COMPONENT 1A - Project 1A4

Integrated Coastal Management - GERSA Project
Hydrology

December 2008

# TECHNICAL REPORT

Coral Reef InitiativeS for the Pacific
Initiatives Corail pour le Pacifique

# Sedimentary contribution of catchments on Efate Island, Vanuatu:

## Instrumentation and modelling

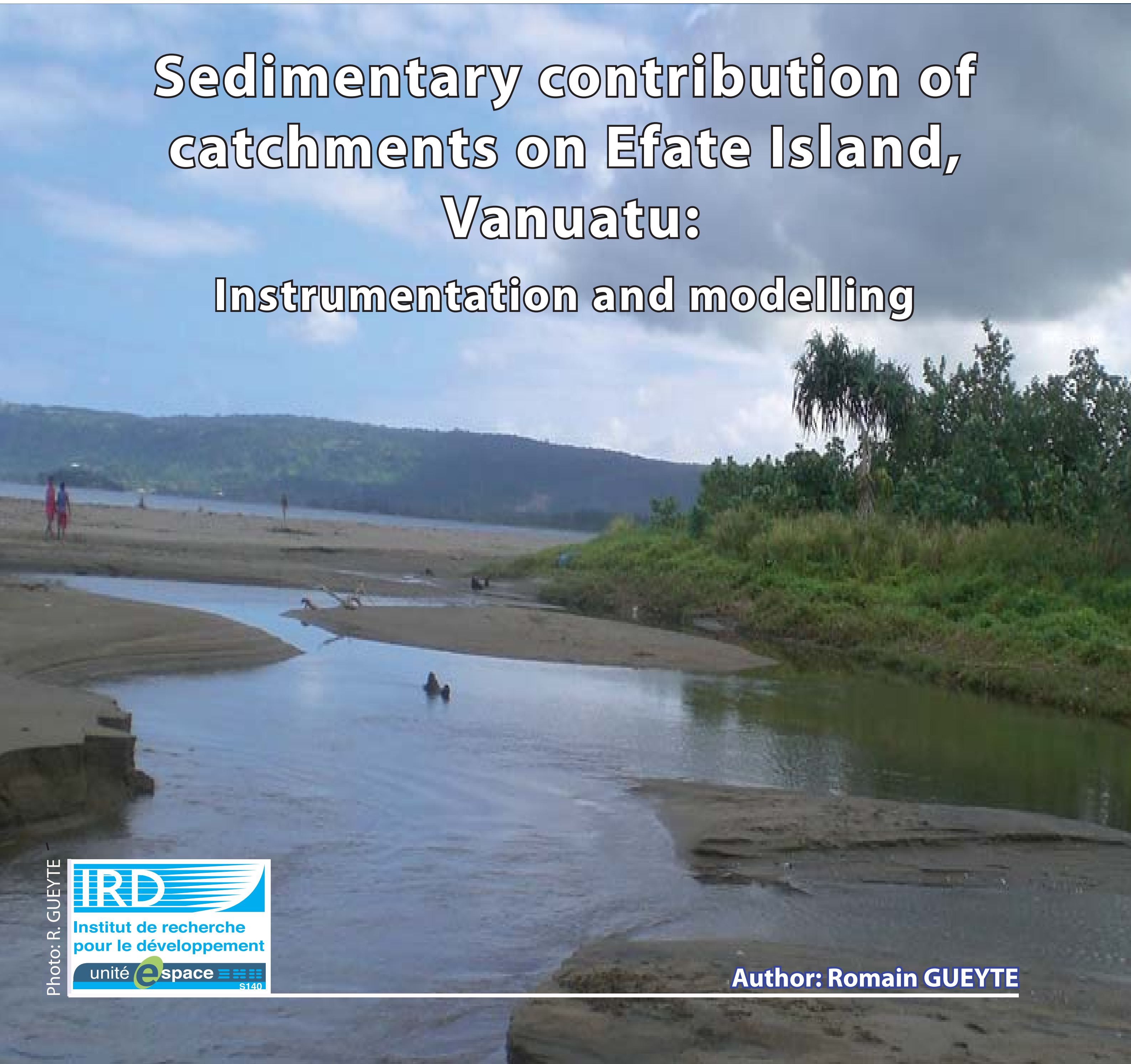


Photo: R. GUEYTE

Institut de recherche pour le développement
unité espace S140

Author: Romain GUEYTE

CRISP

Coral Reef InitiativeS for the Pacific
Initiatives Corail pour le Pacifique

SPREP/PROE

The CRISP programme is implemented as part of the policy developed by the Secretariat of the Pacific Regional Environment Programme for a contribution to conservation and sustainable development of coral reefs in the Pacific.

The Initiative for the Protection and Management of Coral Reefs in the Pacific (CRISP), sponsored by France and prepared by the French Development Agency (AFD) as part of an inter-ministerial project from 2002 onwards, aims to develop a vision for the future of these unique eco-systems and the communities that depend on them and to introduce strategies and projects to conserve their biodiversity, while developing the economic and environmental services that they provide both locally and globally. Also, it is designed as a factor for integration between developed countries (Australia, New Zealand, Japan and USA), French overseas territories and Pacific Island developing countries.

The CRISP Programme comprises three major components, which are:

**Component 1A:** Integrated Coastal Management and Watershed Management
- 1A1: Marine biodiversity conservation planning
- 1A2: Marine Protected Areas (MPAs)
- 1A3: Institutional strengthening and networking
- 1A4: Integrated coastal management

**Component 2:** Development of Coral Ecosystems
- 2A: Knowledge, monitoring and management of coral reef ecosytems
- 2B: Reef rehabilitation
- 2C: Development of active marine substances
- 2D: Development of regional data base (ReefBase Pacific)

**Component 3:** Programme Coordination and Development
- 3A: Capitalisation, value-adding and extension of CRISP activities
- 3B: Coordination, promotion and development of CRISP Programme

CRISP Coordinating Unit (CCU)
Programme Manager: **Eric CLUA**
SPC - PO Box D5
98848 Noumea Cedex
New Caledonia
Tel./Fax: (687) 26 54 71
E-mail: ericc@spc.int
www.crisponline.net

## COMPONENT 1A - PROJECT 1A4 (GERSA)

### Integrated Coastal Reef Zone and Watershed Management

*The purpose of GERSA is to foster the emergence of an integrated cross-cutting approach based on public policy tools and monitoring methodology and local-scale stakeholder dynamics. Ultimately, the goal is to have a scientific foundation and indicators suited to Pacific Island settings so as to set up country sustainable development observatory networks as part of the introduction of MPAs. GERSA is then a cross-cutting project relating also to project 1A2 (MPAs).*

**The project 1A4 is composed of 4 main activities:**

- *ACTIVITY 1: SPATIAL APPROACH*
- *ACTIVITY 2: TERRITORIALITY AND SOCIO-ECONOMIC VALUES*
- *ACTIVITY 3: ENVIRONMENTAL INFORMATION SYSTEMS AND MODELISATION*
- *ACTIVITY 4: DYNAMICS AND MODELISATION OF WATERSHED*

Head of project: **Gilbert DAVID**
Contact: **Jean-Brice HERRENSCHMIDT**
IRD - Unité ESPACE
101, Promenade Roger LARROQUE
BP A5
98848 Noumea Cedex
New Caledonia
Tel./Fax : (687) 26 08 27
E-mail : herren@noumea.ird.nc

Funding:

afd Agence Française de Développement

FFEM

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
FONDS PACIFIQUE

CONSERVATION INTERNATIONAL

## Abstract

Sedimentary processes are complex, they interfere at the geological scale in the relief formation and at the human scale on the land degradation and water quality. These processes are still badly known on the archipelago of Vanuatu, where few data are available concerning the catchments behaviour. In regard to the GERSA project *Integrated Watershed and Coastal Management,* a modelling of the soil loss based on USLE equation was used for Efaté Island, Vanuatu, in order to estimate the zones with high potential of erosion. To validate the model it is necessary to implement on field experiments to get data on the real catchment behaviour. This works includes the three aspects of erosion processes: wrenching, transport and sedimentation. From one hand, transport and sedimentation will be measured and experimental station will be build to monitor wrenching. On the other hand, the model will be used to determine the erosion hazard on the Tagabe catchment.



## Résumé

Les processus d'érosion sont complexes, ils interviennent à l'échelle de temps géologique pour la formation des reliefs et à l'échelle de temps humaine par la dégradation des sols cultivables et de la qualité des eaux. Ces processus sont encore mal connus dans l'archipel du Vanuatu, où peu de données sont disponibles sur le comportement des bassins versants. Dans le cadre de la branche GERSA *Bassin versant et gestion côtière intégrée* du programme CRISP *Initiative Corail pour le Pacifique*, une modélisation de la spatialisation des pertes en sol à été mise en place à partir de l'équation USLE (Universal Soil Loss Equation) pour l'île d'Efaté, Vanuatu, afin de déterminer les zones ayant de fort potentiel érosif. Pour vérifier la justesse de ce modèle et l'affiner, il est nécessaire de mettre en place des expérimentations terrain permettant d'obtenir des données sur le comportement réel des bassins versants. Ce travail prend en compte les trois processus érosifs qui interviennent successivement : arrachement, transport et sédimentation, avec d'une part, des campagnes terrain pour mesurer le transport et la sédimentation ainsi que l'installation de parcelles expérimentales, et, d'autre part, l'utilisation du modèle érosif pour déterminer l'aléa érosion sur le bassin versant de la Tagabe.

**SUMMARY**

1. INTRODUCTION ..... 6

2. CONTEXT ..... 7

2.1. Efate ..... 7

2.2. Objectives ..... 7

3. BIBLIOGRAPHICAL STUDY ..... 8

4. METHODS ..... 10

4.1. Experimental stations ..... 10

*4.1.1. Objectives* ..... 10

*4.1.2. Localization* ..... 10

*4.1.3. Setting* ..... 10

*4.1.3.1. Sites Prospection* ..... 10

*4.1.3.2. Sizing* ..... 10

*4.1.3.3. Constraints* ..... 11

4.2. Sedimentary flow measurements ..... 12

4.3. Sedimentary analysis of Mélé bay ..... 12

*4.3.1. Interest* ..... 12

*4.3.2. Field work* ..... 12

5. TREATMENTS AND RESULTS ..... 12

5.1. Experimental stations ..... 12

*5.1.1. Results* ..... 12

5.2. Sedimentary flow measurements ..... 13

5.2.1. *Analysis protocol* ..... 13

5.2.2. *Results* ..... 13

5.3. Sedimentary analysis of Mélé bay ..... 14

*5.3.1. Analysis protocol* ..... 14

*5.3.2. Results* ..... 14

*5.3.2.1. Grading* ..... 14

*5.3.2.2. Statistical indicators* ..... 14

5.3.2.2.1. Sedimentary facies ..... 14

5.3.2.2.2. Median ..... 15

*5.3.2.3. Interpretation* ... 15

6. TRAINING ... 16

7. MODELLING ... 17

**7.1. Presentation of the empirical model of soil loss USLE** ... 17

**7.2. Application** ... 17

***7.2.1. Interest of use for Vanuatu*** ... 17

***7.2.2. Identification and calculi of the indicators*** ... 17

***7.2.3. Results for Efate and the Tagabe Catchment*** ... 18

8. CONCLUSION ... 19

TABLE OF FIGURES ... 20

TABLE OF TABLES ... 20

BIBLIOGRAPHY ... 21

APPENDIX ... 23

## 1. INTRODUCTION

The Melanesian arc, located in the south West part of the Pacific Ocean, is made of Papua New Guinea, New Caledonia and Vanuatu. These three groups of islands cover around 500 000 km$^2$ for about 6 million inhabitants. They are well known for their cultural and natural diversity, with hundreds of languages still used and very high endemism rates of fauna and flora, but except New Caledonia, it is very hard for them to get integrated into the world economic web.

As shown with the recent acceptance of a part of New Caledonia lagoon at UNESCO world heritage, the protection of these ecosystems becomes a preoccupation for both local and international actors. It is easy understandable that they are everyday more disturbed regarding demography and way of life changes which implicate the rising of deforestation, cultures and fires (Reusing, et al., 2000). Anthropogenic erosion is a resultant of theses pressures that are even more important in developping countries (Bayramin, et al., 2003).

GERSA project aims at developping methodologies and tools to favorise a better management of coastal zone in the Pacifique, by integrating relations between catchment and coastal areas, as well as the implication of local actors in triggering of sustainable management systems, like Protected Marine Areas.

This report of mission is related to the convention CRISP2008/01-IRD established between the Unité Espace of the Institute of Research for Development (IRD) of New Caledonia and the Secretariat of the Pacific Community (SPC) regarding GERSA project. The convention aims at helping local actors in facing resources management problems and participates in the institutional strengthening between actors of Vanuatu and New Caledonia.
It has two specific objectives:

- Improve technical abilities of our partners thanks to the formation of two technicians of the Water Resources Department.
- Acquisition of reliable data to validate the hydrological model.

