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TAKING THE PULSE OF OUR PLANET FROM SPACE

WORLD BANK GROUP
Disaster Risk Financing and Insurance Program

صندوق التضامن ضد الوقائع الكارثية
FONDS DE SOLIDARITÉ CONTRE LES ÉVÈNEMENTS CATASTROPHIQUES

LHIS / Landslide Hazard Information System App:

Earth Observation Data and Models for Near-Real Time Natural Landslide Hazard and Risk Assessments

Clément Michoud, Jean-Philippe Malet, Dalia Kirschbaum,
Thierry Oppikofer, Robert Emberson et al.

Terranum

conectus Alsace

EOST Université de Strasbourg

A2S

USRA

NASA Goddard Space Flight Center

TERRAQUE

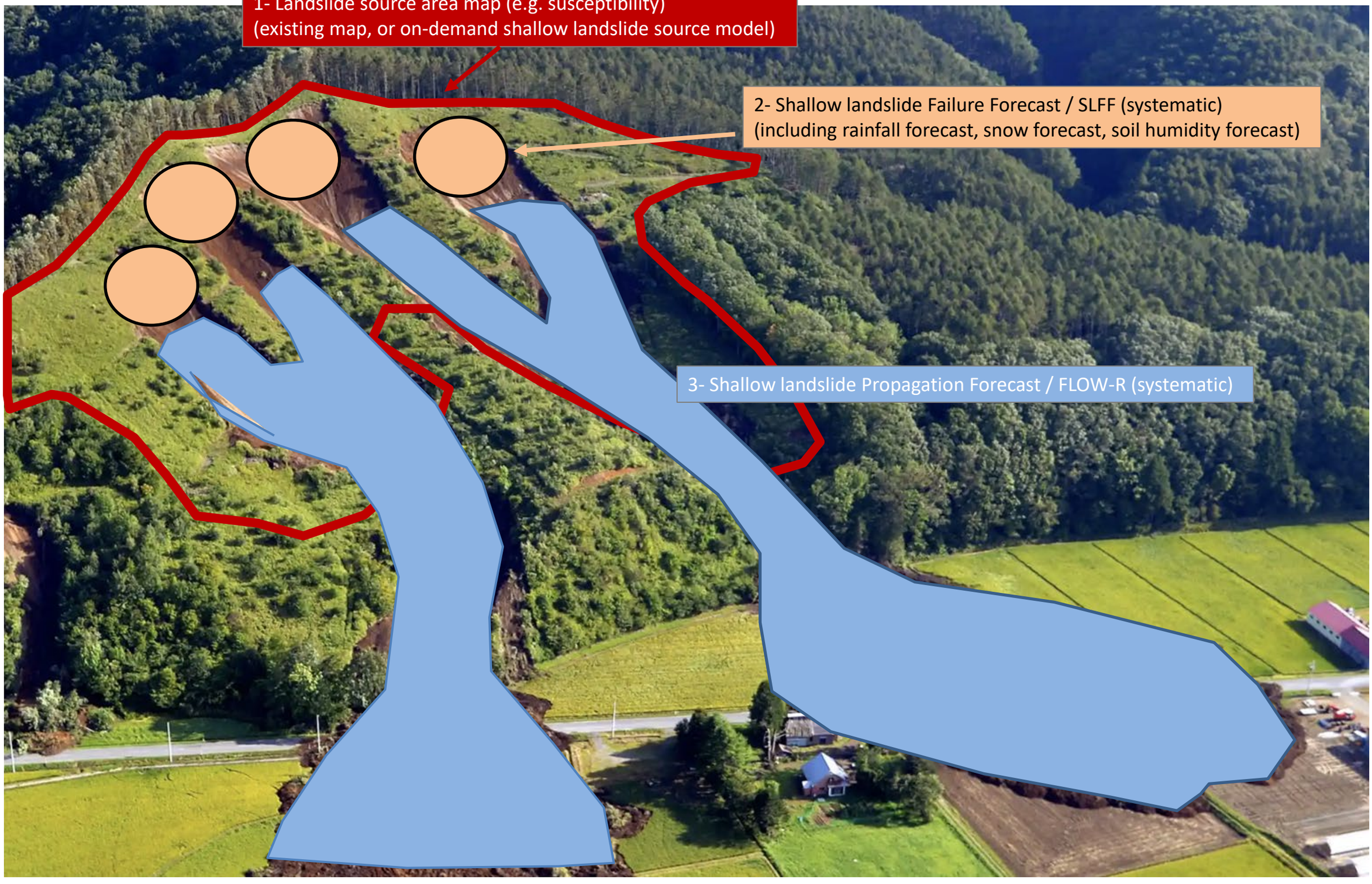
Why?

Are we able to anticipate such type of landslide triggering?
And even better, avec we able to nowcast the surface being affected (and the possible costs)?

Can we use space-based Earth Observation data and products for the nowcasting ? Can we combine landslide-oriented SBEO and landslide models?

Can we use such type of systems for hazard/risk assessments? And Disaster Risk Management through Distaster Risk Financing (DRF) products?

What?


1- Landslide source area map (e.g. susceptibility)
(existing map, or on-demand shallow landslide source model)
2- Shallow landslide Failure Forecast / SLFF (systematic)
(including rainfall forecast, snow forecast, soil humidity forecast)
3- Shallow landslide Propagation Forecast / FLOW-R (systematic)

How?

The **online LHIS App**

LANDSLIDE HAZARD INFORMATION SYSTEM

to nowcast landslide hazard triggered by extreme rainfall events and identify related exposed infrastructures and populations.

- **LHIS aims to use recent satellite data coupled with landslide hazard and risk models, integrated in three interlinked services:**

1. **LHIS-CATALOGUE: landslide detection module**

   To detect new landslide events, assess their progressions in time and create inventory maps

2. **LHIS-HAZARD: landslide nowcasting module**

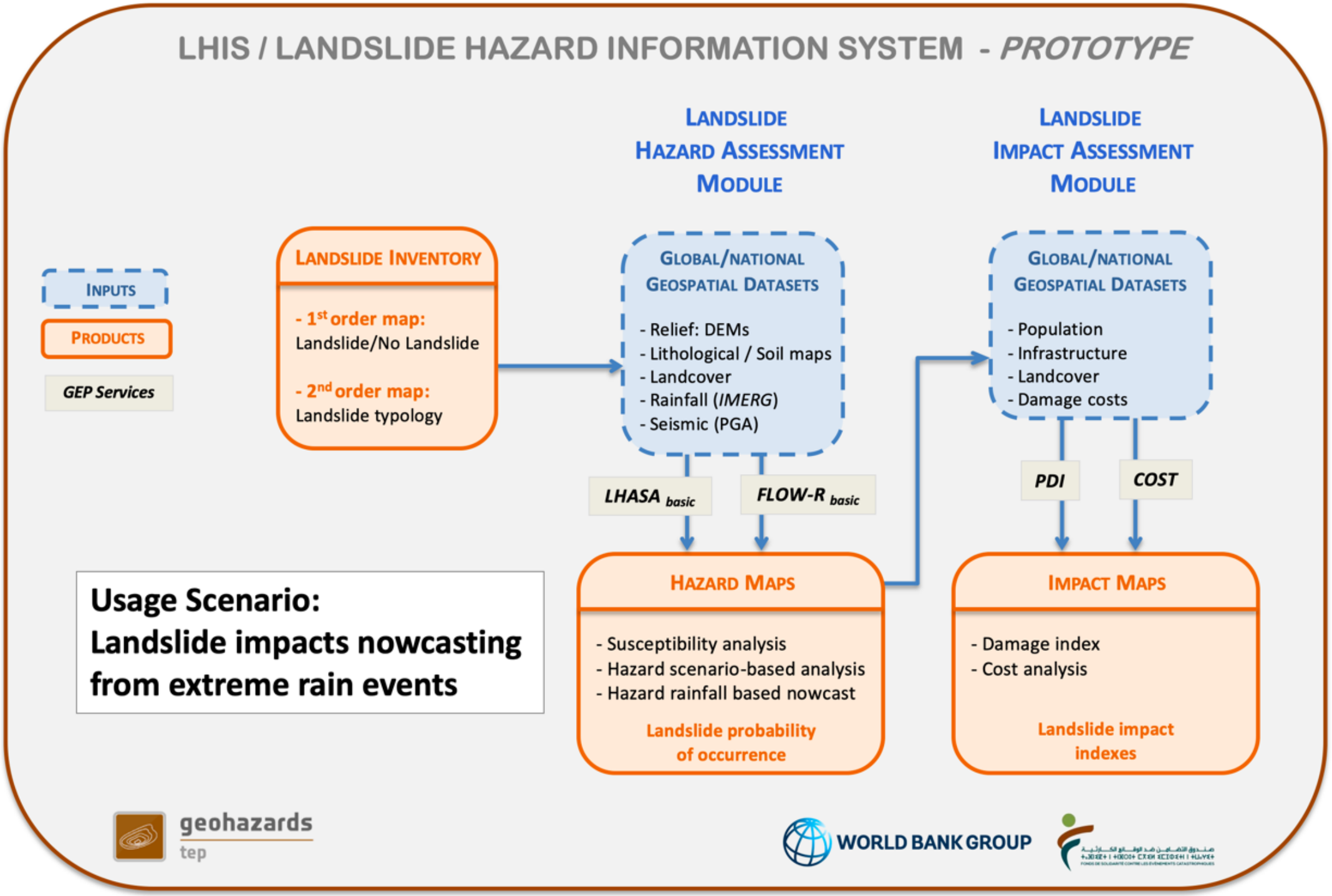
   To forecast spatial landslide hazard based on susceptibility maps and rainfall-based triggering models.

