

# Mapping erosion on Saba

*How to keep the Unspoiled Queen from  
tumbling down*



**BSc thesis by Pim Arendsen**

**August 2017**

**Soil Physics and  
Land Management**



**WAGENINGEN UNIVERSITY**  
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*How to keep the Unspoiled Queen from tumbling down*

Bachelor thesis Soil Physics and Land Management Group  
submitted in partial fulfilment of the degree of Bachelor of  
Science in International Land and Water Management at  
Wageningen University, the Netherlands

**Study program:**

BSc International Land and Water Management

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11/08/2017

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## 1. Introduction

Soil erosion has large contribution to land degradation worldwide and can also result in a loss of marine biodiversity (Rahman *et al.*, 2009). Soil erosion is the detachment, transport and deposition of soil particles. This can be caused by processes and forces like rain, wind, runoff, gravity, tillage, land levelling and crop harvesting (Boardman & Poesen, 2006). To reduce degradation, erosion risk mapping and identifying erosion areas can provide valuable information on sustainable soil management (Martín-Fernández & Martínez-Núñez, 2011; Rahman *et al.*, 2009).

Erosion risk assessment or erosion hazard analysis, which expresses the risk of soil erosion in areas, precedes the implementation of soil conservation measures. It describes the natural tendency of erosion to happen based on variables like rainfall erosivity, soil erodibility and vegetation. It is not a survey of the actual erosion (Stocking *et al.*, 1988). Erosion mapping can be a start for environmental policies regarding soil erosion and conservation (Moussa *et al.*, 2002; Rahman *et al.*, 2009). By combining erosion risk and trends of erosion areas it is possible to determine conservation priorities (Zhang *et al.*, 2010).

Different models to assess erosion risk have been developed. The most widely approved are the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) (Rahman *et al.*, 2009). Most models are, however, only applicable for specific areas. Thus, the use of these models in different regions is limited since they are only validated for a specific region (Nigel & Rughooputh, 2010).

Due to the limitations of this research adapting a current model to local conditions is not possible. Therefore, an existing guideline provided by the FAO is used. This guideline consists of a weighted analysis to produce several erosion maps resulting in an erosion risk map. It also provides guidelines on descriptive mapping of on-site erosion processes and trends. The guidelines are originally conceived and tested in the Mediterranean region. However, as said in the guidelines itself, it can be used in different areas in the world with adaptations if necessary. These adaptations are based on assumptions and local advice and are not tested or validated for this specific region.

Erosion on the BES islands is likely to increase in the coming years. Managing local resilience should be a priority on coping with erosion (Debrot & Bugter, 2010). Part of the BES islands is Saba, on which erosion is an increasing problem (Saba Conservation Foundation, 2016).

In this report; it is discussed where on Saba erosion risk reduction should receive highest priority. This is based on an erosion hazard map and a map with the current erosion processes. First, background information on Saba is given, which is followed by the methodology of the research. Then the resulting erosion maps are presented. In the discussion the representability and the validity of the results are discussed. After which a conclusion on erosion reduction priority is given.

## 2. Study area

### 2.1. Geography

Saba is an island in the north-eastern Caribbean and has a surface of 13 km<sup>2</sup>. It is also known as the 'Unspoiled Queen'. Currently four villages are found on the island: The Bottom (the capital of Saba), Windward side, St. John's and Hell's Gate. The island is a dormant volcano, the peak of which is called Mt. Scenery. At 877 m, this is also the highest point of the Netherlands. (J.A.C. van der Lely *et al.*, 2014). The peak is surrounded by smaller hills like Troy Hill, Mary's Point and Old Booby Hill (figure 1). The slopes of the different peaks are steep, sometimes reaching over 60°. The steep sided valleys or ravines running down Mt. Scenery are locally called 'guts' (Freitas *et al.*, 2016; J.A.C. van der Lely *et al.*, 2014).

The coastline of Saba also consists of steep slopes, almost perpendicular. The coast has some narrow pebble beaches, a beach at Well's Bay and two artificial beaches, but consists mostly of cliffs. The Saba Marine Park (SMP) is surrounding the island. This marine park aims to protect the marine environment while allowing sustainable use of resources. The Saba Conservation Foundation (SCF) manages the SMP and Saba National Land Park (J.A.C. van der Lely *et al.*, 2014).



Figure 1. Map of Saba (made by Paul Illsley)



## 2.2. Climate

The climate on Saba is tropical, annual average rainfall is 760.5 mm at 30 m up to 2000 mm at higher elevations (Freitas *et al.*, 2016). Average temperature is about 25.7 °C but this is highly dependent on the location on the island. At higher altitudes temperatures are lower than near sea level.

Saba is located in the hurricane belt. The hurricane season officially starts from June 1 up to November 30. On average every 4 or 5 years hurricane-like conditions are experienced and every year a hurricane passes within 160 km (Freitas *et al.*, 2016; J.A.C. van der Lely *et al.*, 2014).

## 2.3. Flora and vegetation

Three different vegetation zones are found on Saba: around Mt. Scenery, high hilltops to the lower slopes, meadows and cliffs (SCF, 2010).

Mt. Scenery is surrounded by dense vegetation of a variety of species and has a well-developed tropical rainforest. The Elfin forest covers a part of this zone in which the mountain mahogany is the most dominant. Epiphytes grow on trunks, branches and leaves and can easily absorb water (SCF, 2010).

Just below the top mountain, at the high hilltops, palms and tree ferns species are abundant. It also consists of elephant ears and wild plantain trees. Lower down the vegetation density decreases and the vegetation mostly consists of trees and shrubs (SCF, 2010).

The meadows and cliffs form the last zone. Scattered shrubs and grass are mainly found on the meadows. The cliffs are mostly barren, consisting of rubble and rock. The steep sheer cliffs prevent the growth of mangrove swamps (SCF, 2010).

Freitas (2016) adds another vegetation zone: cultivated areas. In the 18<sup>th</sup> century land was cultivated, due to steep slopes suitable land was scarce. Hurricanes have also influenced the agricultural sector. Around 2500 people worked in the agricultural sector in 1911. When Sabans left the island and abandoned arable land in the 20<sup>th</sup> century, the sector declined (J.A.C. van der Lely *et al.*, 2014). Former agricultural plots can still be found and are recognizable by old terraces. Current agriculture is mainly limited to small plots of banana trees and home gardens. The local government is starting an agricultural project at Hell's Gate, which is going to produce different types of vegetables.

### 3. Background

Erosion is a permanent issue on Saba. The landscape is characterized by its slopes which are the main cause for erosion. Flat areas are limited to the airport and some villages (figure 5). The guts from Mt. Scenery only discharge water after heavy rainfall (Freitas *et al.*, 2016). The erosion damages infrastructure, like the road to Well's Bay. Rocks are falling down from the side slopes on to the road (Saba Conservation Foundation, 2016). Hiking trails are also affected; the North Coast trail is currently inaccessible because it is too dangerous to hike. Furthermore, vegetation is being washed away near the Crispeen trail, Tara's ground and the Spring Bay area (Saba Conservation Foundation, 2016). The loss of vegetation makes the areas less attractive and enhances erosion.

At Well's bay eroded material ends up at the beach. Stones fall on daily basis, which makes the beach unsafe and requires repeated clean-up. This is also seen at a recently created beach near the airport. Material keeps washing down which needs to be removed (Saba Conservation Foundation, 2016).