This report quickly introduces the context of the work before presenting a bibliographical study. Then it details the methodologies and results obtained. It is tackling the training of the technicians. Finally, the last part is about modelling of soil loss using the USLE equations.

## 2. Context

The archipelago of Vanuatu is located in the South-West Pacific, at the North East of New Caledonia. It is made of 83 islands that are covering 900 km from south to north. The total area of Vanuatu is 12195 km². On the 70 inhabited islands, around 215 000 inhabitants are living. According to the HDI[1] indicator, Vanuatu is at the 120th place of development in the world but regarding the HPI[2] indicators calculated by the New Economics Foundation, the archipelago is at the first row. The difference between these two indicators points out how difficult it is to class Vanuatu in pure economical references and contrary, to think that it is a tropical paradise where people keep on living on a traditional way of life. Vanuatu is an insular country in development which must face all the constraints linked to its geographical isolation. When it took its independence, the 30th of July 1980, after 74 years of condominium between England and France, Vanuatu adopted Bislama, French and English, adding three more languages to the 113 already talked in the archipelago.

### 2.1. Efate

Efate Island has a particular position in the archipelago. On one hand the island is located in the geographical centre and, on the other hand, includes the economical and political capital of Vanuatu. Its population is rising very fast because of the growing interest of ni-Vanuatu to find a paid work and quit the traditional model of life.

Efate Island is located between the 17°25'– 17°50' South and 168°9' – 168°35' east and covers a total area of 1014 km² (Appendix 1). The climate of the island belongs to the South-west Pacific equatorial insular regime. It is characterized by two seasons. A cold one from May to October with a low pluviometry and an average temperature of 22.5°C. A hot season from November to April with a high pluviometry and an average temperature of 26°C. The annual temperatures and precipitations are 25.5°C and 2081 mm (Figure 1)

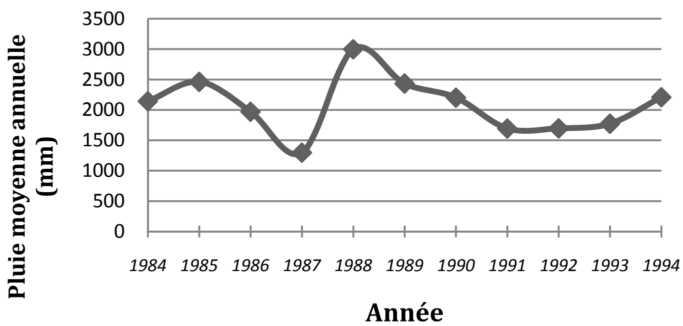



**Figure 1 : Average rain by year for Bauerfield station (Port Vila) from 1984 to 1994**

### 2.2. Objectives

Demographic evolution and soil occupation changes are making erosion and run off problems major issues in environmental development measures. The integrated coastal management is taking into account the whole littoral occupation in order to settle the bases of sustainable development. As a matter of fact it must cover all the fields of activities concentrated on the littoral (environment, urbanism, aquaculture, tourism and transport…). To protect the littoral it is a compulsory to study, upstream, the erosion on catchments (Dumas, 2004). Four key processes must be studied :

- rain with interannual variability,
- run off depending on slope, pedology, soil occupation,
- hydrologic response, with the capacity of hydrologic networks to evacuate water and sediments flux,
- littoral zone, with the impact an lagoon ecosystems.

[1] Human Development Index, http://hdr.undp.org/en/countries
[2] Happy Planet Index, http://www.happyplanetindex.org/map.htm

The work performed is integrated to the convention CRISP2008/01-IRD between the Unité Espace of the Institute of Research for Development (IRD) of New Caledonia, the Secretariat of the Pacific Community (SPC) and the University of New Caledonia (UNC). It is part of the hydrologic modelling on tropical insular catchments used by the Unité Espace.

The following study program was decided:

- Sampling of hydrologic data on three catchments of Efate, Tagabe, Colle and Teouma (Appendix 2).
- Setting up off instrumentation to determine the vegetal cover influence on run off.
- Training of local technicians to monitor the stations.
- Correction of the erosion model on Efate Island.

For the instrumentation and data collect, two missions of one month where performed at Port Vila, in collaboration with the Water Resources Department of the Government of Vanuatu. The first one with my tutor, from August the 13th to September the 10th and the second one, in autonomy, form October the 27th to November the 14th 2008.

## 3. BIBLIOGRAPHICAL STUDY

If the old techniques of defense against erosion were thought on a local scale in order to keep the soil and maintain ground productivity to a sufficient efficiency allowing the rural society subsistence, the anti-erosion means of nowadays must answers challenges of a way larger scale. Urbanization and intensive use of grounds sensible to erosion, which are the response to contemporaneous demography, obligates the modern society to settle lasting techniques which can be easily repeatable. Erosion can be divided in three processes that are taking place successively in the terrigenous transfer from continents to oceans, that is to say wrenching, transport and sedimentation. In insular environment they can occur very quickly, at the scale of a high intensity rain event and encourage destruction of the coral formation downstream. Many different types of erosion can be described and they happened at different time scales. E. Roose gives order of magnitude of soil loss, 0.1 t/ha/yr for geological erosion and 10 to 700 t/ha/yr when man and cattle are rising. According to Guang-hui, the detachment rate of disturbed soil can be from one to 23 times higher than detachment on natural soil with no perturbation (Guang-hui, et al., 2003).

Hydric erosion is the soil degradation process made of wrenching and transport of particles (Owoputi, et al.) by raindrops and superficial stream water on land environment ; detachment and transport by concentrate flow in case of gully erosion (Huang, et al., 1996). Hydric erosion happens when rain waters cannot infiltrate the ground and take out ground particles by streaming on the plot. This soil refusal to absorb exceeding water appears either when rain intensity is higher than surface infiltration capacity or when rain occurs on a surface partially or fully saturated by layer (Le Bissonais, et al., 2002). The main detachment mecanisms are desintegration by bursting, cracking or dispersion and wrenching by raindrop and stream water (Casenave, et al., 1989). Bursting is a result of air pressure traped into dry agregates sudantly moisten ; cracking results of inflation and deflation when moisting-drying cycles ; and dispersion is a consequence of diminution of cohesion strenght between moistened coloïdal particles (Le Bissonais, et al., 1995). Wrenching mecanisms as well as transport processes mainly depend on the kinetic energy of raindrop and stream water. Raindrop impact on soil that leads particles detachment, named splash, is caracterized by raindrop diameter and weight, fall speed, kinetic energy, soil resistance, impact angle and soil permeability. Abrasion capacity of this phenomen has the same order of magnitude than gully erosion (Leguedois, 2003). On short slopes, streaming is diffuse and is coupled with an erosion in layer ; on long slopes, streaming get concentrated and is coupled with linear and gully erosion (Roose, 1994).

Once particles are wrenched from the soil, they can be transported by gravity, wind, ice and water. Water transport is the most frequent in our study. Gravity and wind transports occur more in moutainous and/or desert area. Sedimentary transport combined to streaming, from moutains to ocean, is one of the major composant of hydrosytem dynamic. Two types of flow should be set apart, canalized and savages flows. The quantity of transported elements depends on the fluid caracteristics (velocity and viscosity) and on the elements themeselves (size, shape and density). Water streaming generates an upward strenght, opposite to the particles weight and tend to lift it. This strenght, proportional to current velocity, moves biger particles when the latest is high (Reineck, et al., 1980). Three main means of transport can be detailed, suspension concerning silt and clays, saltation for send and rolling for gravel (Figure 3). Hjulström digram (Figure 2) shows the influence of flow velocity on particles depending on their size. One of the struggles techniques against erosion is to limit the velocity to 25cm.s$^{-1}$.

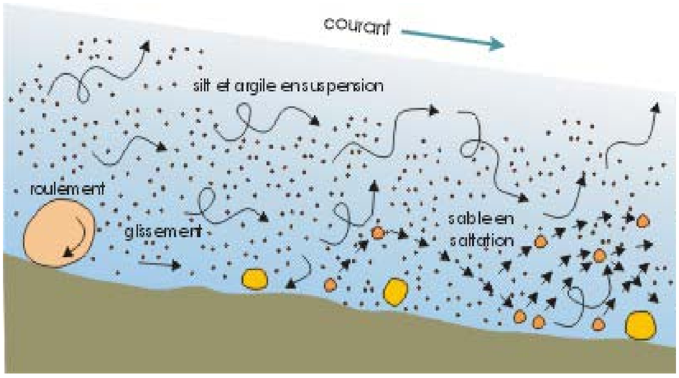



Figure 3 : Particles transports

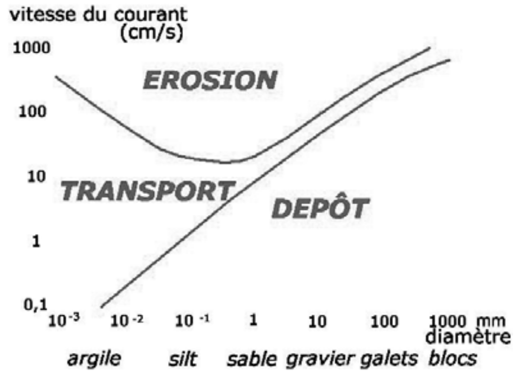



Figure 2 : Hjulström diagram

It is on littoral, at the interface island-ocean, that sedimentation is maximum because the river stream is slowed down when entering into the ocean and cannot assure its carrier work (Figure 2). Detritical and oceanic sediment can be found in this zone (Berthois, 1975). Globally, we have a granulometric and mineralogic variation from the cost to offshore. The proportion of silt and clays is getting higher when going away from the coast. The littoral sedimentary balance is the difference between contribution and loss of sediment, which determine accretion or erosion on the shore (Komar, 1998) (Figure 4).

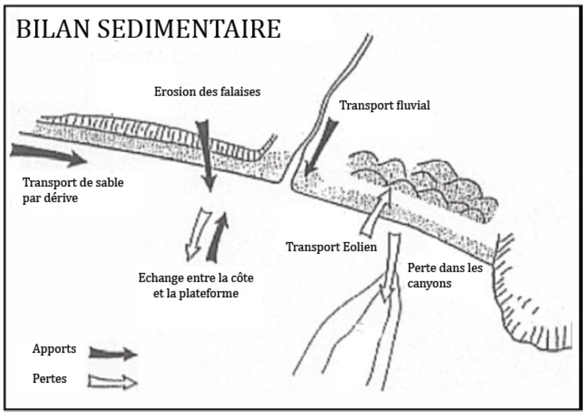



Figure 4 : Sedimentary balance (Komar, 1998).

## 4.1. Experimental stations

### 4.1.1. Objectives

Experimental runoff plots are designed to study hydric erosion of soil. They are usually settled in a row to study influence of vegetation, slope, kinds of soil and cultural techniques on runoff and erosion. Compared to other techniques Hudson (Hudson, 1996) emphasizes the interest of theses plots to estimate the ground loss, to point out the damages and consequences or determine a model of erosion prediction. This kind of experimental facilities allows to study the infiltration dynamic on a few square meters and to extrapolate them on a catchment scale.

When experimental plots have been used a lot in tropical area to estimate erosive abilities of soil (Roose, et al., 1989-90) they are not frequent in the insular South Pacific where few studies were carried out on that topic. The scientific objective of their setting up at Vanuatu is to assure a spatiotemporal monitoring of several hydrologic cycles. Secondly, the plots will give data on the most efficient anti-erosive techniques and be integrated in programs of struggle against erosion. In the same time data from the plots should help us to correct the model of soil loss.

### 4.1.2. Localization

The installation site is on the Tagabé catchment at the 17°42' S and 168°19' E (Appendix 3). It was chosen because of its good representativeness of the alluvial plain of the catchment, its easy access and the presence of the meteorological station of Bauerfield airport at less than one kilometer.

### 4.1.3. Setting

#### 4.1.3.1. Sites Prospection

The manager of the Water Resources Department was interested in building the stations on the Tagabe river catchment because they are triggering of monitoring of that catchment due to its importance concerning water supply of Port Vila. First, the prospection was turned toward two main lands where owners had given the oral authorization to set up the plots. The areas prospected were respectively 150 ha for land A and 60 ha for land B. Regarding these sizes it took us a long to determine sites with the matching covers and slopes. However we found one possible site on area A and two on area B. Finally a government land was chosen, still in the Tagabe catchment but on a different kind of soil (Appendix 4).