3. **LHIS-IMPACT: qualitative and quantitative risk assessment module**

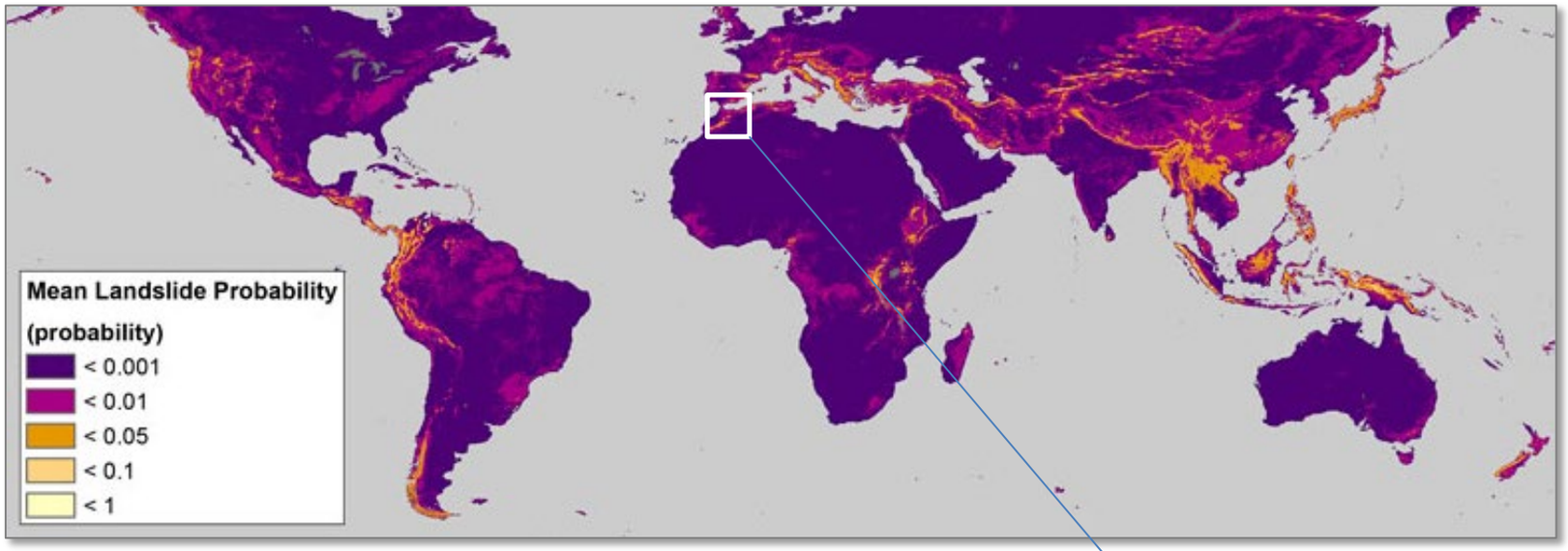
   To create landslide exposure maps, cost analyses and impact indexes by combining both landslide and anthropic datasets.

- **LHIS is implemented as a systematic / on-demand service on** geohazards tep

LHIS App: Usage Scenario



Where?

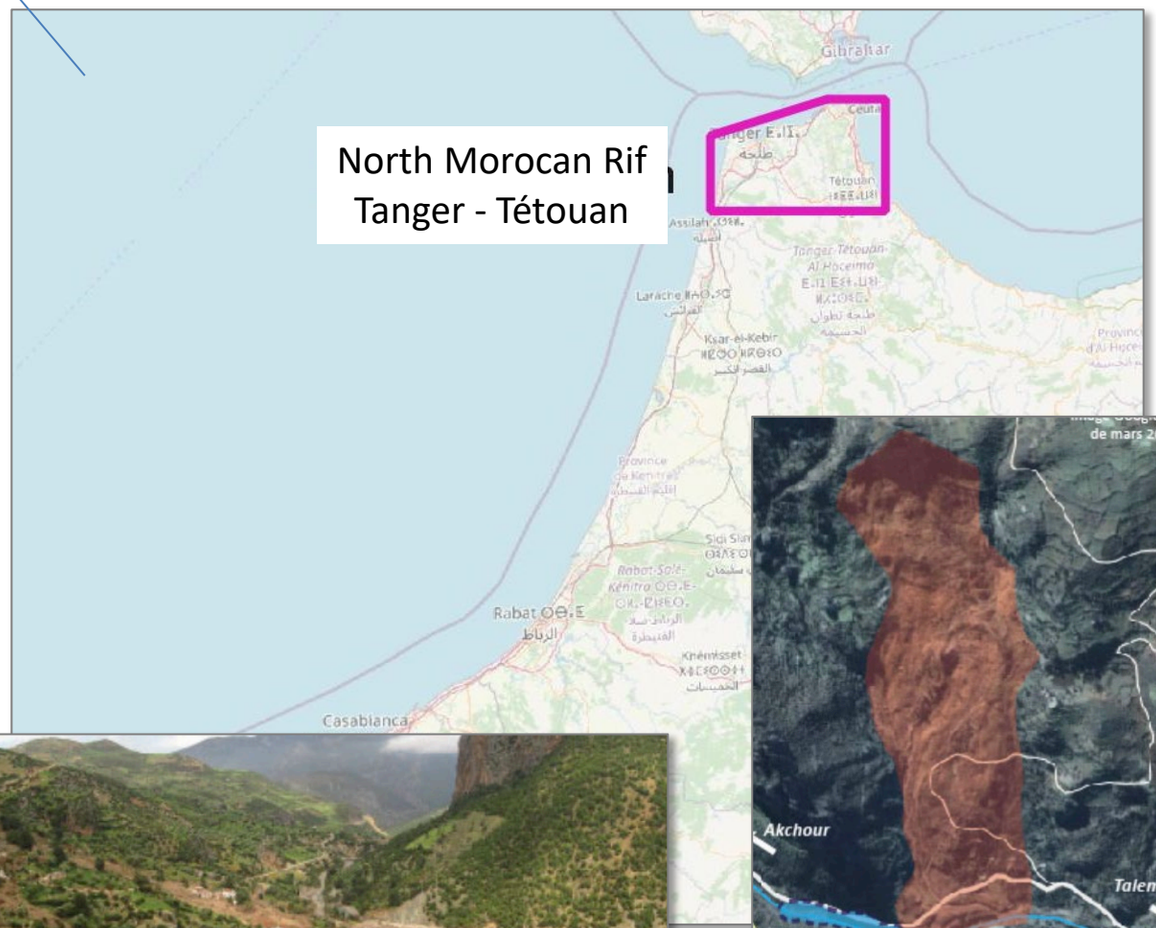


- Developed and tested in **Morocco** with the **FSEC** (Solidarity Fund Against Catastrophic Events) and the **World Bank**

- North Rif area: Tanger-Tétouan (2’950 km²)

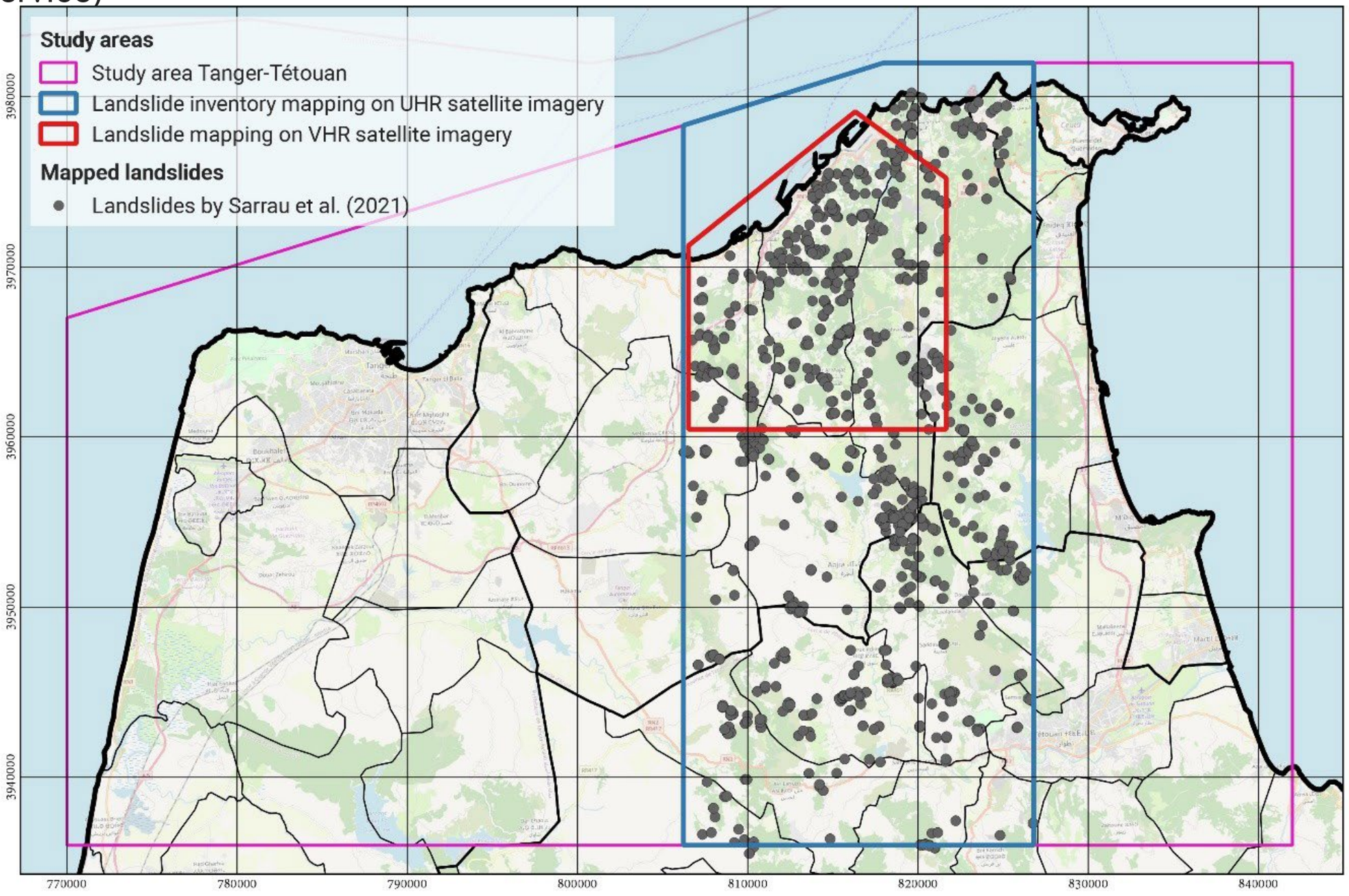
- Main input data:
  - DEM "Copernicus GLO30" (30 m)
  - ESA Land Cover map
  - “Global Forest Changes” map
  - Landslide susceptibility map

