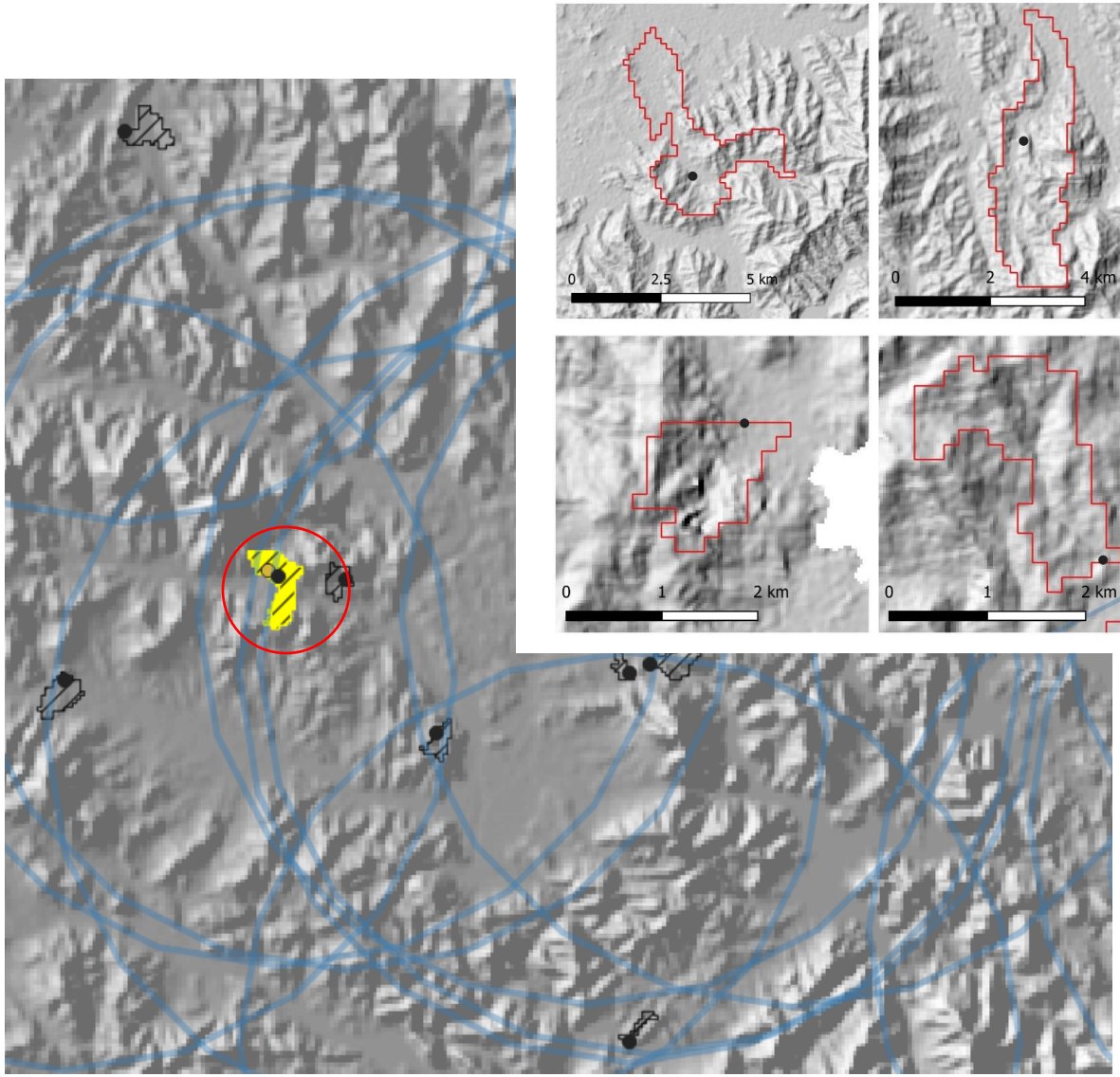


Fig. Filter 4 (Slope unit) , Landslides (black dots), resultant Rain gauges (brown dots) Slope units with (yellow area) and without rain gauges (stripped areas).