The bare soils on the slopes of some hill sides also contribute to the erosion. Free roaming goats are a common sight on Saba and vegetation is affected by the goats (Freitas *et al.*, 2016; Saba Conservation Foundation, 2016). The largest densities and impacts seem to be in the more vulnerable coastal areas, with poor soil conditions and more open and shrubby vegetation. The goats prevent regrowth of vegetation and woodland recovery and enhance erosion (Freitas *et al.*, 2016).

Tourism is one of the largest economic sectors on Saba. Damage to nature, beaches, infrastructure and trails are –therefore- a threat to the local economy (Debrot & Bugter, 2010; Saba Conservation Foundation, 2016). Furthermore, climate change is likely to enhance erosion on the island (Debrot & Bugter, 2010). Therefore, it is necessary to reduce erosion on Saba, and to set conservation priorities for erosion reduction.

## 4. Methodology

The guidelines provided by the FAO, 1997 are used to make an erosion hazard map of Saba. The guideline is adjusted for this research. It uses an erosion hazard map based on available data and a descriptive map of the current erosion processes to locate erosion prone areas.

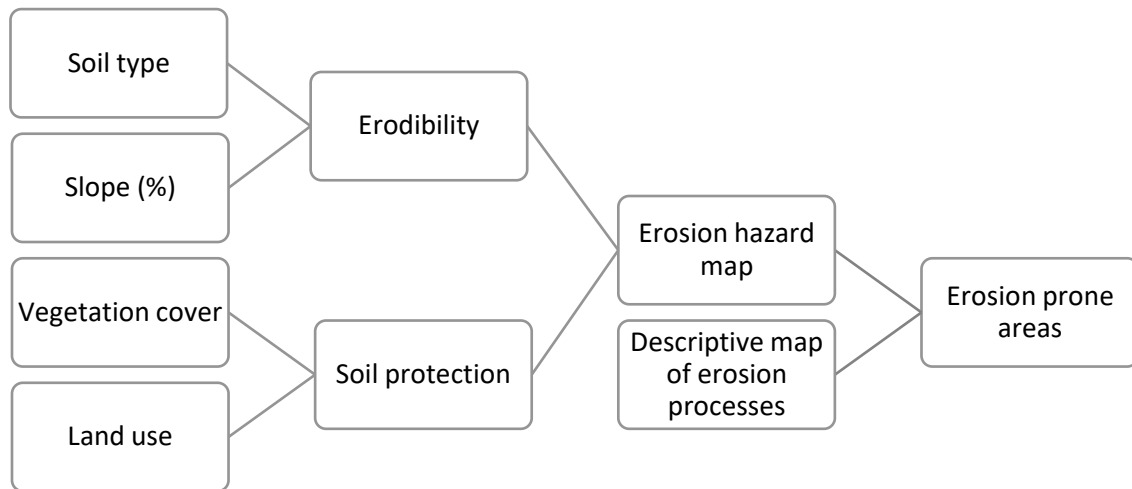


Figure 2. Map making process. The soil types and the slope are combined to an erodibility map, the vegetation cover and land use are combined to a soil protection map. The erodibility and the soil protection are combined to an erosion hazard map. A descriptive map of the current erosion processes is combined with the erosion hazard map, which results in erosion prone areas.

The soil type and the slope are combined to an erodibility map, in which erodibility is defined as ‘the resistance of the soil to both detachment and transport’ (Morgan, 2005). High erodibility implies lower resistance and thus more erosion. The vegetation cover and land use are combined to a soil protection map. Next, the erodibility and the soil protection map are combined to the erosion hazard map. All maps are reclassified to different classes which are combined using different matrixes (FAO *et al.*, 1997). The matrixes are adapted to local circumstances based on own observations and local knowledge.

### 4.1. Erodibility map

The erodibility map consists of the soil types and the slope (in %). The soil map is derived from the Dutch Caribbean Biodiversity Database (DCBC) and is provided by Koomen *et al.*, 2012. To perform spatial analysis in a GIS environment, the available input data are reclassified with the reclassification tool according to their erosion characteristics. Four main soil types are distinguished: clay loam, sandy loam, stony loam and stone. Each different type is assigned a value or class using the reclassify tool. The different values can be combined with the matrices. Clay loam is reclassified to the class 1, sandy loam is reclassified to class 2, stony loam to class 3 and stone to class 4 (table 1). This differs from the FAO guidelines and is based on soil characteristics. The slope is derived from the Digital Elevation Model (DEM) available at [www.sabagis.org](http://www.sabagis.org), the DEM is clipped with the coastline and the slope percentage values are reclassified (table 1): 0-3% to class 1, 3-12% to class 2, 12-20% to class 3, 20-35% to class 4 and >35% to class 5 (FAO *et al.*, 1997). The different classes are combined using the matrix in table 2.



Table 1. Reclassification of slope and soil classes

Slope classes		Soil classes	
Classes	Type of slope	Classes	Soil type
1	0 - 3%	1	Clay loam
2	3 – 12%	2	Sandy loam
3	12 – 20%	3	Stony loam
4	20 – 35%	4	Stone
5	>35%		

Table 2. Soil erodibility matrix

Erodibility classes					Level of erodibility	
Slope class	Soil types				Class	Potential erosion
	1	2	3	4		
1	1	1	1	2	1	Low
2	1	1	2	3	2	Moderate
3	2	2	3	4	3	Medium
4	3	3	4	5	4	High
5	4	4	5	5	5	Extreme

#### 4.2. Soil protection map

The soil protection map is a combination of the vegetation cover and the land use map. Different classes on vegetation cover and land use are provided by the FAO *et al.*, 1997. The vegetation cover is divided into four classes: <25% equals class 1, 25-50% equals class 2, 50-75% equals class 3 and > 75% equals 4 (table 3). The classification of Saba is based on the semi-detailed landscape vegetation map provided by the DCBD. The vegetation types are reclassified in the different vegetation cover classes, grounded on vegetation characteristics and local observations. The classes were confirmed by the local park ranger. The difference in the Philendron-Inga mountain class (table 3) is based on the difference in location, observation and local advice from the park ranger. Urbanized areas and airport are reclassified as class 4 to give a better representation of these areas in the final erosion hazard map.

The land use map is produced by using the land cover map (Smith *et al.*, 2013). The different land covers are assigned six different classes provided by the FAO but adapted to local circumstances (table 4). Next, the vegetation cover and land use map are combined using the matrix presented in table 5, to create the soil protection map. The matrix is adapted to local circumstances.

Table 3. Vegetation cover reclassification

Vegetation type	Coverage (%)	Class
Aristida cliffs	< 25%	1
Bothriochloa mountains		
Coccoloba-Inga mountains	25 – 50%	2
Swietenia mountains	50 – 75%	3
Philendron-Inga mountains (Mm2)		
Coccoloba-Wiedelia mountains		
Cyathea-Charianthus mountains	> 75%	4
Philendron-Marcgravia mountains		
Philendron-Inga mountains (Mg3)		

Philendron-Inga mountains (Mmg7)		
Urbanized areas and airport		

Table 4. Land cover reclassification

Land cover	Land use	Class
Informal housing	Infrastructure	1
Road and rail networks and associated land		
Airport		
Forest dry broadleaved evergreen	Forest (evergreen)	2
Forest broadleaved evergreen		
Forest deciduous seasonal	Forest (seasonal)	3
Thorn scrub	Shrubs	4
Invasive coralita		
Invasive elephant grass		
Pastures	Sparse shrubs	5
Herbaceous rangeland		
Mine, dump and construction sites	Bare rock	6
Rubble		
Bare rock		

Table 5. Soil protection matrix

Land use	Vegetation cover				Soil protection	
	1	2	3	4	Class	Level
1	1	1	1	1	1	Very high
2	3	2	1	1	2	High
3	4	3	2	1	3	Medium
4	5	4	3	2	4	Low
5	5	4	3	2	5	Very low
6	5	5	4	3		

### 4.3. Erosion hazard map

Combining the soil protection and the erodibility map results in the erosion hazard map. The matrix presented in table 6 is used to combine the maps (FAO *et al.*, 1997).