- Nowcaster:
  - NASA GPM/IMERG rainfall data
  - Rainfall Threshold is the TRIGGER



LHIS-CATALOGUE

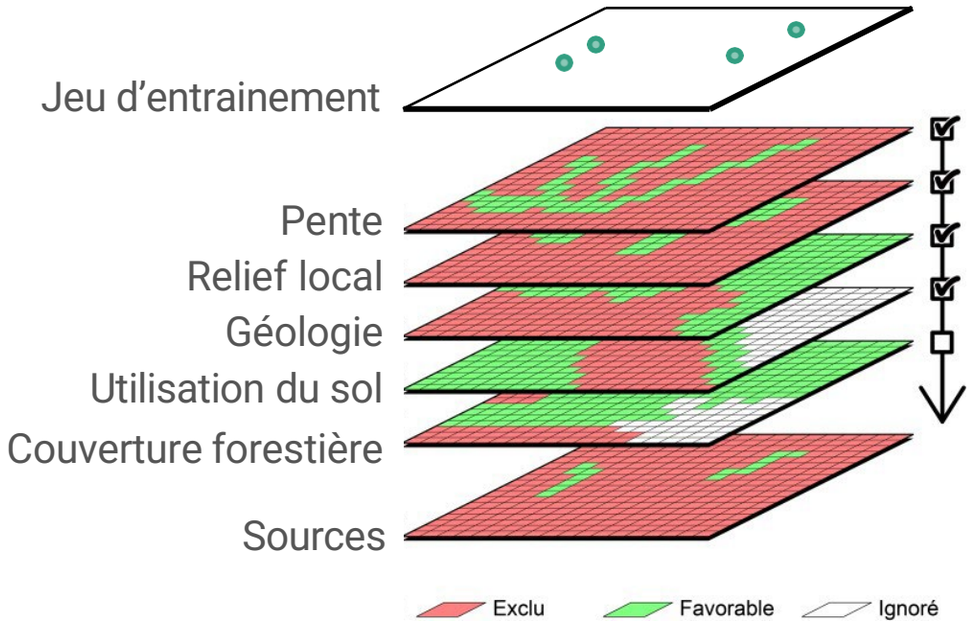
- **Creation of a landslide inventory from optical data (Spot+Pléiades, Sentinel-2):**
  - ground changes mapping by comparison of (very) high resolution optical satellite images before/after the event and therefore delimitates the impacted area (**ALADIM** change detection service)

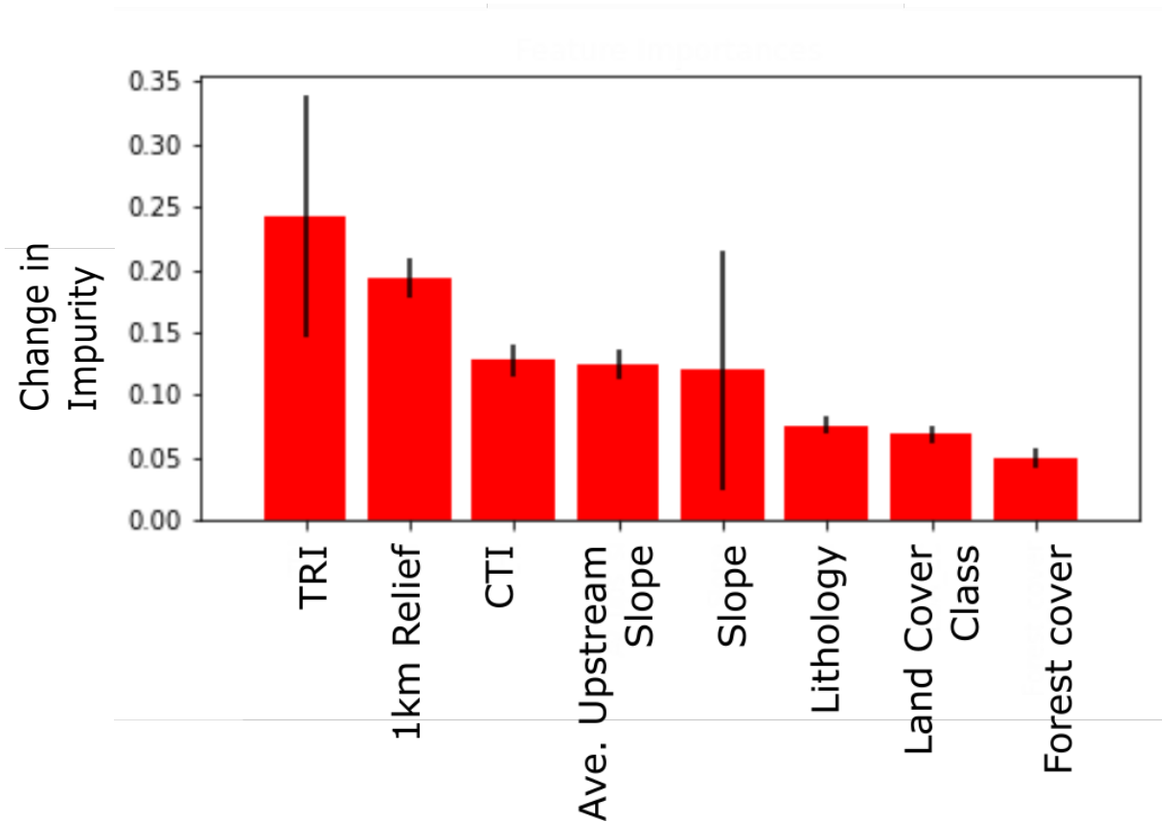


LHIS-HAZARD

1. Locate potential landslide source areas: landslide susceptibility map

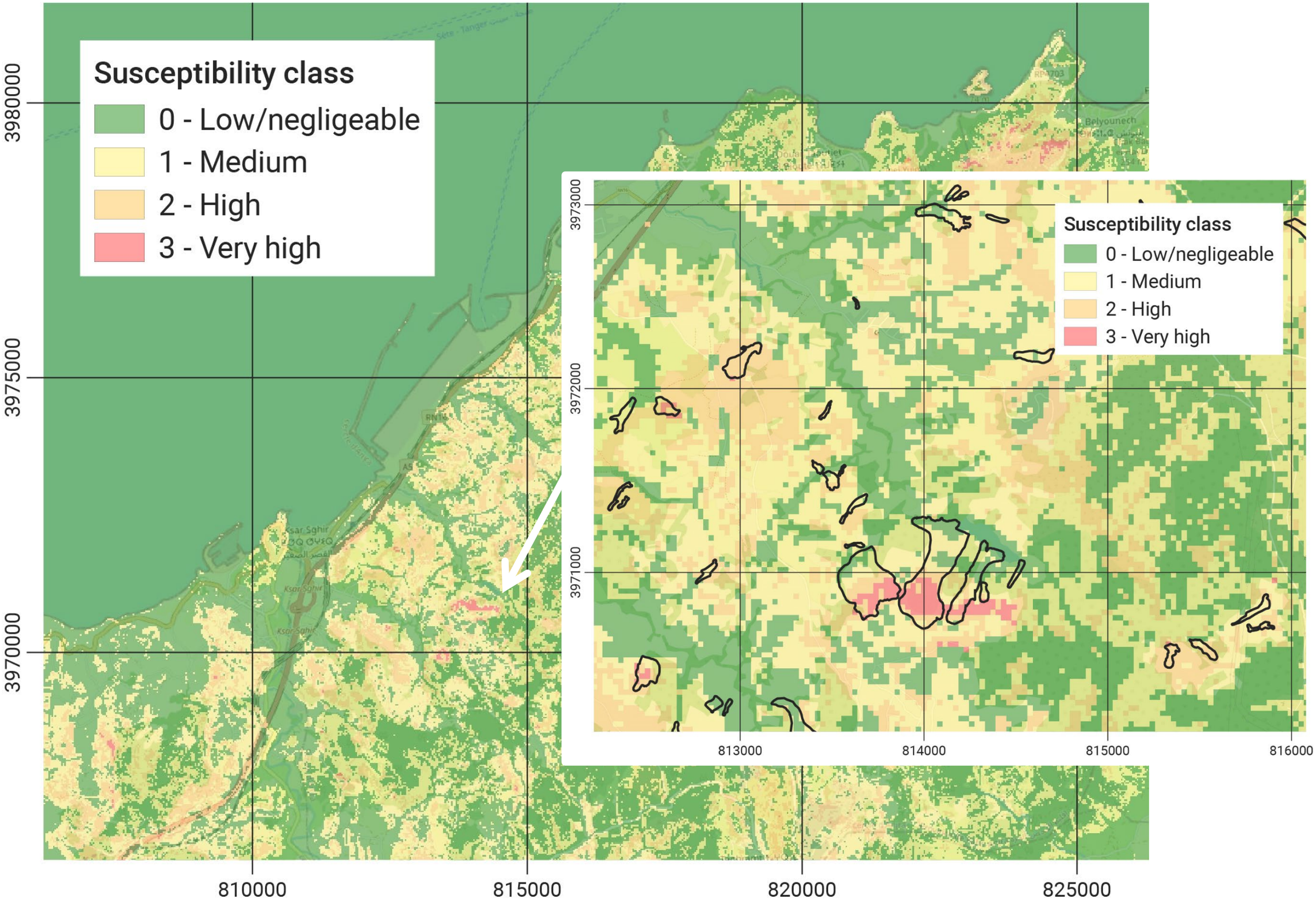
- Modeling the spatial distribution of landslide hazard, controlled by the time-invariant susceptibility of the landscape to landsliding
- Machine-learning based approach, applied on data sources that could approximate the physical parameters that control landslide susceptibility
- Trained on the 852 head scarps of the landslide inventory