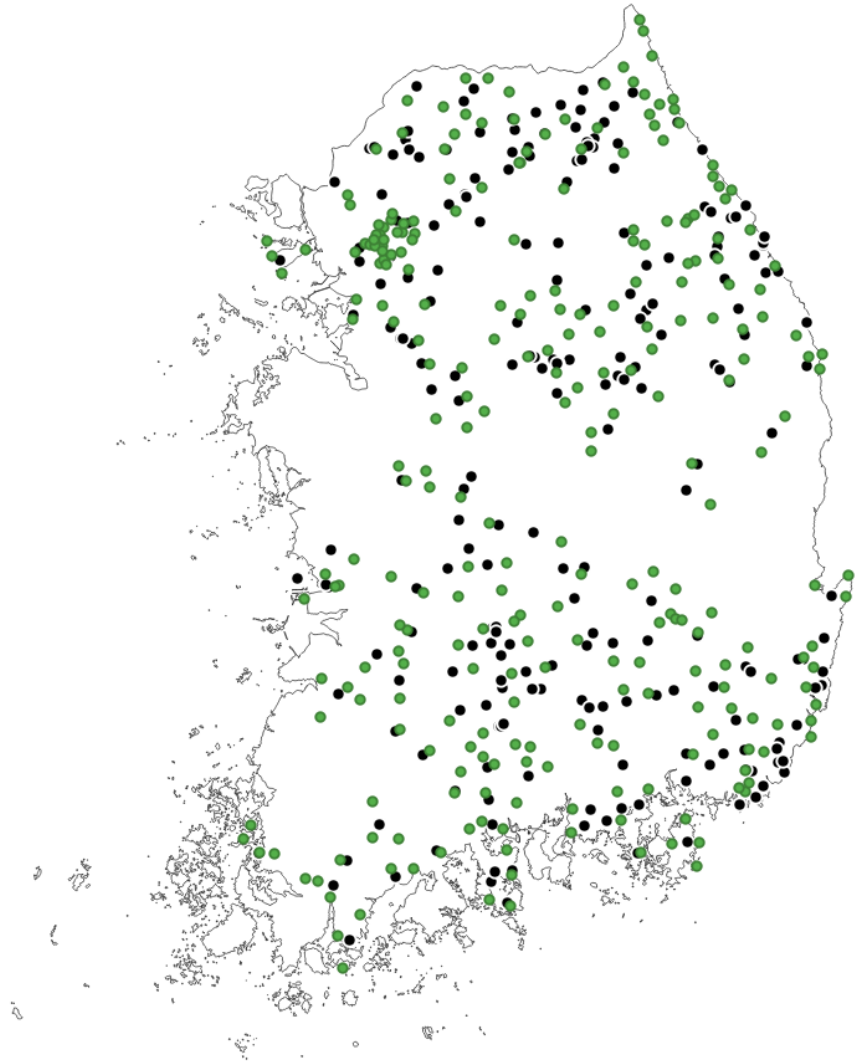
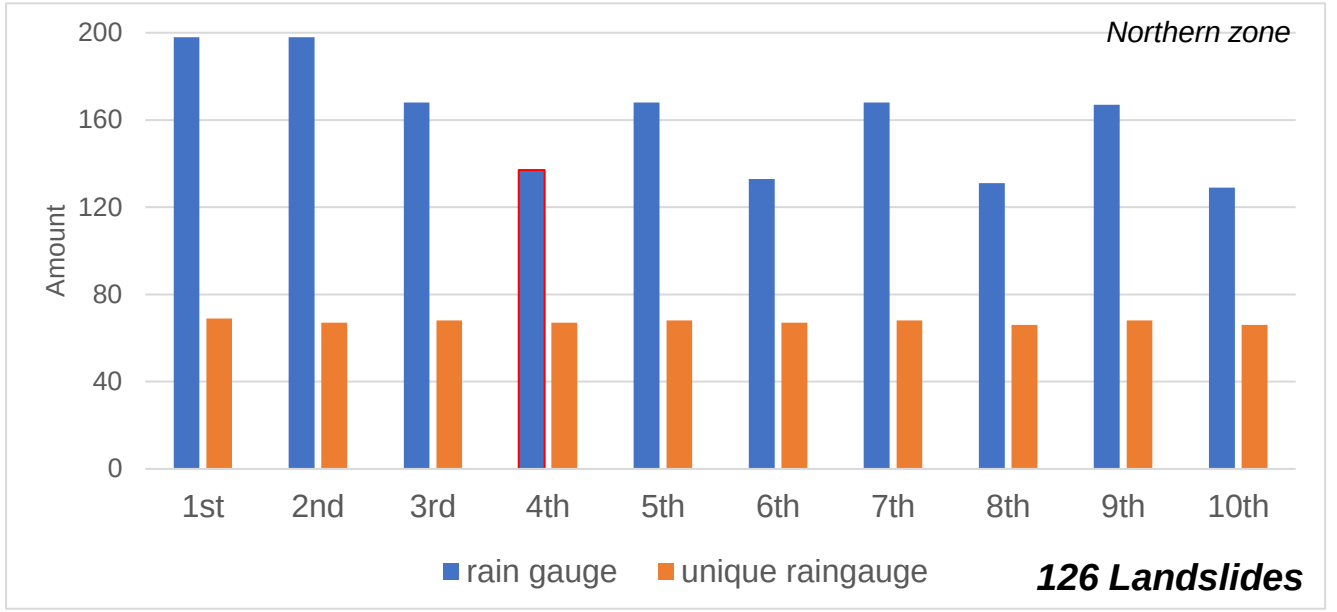