Table 6. Erosion hazard matrix

Erosion hazard matrix						Erosion status	
Level of soil protection	Level of erodibility					Class	Level
	1	2	3	4	5		
1	1	1	1	2	2	1	Very low
2	1	1	2	3	4	2	Low
3	1	2	3	4	4	3	Appreciable
4	2	3	3	5	5	4	High
5	2	3	4	5	5	5	Very high

#### 4.4. Descriptive erosion map

To locate and identify the different erosion processes the legend provided by the FAO *et al.*, 1997 is used. The legend is shown in appendix A. Both field observations and photo-interpretations are used to describe the erosion processes. To collect field observation data the Collector app of ArcGIS was used (figure 3). A digital survey is used to offline store the different erosion types, which are later synchronized to ArcMap. After the identification, the grade of erosion risk, the trend and evolutive trend is described.

Erosion process identification consists several steps and are found in the guidelines by the FAO (1997).

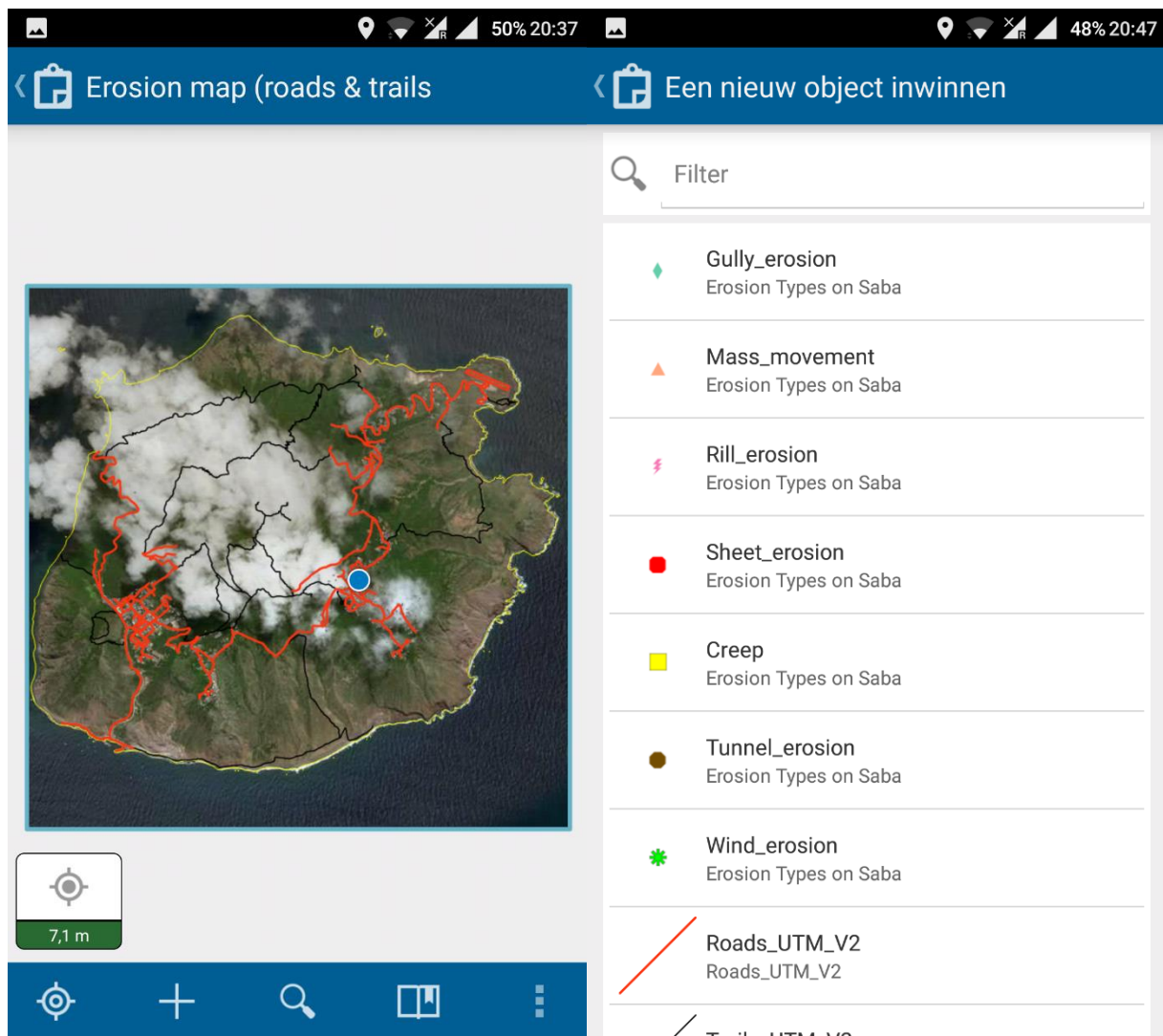


Figure 3. Collector app to store field observations

#### 4.5. Erosion prone areas

The descriptive map and the erosion hazard map are used to locate erosion prone areas. Using the different codes of the stable and unstable areas (appendix A) it is possible to describe the different areas. For example, a stable area can be described as: 032g = a stable managed area with high erosion risk mainly due to geologic factors. An instable area can be described as: (3) C11 = instable area with level 3 erosion status affected by a local gully with a trend of local expansion or intensification.

## 5. Results

### 5.1. Erodibility map

The soil map (figure 4) shows the distribution of the different soil types on Saba. Sandy loam, class 2, is the most common soil type. Clay loam (class 1) can be found on higher altitudes surrounding the peak of Mt. Scenery. It is enclosed by stony loam (class 3). Soils consisting of stones (class 4) are found in smaller individual areas.

The slope map (figure 5) shows that Saba mainly consist of slopes. The flat areas, class 1, covers only 3% of the total area. The less steep areas are mostly urbanized areas. The Bottom, Windwardside, the Level and the airport are the main flat areas.

Combining both maps using the matrix (table 2) results in the erodibility map (figure 6). Most of the map shows high or extreme erodibility (87%). High erodibility has low resistance to the detachment or transport of particles. The largest area with extreme erodibility is the north-western part of the island, the areas near Troy Hill and Mary's Point. Also, the slopes of Great Hill in the south-western part and the slopes of Booby Hill are areas with extreme erodibility. Areas with low to moderate erodibility are the urbanized areas and some of the summits. However, due to the coarse representation of the soil map the erodibility map only shows a rough representation of the areas. The slope map has a high resolution, every pixel on the map has a different value. The soil map only consists of four different types of values. This results in broad scaled areas, with local detailed areas.