** Past results from Moroccan studies on landslide susceptibility (e.g., El-Fengour (2016) for the Amaz Valley, Boualla et al. (2017) for the Safi region, and Ait Brahim et al. (2018) for the Tingitane Peninsula) were taken into account in the development of criteria and factors for the susceptibility map.*

LHIS-HAZARD



Shallow landslide source susceptibility map, for the Tanger-Med international port area (scales 1:100'000 and 1:20'000)

2. Compute landslide propagation areas

- Compute reach zones with a landslide runout model (Flow-R), adapted for regional-scale analyses (Horton et al. 2013)
- Calibrated on the landslide inventory, based on two scenarios
  - Reach angle of 11° for slow creep slides and 18° for flows
  - Velocity limit of 3 m/s for slow creep slides and 10 m/s for flows

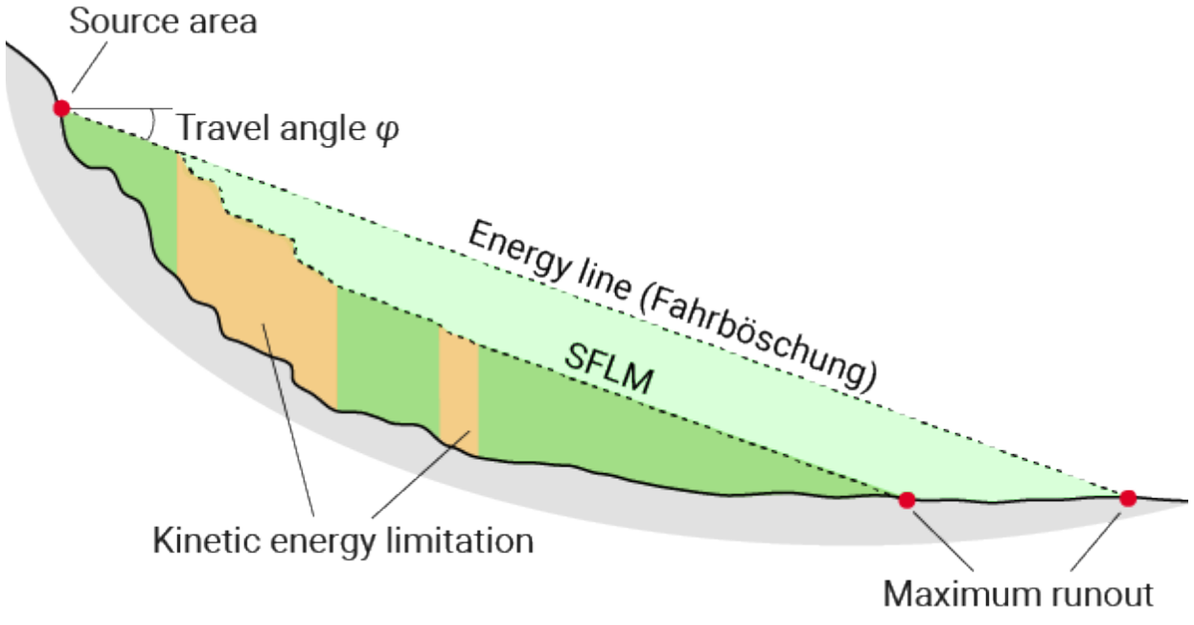
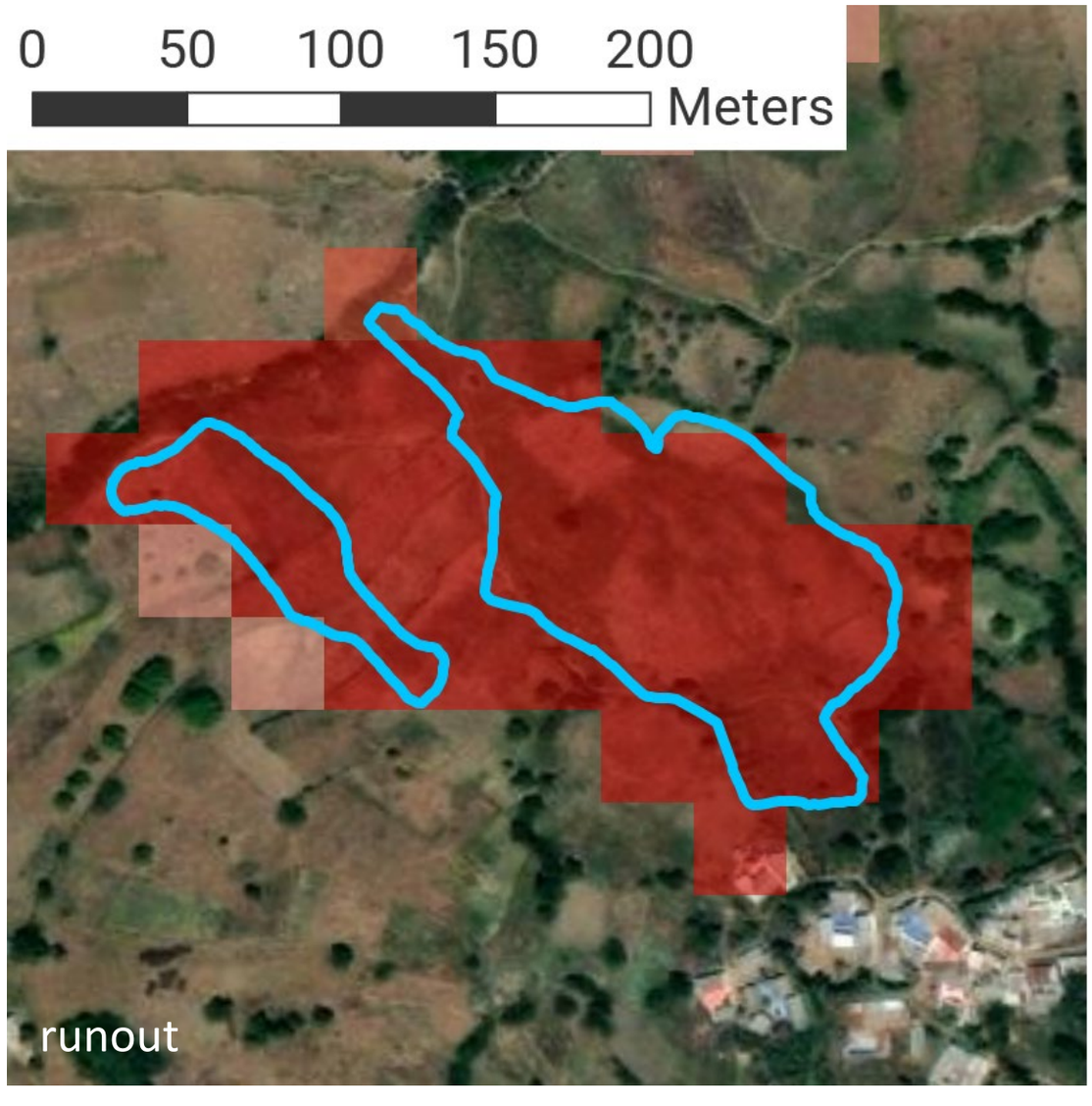
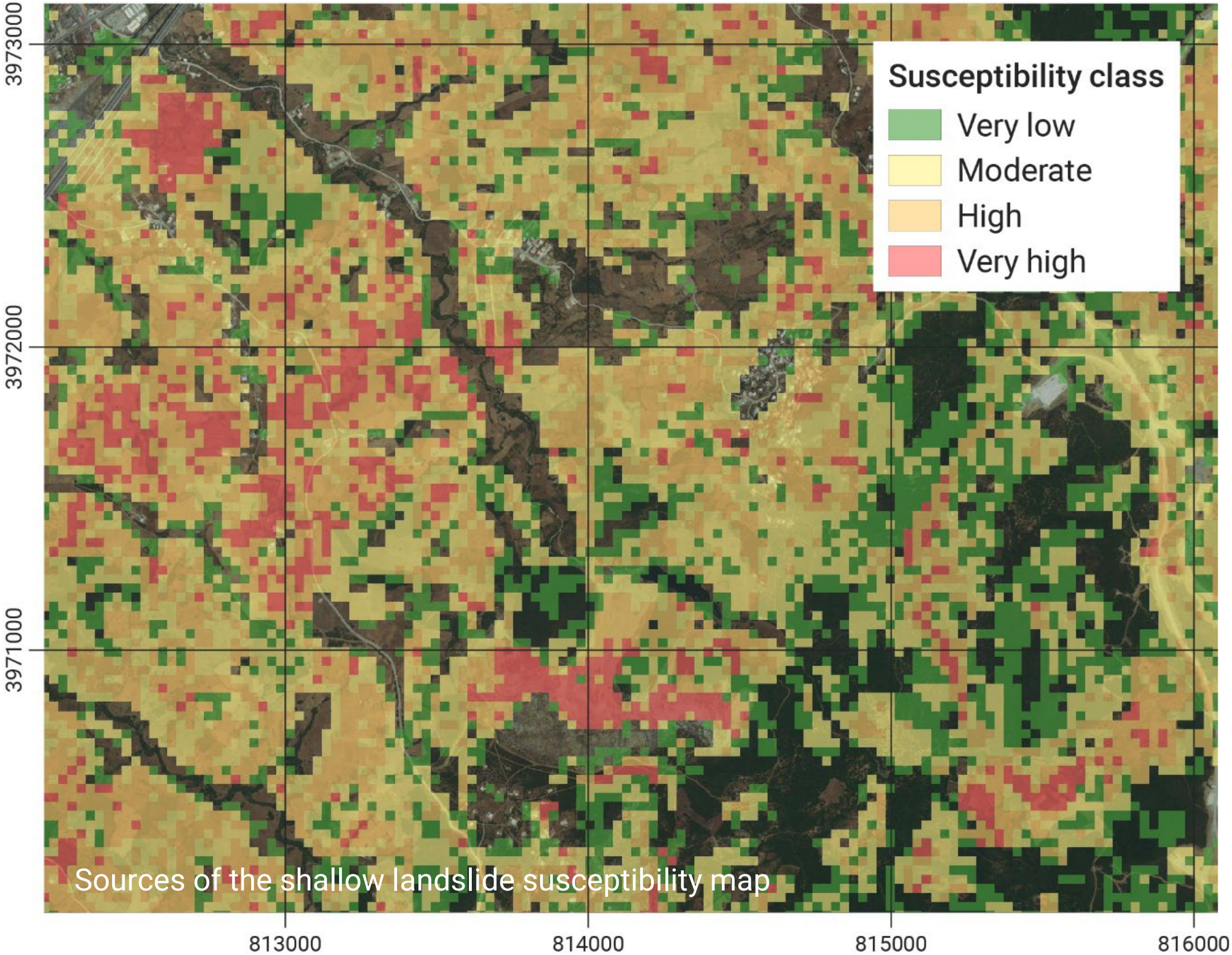
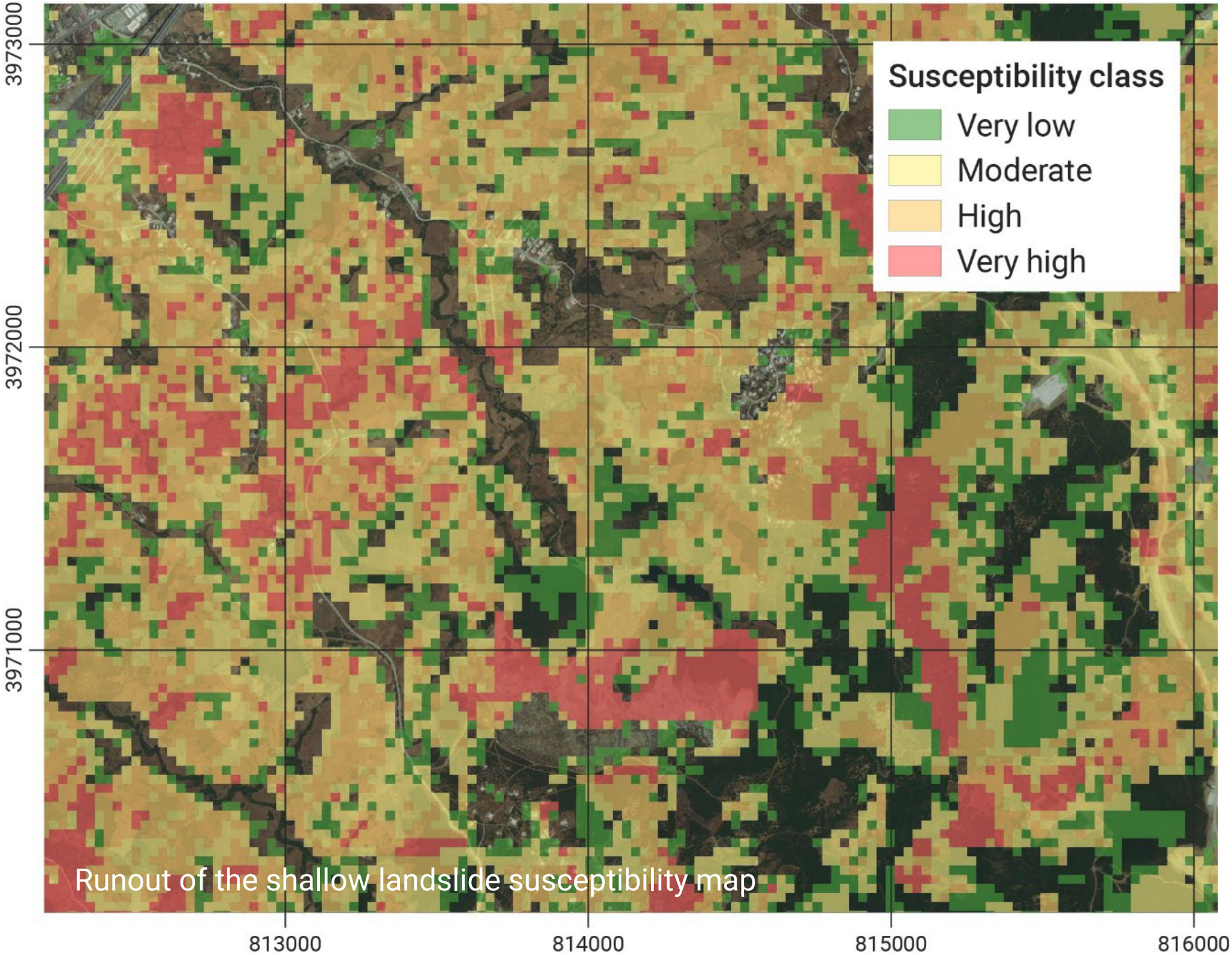