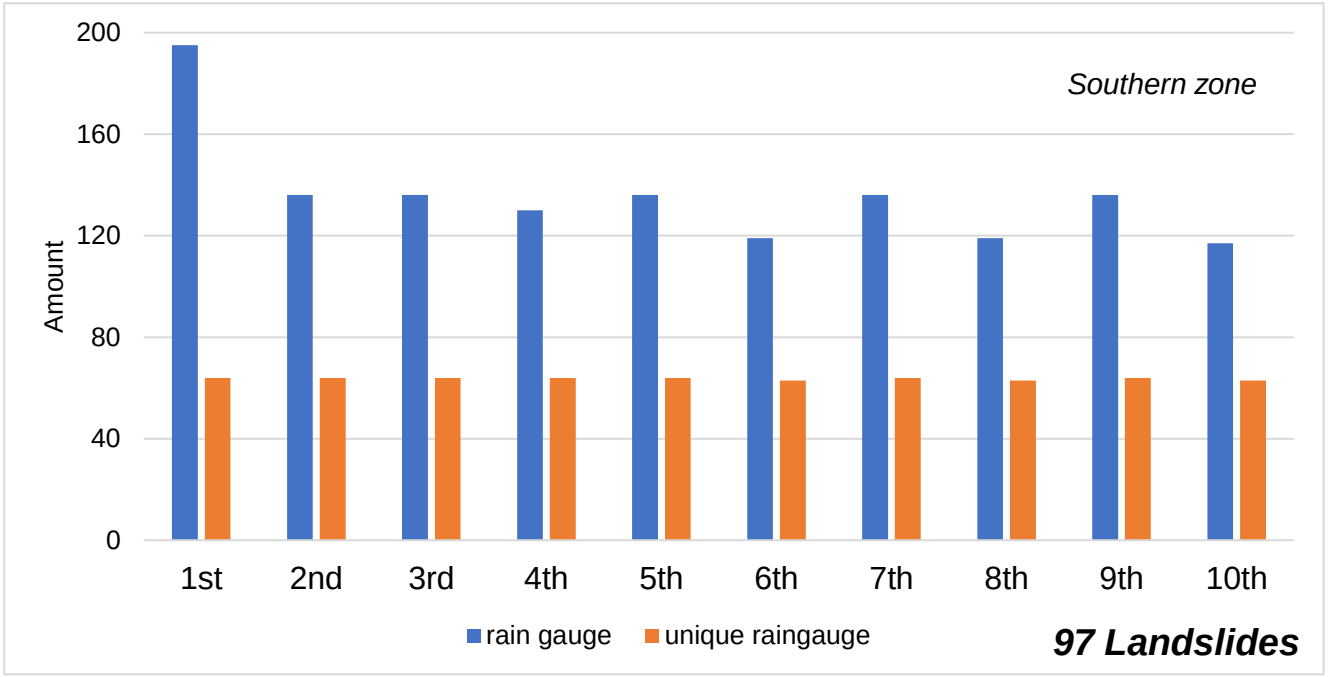
Fig. Final selected rain gauges , Landslides (black dots), resultant Rain gauges (green dots)