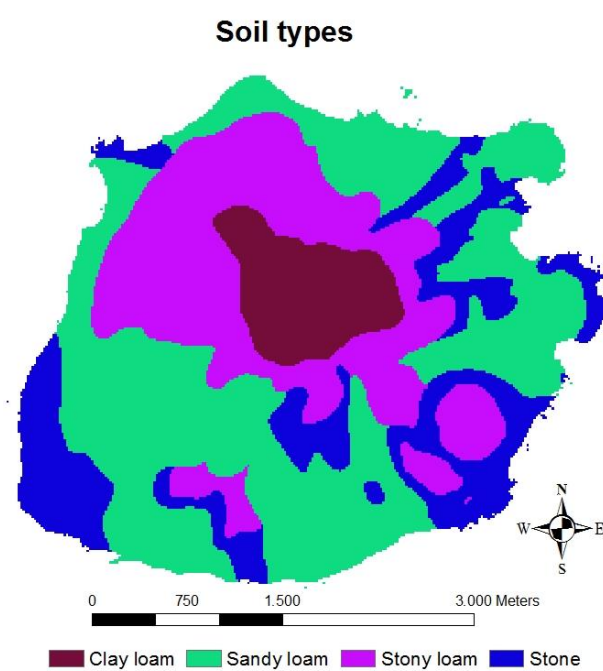


Figure 4. Soil types

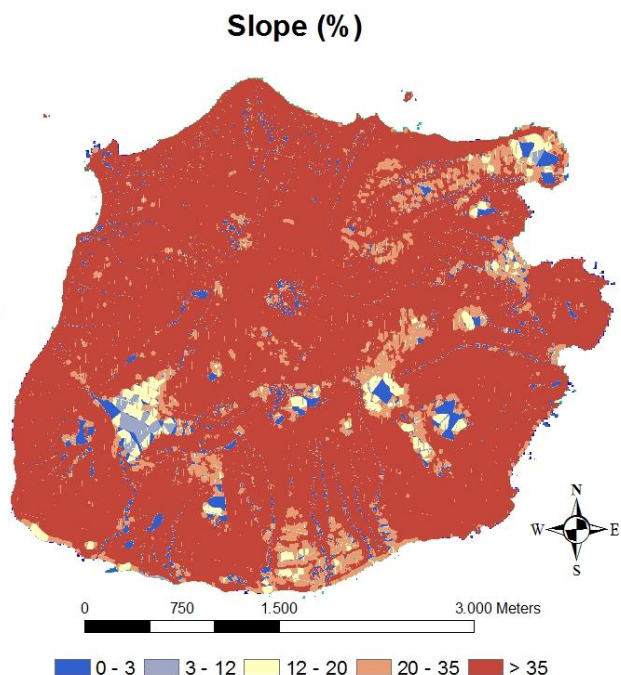


Figure 5. Slope

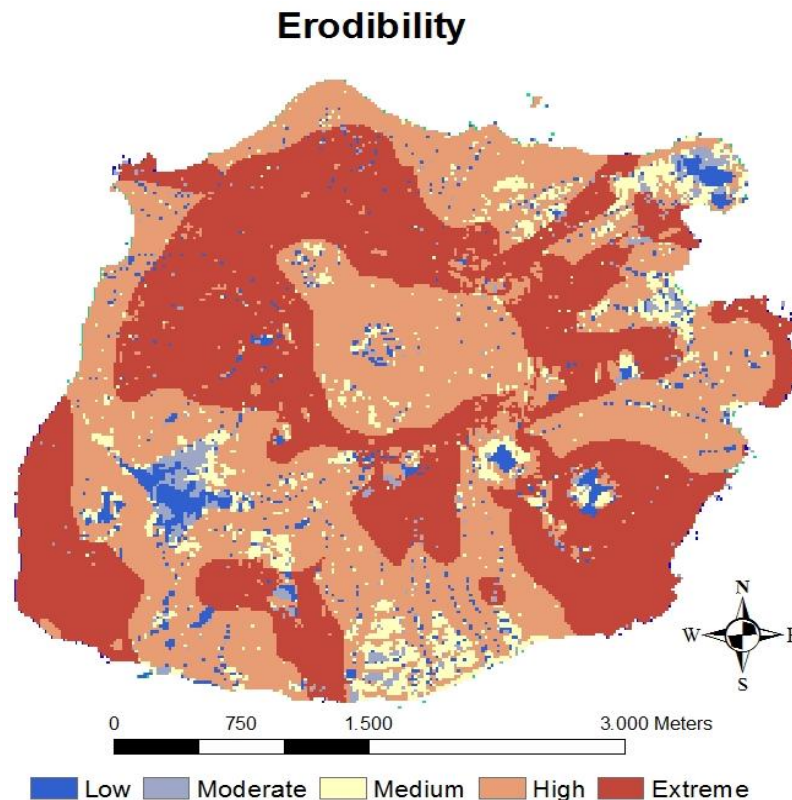


Figure 6. Erodibility

## 5.2. Soil

## protection

The vegetation cover map (figure 7) shows the different classes in vegetation cover. From the summit of Mt. Scenery; the rainforest almost fully covers the soil. Vegetation cover over 75% (class 4) stretches to the northwest of the island after which it changes into class 3. The urbanized areas are considered as fully covered (class 4) areas. This is done because of the better representation of the urbanized areas in the vegetation map compared to the land use map. The coastal zones are mainly consisting of low vegetation cover (class 1). The vegetation cover increases with the altitude.

The land use map gives an overview of the eight different land uses on Saba. Six of the eight classes are used in the matrix. The class 'sea' and 'NoData' are not directly used. The 'sea' only represents a few small areas near the coastline. Unfortunately, there is a large 'NoData' gap in the bottom left corner of the map. It is assumed that this area consists of (sparse) shrubs. These classes use the same matrix grade (table 5).

Combining the vegetation cover and the land use map using the matrix in table 5 results in the soil protection map (figure 9). Local observations show that the 'NoData' area consists of shrubs and sparse shrubs. Using these values in combination with the vegetation cover provides a soil protection area. This results in a less detailed area. The coastal zones show a (very) low soil protection status, with the increase of altitude the vegetation increases and the soil protection status becomes high to very high.



