Consultancy Service for the Development of an Inundation, Flooding and Landslide National Risk Profile, Strategic Framework and Action Plans for Disaster Risk Management for the Republic of Mauritius

Vincenzo Marsala
Geological engineer
SGI Studio Galli Ingegneria SpA

Capacity and validation workshop
Swami Vivekananda International Convention Centre, Pailles, Mauritius, August 22-24, 2012

Capacity Building and Validation Workshop

Wednesday August 22, 2012

Session 2: Water related hazards in the Republic of Mauritius (RoM)– Risk assessment explained - Analysing hazard exposure

14:00 – 14:30 Landslide hazard assessment

Vincenzo Marsala (SGI Studio Galli Ingegneria S.p.A.)

Landslide hazard assessment

Table of contents

Landslide hazard assessment

The work group is characterized of a multidisciplinary experts in the field of earth science and geological engineering

LANDSLIDE WORK GROUP

Team Leader	**Vincenzo Marsala**	**Geological Engineer**	**Coordination of group, in field survey, official meeting**
Scientific Coordinator	**Enrico Miccadei**	**Professor of Geomorphology**	**Scientific supervision, in field survey, landslide model control**
Geomorphologist	**Tommaso Piacentini**	**PHD Geology**	**In field survey, photo-geology, GIS elaboration**
Geomorphology GIS Analyst	**Michele Rocca**	**PHD Engineer geology**	**GIS elaboration, landslide model building**
Photo-geologist	**Marco Sciarra**	**Geologist**	**Photogeologic analysis**

Landslide hazard assessment

1) Approach to assess the Landslide hazard :

a) Landslide phenomena existing according to the surveying

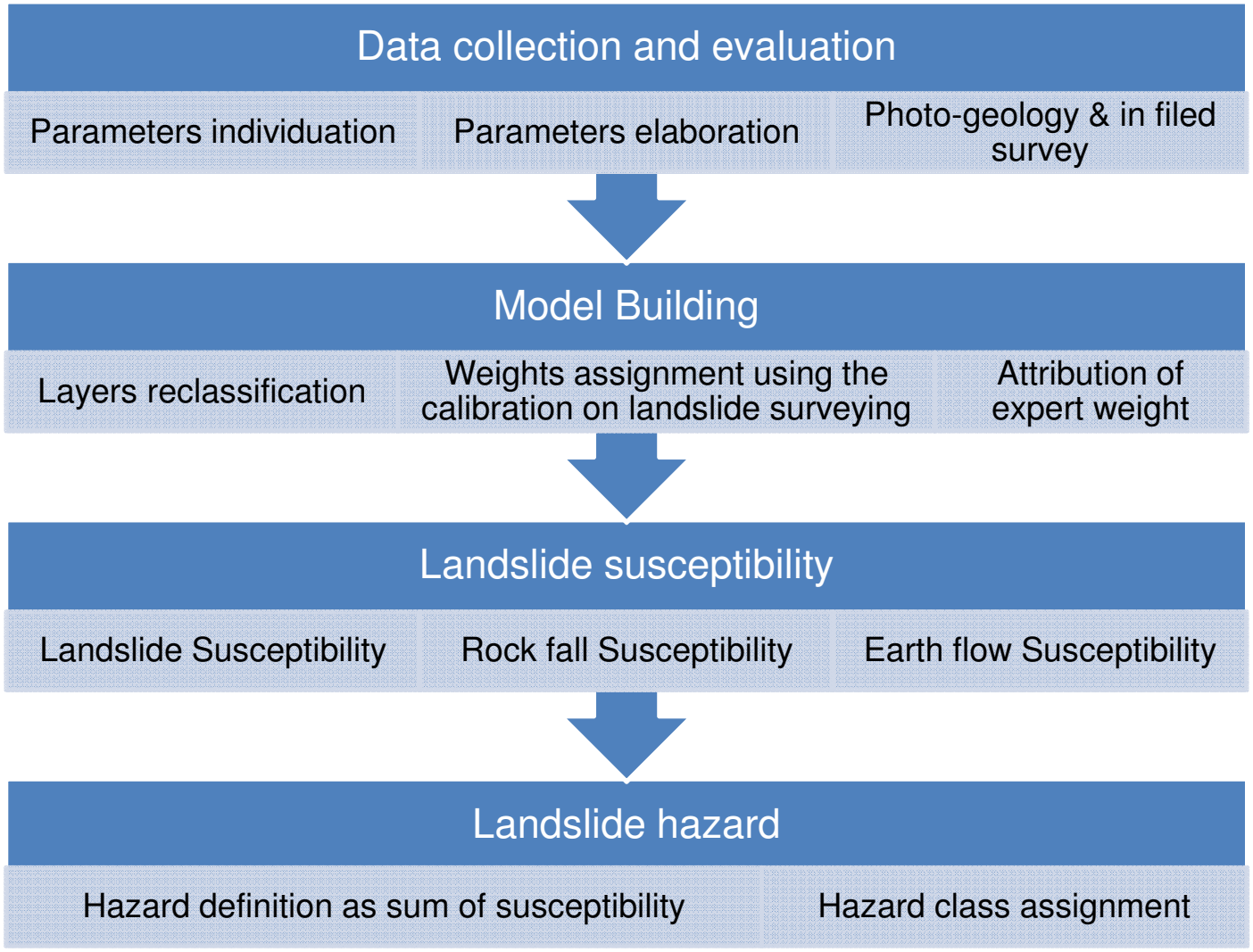
b) Susceptibility model for the three main type of landslides

c) Calibration of the model taking into account the point a)

d) Elaboration of the landslide hazard as sum of three different susceptibility (rock fall, classic landslide, earth flow)

Landslide hazard assessment

1) WORK FLOW



Landslide hazard assessment

2) Tools

Geographic Information System

Mainly two software have been utilized for data management and elaboration:

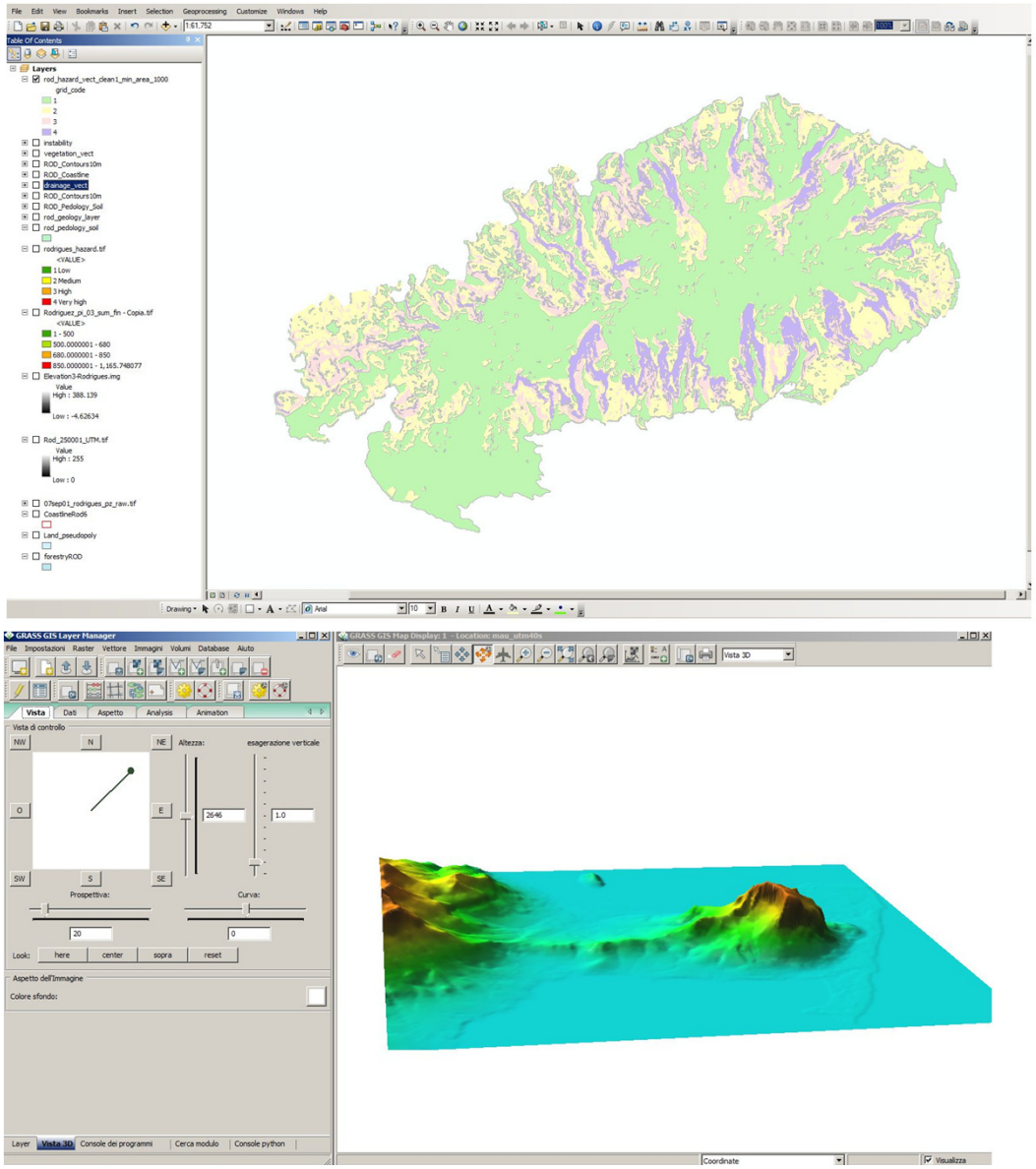
ESRI ArcGIS (commercial)

http://esri.com

GRASS GIS Geographic Resources Analysis Support System (open source) :

http://grass.fbk.eu/

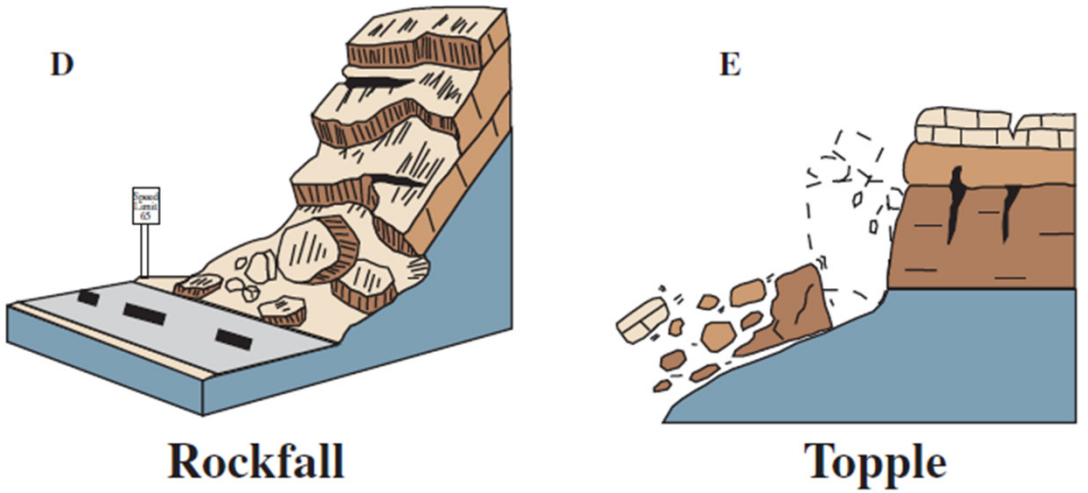
The first as the main data management platform and the second basically to perform automated procedures involved in modeling phase of the work.