Primarily Results

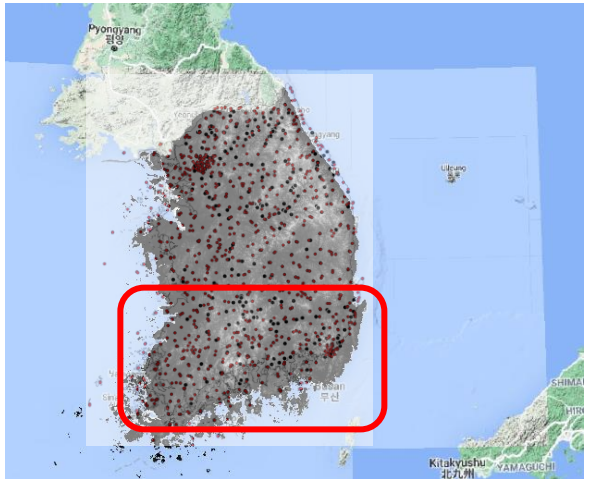
*** Red color "Best combination"**

1st	CTRL20 *(no DEWS)*
2nd	D15_E0_W0_S0
3rd	D15_E50_W0_S1
4th	D15_E50_W1_S1
5th	D15_E100_W0_S1
6th	D15_E100_W1_S1
7th	D15_E200_W0_S1
8th	D15_E200_W1_S1
9th	D15_E400_W0_S1
10th	D15_E400_W1_S1