#### 4.1.3.2. Sizing

The experimental plots are made of rectangular area of 2 meters by 10 meters isolated from outside, which end up on a drain channel and calibrated tanks of water and sediments storage (Figure 5). A filtration system is used at the entrance of the channel to trap the biggest particles in order to not block the tanks. The tanks were proportionate at $2m^3$ to collect the whole runoff water in case of major rain event where a water layer of 200mm would fall on the $20m^2$ plots, generating $4m^3$ of water. Taking into account infiltration and evapotranspiration, only the half of the water should runoff. In our study case, only the vegetal cover is studied, so the four plots have a similar slope. Four types of vegetation were kept: bear land, grassland, agriculture (manioc, tarot and bananas) and grassland with tree protection. The bear land plot is the international standard of Wischmeier (Wischmeier, et al., 1978).

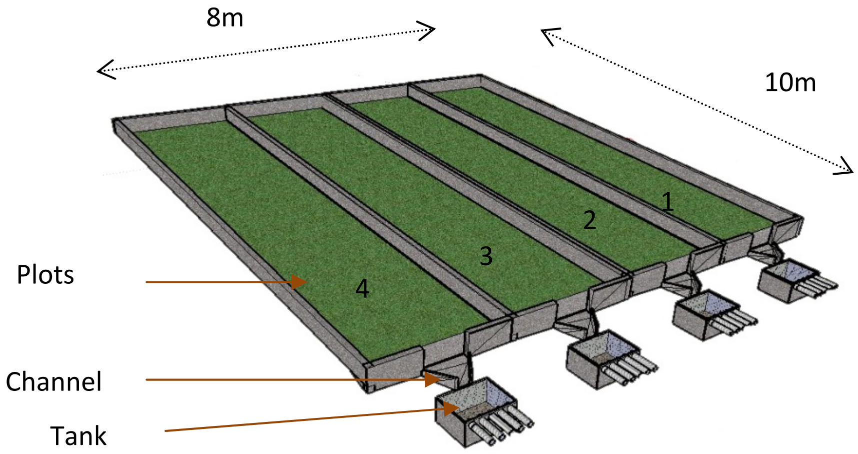



**Figure 5 : Experimental plot scheme.**

*4.1.3.3. Constraints*

The construction was adapted to the necessities of the project, that is to say the financial investment, the time available to build the stations, the building knowledge of each one and the availability of the Department vehicle. We choose to build everything in concrete and blocks (Appendix 6), which needed more time but on one hand, a lower budget compared to fiber glace and iron sheets, and on another hand, it allows us to buy all the material to only one supplier, making easier the payment between IRD Nouméa and Vanuatu.

Three months were needed, from forward planning to the end of building (Table 1). Different administrative and technical problems were at the origin of a loss of time for the achievement of the construction: payment and delivery, misunderstood with the owners of lands, availability of the Water Resources truck and the financial problems of the Ministry of Land of Vanuatu.

**Table 1 : Construction planning.**

| Step | Date |
|---|---|
| Forward planning | 01-15 August |
| Prospection | 15-20 August |
| Material invoice | 20-22 August |
| Material purchase | 25 August |
| Land preparation | 25 Août - 13 September |
| Material delivery | 25 October |
| Building | 25 Octobre - 10 November |

The plots are operational since December the 15th. The final cost of their construction is 210 000 VT, that is to say 1500€ (Appendix 5). The unitary cost of one plot is 375€. The real time of construction, that is to say the number of hours spent on building is 300, which represents 10 days of work of 8 hours for 4 people.

### 4.2. Sedimentary flow measurements

Gauging at river mouths are used to determine the flow of water passing from the catchment to the ocean. Water samplings give data on the quantity of solid material passing into the ocean (Gueyte, 2008). Four rivers were picked out (Appendix 7) for their localization, three of them have output into the North East part of the Mele bay where we study the sediment distribution, the fourth one (Teouma) is the main river of Efate. Gauging were carried out with a gauging reel and water sampling with a sampler. Six campaigns were undergone (Table 2) during the two months.

**Table 2 : Date and place of gauging and sampling.**

| Place | Date |
|---|---|
| Tepoukoa | 04/09/2008 |
| | 30/10/2008 |
| La Colle | 04/08/2008 |
| | 30/10/2008 |
| La Tagabe | 28/10/2008 |
| La Teouma | 31/10/2008 |

### 4.3. Sedimentary analysis of Mélé bay

#### *4.3.1. Interest*

The sediment sampling on the ocean floor of a bay is used to determine the sedimentary dynamic as well as the proportion of bioclastic material and terrigenous material. The composition of ocean floor sediment gives data on the role of erosion and transport of materiel by rivers. In relation with the gauging and sampling, the sedimentary analysis of the North East part of Mele bay was carried out.

#### *4.3.2. Field work*

A sampling grid was made with ArcGis to determine the geographic coordinates of the 65 points. The grid pace was chosen regarding the NE Mele Bay dimensions, 5km long on 1.2km wide. To obtain enough data on the sedimentary distribution, 11 transects separated by 400 meters with a point every 200 meters were performed (Appendix 8). The field work needed two days to a 6 people team. The top ten centimeters of floor sediment are sampled with a Van Veen tub. The sample weight must be around 1 kg. Depths are noted with a depth sounder. Samples are stored in plastic bags away from light at 5°C to avoid destruction of organic material.

## 5. Treatments and results

### 5.1. Experimental stations

The calibration and monitoring is presented in the technical note given to the technicians of the Water Resources Department (Appendix 9).

#### *5.1.1. Results*

The plots startup was plan for September 2008 in order to get the first data in December 2008 but the delay taken during the building prevent us to get data. The first data should be available by the end of January 2009.

### 5.2. Sedimentary flow measurements

#### 5.2.1. *Analysis protocol*

Suspended materials sampled during the field work at the river mouths don't need any chemical treatment. The filters are stored in a drying area for 24 hours then they are weighted. The suspended material weight is the differences of weight of the filter before and after the filtration. A software calibrated with the gauging reel (NIWA TDGauge) is used to determinate the different flows and the river section. The sediment flow is obtained as fallow:

$$Flow_{Sediment} = Flow_{water} * Concentration_{sediment}$$

#### 5.2.2. *Results*

| Place | Date | Flow (m3/s) | Section area (m2) | Maximum depth (m) |
|---|---|---|---|---|
| La Tagabe bridge | 28/10/2008 | 0,49 | 2,57 | 0,470 |
| La Tepukoa bridge | 30/10/2008 | 1,03 | 1,73 | 0,470 |
| | 04/09/08 | 0,80 | 1,58 | 0,38 |
| Tepukoa embouchure | 04/09/08 | 0,66 | 1,26 | 0,340 |
| La Colle bridge | 30/10/2008 | 2,52 | 3,89 | 0,580 |
| | 04/09/08 | 1,97 | 2,72 | 0,650 |
| La Colle Embouchure | 04/09/08 | 1,79 | 3,23 | 0,500 |
| La Teouma bridge | 31/10/2008 | 6,13 | 11,11 | 1,130 |

At the date the report was written, we are still waiting for the sediment sampling results from the Water Resources Department.

### 5.3. Sedimentary analysis of Mélé bay

#### *5.3.1. Analysis protocol*

The preparation of samples is used to destroy organic material, adsorbed ions and all coagulation phenomenon. Samples are not anymore in natural conditions of sedimentation, dispersed elements can sediment on a total different way than the sedimentary whole which they belong to (Berthois, 1975). Grading is performed with a standard sieving with sieves matching the AFNOR regulation. Micrograding of the mineral phase depends on the particles velocity of fall based on Stockes law. This method gives the particles diameter still in solution at the instant t and enables to calculate their mass percentages at the end of the experience. The percentage of organic material is calculated by burning the sample at 500°C and measuring the weight difference (Appendix 10).

#### *5.3.2. Results*

*5.3.2.1. Grading*

Granularity size is usually spread into three categories (Table 3). For each sample treated with grading, one histogram and one cumulative chart are made. They help us knowing the repartition of the granularity size. An example is given in Appendix 11. The respective ratios of Rudites-Arenites-Lutites are used to create the different maps of distribution.

**Table 3 : Size categories**

| Names | Diameters |
|---|---|
| Rudites (gravel) | > 2 mm |
| Arenites (send) | 0,063 mm < ϕ < 2 mm |
| Lutites (sludge) | < 0,063 mm |

*5.3.2.2. Statistical indicators*

5.3.2.2.1. Sedimentary facies

The ternary diagram Rudites-Arenites-Lutites shows the repartition of the samples. The majority of samples are a mix between send and sludge (Figure 6). The map of the distribution of lutites is presented in Appendix 12.

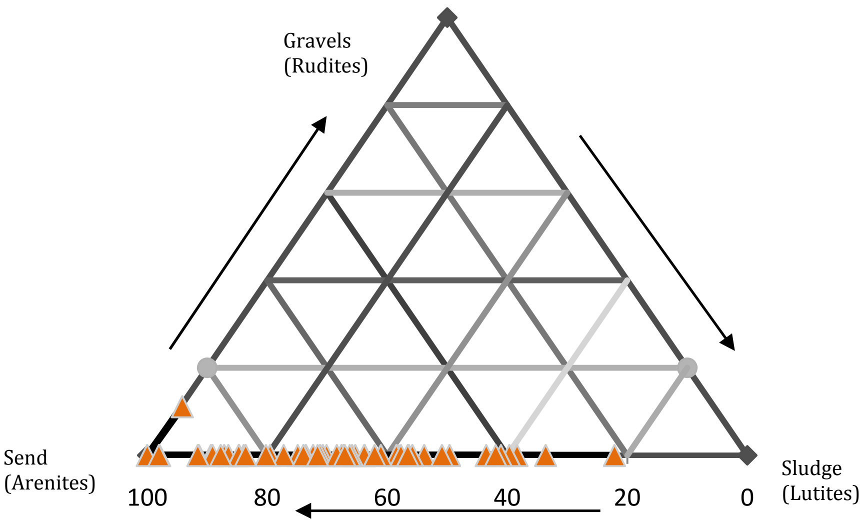



**Figure 6 : Ternary diagram**

5.3.2.2.2. Median

Median corresponds to the 50% granularity on the cumulative chart. It shows the grading distribution of the sediment. Maps of the medians repartition (Appendix 13), as well as an interpolation by natural neighbor (Appendix 14) were created in order to evaluate the sedimentary dynamic on the study area.

*5.3.2.3. Interpretation*

Coastal morphology depends first on water level variations. It groups together beaches, sand dunes and the underwater slope leading to the beaches. Coasts which have a configuration mainly resulting of marine processes and organisms are named secondary (Shepard, 1963). According to Davis and Hayes classification (Davis, et al., 1984) taking into account ties and waves effects on coastal morphology, Vanuatu's one belong to the type "Mixed energy dominated by waves" since the mean range of ties is 1.5 m and the mean height of waves is 1.5m.

With the interpretation of the lutites and median maps we obtain the following sedimentary dynamic (Appendix 14) where there is 3 costal drifts, two east-west (Tepukoa and Tagabe) and one west-east (Colle). The coastal drift of Tagabe River can be explained from the coral reef south-west that is creating a perturbation on the current. We can see that at the center of the study area, the distribution of sediment is uniform, showing the linear strength of current on this part.

## 6. Training

Knowledge transfer has been realized on two different levels, theoretical and practical. First of all, the theoretical sides of runoff, wrenching and sedimentation were introduced to the Water Resources Department technicians. Concerning the experimental plots, the central point of my missions to Port Vila, were discussed the different types of construction, material and sizing of both plots and tanks.

Practical training was more interactive (Figure 7) since it was performed on field in real time. Regarding the sampling of suspended material, the two technicians were trained in a new sampling technique with a sampler they received from SOPAC[3] as part of the WQM *Water Quality Monitoring* Program. The vacuum filtration was presented as well. The two days on field to collect samples in the Mele bay were used to teach the technicians how to use a GPS system, that is to say to follow a route and to transfer data to a computer platform. They also learnt how to use the Van Veen tub for sediment sampling.

The two technicians were trained to be able to do the monitoring of the experimental plots. Reminding that the plots were built in order to increase the partnership with Vanuatu, the agents of the DGWMR have the main role in data collect and analysis. Monitoring includes sediment measures, water volume measuring, tanks and channels cleaning and data collect in the database.

**Figure 7 : Technicians training.**

[3] South Pacific Applied Geosciences Commission.

## 7. MODELLING

### 7.1. Presentation of the empirical model of soil loss USLE

Modelling is based on the Universal Soil Loss equation USLE of Wischmeier and Smith which is an empirical equation resulting from thousands of experiments on plots in the United States between 1960 and 1970. This method is used to get knowledge on the erosion hazard on catchments. According to USLE equation, the annual mean soil loss is determined as follow:

$$A_w = R.K.LS.C.P_w$$

$A_w$ represents the mean annual soil loss and its unit is $t.ha^{-1}yr^{-1}$ .