Illustration of the reach angle principle (or Fahrböschung) and of the effect of the maximum velocity parameter introduced in the SFLM (after Horton et al., 2013)




Susceptibility class
Very low
Moderate
High
Very high
3973000
3972000
3971000
813000
814000
815000
816000
Sources of the shallow landslide susceptibility map



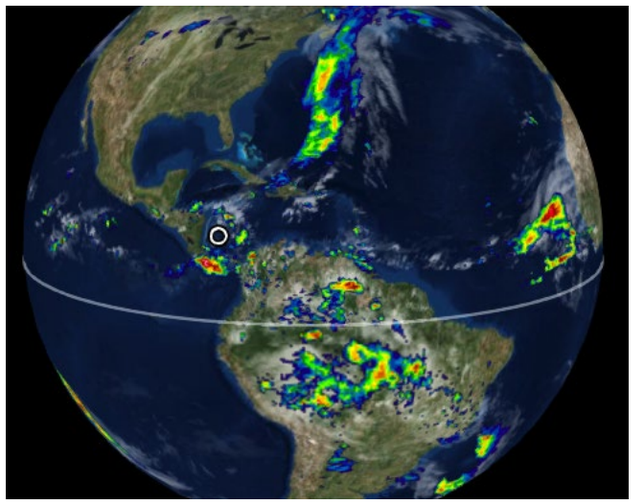
Runout of the shallow landslide susceptibility map

LHIS-HAZARD

3. Landslide nowcasting from rainfall estimates

– Forecast possible spatial landslide occurrences by combining susceptibility maps with rainfall-based triggers (Kirschbaum and Stanley, 2018)

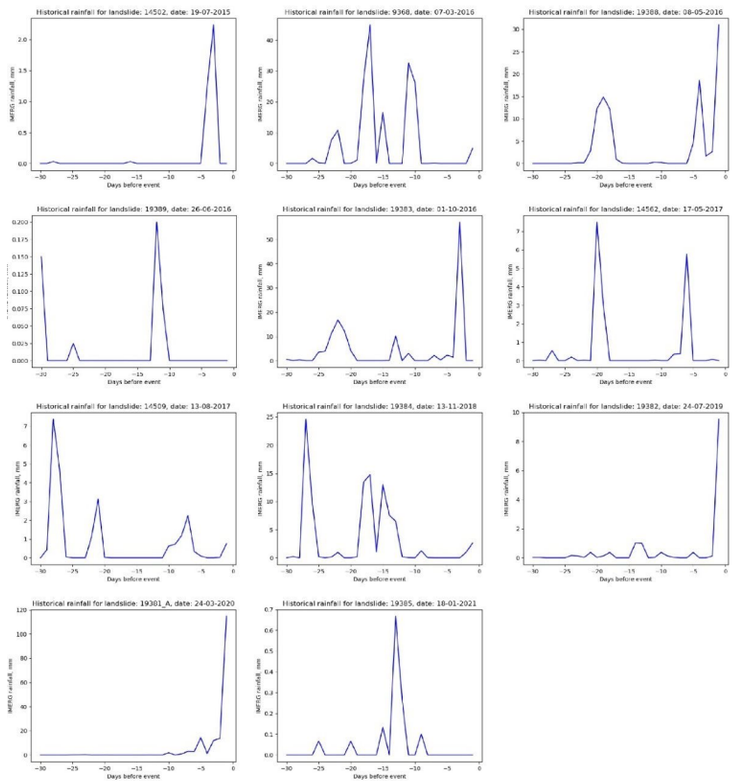
IMERG precipitation nowcast



- Based on weighted Antecedent Rainfall Index (ARI)

- When ARI exceeds the historical 95th per-centile, the LHASA model provides a landslide ‘nowcast’, indicating that there is a high likelihood of landslide events.