Landslide hazard assessment

The major types of landslides movement

Rock falls are abrupt movements of masses of geologic materials, such as rocks and boulders, that become detached from steep slopes or cliffs

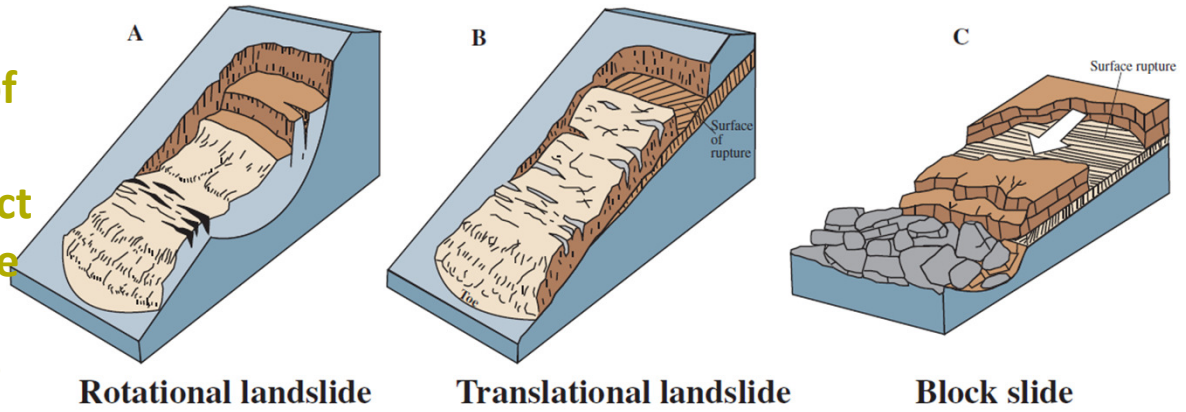


From US Geological Survey Fact Sheet 2004-3072, July 2004

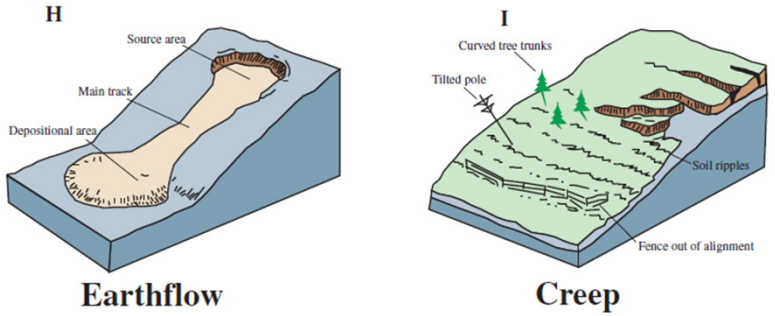
Landslide hazard assessment

The major types of landslides movement

Many types of mass movements are included in the general term "landslide", a more restrictive use of the term refers only to mass movements, where there is a distinct zone of weakness that separates the slide material from more stable underlying material. The two major types of slides are rotational slides and translational slides



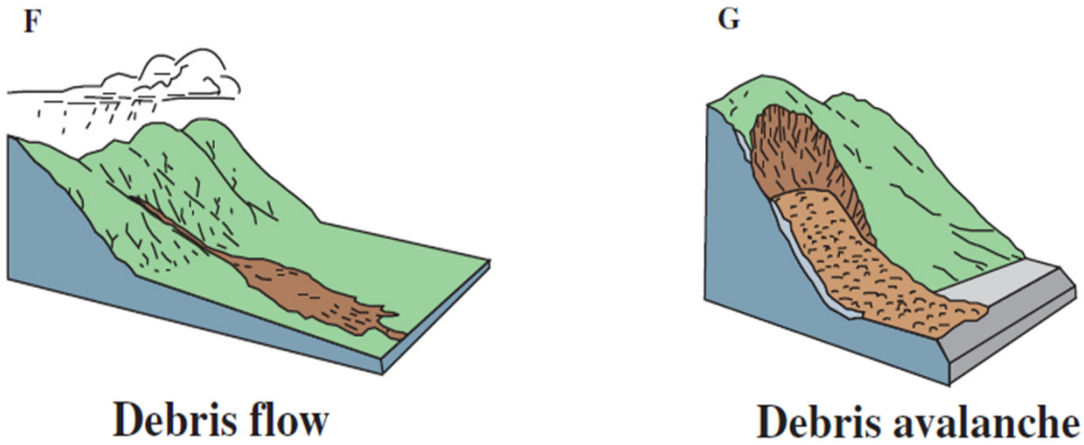
In this work landslides include also other slow movements such as slow earth flows and creep



From US Geological Survey Fact Sheet 2004-3072, July 2004

The major types of landslides movement

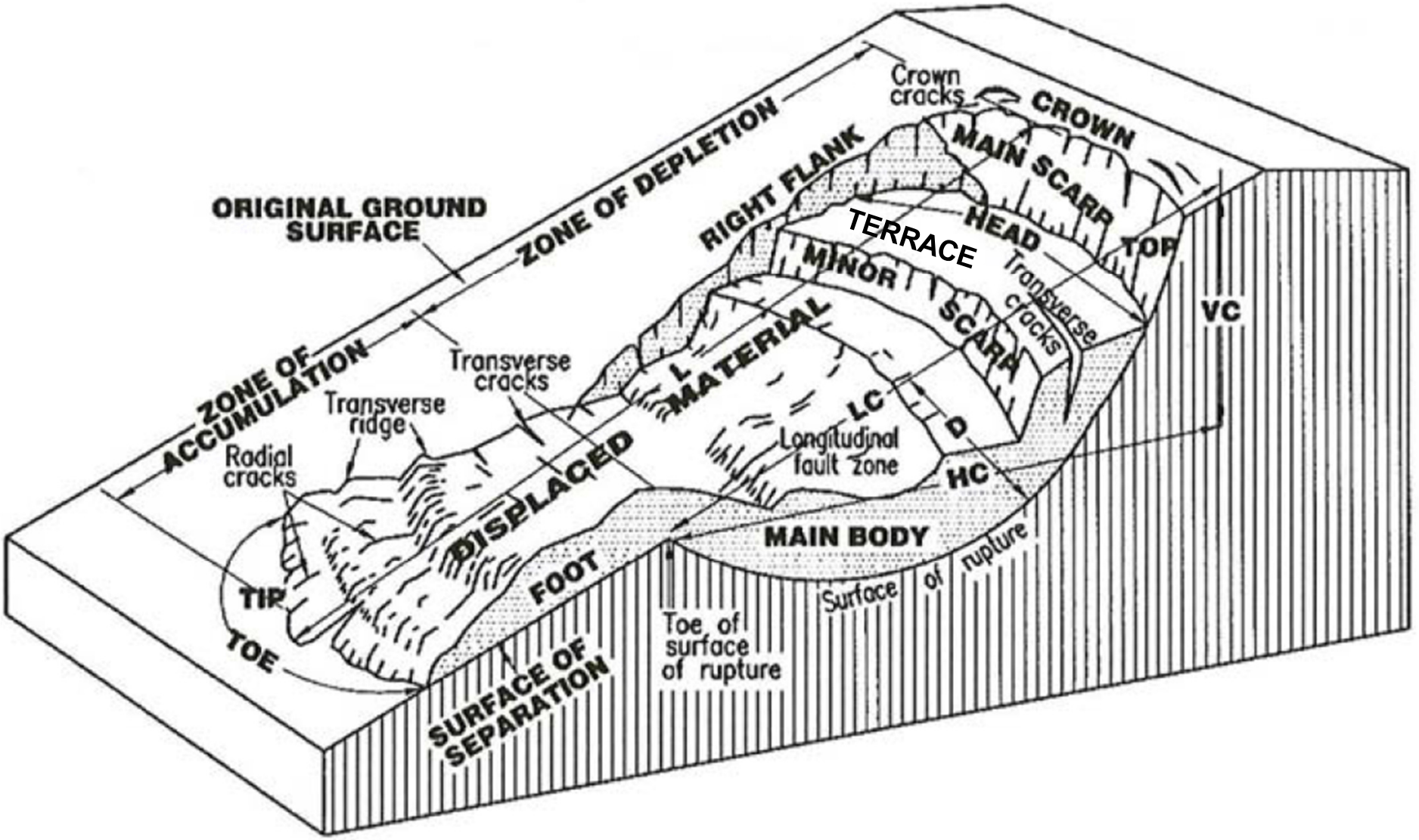
RAPID EARTH FLOWS:
This category includes rapid mass movement such as mudflows and debris flows and avalanches



From US Geological Survey Fact Sheet 2004-3072, July 2004

Landslide hazard assessment

3. Methodological description



Varnes, D J (1978,) Slope Movement Types and Processes. In Special Report 176: Landslides: Analysis and Control(R L Schuster & R J Krizek, eds.), TRB, National Research Council, Washington, DC, pp.11-33