The different factor of the equation mean:

R : rainfall erosivity factor in $MJ.mm.ha^{-1}h^{-1}$. The soil loss is closely related to rainfall partly through the detaching power of raindrop striking the soil surface and partly through the contribution of rain to runoff (Morgan, 1994).

K : soil erodibility factor in $T.h.MJ^{-1}mm^{-1}$. It represent the soil susceptibility to be desintegrated and taken away (Dumas, 2004)

LS : topographical factor**,** undimensional, function of the slope lenght an field slope.

L : Length factor.

S : Slope steepness factor.

C : Crop management factor.

$P_w$ : Erosion control practice or land management factor.

The value $A_w = 10\ t.ha^{-1}yr^{-1}$ is often admitted as an acceptable maximum. It corresponds to a soil loss of 0.8 mm a year. Conversely the value $A_w = 1\ t.ha^{-1}yr^{-1}$ represents a recommended minimum regarding the available free soil thickness and its renewal accuracy (Dautrebande, et al., 2006).

The soil loss equation is used as a base for the creation of GIS modelling. Modelling is the most efficient way to predict erosion processes by using GIS and sensors (Bayramin, et al., 2003). Modelling work is based on the integration of a digital elevation model (DEM) in a hydrological model of transfer of sediment from catchments to the ocean (Fossey, 2007).

### 7.2. Application

#### *7.2.1. Interest of use for Vanuatu*

Developing countries suffer from a lack of funds to carry out research, monitoring and modelling of origins and consequences of environmental damages (Landa, et al., 1997). USLE model was used because entry data are not to complexes, it is compatible with a GIS, easy to put in place and understandable on the functional side (Wischmeier, et al., 1978).

#### *7.2.2. Identification and calculi of the indicators*

First of all it is necessary to collect all the data needed to calculate the different factors (Table 4). Fossey (Fossey, 2007)performed this work during its missions to Vanuatu (Table 5).

**Table 4 : Equations of the USLE equation factor.**

| Factor | Equation | Unit |
|---|---|---|
| R | $E_c \times I_{30}$ ou $0{,}5 \times P \times 1{,}73$ | $MJ.mm.ha^{-1}h^{-1}$ |
| K | $(28 \times 1{,}14m \times 10 - 8 \times (12 - a)) + (0{,}043 \times (b - 2)) + (0{,}0033 \times (c - 3))$ | en $T.h.MJ^{-1}mm^{-1}$ |
| LS | $\left(\lambda/_{22,1}\right)^m (0{,}065 + 0{,}045s + 0{,}065s^2)$ | No dimension |

$E_c = Rainfall\ kinetic\ energy\ (MJ.ha^{-1})$
$I_{30} = Rainfall\ maximum\ intensity\ during\ 30\ min\ (mm.h^{-1})$
$P = Annual\ mean\ rainfall$
$m = Soil\ texture = (\%fine\ sand + silt) \times (100 - \%clay)$
$a = \%\ Organical\ material$
$b = based\ on\ soil\ structure. From\ 1\ to\ 4, from\ the\ most\ fine$
$c = soil\ permeability. From\ 1\ to\ 6, from\ the\ most\ permeable$
$\lambda = slope\ lenght\ (m).$
$S = Slope\ gradients\ (\%).$

The factor λ and S are calculated from the DEM (Bizuwerk, et al.).

ArcGis software is used to multiply the raster layers corresponding to the different factors of the USLE equation (Appendix 15). We obtain a spatial distribution of the soil loss.

**Table 5 : Available data for Efate Island (Fossey, 2007).**

| Data | Localization | Scale | Owning organism |
|---|---|---|---|
| Rainfall | Efaté | Monthly average | Geology & Mines (Vanuatu) |
| Topography (VANRIS) | Efaté | 20m | |
| Soil map (paper) | Efaté | 1 / 100 000 | Atlas Quantin -IRD |
| Pedology | Efaté | Sampling | IRD |
| Vegetation map (paper) | Efaté | 1 / 250 000 | Atlas Quantin -IRD |
| Soil occupation classification (SPOT 5) | Efaté | 10 m | IRD |

#### *7.2.3. Results for Efate and the Tagabe Catchment*

Results obtained for Efate Island by Fossey (Fossey, 2007) are between 0 and 1720 $t.ha^{-1}yr^{-1}$ with an average of 8 $t.ha^{-1}yr^{-1}$ which represents 0.75 mm of annual soil loss (Appendix 16). The model was applied to the whole island since it aims at being quantitative and repeatable to all the study areas of GERSA program. In order to ripen the model with experimental data it is necessary to reduce it to the catchment scale.

Modelling was then made for the Tagabe catchment for the two seasons (Appendix 17). The difference between dry and wet season is striking, 761 T/ha/semester for the wet season and 377 T/ha/semester for the dry season (Appendix 17). The average soil loss for each cell of the calculi grid (20m x 20m) is 5.85 T/ha/semester for the wet season and 2.98 T/ha/semester or the dry season. For the study area, the soil loss is twice superior for the period November – April than the period May – October.

## 8. Conclusion

One of the objectives of GERSA program is to study soil loss caused by erosion processes in order to get quantitative and qualitative models. It is based on the USLE empirical model that has the advantage to be based on a reduced number of entry variables limiting accumulation of uncertainties. The need to calibrate the model with *in-situ* data led to instrumentation.

The main objective of the study was not to get direct data but was the setting up of an experimental system that will allow, at least, five years of homogenous measures and represents an innovation for Vanuatu regarding applied scientific research. Finalization of the experimental plots represents a direct skills transfer toward the Water Resources Department and gives them a tool to measure soil loss and runoff. This project was carried out in order to put the Water Resources Department in first stage concerning soil loss monitoring on Efate Island.

According to the funds available and the will of local managers, this tool can be repeatable to different scales and especially on different kind of soil which will help us getting runoff data corresponding to the different soil of a catchment.

In order to be helpful, this skills transfer could not be only based on the technical side but needed to come-along with a matching training. Theoretical and practical Knowledge were given to the technicians and one manager of the Water Resources Department of Vanuatu in order to give them the tools to use as better as possible the experimental stations and to be independent in data acquisition and post-treatment.

In the meanwhile, gauging and suspended material sampling triggered off regular campaigns that the technicians will used in order to calibrate the new apparatus they have received inside the WQM program from SOPAC. These data will help us getting better knowledge on the hydrologic answer of studied catchments. The integrated coastal management is completed with the study of the sedimentary dynamic of the bay containing the output of studied catchments. The relationship between river gauging and sedimentary dynamic could not have been establish yet, the amount of data is not sufficient to take out a valuable relation between different flows of suspended material.

Because of difficulties of communication with our partners, it is very hard to get precise data aiming at modeling erosion hazard on a smaller time scale. No matter what, this represents the next step of modeling since it can be performed on a more accurate way, with less uncertainties due to extrapolation of characteristics of entry data.

**TABLE OF FIGURES**

Figure 1 : Average rain by year for Bauerfield station (Port Vila) from 1984 to 1994 ....7
Figure 4 : Sedimentary balance (Komar, 1998). ....9
Figure 2 : Hjulström diagram....
Figure 3 : Particles transports ....
Figure 5 : Experimental plot scheme. ....11
Figure 6 : Ternary diagram ....14
Figure 7 : Technicians training. ....16

**TABLE OF TABLES**

Table 1 : Construction planning. ....11
Table 2 : Date and place of gauging and sampling. ....12
Table 3 : Size categories ....14
Table 4 : Equations of the USLE equation factor ....18
Table 5 : Available data for Efate Island (Fossey, 2007). ....18

**Bibliography**


**Bayramin I. [et al.]** Soil Erosion Risk Assessment with ICONA Model; Case Study: Beypazari Area [Revue] // Turk Journal of Agriculture and Forestry 27. - [s.l.] : International Livestock Research Institute (ILRI), Addis Ababa, Ethipioa, 2003.

**Berthois L.** Etude sédimentologique des roches meubles [Livre]. - [s.l.] : doin, 1975.

**Bizuwerk Atesmachew, Taddese Girma et Getahun Yasin** Application of GIS for Modelling Soil loss rate in Awah river Basin, Ethiopia. [Rapport]. - [s.l.] : International Livestock Research Institute (ILRI), Adis Ababa, Ethiopia.

**Bonnemaison Joël** Gens de pirogue et gens de la terre. Les fondements géographiques d'une identité. L'archipel du Vanuatu. Essai géographique culturelle - Livre 1. [Livre]. - [s.l.] : ORSTOM, 1996.

**Casenave A. et Valentin C.** Les états de surface de la zone sahélienne. Influence sur l'infiltration. [Livre]. - Paris : Collection Didactiques, Orstom, 1989. - p. 229 p.

**Dautrebande S. et Sohier C.** L'érosion hydrique et les pertes en sol agricoles en Région Wallonne [Livre]. - [s.l.] : Gembloux faculté universitaire des sciences agronomiques, 2006.

**Davies J.L.** Geographical Variation in Coastal Development [Livre]. - New York : Longman, 1980. - 2nd.

**Davis R.A. et Hayes M.O.** What is wave dominated coast ? [Revue] // Marine Geology. - 1984. - Vol. 60. - pp. 313-329.

**Dumas P.** Caractérisation des littoraux insulaires : approche géographique par télédétection et S.I.G. pour une gestion intégrée, Application en Nouvelle Calédonie. Thèse de doctorat [Livre]. - Orléans : [s.n.], 2004. - p. 402.

**Fossey Maxime** Développement méthodologique et spatialisation hydrique à Efate (Vanuatu) [Rapport]. - 2007.

**Guang-hui Zhang [et al.]** Detachment of Undisturbed Soil by Shallow Flow [Article] // Science Soil Society Am. J.. - 2003. - 67 : Vol. 713-719.

**Gueyte Romain** Mission Report at Efate. Erosion study : training, instrumentation and monitoring [Rapport]. - 2008.

**Gueyte Romain** Rapport d'Evaluation, Processus sédimentaire à Port Vila, Efate, Vanuatu [Rapport]. - 2008.

**Huang C.H, Bradford J.M. et Laflen J.M.** Evaluation of the detachment-transport coupling concept in the WEPP rill erosion equation [Article] // Soil Sciences Society Am.J.l. - 1996. - 60 : Vol. 734-739.

**Hudson N.W.** Mesures de terrain de l'érosion et de l'écoulement des eaux de surface [Revue] // Bulletin pédologique FAO (Rome). - 1996. - p. 324 p.

**Komar P.D.** Beach process and sedimentation. [Livre]. - Prentice-Hall. New Jersey : [s.n.], 1998.

**Landa R., Meave J. et Carabias J.** Environmental deterioration in rural Mexico: an examination of the concept. [Revue] // Ecological Applications. - 1997. - Vol. 7. - pp. 316-329.

**Le Bissonais Y. [et al.]** L'érosion hydrique des sols en France [Revue]. - [s.l.] : IFEN - INRA, 2002.

**Le Bissonais Y. et Le Souder C.** Mesurer la stabilité structurale des sols pour évaluer leur sensibilité à la battance et à l'érosion. [Revue] // Etude et Gestion des Sols. - 1995. - Vol. 2. - pp. 43-56.

**Leguedois S.** Mécanisme de l'érosion diffuse des sols : modélisation du transfert et l'évolution granuloomètrique des fragments de terre érodés [Livre]. - [s.l.] : Thèse Université Orléans, INRA, 2003.

**Merritt W.S., Letcher R.A. et Jakeman A.J.** A review of erosion and sediment transport models [Revue] // Environmental Modelling & Software. - 2003. - 18. - pp. 761-799.

**Morgan** Soil Erosion and conservation. - [s.l.] : Silsoe College, Cranfield University, 1994.

**Owoputi L.O. et Stolte W.J.** Soil detachment in the physically based soil erosion process : A review [Article] // Trans. ASAE. - 38 : Vol. 1099-1110.

**Quantin P.** Archipel des Nouvelles Hébrides: Sols et quelques données du milieu naturel. Atlas des sols des Nouvelles Hébrides [Livre]. - [s.l.] : ORSTOM Nouméa, 1967.

**Reineck H.E. et Singh I.B.** Depositional sedimentary environments [Livre]. - [s.l.] : Springer-Verlag, 1980.

**Reusing M., Schneider T. et Ammer U.** Modelling Soil Loss rates In the Ethiopian Highlands by Integration of High Resolution MOMS-02-D2-Streao-data in a GIS. [Revue] // International Journal of Remote Sensing. - 2000. - 9 : Vol. 21.

**Roose E. et Sarrailh JM.** Erodibillité des sols tropicaux : Vingt années de mesure en parcelles dérosion sous pluies naturelles [Revue]. - [s.l.] : Cahier ORSTOM, série pédologique, 1989-90. - Vol. 1-2.