**Vegetation cover**

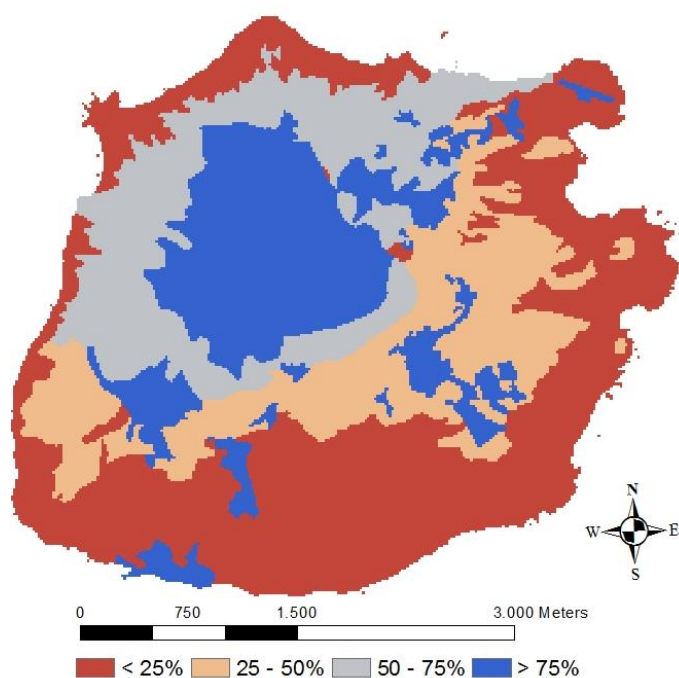


Figure 7. Vegetation cover

**Land use**

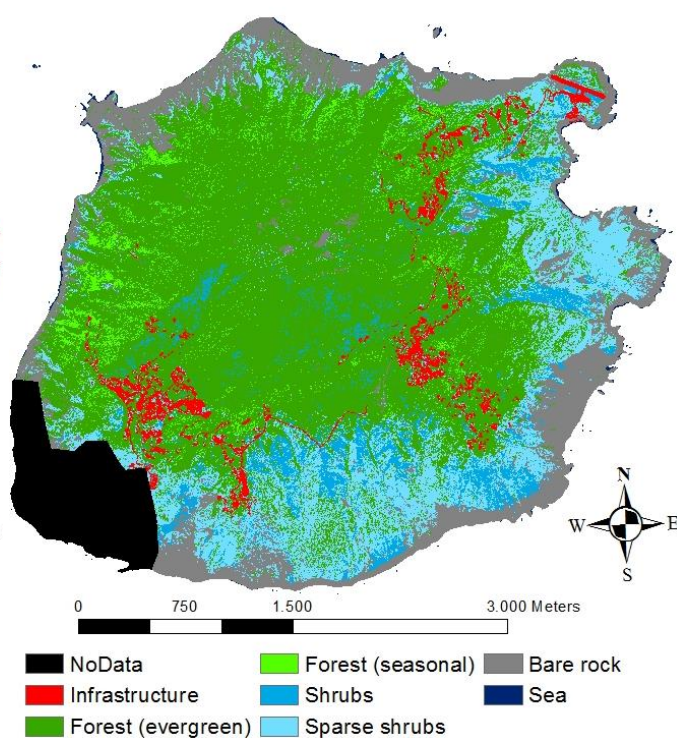


Figure 8. Land use

**Soil protection**

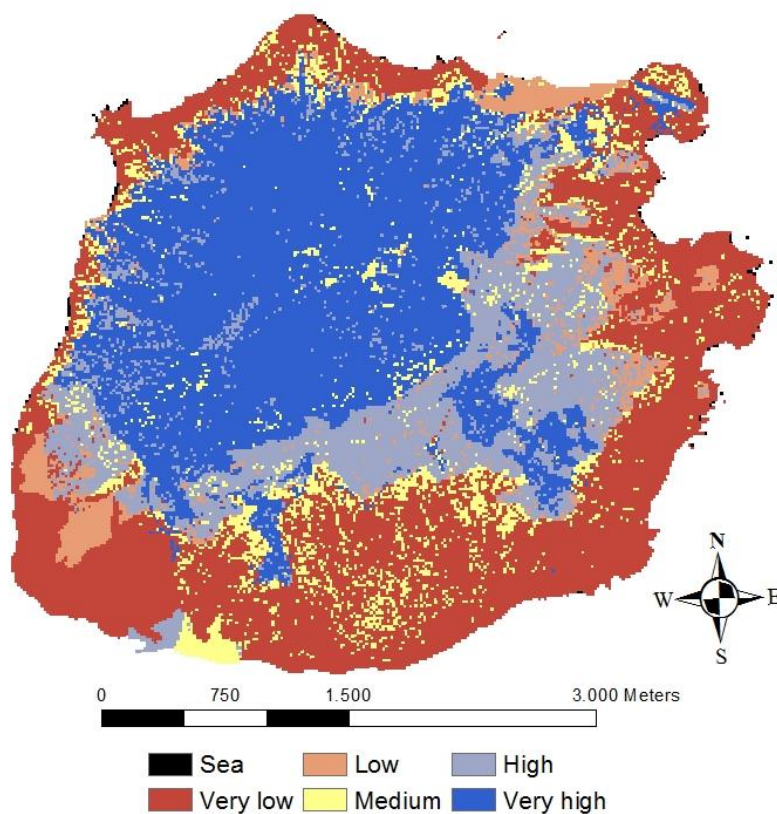


Figure 9. Soil protection



### 5.3. Erosion hazard map

Combining the erodibility (figure 6) and the soil protection map (figure 9) by using the matrix presented in table 6 results in the erosion hazard map (figure 10). A 'very high' erosion status characterizes the coastal areas. High risk is mostly found on the southeast side of the island. The 'very low' risk areas are largely the urbanized areas and the peaks of the domes. The 'low' risk status covers a large middle part of the island.

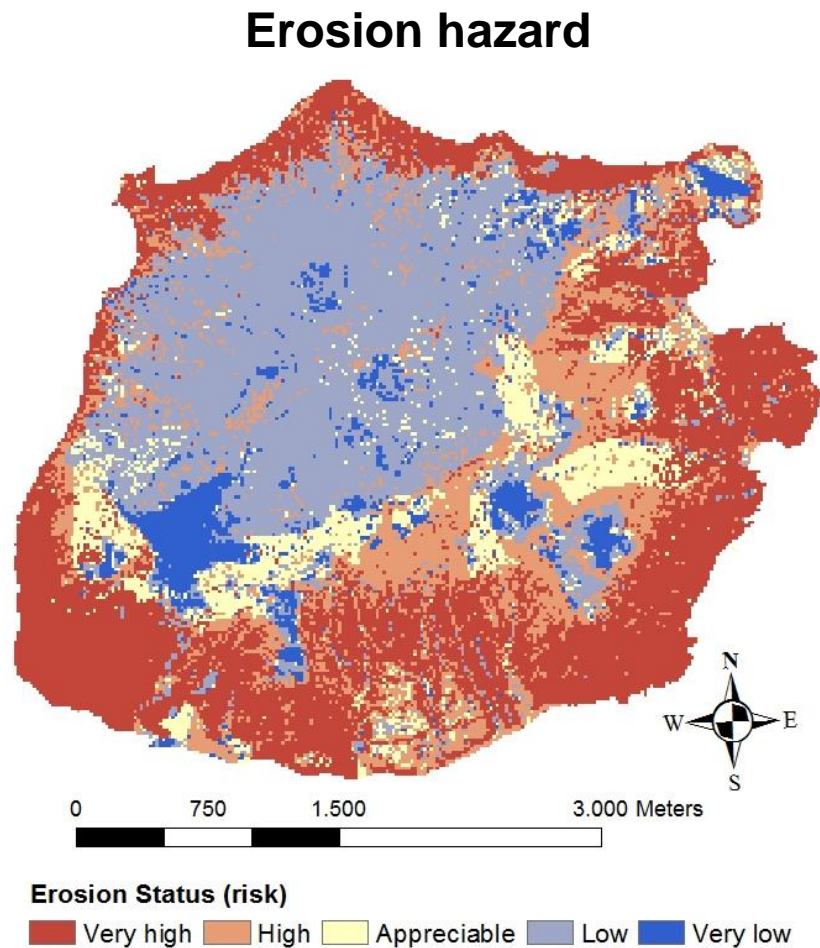


Figure 10. Erosion hazard map

#### 5.4. Descriptive map

The map presented in figure 11 shows the different erosion processes and landscape related areas. It will be referred to as the descriptive map. The watersheds are added to emphasize the gullies and to show that more gullies are found in the coastal zones. The trails and roads are added for orientation. In appendix B a larger map can be found.

Unfortunately, data collection was only possible near trails and roads. Not all areas have been visited but are either classified by aerial photos, descriptions from park rangers and boat observations. On the boat, it is easy to get an overview of the island and especially the coastal zones. To clearly distinguish the different areas and processes both are combined in the same map. The coast mostly consists of cliffs, where landslides and gullies are erosion processes. Creep erosion is mainly found in the rainforest areas around Mt. Scenery. The soil is almost fully covered but due to the steep slopes signs of creep are clearly visible. Bare tree roots and sloping tree trunks are a common sight. Creep can be seen as a type of mass movement but to make a clear distinction of the different processes it is shown separately. The gullies locally called 'guts' are clearly visible. Most catchment areas are starting from the top of Mt. Scenery.