Landslide hazard assessment

3. Methodological description

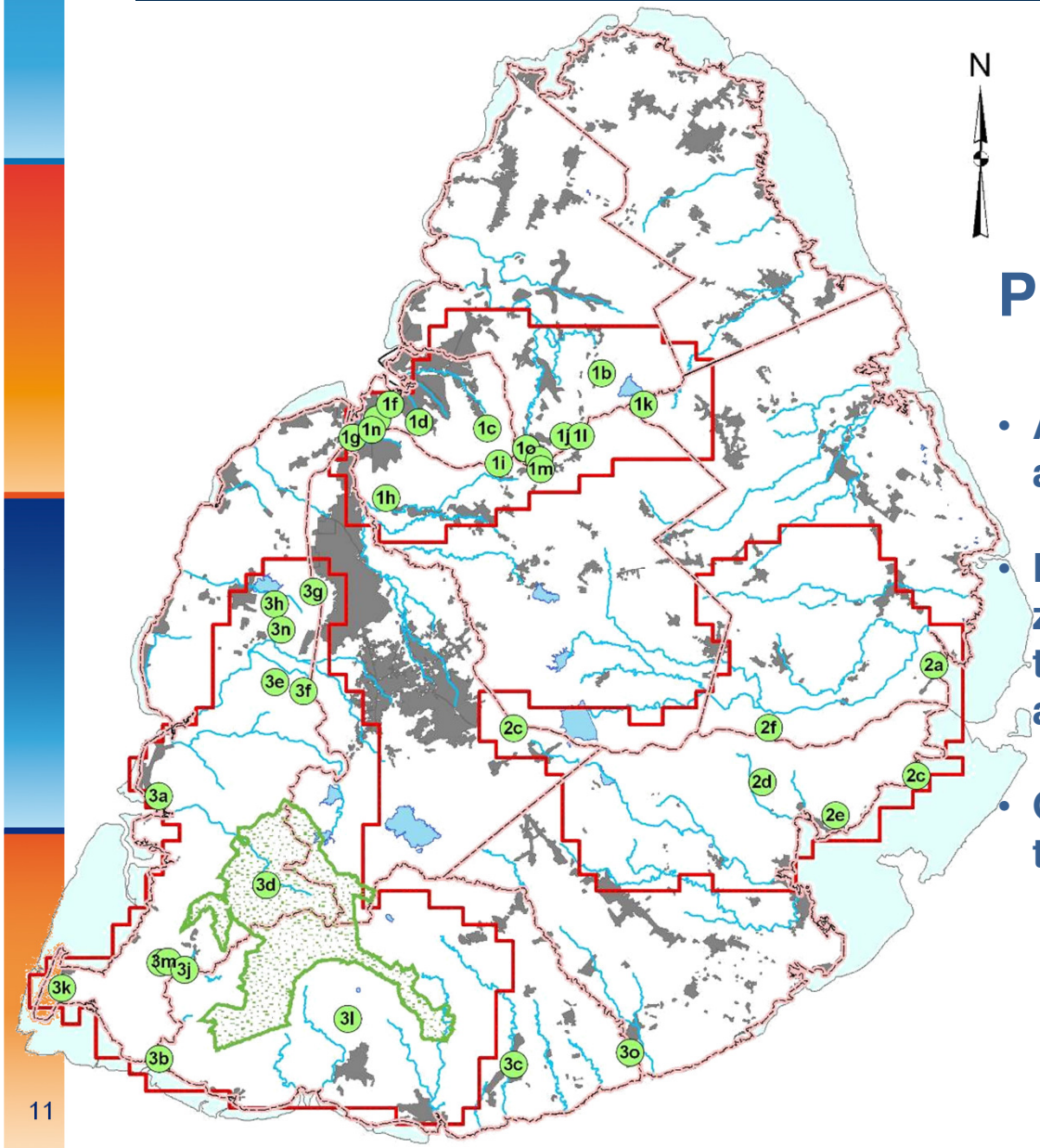


Photo-geologic analysis

- Analysis of landslide prone areas from available documents
- Defining of three main mountainous/hilly zones, according to the potential contribution to slope instabilities for Mauritius, and analysis of whole island of Rodrigues
- Overview of the areas with critical landforms to drive the surveying

Landslide hazard assessment

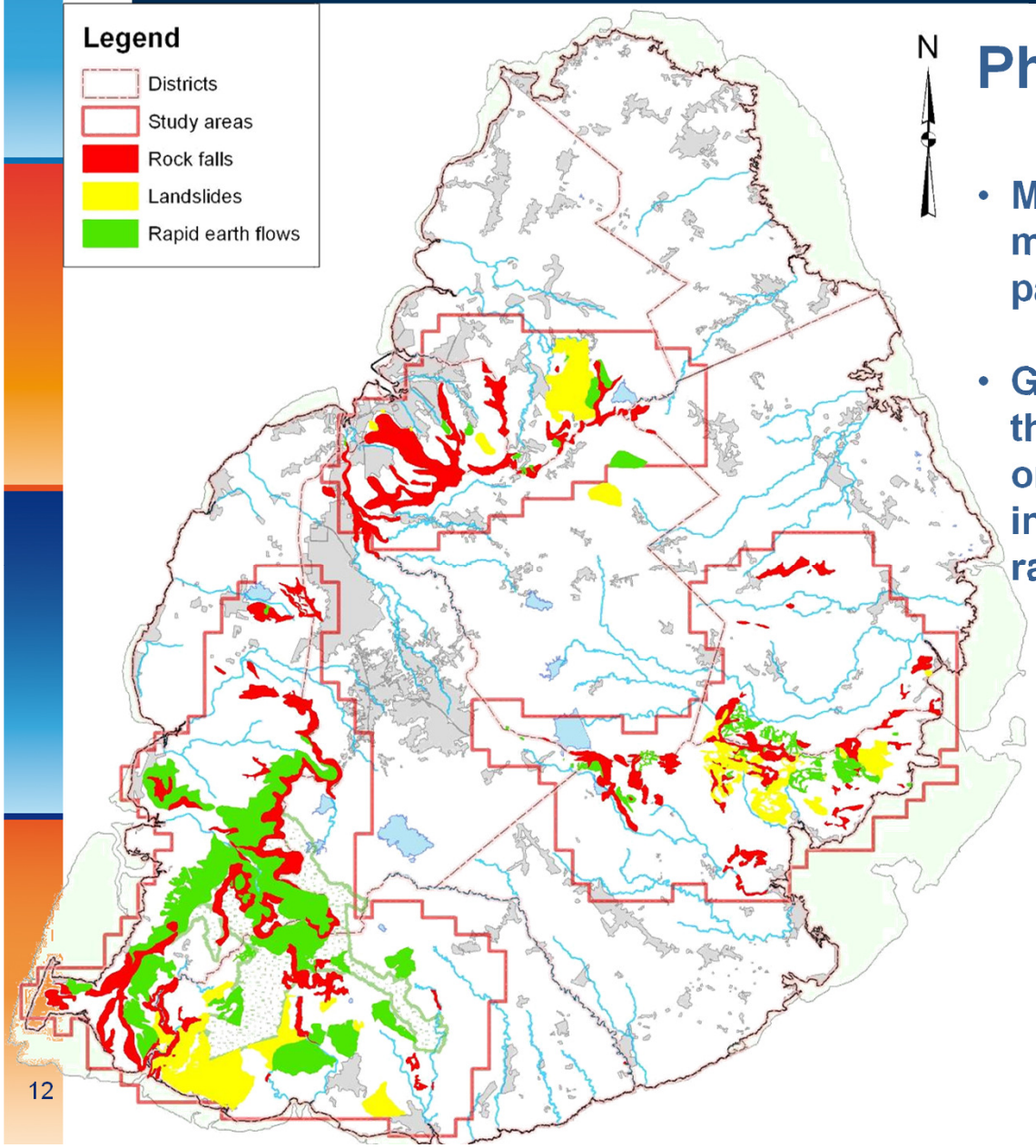
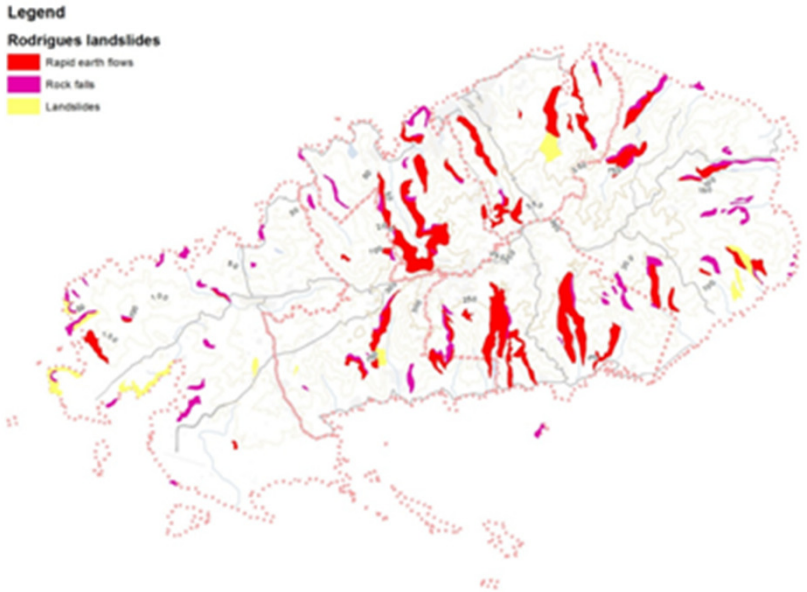


Photo-geologic results

- **Mapping of homogeneous areas related to the main orographic, geomorphologic and land parameters**
- **GIS mapping of principal factors allowed for the definition of homogeneous zones that are, or can be, affected by different type of slope instabilities such as rock falls, landslides and rapid earth flows.**



Landslide hazard assessment

3. Methodological description

Photo-geologic results

- **Mapping of homogeneous areas related to the main orographic, geomorphologic and land parameters**
- **GIS mapping of principal factors allowed for the definition of homogeneous zones that are, or can be, affected by different type of slope instabilities such as rock falls, landslides and rapid earth flows.**

SOME EXAMPLE

1c - VALLÉE DES PRETRES-CHITRAKOOT (Port Louis district- ZONE 1)

Landslide hazard assessment

3. Methodological description

1C - VALLÉE DES PRETRES-CHITRAKOOT (PORT LOUIS DISTRIC- ZONE 1)

Elevation (m)	*Slope (%)*	*Hydrography drainage pattern*	*Vegetation*	*Lithology*	*Soil*	*Soil thickness*	*Slope gravity processes*
150-500	10-25	Subdendritic	Sparse tree	Landslide deposits	Brown rocky soil of moderate thickness in low slope areas	10-20	Landslides

Landslide hazard assessment

3. Methodological description

k – Petit Gabriel

Part 1

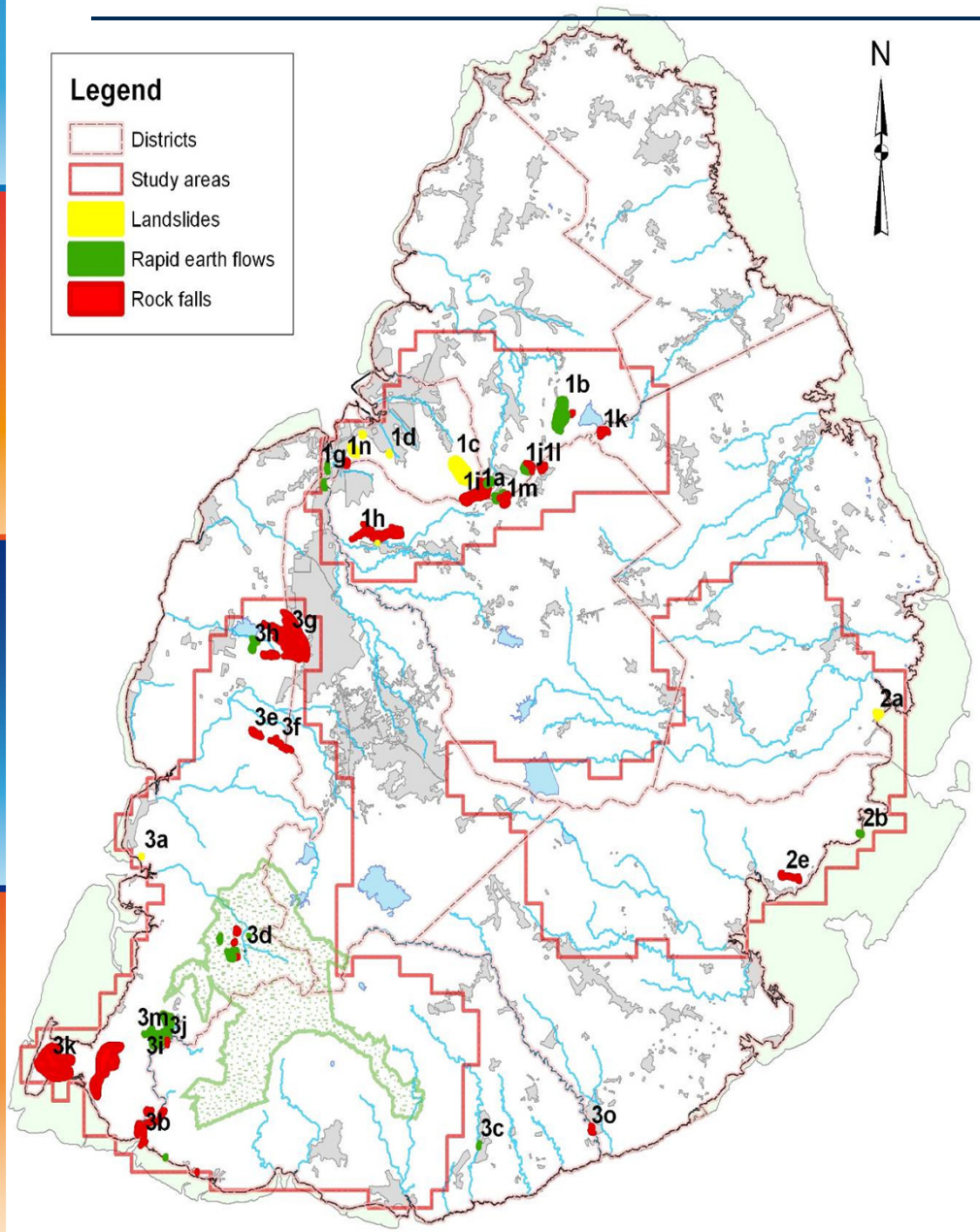
Elevation (m)	*Slope (%)*	*Hydrography drainage pattern*	*Vegetation*	*Lithology*	*Soil*	*Soil thickness*	*Slope gravity processes*
0-150	25-45	Subdendritic	Sparse trees	Colluvial deposits		0-5	Landslides