**Roose E.** Introduction à la gestion conservatrice de l'eau, de la biomasse et de la fertilité des sols (CGES) [Revue] // Bulletin Pédologique FAO (Rome). - 1994. - 70. - p. 422 p.

**Roose E.** L'érosion, un problème actuel d'environnement ? [Compte rendu d'audience]. - Symposium International de Saint Cloud : [s.n.], 1992.

**Roose Eric** Ruissellement et érosion d'un sol volcanique tropical cultivé en sytèmes intensifs en Martinique. [Revue] // Cahier d'études et de recherches francophones / Agriculture, Volume 12, Numéro 3. - Mai-Juin 2003. - pp. 145-51.

**Shepard F.P.** Submarine Geology [Livre]. - New York : harper & Row, 1963. - 2nd.

**Van Dijk A.I.J.M, Meesters A.G.C.A. et Bruijnzeel L.A.** Exponential ditribution theory and the interpretation of splash detachmentand transport experiments. [Article] // Soil Science Society Am. J.. - 2002. - 66 : Vol. 1466-1474.

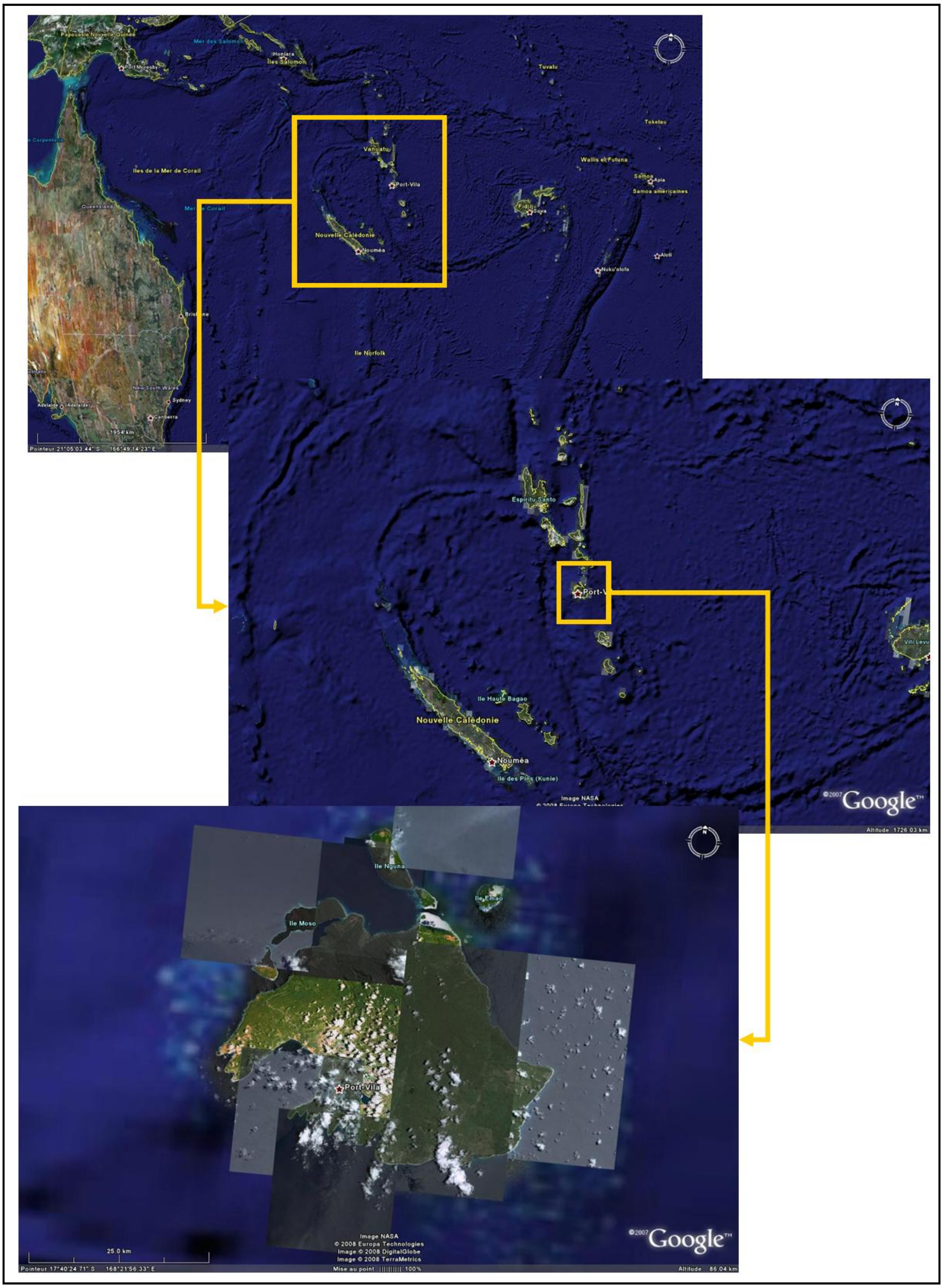
**Veiga F.A.** Processos morfodinâmicos e sedimentololgicaos na plataforma continental rasa paranaense. Thèse [Livre]. - Curitiba : [s.n.], 2005.

**Wischmeier WH. et Smith DD.** Predicting rainfall erosion losses - A guide to conservation planning [Revue] // US Department Agriculural Handbook. - 1978. - p. 282p.

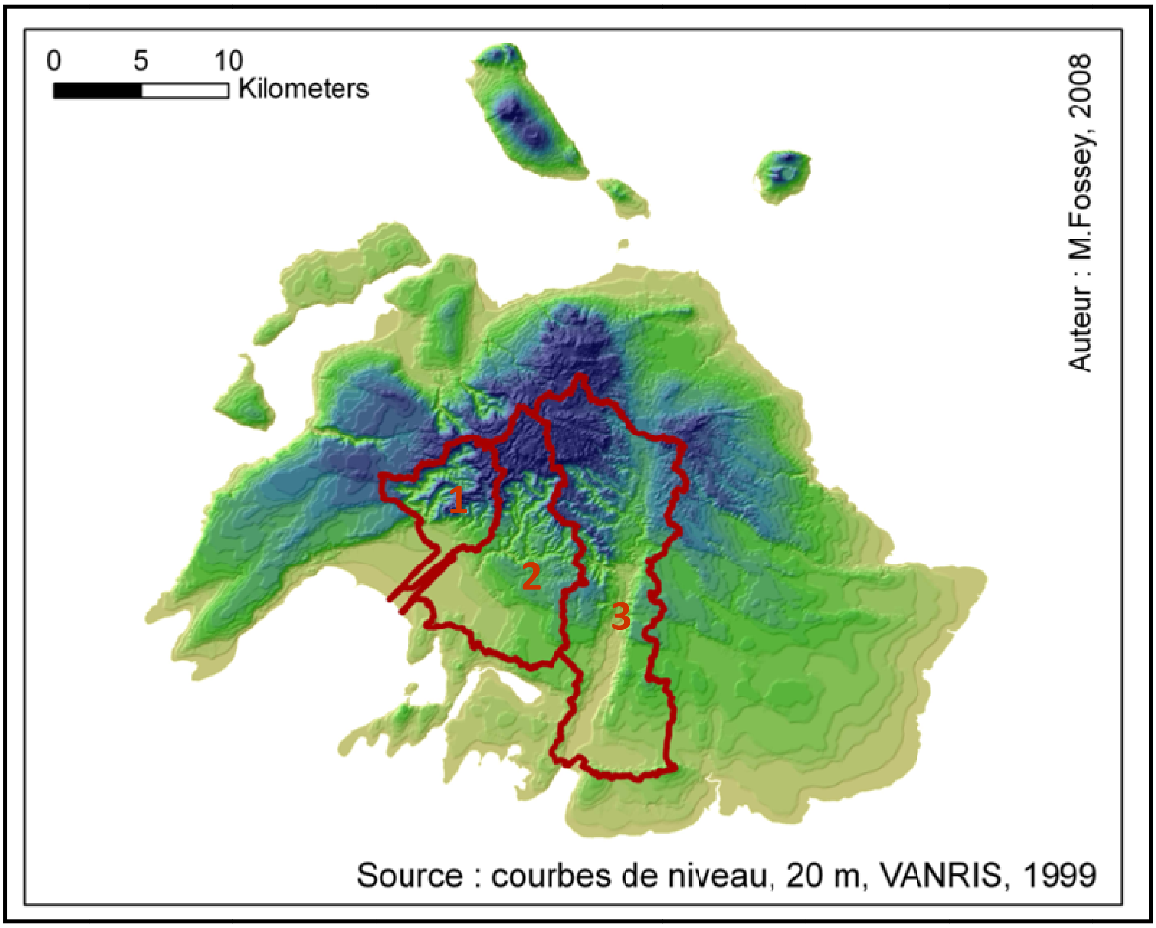
## APPENDIX

Appendix 1 :  Study area (Google Earth, 2008). ....... 24
Appendix 2 : Localization and morphologic details of the studied catchments. ....... 25
Appendix 3 : Installation site ....... 26
Appendix 4 : Prospection and installation sites. ....... 27
Appendix 5 : Material needed for construction. ....... 28
Appendix 6 : Plots building. ....... 29
Appendix 7 : Gauging sites. ....... 31
Appendix 8 : Sedimentary analysis. ....... 32
Appendix 9 : Technical note. ....... 33
Appendix 10 : Samples treatment organization chart. ....... 41
Appendix 11 : Histogram and cumulative chart of sample 10 of Mele bay. ....... 42
Appendix 12 : Distribution map of Lutites on the study area. ....... 43
Appendix 13 : Distribution of medians on the study area. ....... 44
Appendix 14 : Medians interpolation. ....... 45
Appendix 15 : Cartography of distribution of USLE Equation factors ( (Fossey, 2007) ....... 46
Appendix 16 : Cartography of erosion hazard (Fossey, 2007). ....... 47
Appendix 17 : Factors and erosion hazard for the dry and humid season for Tagabe catchment. ....... 48