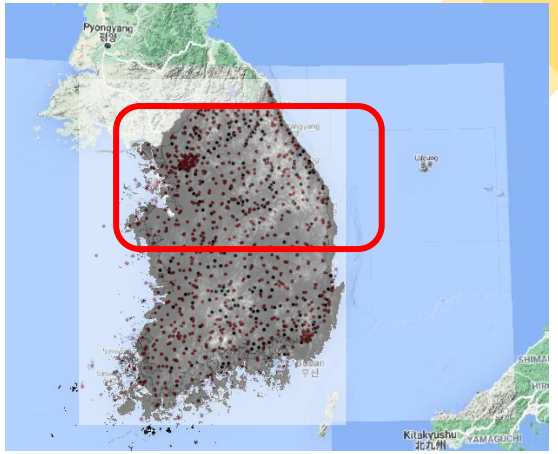




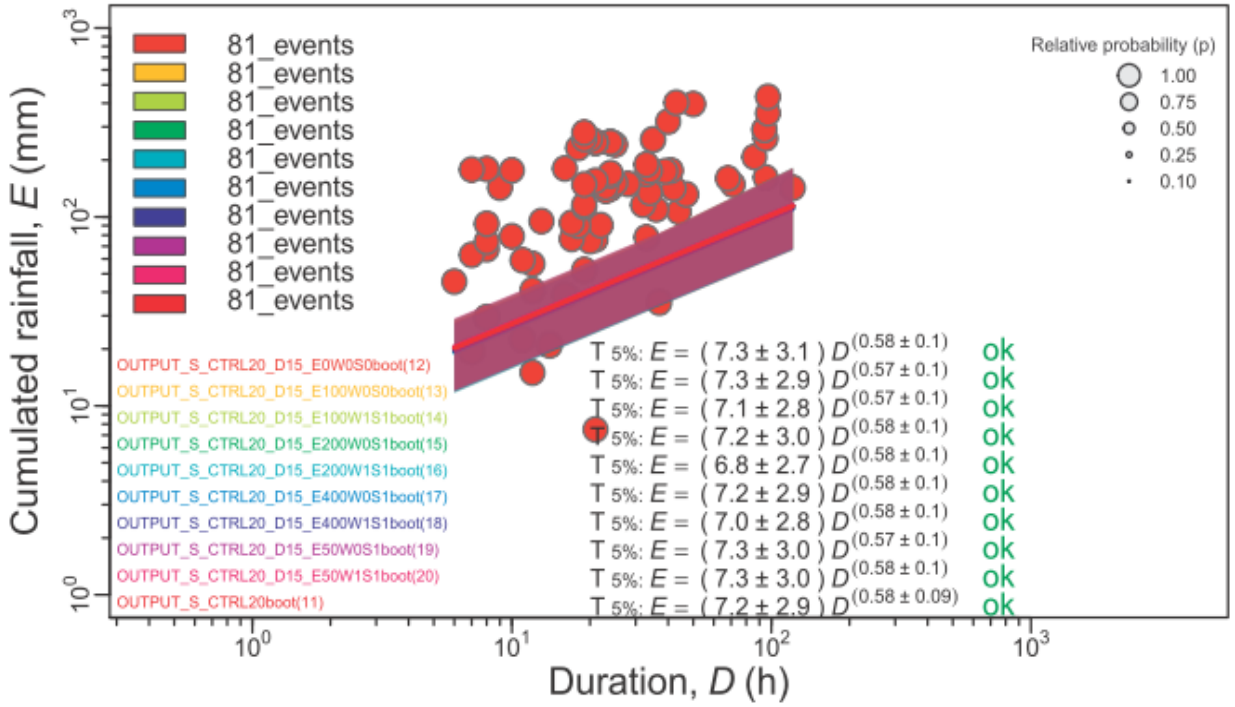
Primarily Results CTRL-T

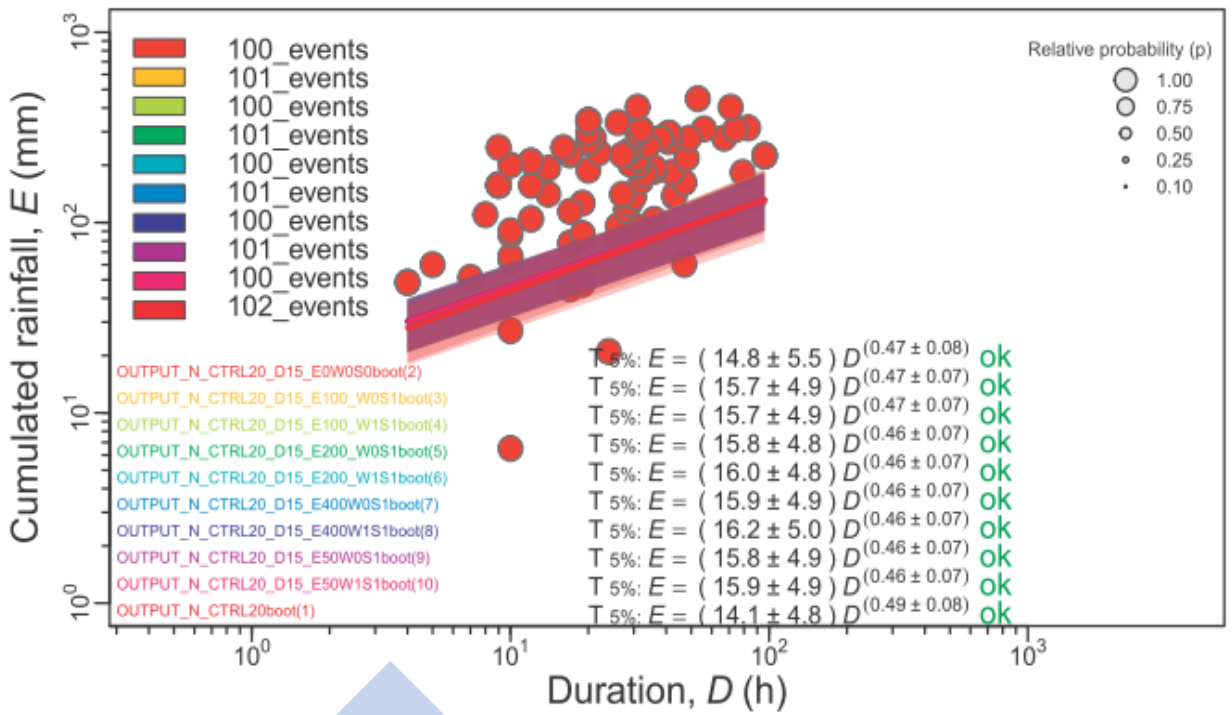


97 Landslides



126 Landslides





Conclusion

1. Rain gauges record was optimized by 33% using DEWS (393 to 266 stations)
2. Its not about installing a greater number of rain gauges rather than more spatially correlated

DEWS

3. Can be **used by non-experts** because it works on the front end of the GUI with no programming skills needed.
4. **Fast processing** of a large amount of data.
5. **User preferences**, highly flexible in updating used functions .
6. open-source package (**open-source, offline** GIS software)

Software availability

Name: **DEWS (distance, elevation, watershed, and slope) unit for rainfall-induced landslide reference station selection**

Developer: **Omar F. Althuwaynee, omar.faisel@gmail.com**

Software required: **QGIS versions 3.10 - 3.14.0**

Availability: **Free of charge, public**

Integrated development environment suggested: **Open-source QGIS (geographic information software)**

Tool pack direct download address: **Github.com**

References

Althuwaynee OF, Asikoglu O, Eris E (2018) Threshold contour production of rainfall intensity that induces landslides in susceptible regions of northern Turkey. Landslides 15:. https://doi.org/10.1007/s10346-018-0968-2

Budimir, M. E. A., P. M. Atkinson, and H. G. Lewis. "A systematic review of landslide probability mapping using logistic regression." *Landslides* 12.3 (2015): 419-436.

Dolidon N, Hofer T, Jansky L, Sidle R (2009) Watershed and forest management for landslide risk reduction. In: Landslides - Disaster Risk Reduction

Gariano SL, Brunetti MT, Iovine G, et al (2015) Calibration and validation of rainfall thresholds for shallow landslide forecasting in Sicily, southern Italy. Geomorphology. https://doi.org/10.1016/j.geomorph.2014.10.019