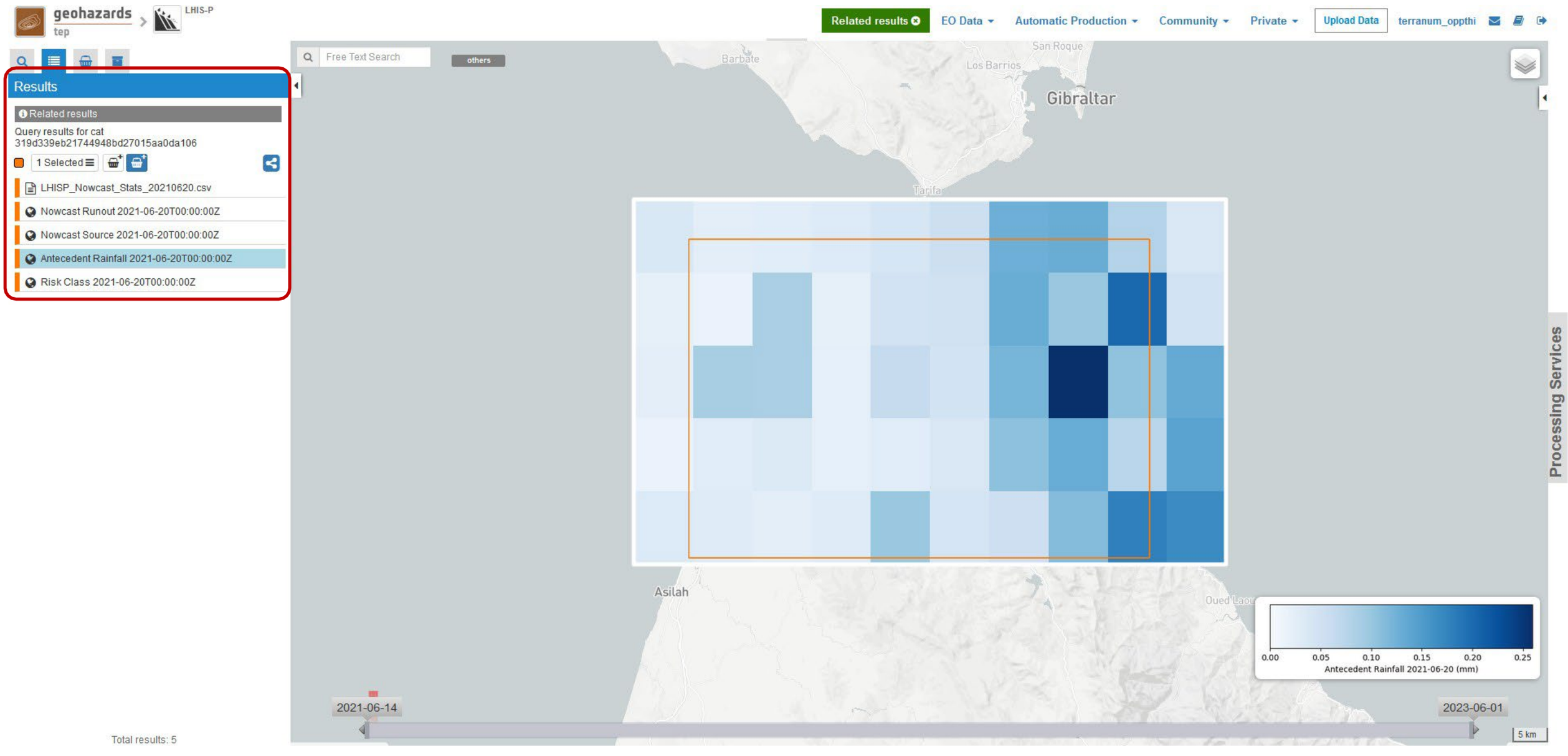
Pre-calculated landslide rainfall thresholds



< Example of time-series of rainfall measurements from NASA GPM/IMERG program for a subset of inventoried landslides in North Morocco over 30 days prior to the event.

LHIS Nowcast: outputs

- Five outputs are automatically computed once a day:
  - Antecedent rainfall index, nowcasted landslide sources, nowcasted runout extents, elements at risk and statistics per municipality



Antecedent rainfall index computed in LHIS Nowcast displayed in GEP

LHIS Nowcast: outputs

- Five outputs are automatically computed once a day:
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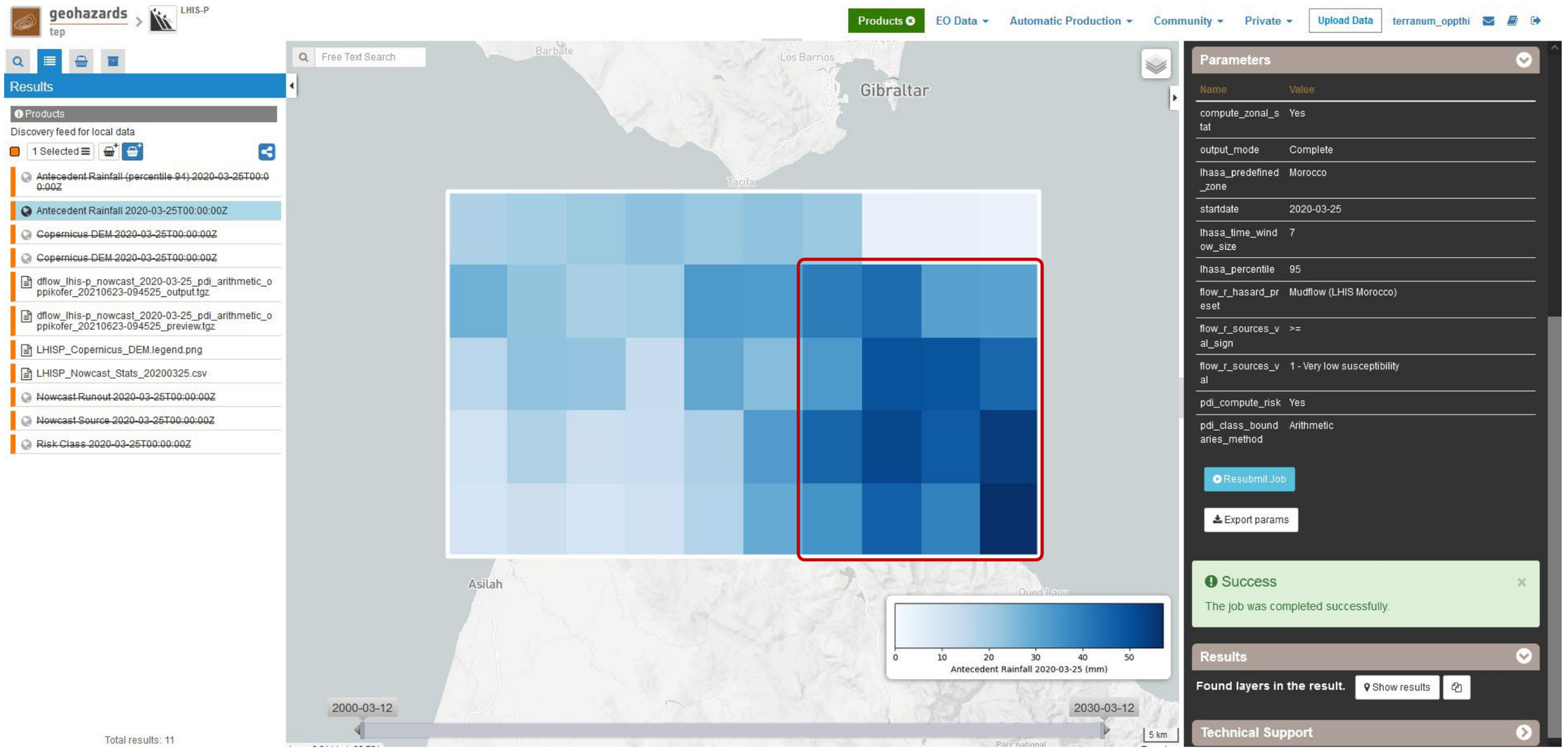
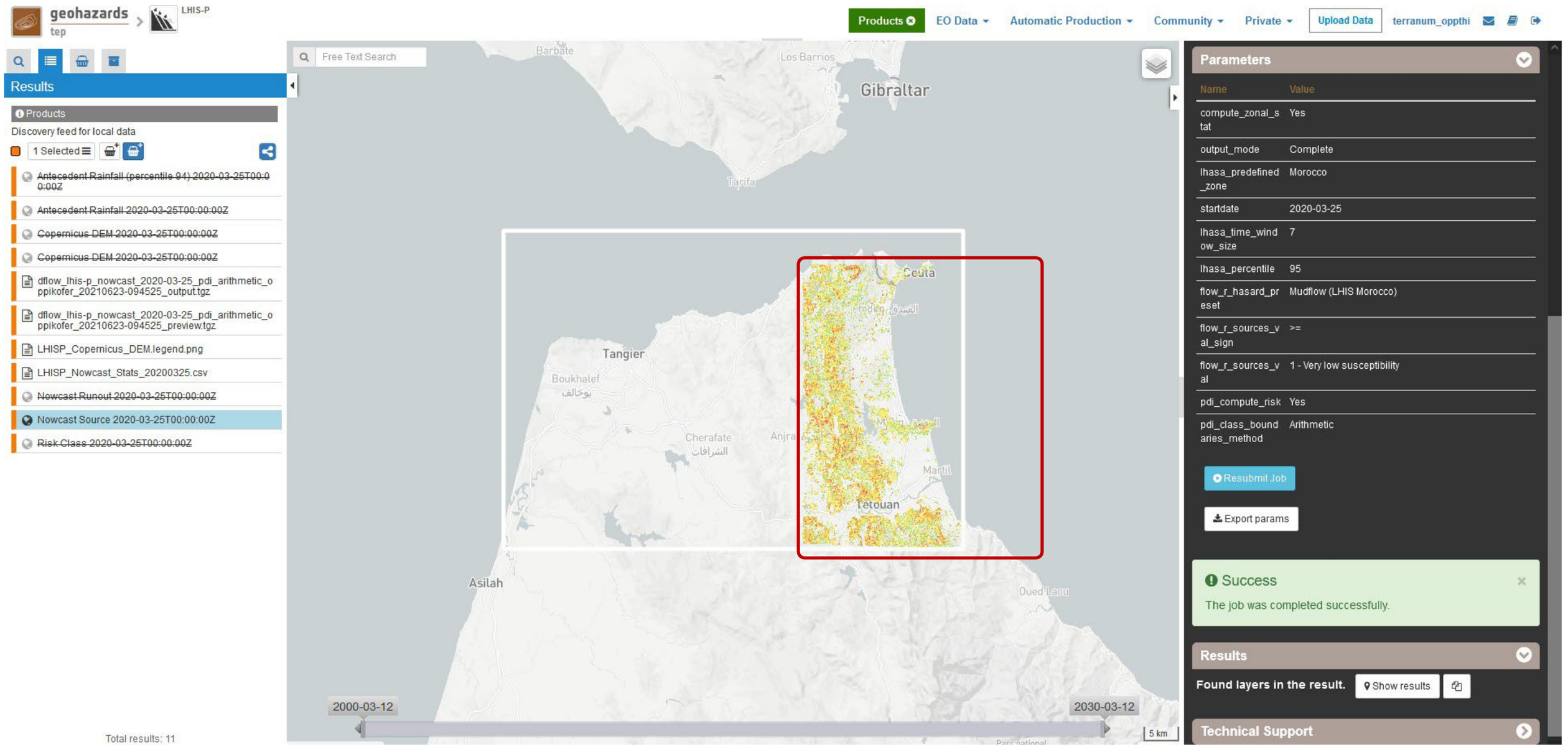