**Appendix 1 : Study area (Google Earth, 2008).**

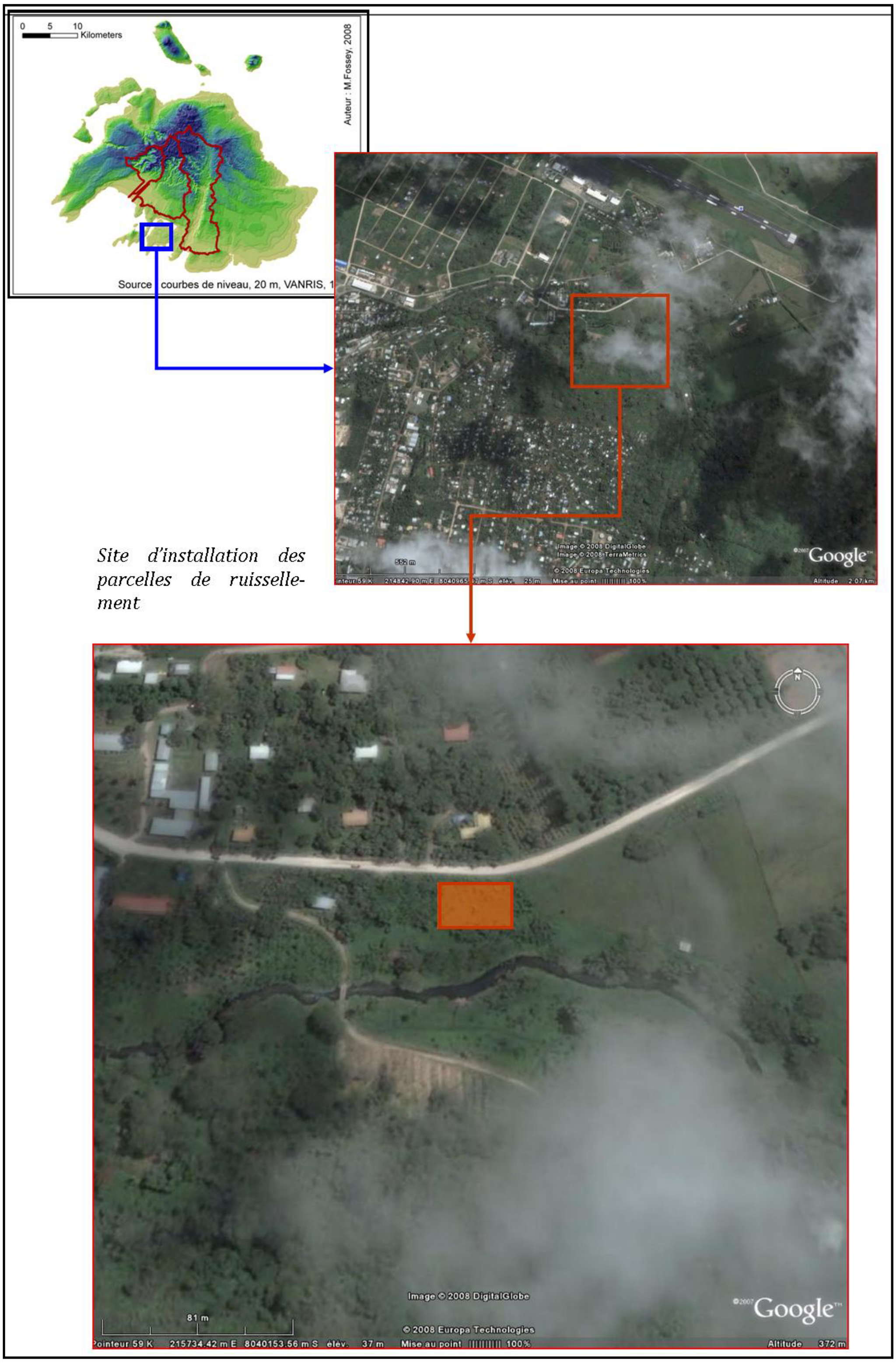


**Appendix 2 : Localization and morphologic details of the studied catchments.**

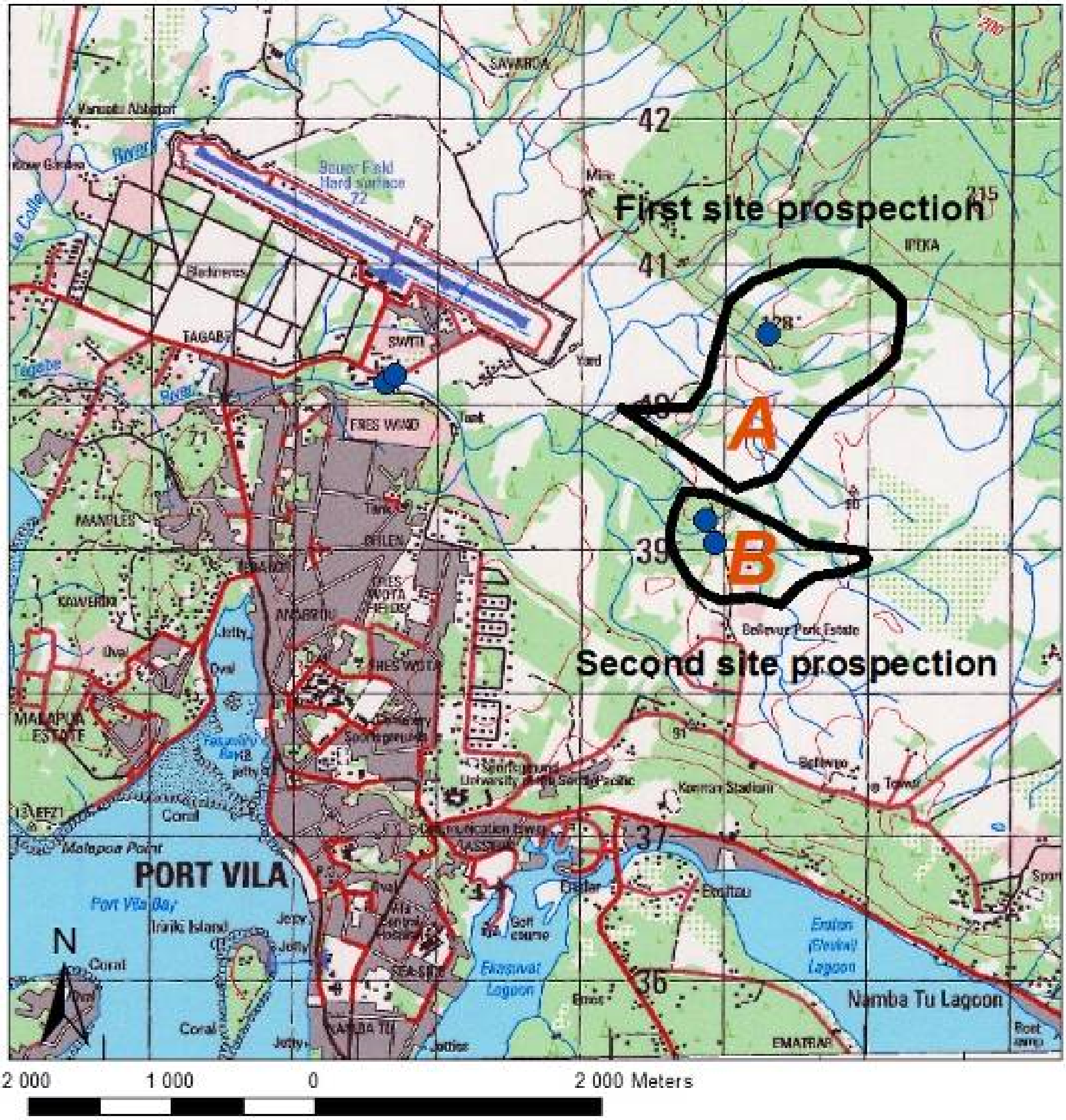



| Characteritics | 1.Colle | 2.Tagabe | 3.Teouma |
|---|---|---|---|
| Area (km2) | 30 | 73 | 123 |
| Perimeter ((km) | 35 | 54 | 78 |
| Mean slope (°) | 18° | 9° | 9° |
| Lmax (km) | 10 | 17 | 31 |
| Altitude max (m) | 540 | 660 | 660 |
| Altitude output (m) | 0 | 0 | 0 |
| Mean altitude (m) | 236 | 188 | 193 |

**Appendix 3 : Installation site**



**Appendix 4 : Prospection and installation sites.**



**Appendix 5 : Material needed for construction.**

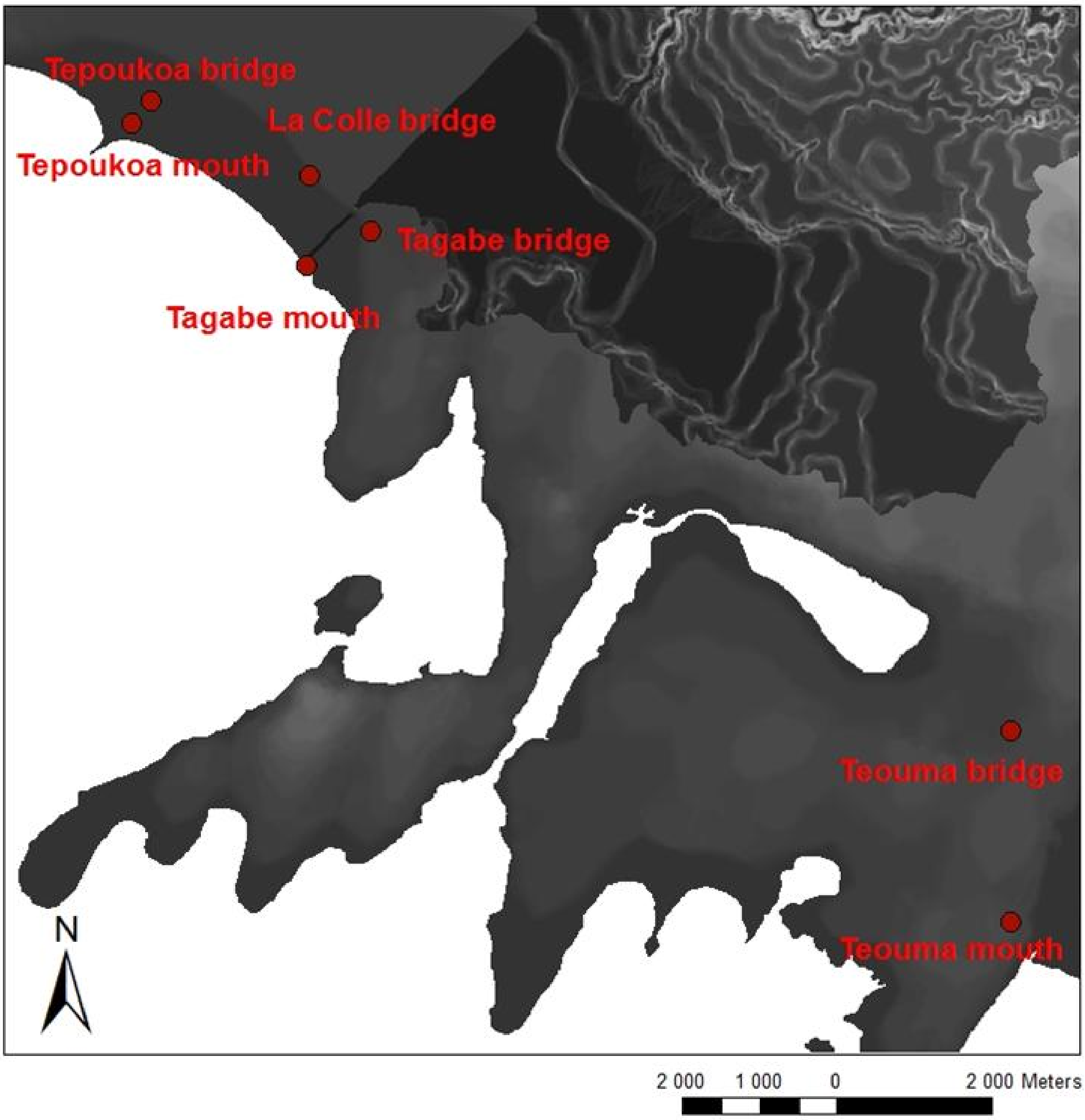
| Material | Use | Unity | Quantity | Price unit (€) | Total Price (€) |
|---|---|---|---|---|---|
| **Material** | | | | | |
| Ciment | Groundwork - tanks - plots | 40kg | 38 | 7.9 | 298.6 |
| Brick | Tanks - Plots | | 550 | 0.9 | 510.7 |
| Send | Mortar | m3 | 5 | 28.6 | 142.9 |
| Coral | Mortar | m3 | 1 | 28.6 | 28.6 |
| Wire | Groundwork - tanks | 585cm / ø6mm | 47 | 1.9 | 87.3 |
| Softwood | Form | 500cm x 5cm x 20cm | 12 | 3.6 | 42.9 |
| Softwood | Form | 500cm x 5cm x 5cm | 5 | 3.6 | 17.9 |
| Iron sheet | Tanks protection | 600 cm x 80cm x 0,5cm | 4 | 42.9 | 171.4 |
| Tie wire | | 1 kg | 5 | 2.5 | 12.5 |
| Black cover | | 400cm x 1m | 8 | 2.1 | 17.1 |
| **Tools** | | | | | |
| Tarpaulin | | 500cm x 800cm | 1 | 22.9 | 22.9 |
| Knife | | | 3 | 4.3 | 12.9 |
| Nail | | 1 kg | 1 | 1.8 | 1.8 |
| Iron nail | | 1kg | 1 | 2.1 | 2.1 |
| Plier | | | 2 | 4.6 | 9.3 |
| Shears | | | 1 | 78.6 | 78.6 |
| Hamer | | | 1 | 4.3 | 4.3 |
| Trowel | | | 1 | 1.4 | 1.4 |
| Taloche | | | 1 | 6.4 | 6.4 |
| Spade round | | | 1 | 7.9 | 7.9 |
| Balance | | 50 kg | 1 | 8.6 | 8.6 |
| Bucket | | | 5 | 4.3 | 21.4 |
| Essence | | | 50 | 1.2 | 60.7 |
| **Total** | | | | | **1507.3** |