Part 2

Elevation (m)	*Slope (%)*	*Hydrography drainage pattern*	*Vegetation*	*Lithology*	*Soil*	*Soil thickness*	*Slope gravity processes*
0-150	45-100	Subdendritic	Heavy tree canopy	Colluvial deposits		0-5	Landslides

Landslide hazard assessment

3. Methodological description

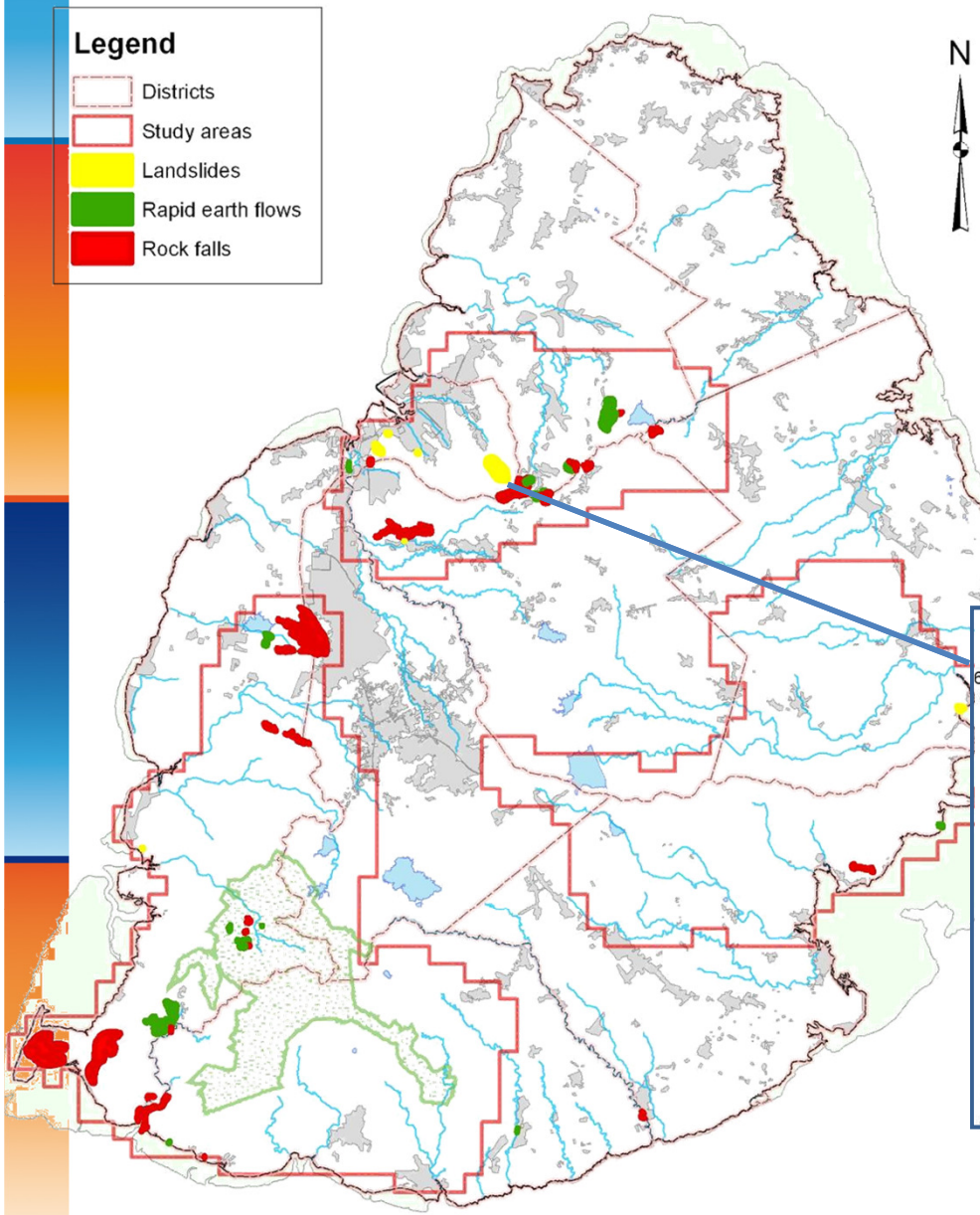


In field survey

- In field survey on the landslide prone areas included in the available documents and considering the photo-geologic results
- Elaboration of geomorphological simplified profiled