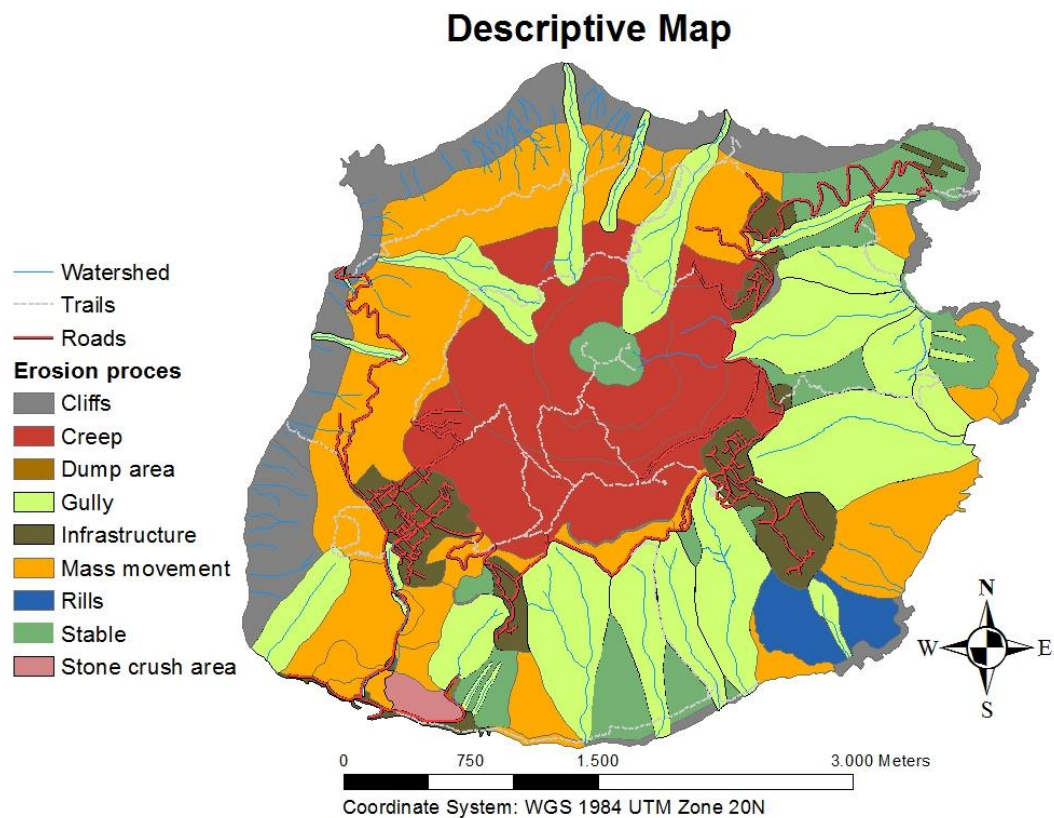


Figure 11. Descriptive map

In Appendix C the attribute table of the erosion hazard map describes the different erosion processes and shows the expansions trends of the different processes by using the codes from the FAO guidelines.

### 5.5. Integration

Combining the erosion hazard map and the descriptive map provides information about the different erosion areas. This also provides different combinations of different codes and erosion risk. Mainly due the high resolution of the erosion hazard map which contains very specific information. Not all combinations are shown as results an only the major areas will be discussed.

#### Stable areas:

The main stable areas are the villages, the airport and the harbour. These areas do not have an erosion code. The most common erosion code is 002t, these are stable, unmanaged areas. Another stable area is the top of Mt. Scenery, the slopes are less steep and the vegetation cover is dense.

#### Unstable areas:

Half of the coast consists of cliff-like structures. These areas are described as unstable areas with a very high erosion risk status affected by different types of mass movement combined with dominant gully networks with a trend to expansion or intensification. Several unstable individual gullies with a high to very high erosion risk and a trend for local expansion or intensification are found. Also larger unstable gully networks combined with mass movement are located on low to high erosion risk status.

On the slopes of Mt. Scenery, a large soil creep affected area is located. This area consists low erosion risk status and mainly affected by local gravitational soil creep with a trend to local expansion. The main cause is the steep slopes surrounding the peak.

Heavy mass movement is found on the northern part of the island. These are areas where mass movement is combined with gully erosion, which tends to expansion and intensification. The erosion risk status is, however, low in this part. The same class is found around Old Booby Hill and near the harbour area, next the Fort Bay road. These areas have a high erosion risk status. Less severe mass movement is located on the east side with a low erosion risk status. Also areas surrounding the harbour are indicating dominant mass movement.

An area with mainly rill erosion is located beneath The Level and Booby Hill. This area has a high erosion risk status show a trend to intensification and a change to mass movement.

## 6. Discussion

The results presented give a first and general perspective on the erosion prone areas on Saba. The erosion hazard map shows that the coastal areas are the most vulnerable areas on Saba, which is also concluded by Debrot (2010). The descriptive map shows an overview of the different erosion processes on the island. Both maps can be used for basic conservation planning.

The erosion hazard map is derived from detailed and less detailed information. The DEM is accurate, but is combined with a general soil map. A more detailed soil map result in a better representation of the erodibility. The same holds for the soil protection map. The land use is detailed but combined with a general map of vegetation cover. Several errors occur due to this rough scale of the original map. Figure 7 shows a vegetation cover of 50 – 75% at the Pirate Cliffs, the area left of the airport. However, the land use map (figure 8) indicates that the same area is mainly bare rock. The latter is confirmed by local observations. For improvement, the vegetation map should be based on the land cover map and divided in different classes. To improve the resolution of the vegetation cover map, a more detailed vegetation map is needed. Preferably a land cover map is needed without any 'NoData' areas. This should result in an improved soil protection map. Improving both the erodibility and soil protection map will result in a more accurate erosion hazard map. The current map shows a 'low' risk status where currently the North Coast trail is inaccessible due to erosion.

Not only current maps could be improved, extra data could also provide more accurate maps. For example rainfall data, accurate rainfall data provides a more detailed erosion hazard map since this is one of the main causes for erosion (Stocking *et al.*, 1988). However, due to huge topographical differences on Saba accurate rainfall data is difficult to obtain.

For further improvements a model for erosion hazard mapping should be used. The current guidelines provided by the FAO were published in 1997. Current models are more advanced; however, these also require more specific data (Rahman *et al.*, 2009). The matrices based on the guidelines are adjusted for local circumstances. This was done using local knowledge from park rangers and could cause errors or irregularities in the erosion hazard map. For example, stone is one of the soil types in the soil map, which is reclassified to class 4. However, the size of stone is not defined – it might mean big boulders or rubble. Bigger boulders would be classified as 1 rather than class 4. Another example is the vegetation cover map. The different classes are based on different types of vegetation. However, the vegetation cover changes in the dry and rainy season. This is not accounted for in the maps.

The descriptive map of erosion processes is not accurate. Broad processes and large areas are provided. Small scale processes, for example local landslides, are not included. Not all areas were visited during the research, most areas are unreachable. These processes are mostly identified by aerial photos and similar conditions seen on reachable areas. Furthermore, in most areas different erosion processes are seen. This is also shown in the table (appendix C), however, the map only shows individual processes. In the used method; more attention should be paid to the erosion trend by making a more detailed description of the process and trends. The erosion trend is important information about erosion processes, especially when a map will be used to plan conservation priorities. In the current layout, the erosion trends are hard put into codes which need to be 'translated' to understand the trend. Improving the focus on the erosion trend with the process will highlight the needed information better.