**Appendix 6 : Plots building.**

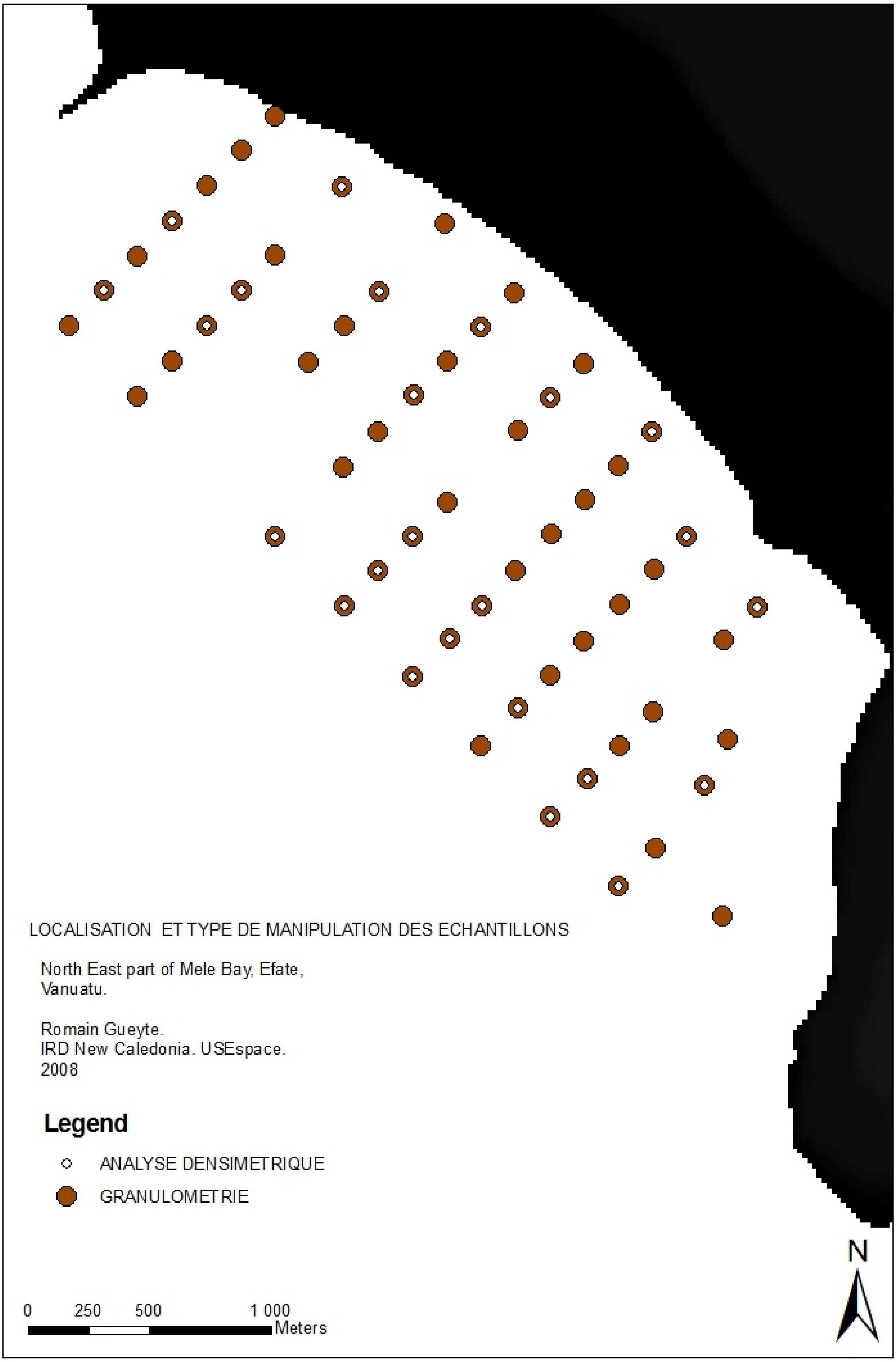


02/01/2007

**Appendix 7 : Gauging sites.**



**Appendix 8 : Sedimentary analysis.**



**Appendix 9 : Technical note.**

# GERSA PROJECT – VANUATU

## CRISP PROJECT

INTEGRATED WATERSHED AND COASTAL MANAGEMENT

TECHNICAL NOTE

# NEEDED PARAMETERS FOR THE STUDY OF THE EXPERIMENTAL RUNOFF STATIONS

**ROMAIN GUEYTE – DECEMBER 2008**

DGMWR

Table des matières

1. Introduction ........ 34
2. Calibration of the measurement bucket ........ 35
3. Slope measure ........ 37
4. Measure after a rain event ........ 38
4.1. Erosion measure ........ 38
4.2. Rain event data ........ 38
4.3. Runoff measure ........ 38
4.3.1. Cram ........ 39
4.3.2. Crmax ........ 39
5. Witness stations of Wischemeier: Bear Land ........ 39
5.1. Presentation ........ 39
5.2. Determination of the roughness ........ 39
6. Excel files enclosed with the note. ........ 40

## 1. Introduction

The present paper aims at helping the Water Resources Department in the runoff experimental stations monitoring. These stations were set up jointly with the Unity Espace from IRD Nouméa and the Water Resources Department of Vanuatu under the CRISP-GERSA program. It will introduce the different files used for monitoring and calibration of the stations. Two Excel files are enclosed to this paper:

- *Stations.xls*
- *Slopes.xls*

The three most important parameters to measure on a run off experimental plots are the **rain**, the **runoff** and the **erosion**.

**Remarque:** The cells of the files including formulas are locked in order to prevent damages. If it was needed to change any of them, the password is “r”.

## 2. Calibration of the measurement bucket

The calibration technique is made by several measures of the total weight with different weight of sediment. These measures will allow us to generate a calibration chart which will give us the sediment weight when knowing the sediment weight.

We have $total\ weight = bucket\ weight + sediment\ weight + water\ weight$

The calibration is based on two hypotheses:

- The water density is considered as constant, with d = 1 or $\rho = 1\ kg/l = 1000\ kg/m^3$. This hypothesis is used to transform one liter of water into one kilogram of water.
- The terrigenous particles also have a constant density.

Calibration protocol:

1. Collect ground around the stations.
2. Weight the empty bucket.
3. Weight the bucket with the terrigenous particles.
4. Fill up the bucket (always to the same level) with water.
5. Weight the whole thing.

Steps 3, 4 and 5 must be repeated for the different weight of sediment.

The hook scale has a ±500 grams accuracy, as a matter of fact it cannot be used for the sediment weights inferior to 1 kg. It can therefore be used for the sediment weight between 1 and 5 kg (this limit should never be reach in real case of wrenching).

For the weights of sediment inferior to 1 kg it would sensible to use a precision scale with a ±100 grams accuracy. In those cases, instead of using the bucket, a laboratory beaker of 500 ml can be used.

Calibration protocol:

1. Collect ground around the stations.
2. Weight the empty beaker.
3. Weight the beaker with the terrigenous particles.
4. Fill up the bucket (always to the same level) with water.
5. Weight the whole thing.

Steps 3, 4 and 5 must be repeated for the different weight of sediment.

In both cases, the volume of water is obtained with the following equation:
$total\ weight = bucket\ weight + sediment\ weight + water\ weight$ where the only unknown is the quantity of water. Indeed we have:
$water\ weight = total\ weight - bucket\ weight - sediment\ weight$

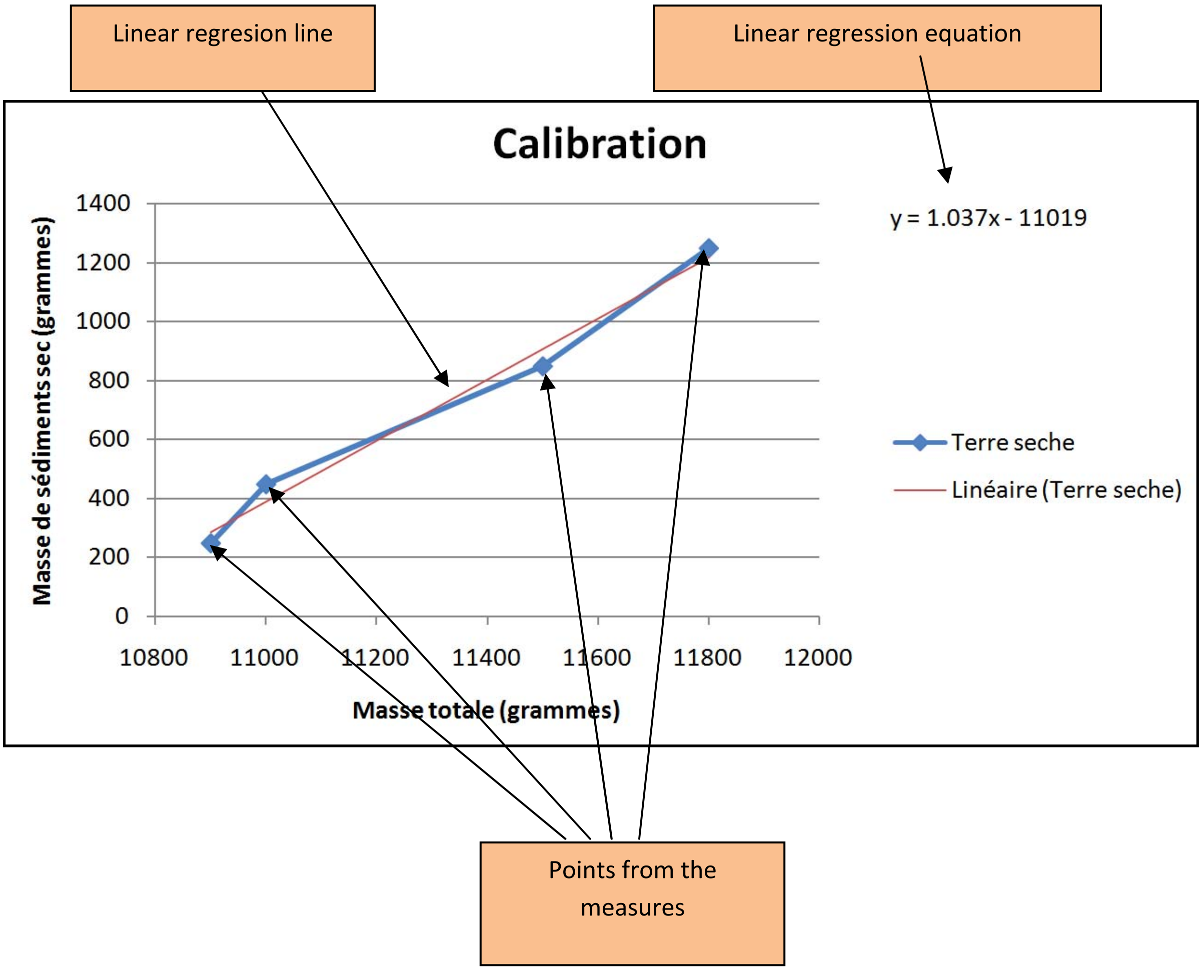
In the calibration sheet of the file *stations.xls* enclosed with this note, it is necessary to compute the following data: weight of the empty bucket, weight of the bucket + sediment and total weight.

The column “% sediment” is the link between the data made with the bucket and the beaker.

The file *station.xls* contains two sheets. The first one is the calibration chart with the bucket. The second one is the measurement chart. These tables are already calibrated with the calculi explained above.
The calibration table is linked with a graph where are in x-axis the total weight and in y-axis the weight of dry sediment. On the graph appears as well the linear regression equation:

$$ZWeight_{dry\ sediment} = a \times Weight_{total} + b$$

Example of the graphs linked with the calibration table:




In this example made with the first measures, the calibration equation is

$$W_{dry} = 1.37 \times W_{total} - 11019$$

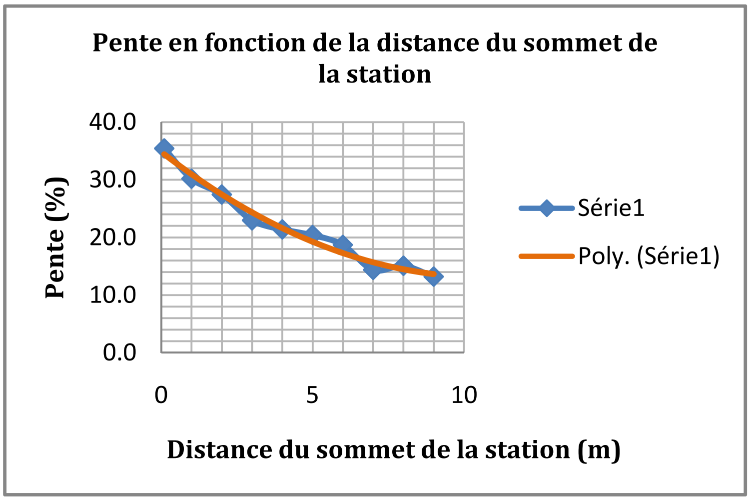
This equation will give you the dry sediment weight when knowing the total weight of the bucket.

Once you will have entered the calibration data in the Excel file, the linear regression equation will appear on the graph.

## 3. Slope measure

The first station slope (bear land) was measured every meter:

| Bear Land (1) | |
|---|---|
| Distance from top | Slope (%) |
| 0.1 | 35.4 |
| 1 | 30.2 |
| 2 | 27.4 |
| 3 | 23.0 |
| 4 | 21.4 |
| 5 | 20.4 |
| 6 | 18.7 |
| 7 | 14.4 |
| 8 | 15.1 |
| 9 | 13.2 |
| Average slope (%) | 21.9 |




In the same time, a global slope measure was performed, by taken into account the total length and difference in height. It was obtained:

- $Lenght_{total} = 10.30\ m$
- $height_{total} = 1.76\ cm,$

which means an average slope of 17.09 %. The difference between the average slope calculated from the ten points and the one directly calculated is about 20%. It is assumed that the average slope is more precise due to the uncertainty created when measuring the whole difference of level. This method of measure will not be used for the other stations.