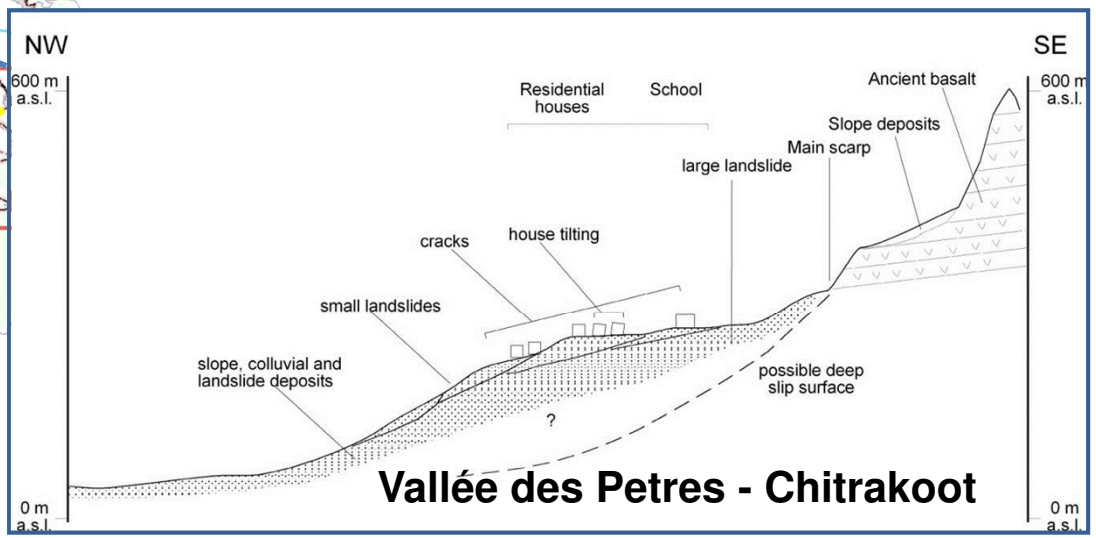
Landslide hazard assessment

3. Methodological description

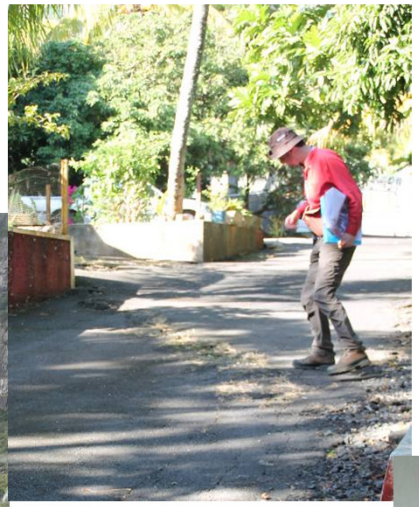


In field survey

- **Preliminary definition of landslide**



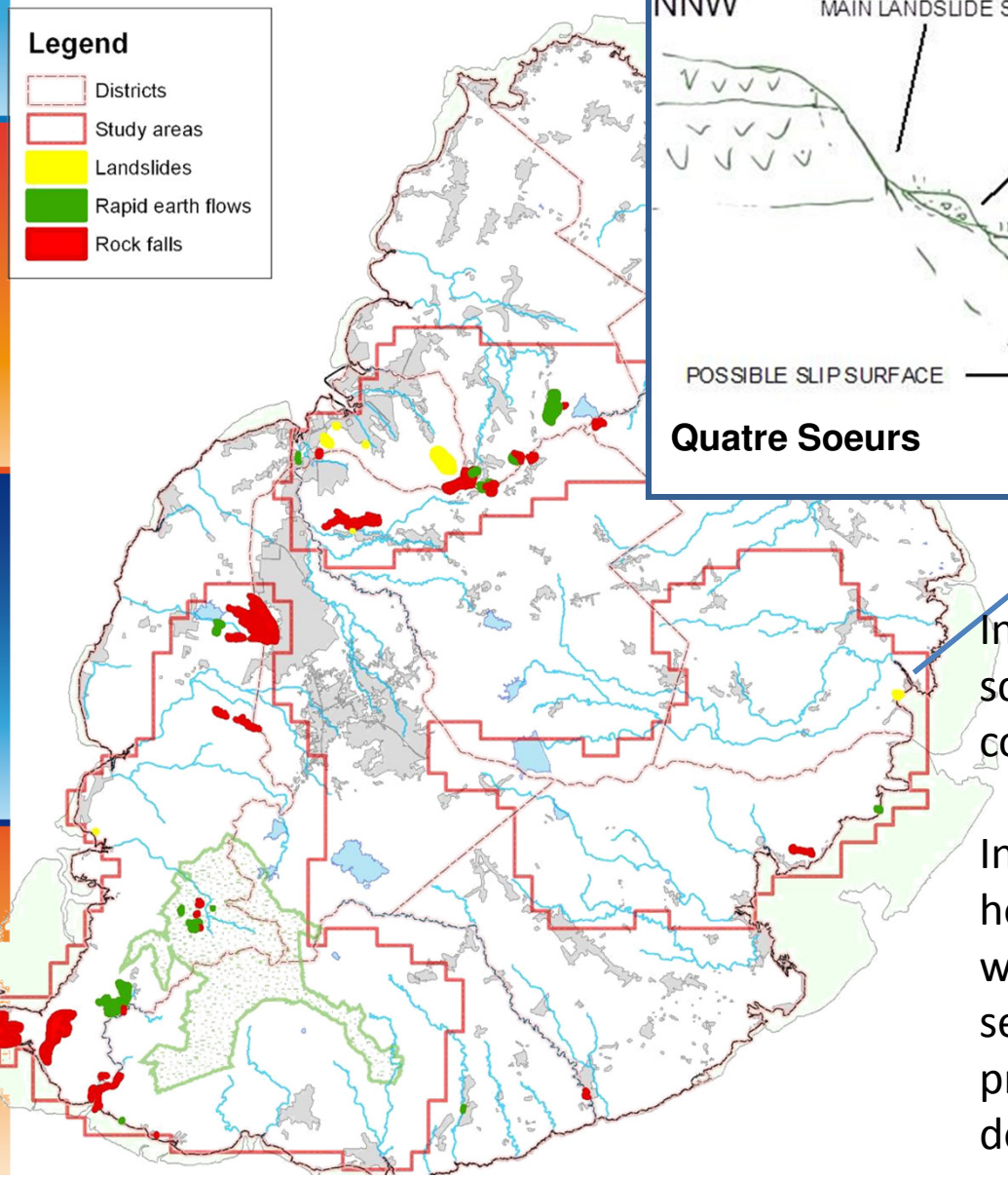
Vallée des Petres - Chitrakoot

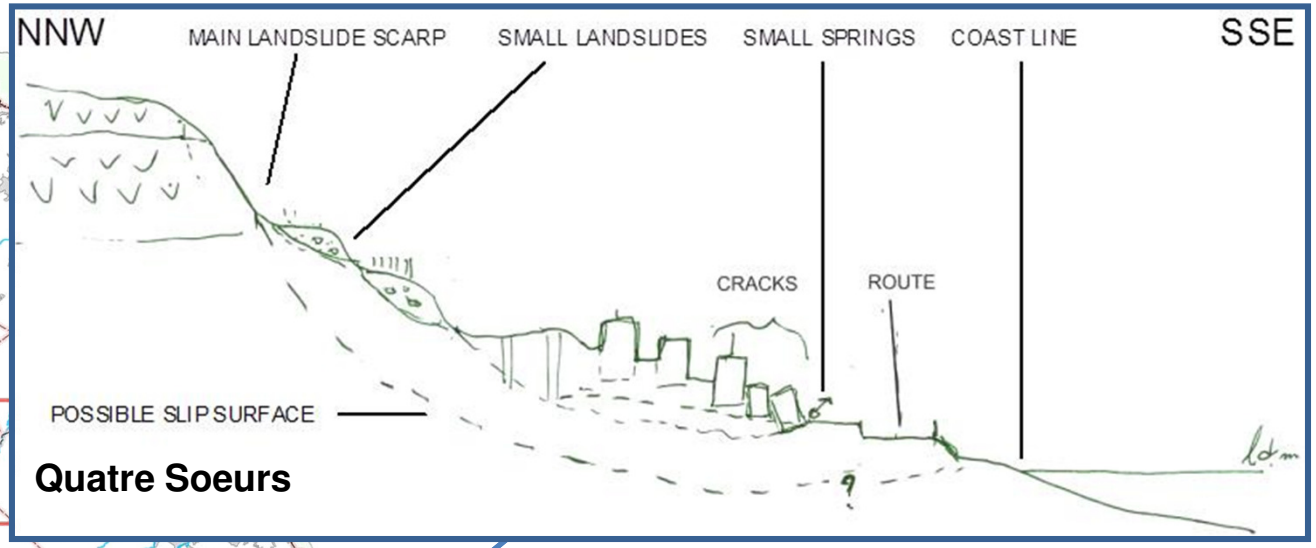


In the upper part of the slope, a main landslide scarp is present, on the ancient basalts
In the middle part of the slope the wide gently rolling area is referable to a landslide terrace, with small counter slopes, that could be referable to a large landslide involving the whole slope, with a deep slip surface (> 20-30 m).
This area is affected also by shallow to moderately deep slow landslides involving the colluvial deposits and inducing tilting, severe cracks and damages to residential houses and to the Chitrakoot school.
According to the information collected during the in field survey and to the previous study, the landslides are reactivated by the major rainfall events. The progress of this landslide could heavily damage the residential houses and the school of the Chitrakoot area.

Landslide hazard assessment

3. Methodological description





In the upper part of the slope, a main landslide scarp is present, on the ancient basalts, partly covered by slope deposits.

In the middle part of the slope just above the houses of Quatre Soeurs – Deux Frere villages a wide counter slope, with small swamps, and several small scarps and shallow landslides are present, affecting weathered colluvial and slope deposits

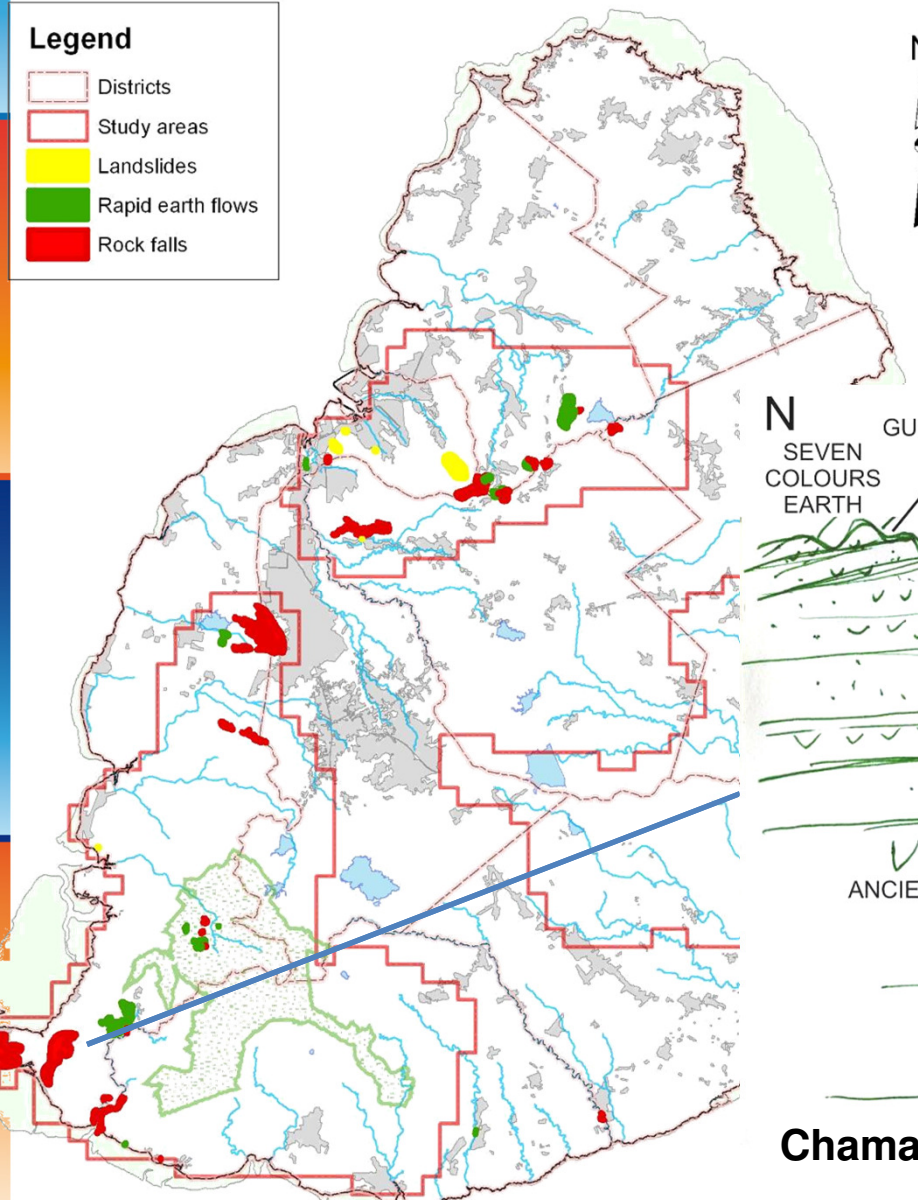
Quatre Soeurs

Panoramic view of the of the upper part of the slope of Mt. Beau Camp. At the boundary between vegetation and crops runs the main landslide scarp; in the foreground evidence of shallow landslides

According to the information collected during the in field survey and to the previous study, the landslide is reactivated by the major rainfall events.
The progress of this landslide could heavily damage the houses of Quatre Soeurs – Deux Frere villages

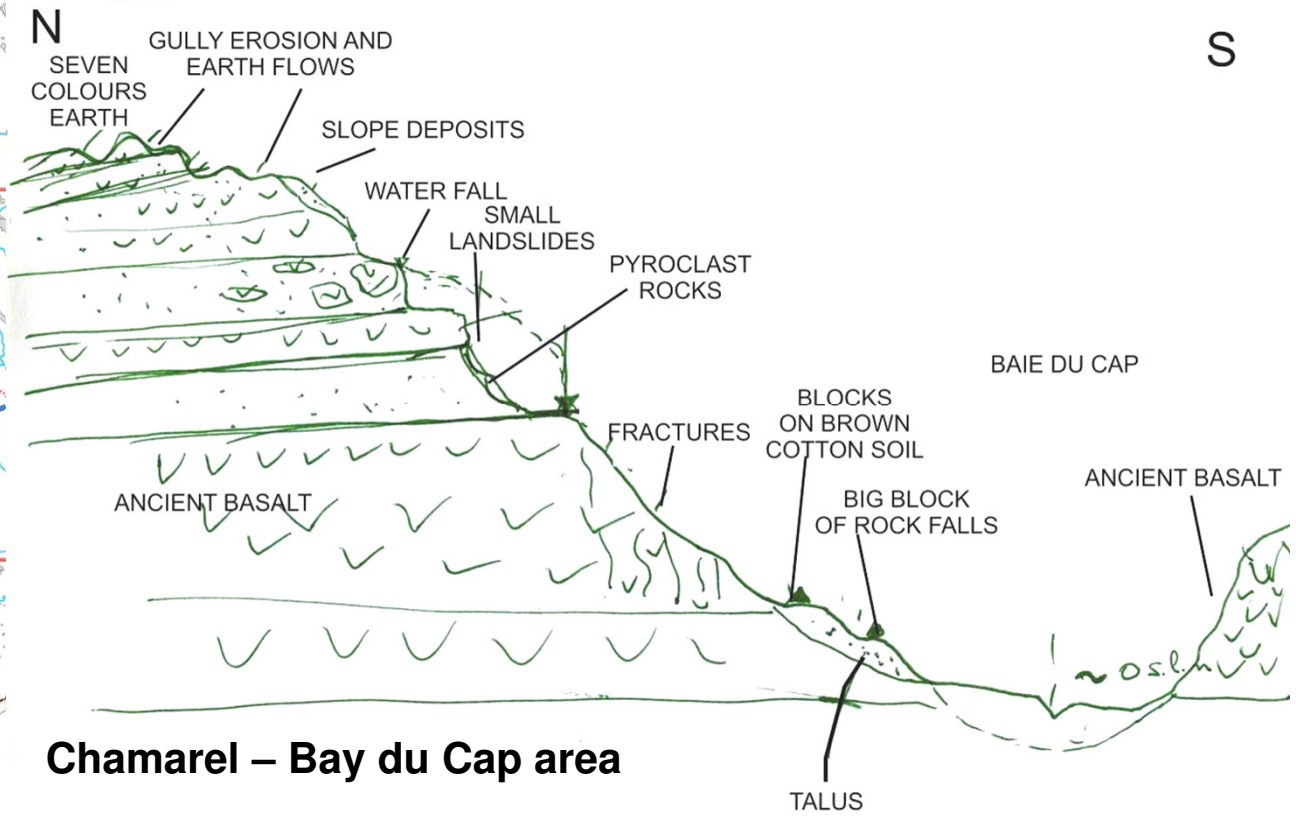
Landslide hazard assessment

3. Methodological description



In field survey

- **Preliminary definition of landslide**



Chamarel – Bay du Cap area

Model Building: Statistical analysis

In the traditional heuristic methodology, parameters reclassification and weight assignment is commonly controlled thought the sensibility procedures.