Once priority areas are chosen conservation measures should be introduced. However, not only hard measures should be used, other solutions should be considered as well. Goats are a major problem

on Saba, they enhance erosion and prevent regrowth of vegetation (Freitas *et al.*, 2016). Solving these indirect problems should be of priority as well.



## 7. Conclusion

The erosion hazard map gives a general overview on the potential erosion risk on Saba. The descriptive erosion map provides a broad overview of the current erosion processes on the island. Combining both maps results in erosion risk areas. The coastal areas have a high erosion status risk. Together with current common landslides and gullies with a trend to expansion or intensification makes them (the coastal areas) a high priority area. However, coastal erosion is difficult to prevent with the ocean continuously bashing on the coastal cliffs. If reducing coastal erosion is a priority, areas near popular dive sites should be given priority.



*Figure 12. Erosion fence at Fort Bay road*

Another area which should receive high priority is near the road to the harbour. This area has a high erosion risk status with dominant mass movement combined with gullies and a trend to intensification. During the research rocks on the road were a continuous problem. The current erosion measure taken is a fence which is supposed to block stones from falling on the road. However, as shown, this erosion measure is about to fail. The concrete foundation of the fence slowly becoming more clear. During rainfall the road becomes a waterway which transports all the sediment down to the harbour and afterwards big stones can be found on the road. Improved erosion measures should stop bigger stones and increase safety on the road.

The erosion hazard map and the descriptive map can be used to plan conservation priorities on a general scale. More detailed information is needed for specific areas. The maps should – therefore – only be used as an indication of the erosion problems on the island and not as a detailed erosion reference. Also, the maps should not be the only basis for conservation planning. Important factors like climate change, overgrazing and the current land use should be considered as well.



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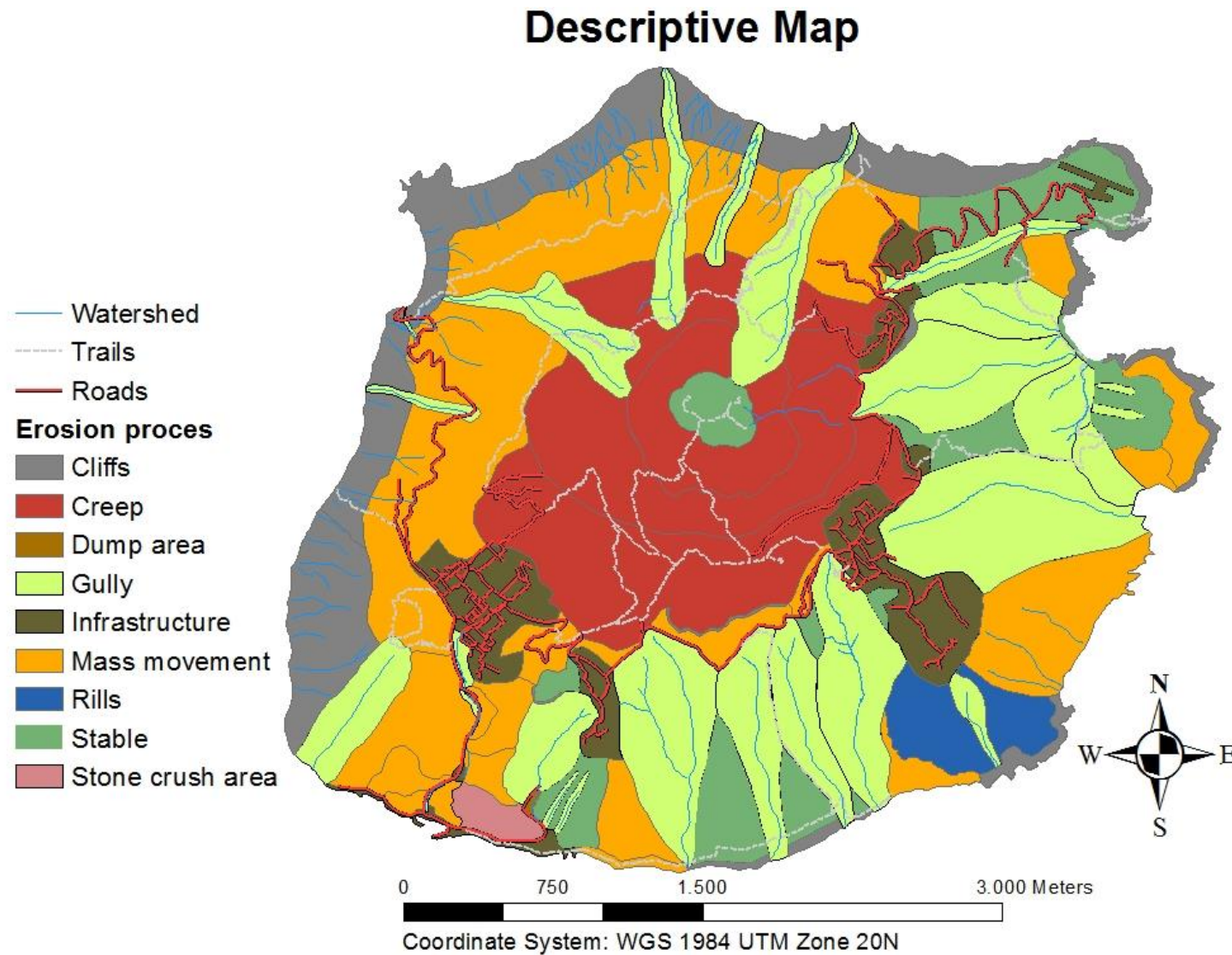
## Appendix A. Site-descriptive erosion legend

I. <b>Stable</b> , non-erosion-affected areas (*)	
00	stable, non-used wasteland (rock outcrops, cliffs, stony or sandy areas)
01	stable, unmanaged areas with potential for forestry use only
02	stable, unmanaged areas with agricultural potential (crops and pasture)
03	stable, managed areas with forestry use only
04	stable, managed areas with agricultural use (crops and pasture)
<ul style="list-style-type: none"> <li>Rehabilitated areas by means of:</li> </ul>	
05	natural or artificial re-vegetation
06	physical infrastructures (terraces, check dams, etc.)
<b>*Grade of instability risk</b>	
Assessment of <b>instability risk</b> for all <b>stable</b> environments (00 to 04) and of risk for <b>rehabilitated</b> environments, i.e. 05+06 (i.e. a risk in the first years of rehabilitation;) to be expressed by a complementary digit (0 to 3) to the original <b>stable unite</b> ' code:	
0: No risk (= highest grade of <b>stability</b> )	
1: Low to moderate	
2: High	
3: Areas in hazardous/precarious/critical state (Stability threshold = highest grade of <b>instability risk</b> )	
<b>Example :</b> 03 = <b>stable</b> managed areas'; 032 = <b>stable</b> managed areas with a high <b>erosion risk</b>	
<b>*Identification of main causative agents</b>	
<b>Instability</b> risk assessment may be reinforced by the identification of its most probable/prevaling <b>causative agents</b> inherent in the <b>landscapes'</b> main basic components, i.e.:	
<b>t:</b> Topography	
<b>g:</b> Geology	
<b>v:</b> Vegetation	
<b>h:</b> Human activities	
<b>a:</b> Animal activities (trampling, terracing, etc.)	