24 March 2020 back-analysis: antecedent rainfalls were higher than thresholds in the South-Eastern part, creating a shallow landslide alert

LHIS Nowcast: Outputs

- Five outputs are automatically computed once a day:
  - Antecedent rainfall index**, nowcasted landslide sources and related runout extents**, objects at risks and statistics per municipality

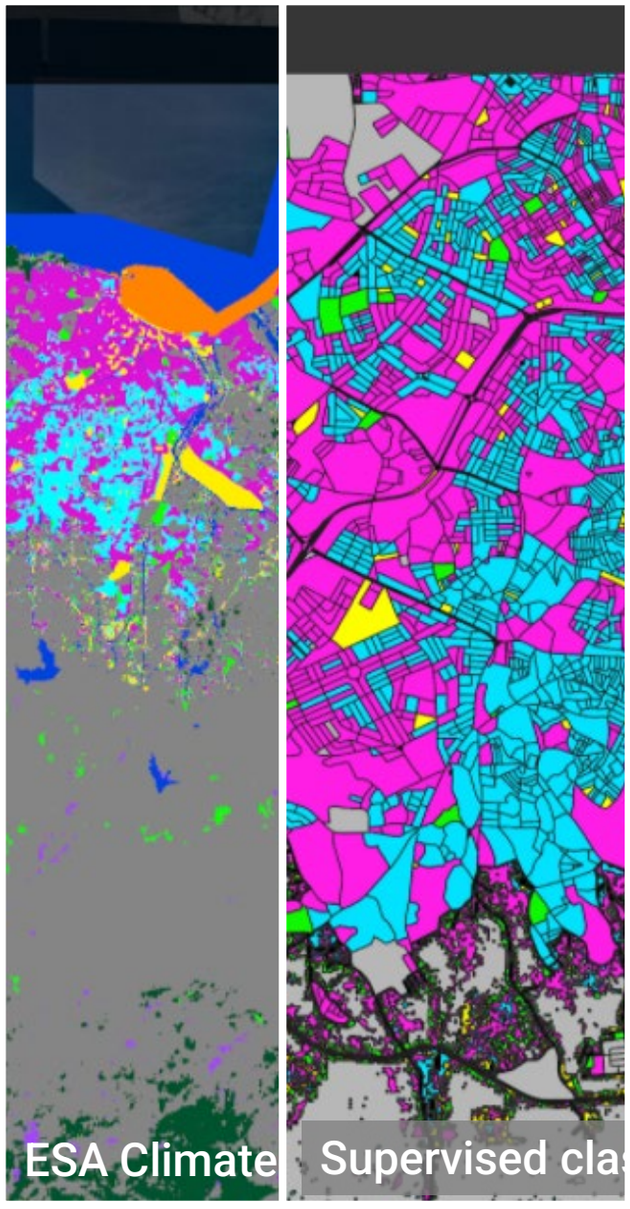


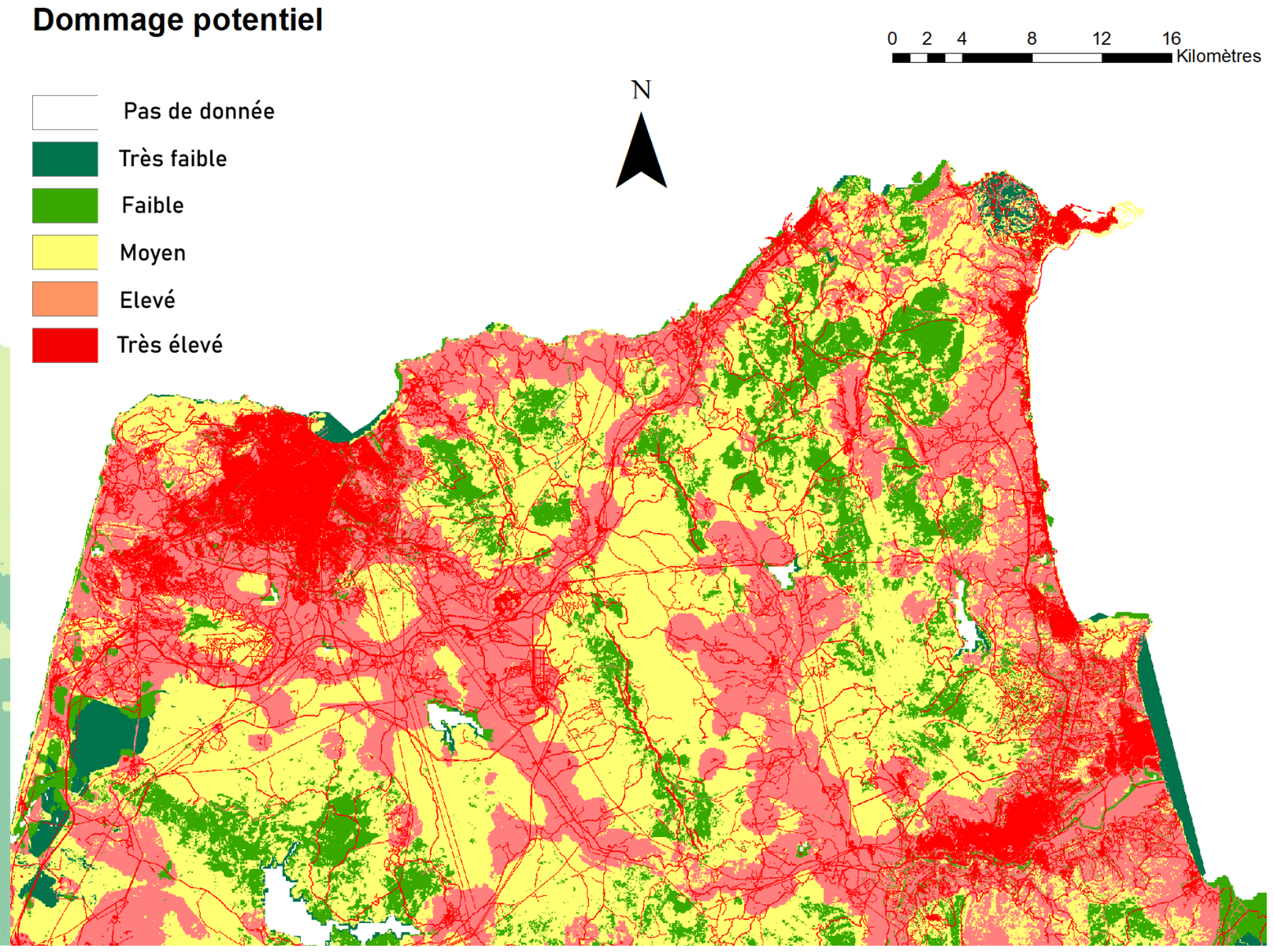
24 March 2020 back-analysis: computed runout extents of alarmed potential source areas