A first statistical analysis is performed to identify a "Landslide index“ (Li) for each parameter.

Landslide hazard assessment

Statistical analysis

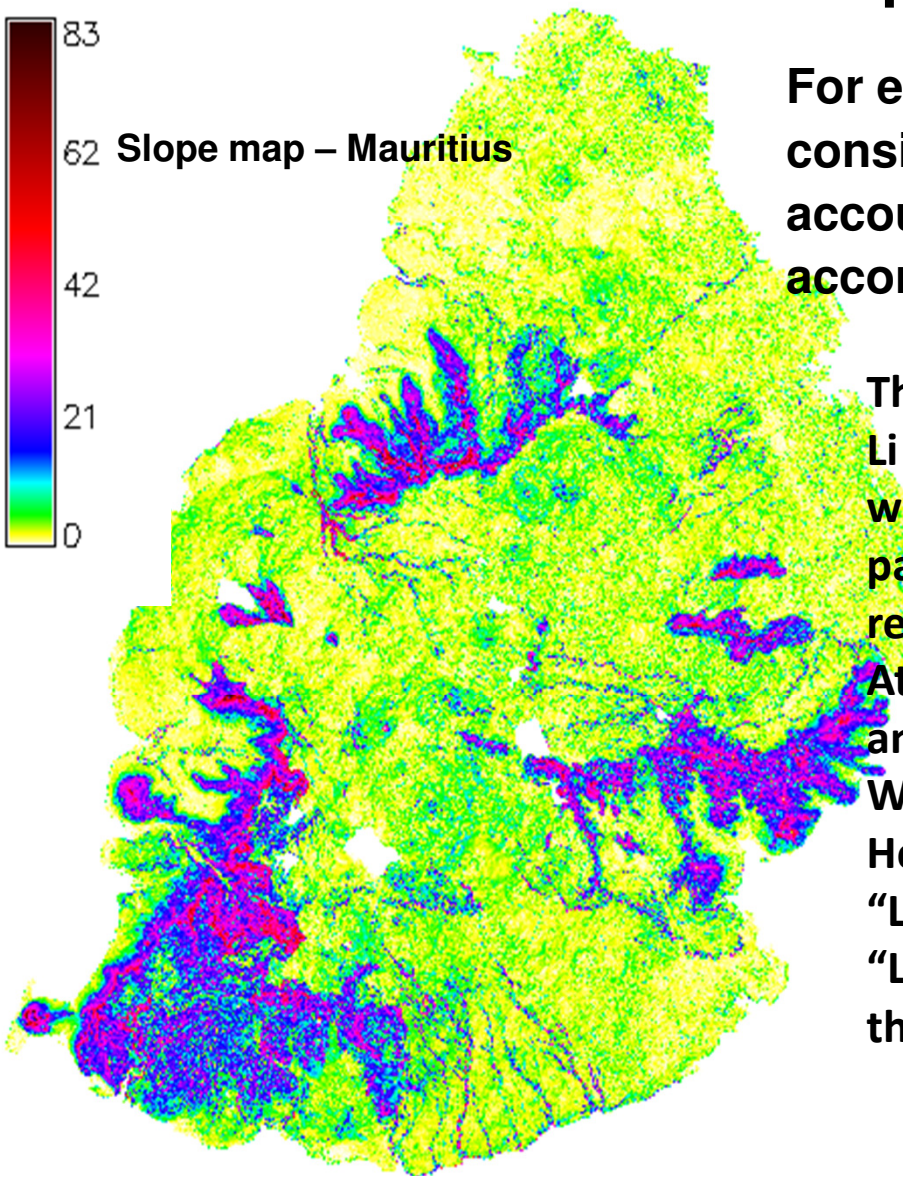
The "landslide index", as described, allow to further refine the parameters classification, with a distribution function analysis, and to proceed to parameters (or layers) normalization and weight assignment:

WEIGHT $$P = \left[\frac{(IF_0 - IF_{min})}{(IF_{max} - IF_{min})} \right] \cdot 100$$

Where IF_0 is the landslide index of the considered class;
IF_{max} is the maximum landslide index value of all classes for a given parameter
IF_{min} is the minimum landslide index value of all classes for a given parameter

Landslide hazard assessment

Susceptibility model



Slope map – Mauritius

For each factors has been elaborate a raster considering the procedure of calibration taking into account the Landslide existing phenomena according to the surveying

The landslide index (Li) was calculate :
Li = (Al/At)
where Al (landslide area) is the area of every parameter class involved on a landslide event (in filed results)
At: (t… …ter class and t…
W = […
Here … class;
"Lima… …of all
"Limi… …f all
the re…

Mauritius - Slope factor weights based on rock fall distribution

Layer class	Slope (from)	Slope (to)	Landslide index	Weight
1	0	8	0,000290801	0
2	8	17	0,004833257	1
3	17	25	0,008354069	2
4	25	33	0,021828967	5
5	33	42	0,041691674	10
6	42	50	0,075549419	19
7	50	58	0,154420054	39
8	58	67	0,239143367	60
9	67	75	0,397951977	100
10	75	83	0,366229761	92

Landslide hazard assessment

3. Methodological description

Geomorphological Factor	Factor Weight (expert attribution)		
	Rock falls	Landslides	Rapid earth flows
Slope	2	1	1
Aspect	0,2	0,2	0,2
Profile curvature	0,2	1	1
Planar curvature	0,2	1	1
Drainage pattern	0,4	1	1,4
Vegetation	1	1	1
Lithology	1	0,8	0,8
Soil	1	1	1
Rainfall	0,2	0,2	0,2

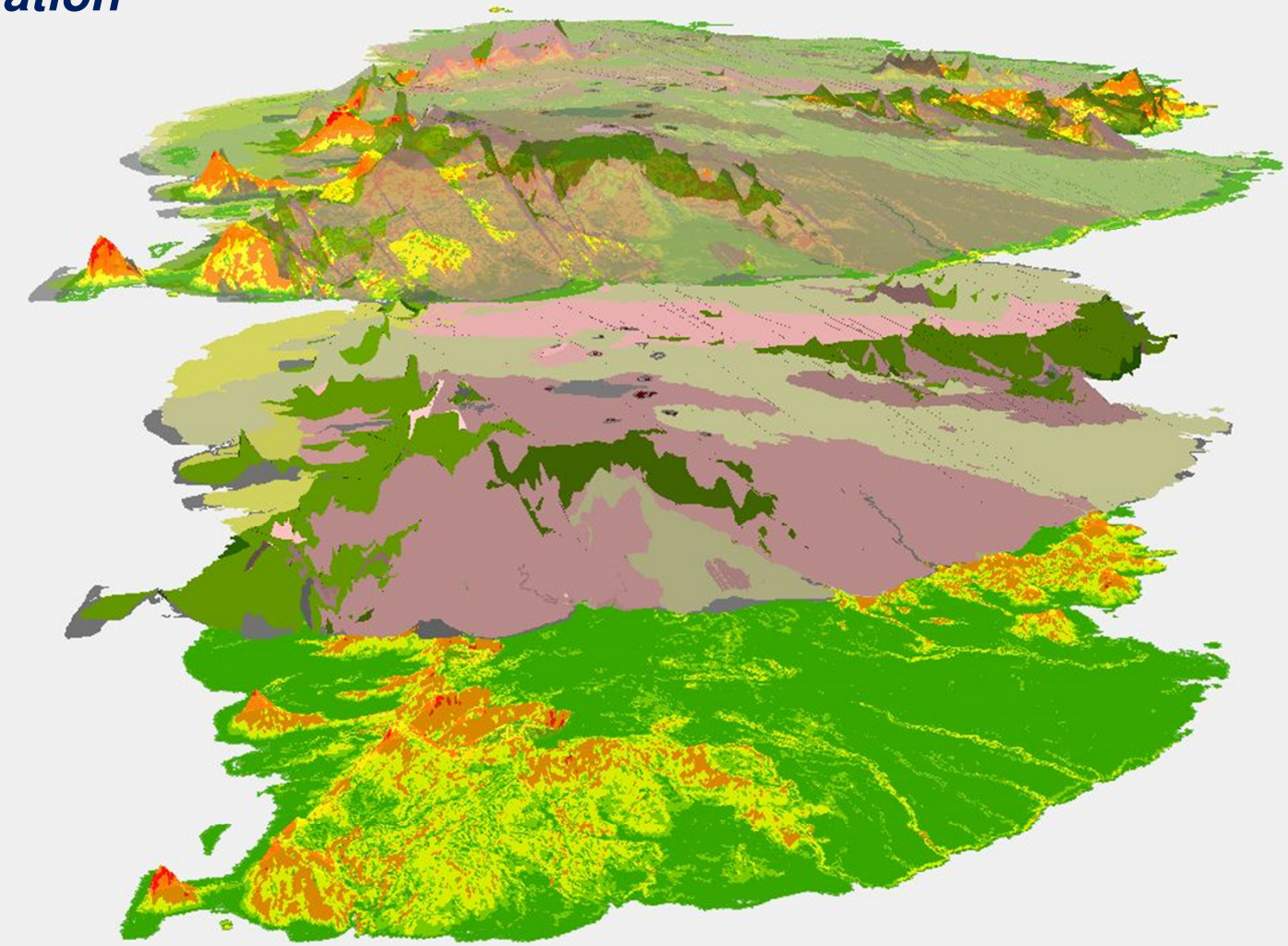
3. Susceptibility model

Factors and related weight (expert weight) used in the susceptibility model for each type of landslide:

- **Rock falls,**
- **Landslides**
- **Rapid earth flows**

Landslide hazard assessment

GIS elaboration

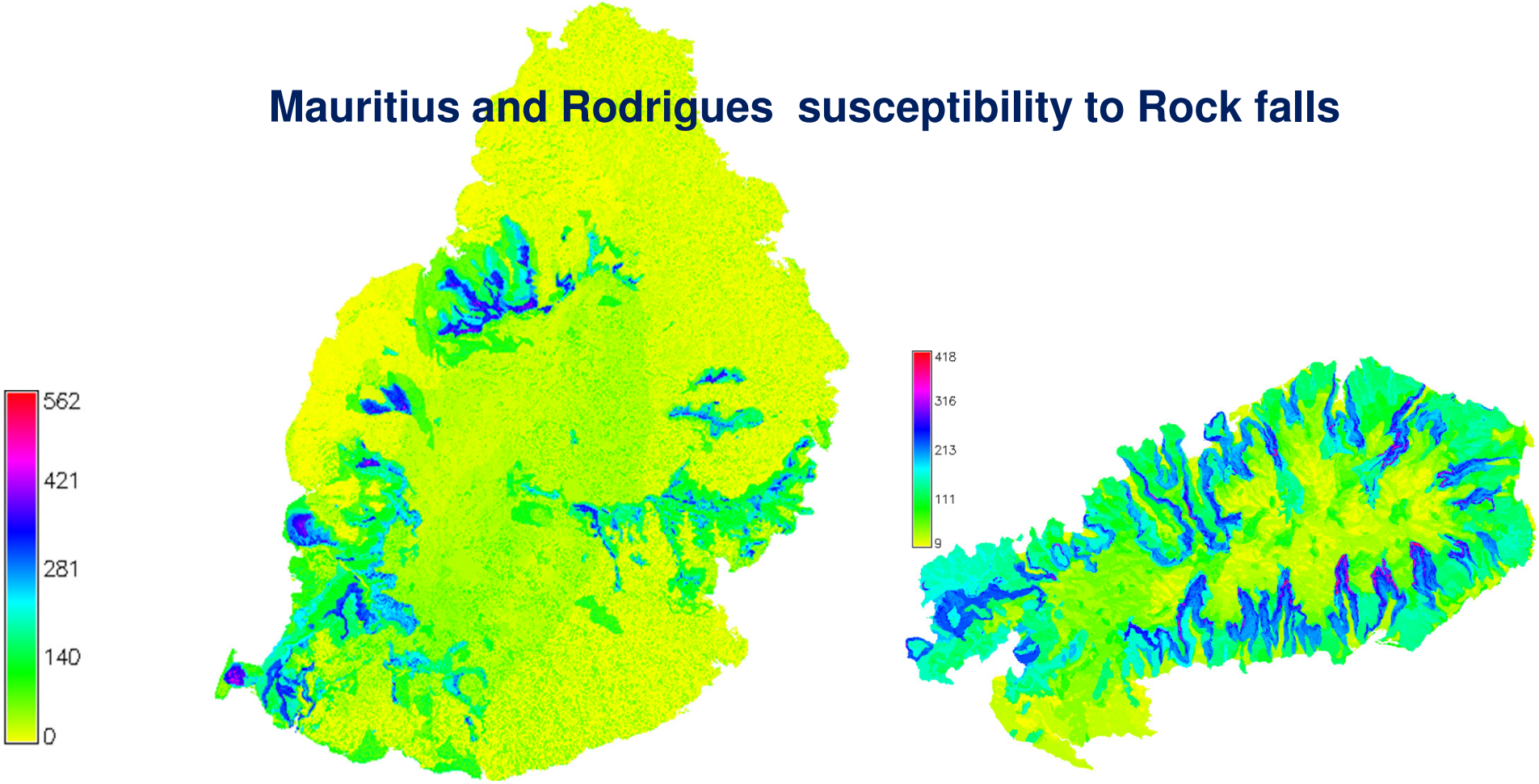


GIS application to overlay the different descriptor considering the expert weight to generate the susceptibility

Landslide hazard assessment

This process is applied to every factor and as then next step in the procedure all weighted factors are summed together to obtain the final susceptibility map concerning each landslide type (rock-fall, landslide and earth flow)

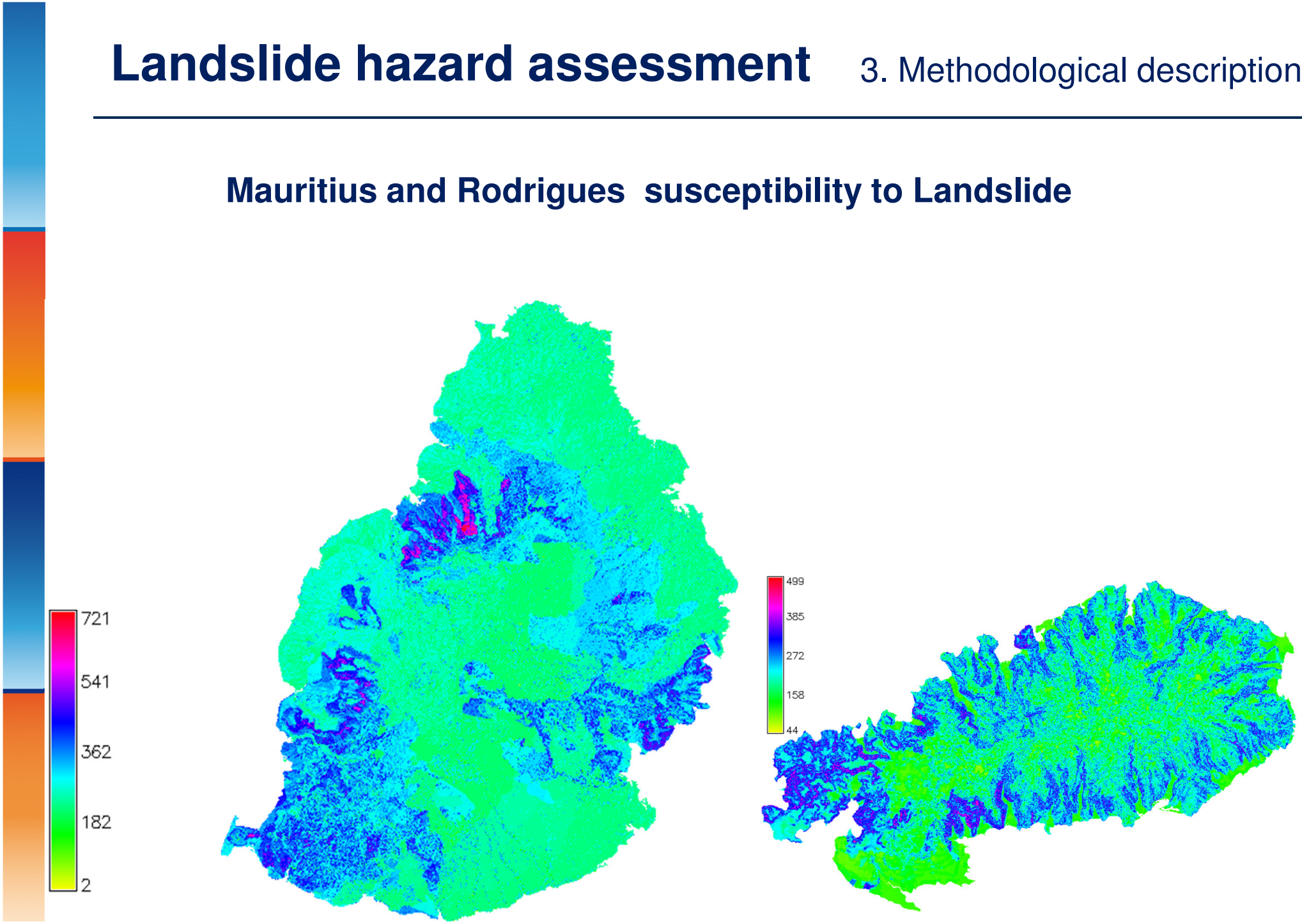
Mauritius and Rodrigues susceptibility to Rock falls



Landslide hazard assessment

3. Methodological description

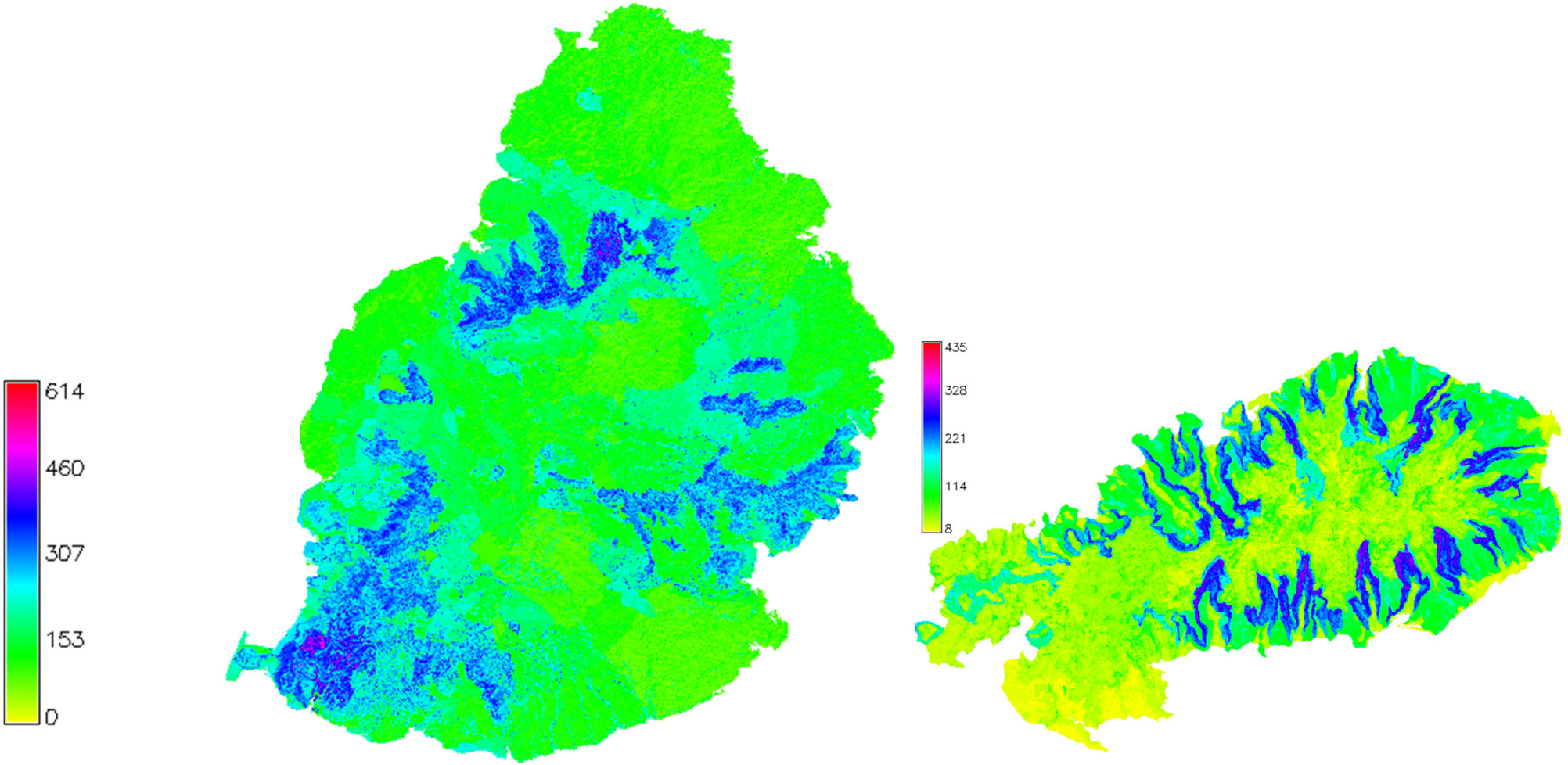
Mauritius and Rodrigues susceptibility to Landslide