Gariano SL, Segoni S, Piciullo L (2020) Advances in Rainfall Thresholds for Landslide Triggering in Italy. In: Applied Geology

Iadanza C, Trigila A, Napolitano F (2016) Identification and characterization of rainfall events responsible for triggering of debris flows and shallow landslides. J Hydrol. https://doi.org/10.1016/j.jhydrol.2016.01.018

Jan CD, Chen TH, Lo WC (2007) Effect of rainfall intensity and distribution on groundwater level fluctuations. J Hydrol. https://doi.org/10.1016/j.jhydrol.2006.07.010

Jordanova G, Gariano SL, Melillo M, et al (2020) Determination of empirical rainfall thresholds for shallow landslides in slovenia using an automatic tool. Water (Switzerland). https://doi.org/10.3390/w12051449

Melillo M, Brunetti MT, Peruccacci S, et al (2018) A tool for the automatic calculation of rainfall thresholds for landslide occurrence. Environ Model Softw. https://doi.org/10.1016/j.envsoft.2018.03.024

Peruccacci S, Brunetti MT, Luciani S, et al (2012) Lithological and seasonal control on rainfall thresholds for the possible initiation of landslides in central Italy. Geomorphology. https://doi.org/10.1016/j.geomorph.2011.10.005

Segoni S, Piciullo L, Gariano SL (2018) A review of the recent literature on rainfall thresholds for landslide occurrence. Landslides

Wang F, Xu P, Wang C, et al (2017) Application of a gis-based slope unit method for landslide susceptibility mapping along the longzi river, southeastern tibetan plateau, China. ISPRS Int J Geo-Information. https://doi.org/10.3390/ijgi6060172

Yu C, Chen J (2020) Landslide Susceptibility Mapping Using the Slope Unit for Southeastern Helong City, Jilin Province, China: A Comparison of ANN and SVM. Symmetry (Basel). https://doi.org/10.3390/sym12061047

Thank you