	Extra codes might be freely added according to local specific contexts and situations.
	<b>Example:</b> 023 g = stable managed areas with erosion risk mainly due to geologic factors.
<b>II. Unstable areas (**)</b>	
<b>• <i>Splash erosion</i></b>	
A1	localized (<30% of the area is affected)
A2	dominant (30-60%)
A3	generalized (>60%)
<b>• <i>Sheet erosion</i></b>	
L1	localized
L2	dominant
L3	generalized with soil profile removal
Lx	= unreclaimable areas due to total soil removal
<b>• <i>Rill erosion</i></b>	
D1	localized
D2	dominant
D3	generalized
<b>• <i>Gully erosion</i></b>	
C1	individual gullies
C2	localized gully networks
C3	dominant
C4	generalized
Cx	= unreclaimable areas due to generalized band lands
<b>• <i>Wind erosion</i></b>	
E1	localized loss of topsoil/overblowing/deflection
E2	dominant
E3	generalized
Ex	= unreclaimable areas due to total sand or sediment burying or topsoil removal
<b>• <i>Mass earth movements</i></b>	
M1	local gravitational soil creep/solifluction
M2	localized land slides/mudflows

M3	dominant
M4	generalized
MX	= unreclaimable areas due to total slope slides
• <b>Water or sediment excess</b>	
W1	areas periodically flooded and/or sediment buried
W2	areas permanently flooded and/or sediment buried/waterlogged areas
• <b>Degradation induced by land management</b>	
S1	soil compacting
K1	soil crusting
Z1	cattle trampling/terracing
H1	salinization
• <b>Associated processes</b>	
	See "Note" in pare (**)
<b>Multiple processes</b>	
	P1 P2 P3 etc. (for description of different closely interacting erosion processes)
<b>**Erosion expansion trend (rate)</b>	
	Assessment of erosion rate/trend for all <b>unstable</b> erosion-affected areas to be expressed by a complementary digit (0 to 3) to the original <b>unstable units'</b> code:
	0: Trend to <b>stabilization, recession</b> or limitation of spatial <b>expansion</b>
	1: Trend to local <b>expansion</b> or <b>intensification</b>
	2: Trend to widespread <b>expansion</b> or <b>intensification</b>
	3: Trend to increase <b>generalized degradation</b> towards an <b>irreversible state</b>
	Example:
	L2 = dominant sheet erosion
	L23 = dominant sheet erosion with a trend towards generalization and an irreversible state (Lx type units)
	<b>Note:</b> All multiple or mixed but clearly identifiable erosion processes can be mapped by associating or combining the corresponding codes (the sequence of the codes should be established according to the relative importance of the processes: first code = the most important process):
	Example: L11/C12 = Localized sheet erosion combined with dominant gully networks with a trend to widespread expansion or intensification. Source: FAO <i>et al.</i> , 1997

## Appendix B. Descriptive erosion map



## Appendix C. Table erosion codes

The table contains the ID number of every polygon on the map, the name of the area, the erosion code and the different erosion processes corresponding with the code. The codes are based on the major erosion process in the area. Possible other processes are added in the table but these have less effect on the area.

ID	Name	Code	Erosion process	Erosion process (2)	Erosion process (3)
2	Crispeen Gut	C21/M21/D11	Gully	Mm	Rill
3	Troy's Gut	C11/D11	Gully	Rill	
5	Banana Gut	C11/D12/M21	Gully	Rill	Mm
6	Core Gut	C11/M21/D11	Gully	Mm	Rill
7	Cliffs	M41	Cliffs		
8	Cliffs	M41	Cliffs		
9	Stable	002t	Stable		
10	Stable	002t	Stable		
11	Cliffs	M41	Cliffs		
12	Stable	002t	Stable		
15	Stable	001g	Stable		
16	Windwardside, The Level and Booby Hill	0	Infrastructure		
17	Stable	031v	Stable		
18	Booby Hill gully	C32	Gully		
			Mass movement		
20	Booby Hill (east)	M32/C22	(Mm)	Gully	
21	Booby Hill landslide	3	Mm		
22	Booby Hill cliffs	M42	Cliffs		
23	Parish Hill gully	C11	Gully		
24	Parish Hill cliffs	M43/C32	Cliffs	Gully	
25	St. John;s	0	Infrastructure		
26	The Bottom	0	Infrastructure		
27	Ladder Bay cliffs	M43/C32	Cliffs	Gully	
30	Wells Bay and Cave of Rum Bay cliffs	M43/C32	Cliffs	Gully	
31	Saba Terrestrial Park cliffs	M43	Cliffs		
32	Airport	0	Infrastructure		
33	Cliffs	M10	Cliffs		
35	Cliffs	M41/C31	Cliffs	Gully	
36	Peddle beach	000t	Stable		
37	Cliffs	M43/C21	Cliffs	Gully	
38	Kelbeys Rigde gully	C21/M21	Gully	Mm	
39	Spring Bay gullies and landslides	C22/M21	Gully	Mm	
40	Spring Bay gully	C21/M21	Gully	Mm	
41	Old Booby Hill (side slope)	M3	Mm		
42	Old Booby Hill (side slope)	M41	Mm		
43	Deep Gut	C22/M21	Gully	Mm	
44	Booby Hill	D32	Rills	Sheet	
45	Booby Hill	D32	Rills	Sheet	
46	Harbor	0	Infrastructure		
48	Great Level Gully	C11/M21	Gully	Landslides	
49		M42	Mm	Gully	
50	Parish Hill	M32	Mm		
51	Fort Bay road	C11	Gully		
52	Thai's Hill to Fort Bay road	M32	Mm		



53	Tent Bay road	0	Infrastructure	
54	English Quarter	0	Infrastructure	
55	Upper Hell's Gate	0	Infrastructure	
56	Upper Hell's Gate cliffs	Mx0	Cliffs	
57	Lower Hell's Gate	0	Infrastructure	
58	Old Booby Hill gully	C11	Gully	
59	Old Booby Hill gully	C11	Gully	
60	Solar panels	001h	Stable	
61	Airport area	001h	Stable	
62	Cove Bay beach	000h	Stable	
63	Victory Gut	C22/M21	Gully	Mm
64	Fort Bay bare slopes	M41	Mm	Gully
65	Bunker Hill mass landslides	M42	Mm	Loose stones
66		M42	Mm	
67	Fort Bay road gully	C11	Gully	
68	Thai's Hill cliff	Mx2	Cliffs	
69		C11	Gully	
70		C11	Gully	
73		M32	Mm	
74	Fort Bay road and Bunker Hill	M42/C22	Mm	Landslides
75			Stone Quarry	
76	Sabaletric and workplaces	0	Infrastructure	
77	Thai's Hill and Fort Bay road	M32	Mm	
78	Dump area and recycling area		Dump area	
79	St. John's Flat	002t	Stable	
80	St. John's Flat & Great level	M31	Mm	
82		C21	Gully	
83	Spring Bay Flat	032t	Stable	
84	Mt. Scenery top	031v	Stable	
85	Mary's Point Gully	C22/M21	Gully	Mm
86		M11	Creep	
87		M11	Creep	
88		M12	Creep	
89		M12	Creep	
90		C21/M21	Gully	Mm
91		C11	Gully	
92		M42	Mm	
93	Thai's Hill	001g	Stable	
94	Bottom road	M31	Mm	
95		C11	Gully	
96		M42/C22	Mm	Gully
97		M42/C22	Mm	Gully
98	Kelbey's Ridge	002t	Stable	
99	Old Booby Hill	002t	Stable	
100		001t	Stable	
101		C21/D21	Gully	Rill
102	The Road clifflike	Mx2	Cliffs	
103	The Road, above gullies	M31	Mm	
104	Kelby's Ridge	M41	Mm	
105	Hells Gate	M31	Mm	
106		M21	Creep	
107		M31	Mm	
108		C11	Gully	
109	Crab Rock Gut	C22/M21	Gully	Mm