Landslide hazard assessment

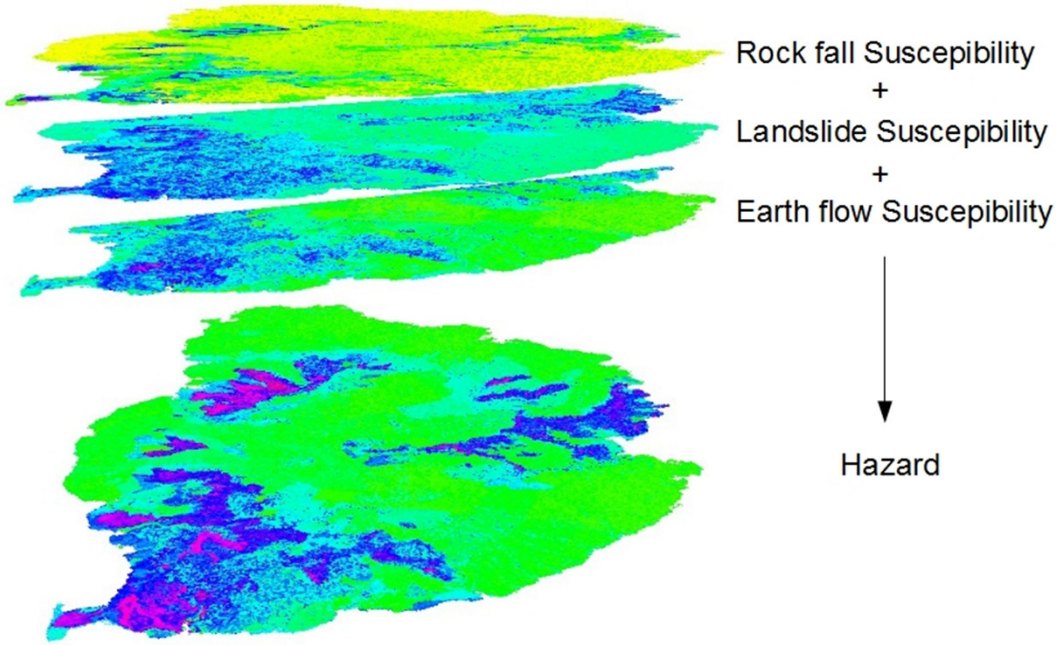
3. Methodological description

Mauritius and Rodrigues susceptibility to Earth Flow



Landslide hazard assessment

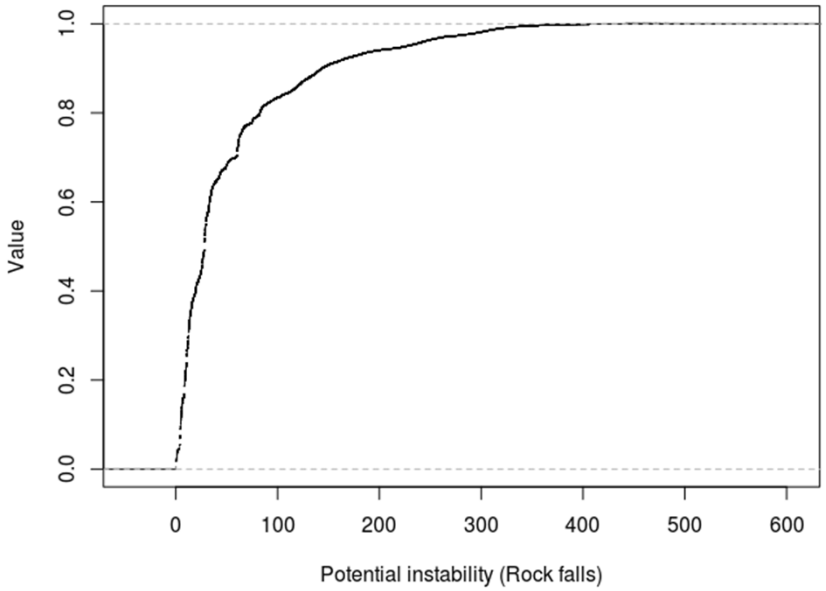
Elaboration of the landslide hazard as sum of the different three susceptibility (rock fall, classic landslide, earth flow)



Landslide hazard as result of the overlaying of the susceptibility map

Landslide hazard assessment

The cumulative distribution function is used to choose the values ranges that fall into four classes, this reclassification is performed with the aim to represent the map on a more readable way.

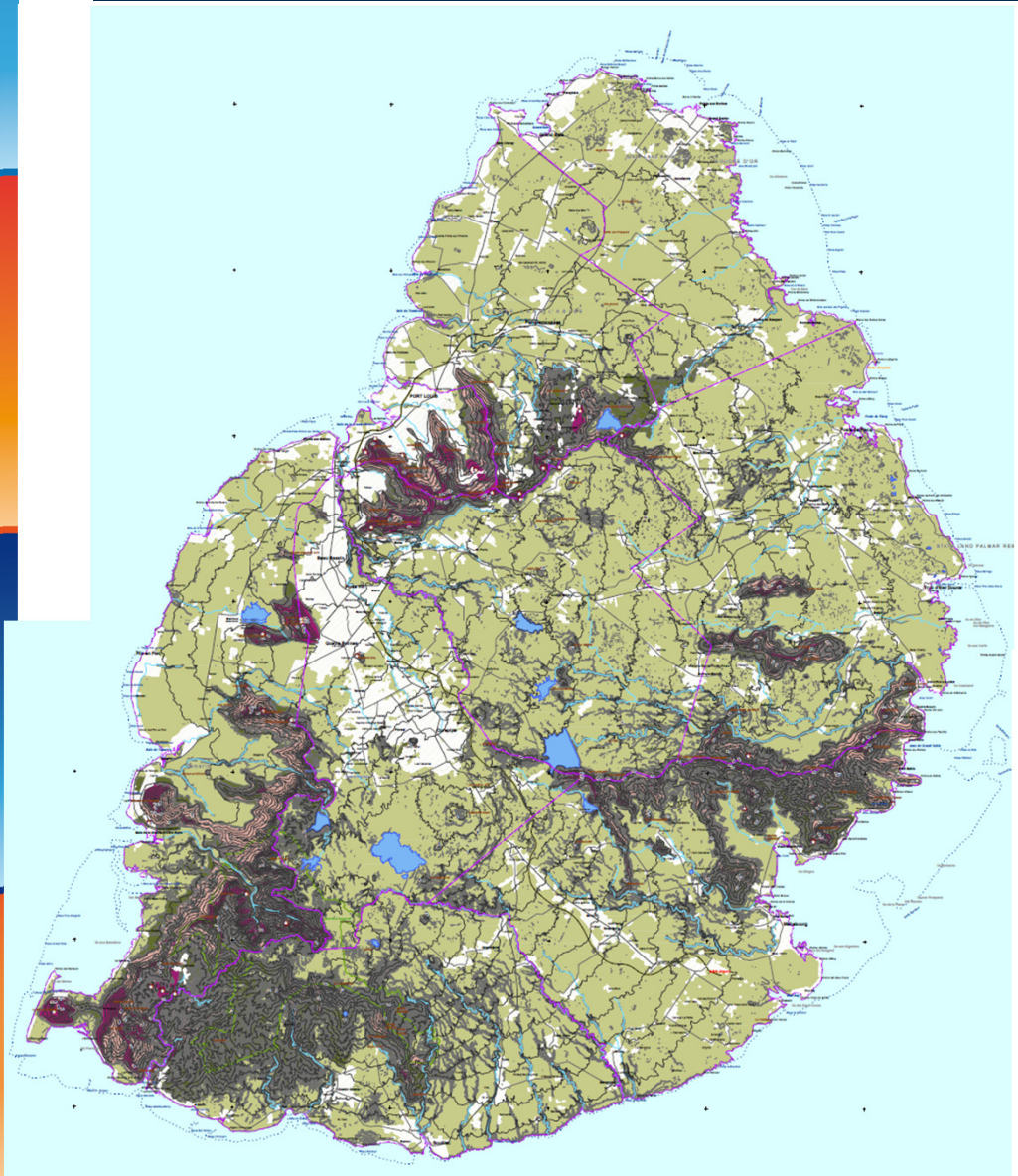


Graph of the cumulative distribution function of the susceptibility values

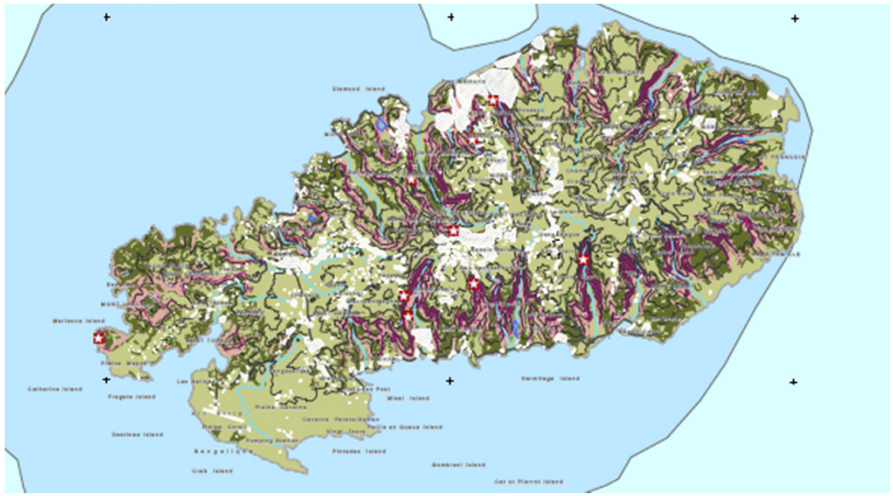
Class	Value
1	*Low*
2	*Medium*
3	*High*
4	*Very high*

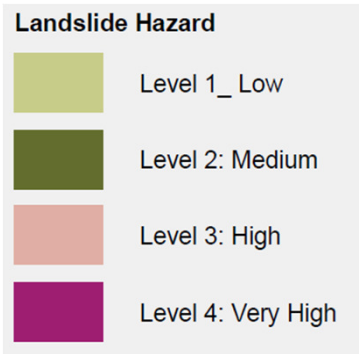
Landslide hazard assessment

3. Methodological description



HAZARD MAPS





Thank you for your attention