LHIS-IMPACT

- Based on the **Potential Damage Index** (Puissant et al., 2013):
  - Landslide exposure maps, cost analyses and impact indexes by combining both landslide and anthropic datasets

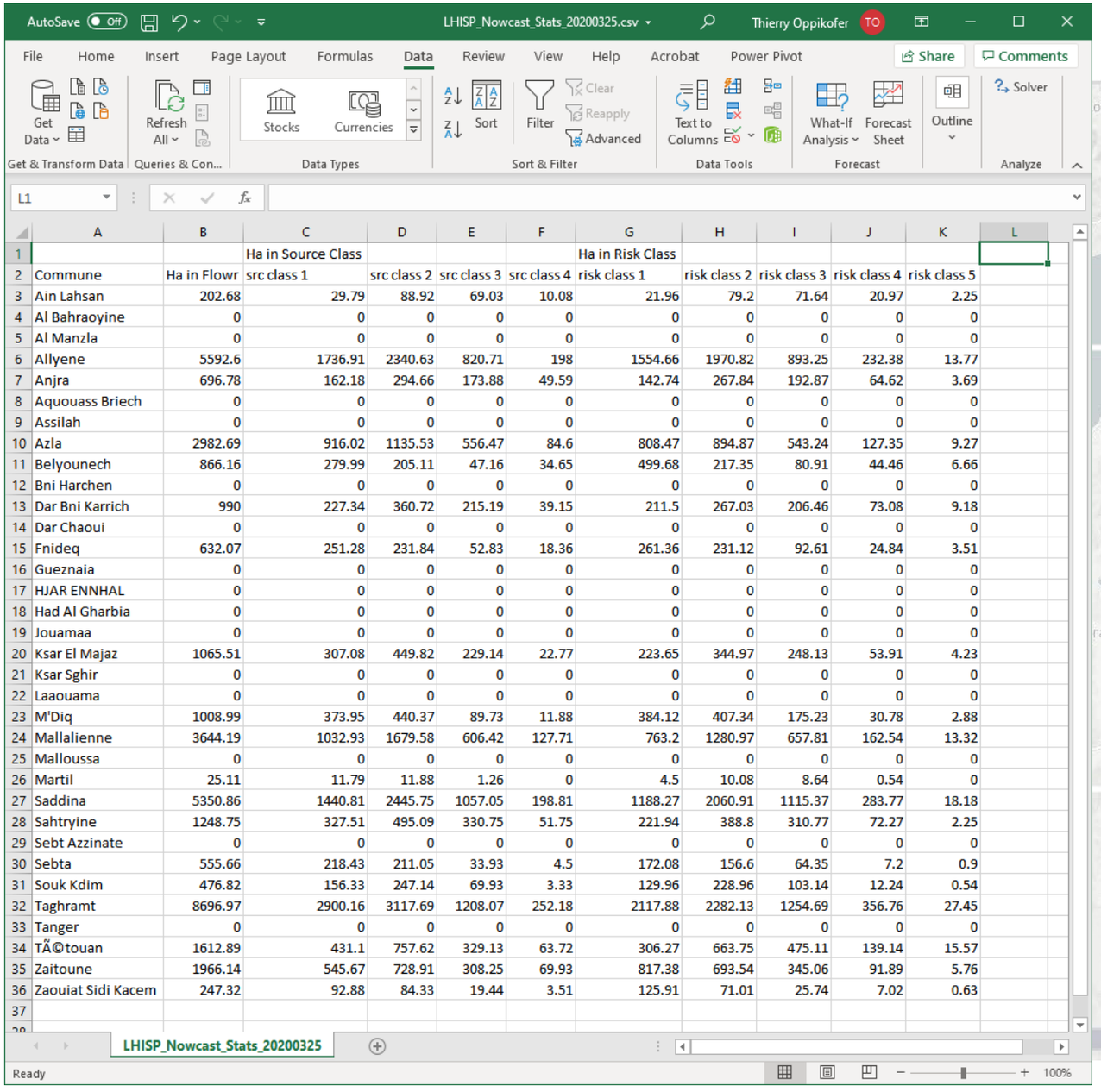
  → Identification and ranking of elements at risk and populations exposed to physical, direct/indirect, and social consequence impacts of damaging landslide events.





LHIS Nowcast: Outputs

- Five outputs are automatically computed once a day:
  - Antecedent rainfall index, nowcasted landslide sources and related runout extents, **objects at risks (potential damage) and statistics per municipality**



	A	B	C	D	E	F	G	H	I	J	K
1			Ha in Source Class				Ha in Risk Class				
2	Commune	Ha in Flowr	src class 1	src class 2	src class 3	src class 4	risk class 1	risk class 2	risk class 3	risk class 4	risk class 5
3	Ain Lahsan	202.68	29.79	88.92	69.03	10.08	21.96	79.2	71.64	20.97	2.25
4	Al Bahraoyine	0	0	0	0	0	0	0	0	0	0
5	Al Manzla	0	0	0	0	0	0	0	0	0	0
6	Allyene	5592.6	1736.91	2340.63	820.71	198	1554.66	1970.82	893.25	232.38	13.77
7	Anjra	696.78	162.18	294.66	173.88	49.59	142.74	267.84	192.87	64.62	3.69
8	Aquouass Briech	0	0	0	0	0	0	0	0	0	0
9	Assilah	0	0	0	0	0	0	0	0	0	0
10	Azla	2982.69	916.02	1135.53	556.47	84.6	808.47	894.87	543.24	127.35	9.27
11	Belyounech	866.16	279.99	205.11	47.16	34.65	499.68	217.35	80.91	44.46	6.66
12	Bni Harchen	0	0	0	0	0	0	0	0	0	0
13	Dar Bni Karrich	990	227.34	360.72	215.19	39.15	211.5	267.03	206.46	73.08	9.18
14	Dar Chaoui	0	0	0	0	0	0	0	0	0	0
15	Fnideq	632.07	251.28	231.84	52.83	18.36	261.36	231.12	92.61	24.84	3.51
16	Gueznaia	0	0	0	0	0	0	0	0	0	0
17	HJAR ENNHAL	0	0	0	0	0	0	0	0	0	0
18	Had Al Gharbia	0	0	0	0	0	0	0	0	0	0
19	Jouamaa	0	0	0	0	0	0	0	0	0	0
20	Ksar El Majaz	1065.51	307.08	449.82	229.14	22.77	223.65	344.97	248.13	53.91	4.23
21	Ksar Sghir	0	0	0	0	0	0	0	0	0	0
22	Laaouama	0	0	0	0	0	0	0	0	0	0
23	M'Diq	1008.99	373.95	440.37	89.73	11.88	384.12	407.34	175.23	30.78	2.88
24	Mallalienne	3644.19	1032.93	1679.58	606.42	127.71	763.2	1280.97	657.81	162.54	13.32
25	Malloussa	0	0	0	0	0	0	0	0	0	0
26	Martil	25.11	11.79	11.88	1.26	0	4.5	10.08	8.64	0.54	0
27	Saddina	5350.86	1440.81	2445.75	1057.05	198.81	1188.27	2060.91	1115.37	283.77	18.18
28	Sahtryine	1248.75	327.51	495.09	330.75	51.75	221.94	388.8	310.77	72.27	2.25
29	Sebt Azzinate	0	0	0	0	0	0	0	0	0	0
30	Sebta	555.66	218.43	211.05	33.93	4.5	172.08	156.6	64.35	7.2	0.9
31	Souk Kdim	476.82	156.33	247.14	69.93	3.33	129.96	228.96	103.14	12.24	0.54
32	Taghramt	8696.97	2900.16	3117.69	1208.07	252.18	2117.88	2282.13	1254.69	356.76	27.45
33	Tanger	0	0	0	0	0	0	0	0	0	0
34	TÃ©touan	1612.89	431.1	757.62	329.13	63.72	306.27	663.75	475.11	139.14	15.57
35	Zaitoune	1966.14	545.67	728.91	308.25	69.93	817.38	693.54	345.06	91.89	5.76
36	Zaouiat Sidi Kacem	247.32	92.88	84.33	19.44	3.51	125.91	71.01	25.74	7.02	0.63
37											

24 March 2020 back-analysis: objects at risks exposed to computed runout extents of alarmed potential source areas

Outcomes

- LHIS is a working demonstrator running every day since July 2021.
- Additional developments are still required to be fully operational and generic:
  - For the Morocco use case, local fine model calibrations are required, instead of global parameterizations (landslide AI training set to refine the source susceptibility map, calibration of the threshold of critical rainfall necessary with Moroccan data).
  - Current deployment of a LHIS second demonstrator for Haiti (CEOS RO + Caribact program)
  - Bringing the platform to the market: interest of AXA and Paribas Cardif to use the system
  - Now some general methodological improvements are planed for future applications, such as:
    - The use of weather forecasting models, as the free global model GFS instead of the GPM model, in order to forecast landslide occurrence susceptibility up to D+5 instead of the current nowcast.
    - The possibility to integrate other types of landslides related to extreme precipitation, such as debris flows and torrential floods.

Thank you for your time

Comments or questions can be addressed to

clement.michoud@terranum.ch

jeanphilippe.malet@unistra.fr