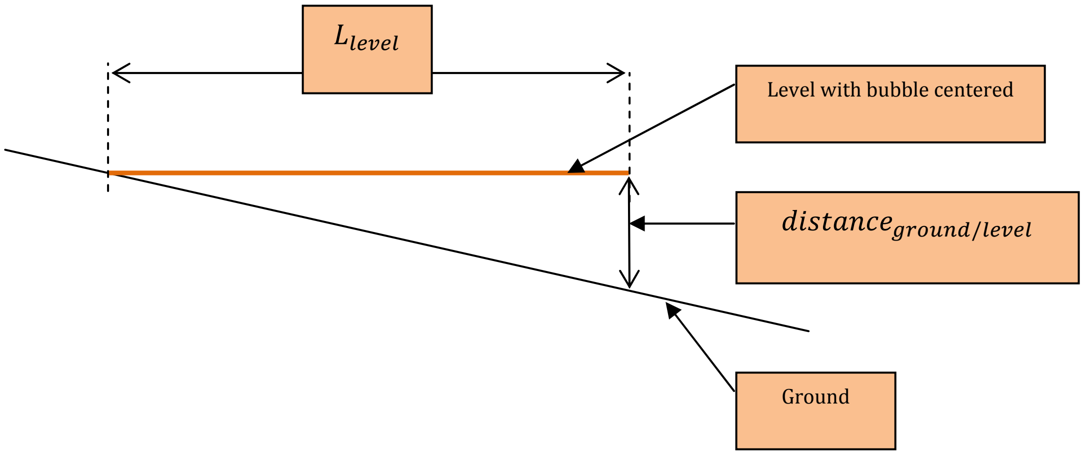
The slopes of the stations 2, 3 and 4 were measured in two points :

| N° Station | Sup | Inf | Average slope (%) |
|---|---|---|---|
| 2 | 26 | 14 | 20 |
| 3 | 25 | 9 | 17 |
| 4 | 31 | 14 | 23 |

It is needed to measure the accurate slope for each station as it was performed for the station 1:

1. Measure the level length (it should be 152.4 cm)
2. Put the top of the level at the desired distance from top (as indicate in the Excel file).
3. Lift the down part until the bubble indicates the level is straight.
4. Measure the distance between the ground and the level.

The slope in percent is given by $Slope_{\%} = \frac{Distance_{ground/level}}{Lenght_{level}} \times 100$




The file*slopes.xls* was made to compute the slopes and the mean slopes from the data measured on field.

## 4. Measure after a rain event

### 4.1. Erosion measure

After a rain event it is necessary to **mix up the water inside the tank** in order to re-put the terrigenous particles in suspension. The measurement bucket is then sink inside the water and fill until is full. If the tank doesn't contain enough water, it is possible to use the calibration beaker.

The volume of water in the tank is measured using a meter. It is also necessary to measure the area of the tank at the matching height. The volume of water is given by the following relation: $V_{water} = height_{water} \times Area_{tank\ at\ h}$. The knowledge of the percentage of particles will help us correcting the volume of water from the volume of sediment.

It is a compulsory to use the same bucket for calibration and measurements.

### 4.2. Rain event data

The indication of the water level that fell during the rain event will enable us to know the quantity of water that has streamed and the amount that infiltrate and evaporate.

It would be necessary to fill the next three parameters of the rain event:
The water gap (mm/min)
The maximal intensity in 30 minutes.
The aggressiveness (J/m$^2$/h)

Of course theses data will depend on what the Meteorology Department of Vanuatu is calculating and able to give to you.

### 4.3. Runoff measure

Two indicators must take into account for the runoff:
- The coefficient of average annual runoff (Cram).
- The coefficient of maximal runoff (Crmax).

#### 4.3.1. Cram

This coefficient is the ratio between the water gap that has streamed annually and the annual wetness:

$$Cram = \frac{Elevation_{annualy\ streamed\ water}}{Annualy\ wetness}$$

#### 4.3.2. Crmax

This coefficient is the ratio between the maximum water gap that has streamed within a year and the matching wetness:

$$Crmax = \frac{Elevation_{maximum\ streamed\ water}}{Wetness_{matching\ the\ elevation}}$$

## 5. Witness stations of Wischemeier: Bear Land

### 5.1. Presentation

The first station (Bear Land) is an international witness called standard station as well as reference of Wischmeier. It needs a special care:

- Empty of grass or any vegetation during the whole year.
- Worked on five centimeter deep in order to break the surface crust at the beginning of the year before the measuring campaign.

### 5.2. Determination of the roughness

The roughness of soil encourages water storage refusing to infiltrate into depression and slow down the runoff. The experience also shows that the roughness influence is getting smaller when the slope gets sharp and disappears after 30%.

The chain method is presented below since it is quickly useable and low cost.

The chain used in this method is made of small ball sliding on a rope. For a 2 meters wide station, it is necessary to have a 3.5 meters long chain.

- Put the chain on the width of the station to explain erosion.
- Put the chain on the length to explain runoff.

The chain takes on the roughness of the ground and the length necessary to cover the ground will be superior to the station width. The roughness in percent (%) is given with the following relation:h

$$Roughness = \left(Length_{chhhhhhhhhhhhain\ on\ ground} - width_{\ station}\right)/2$$

## 6. Excel files enclosed with the note.

The excel files enable to do the monitoring of the stations, with on one hand, the accurate calibration and size, and on the other hand, to collect data from the monitoring.

The file ***station.xls*** is separated into two sheets:

- *Calibration* where the data will be noted in order to generate the equation that links the total weight of the measures bucket with the real weight of dry sediment.
- *Measures* where all data from monitoring will be collect.

For each measurement, it is necessary to collect the following data:

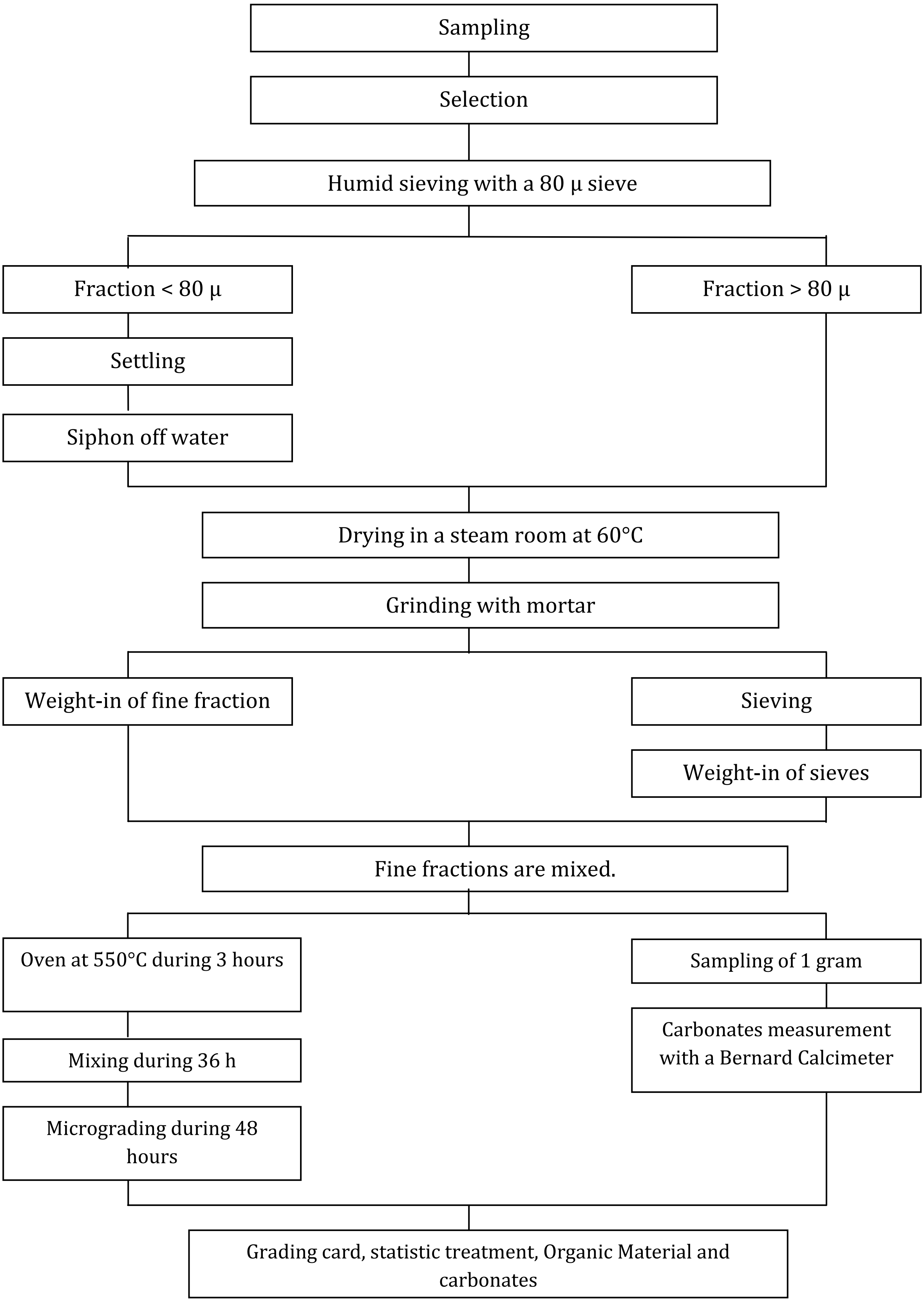
- A. Number
- B. Date
- C. Hour
- D. Person on field
- F. If the bucket was used put a 1. If the beaker was used put 2.
- H. The length of the last rain event.
- I. The high of the rain.
- J. The intensity of the rain.
- L.M.N.O. : the total weight of the bucket for each station.
- Q.R.S.T.: The total volumes of (water + sediment) in the tanks.

The program will compute the following data:

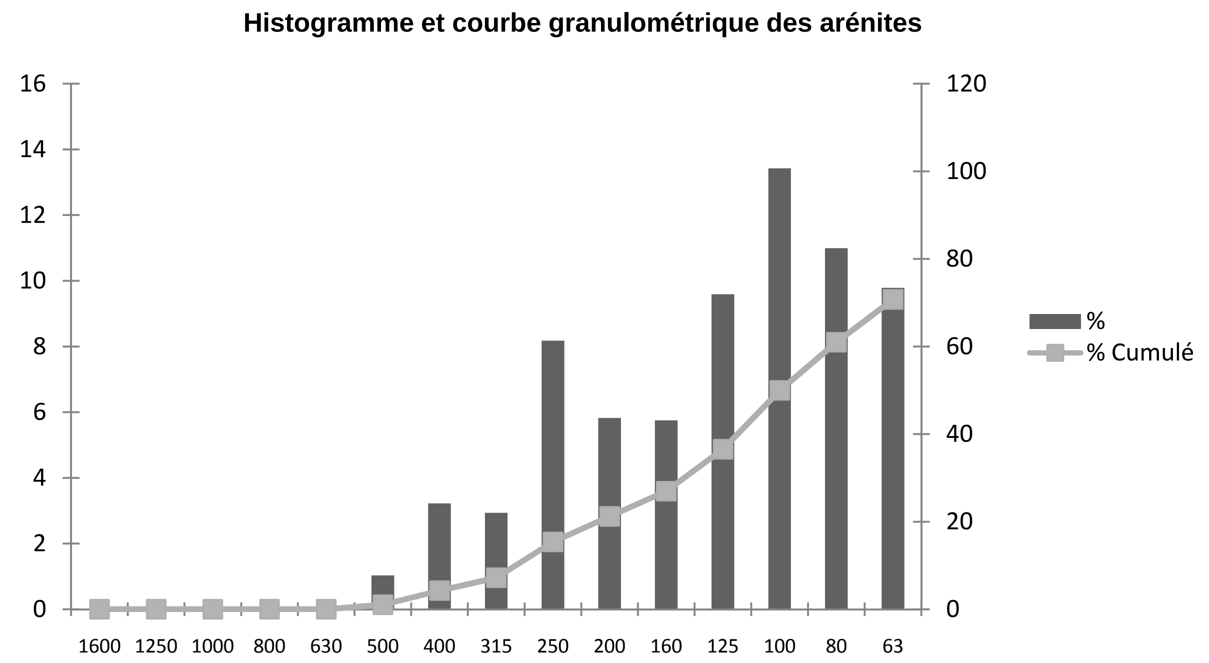
- Sediment weight (V.X.Z.AB) and the volume of water (W.Y.AA.AC) for the four stations.
- Total volume in the tanks (AE.AF.AG.AH).
- Total sediment weight in the tanks (AJ.AK.AL.AM).

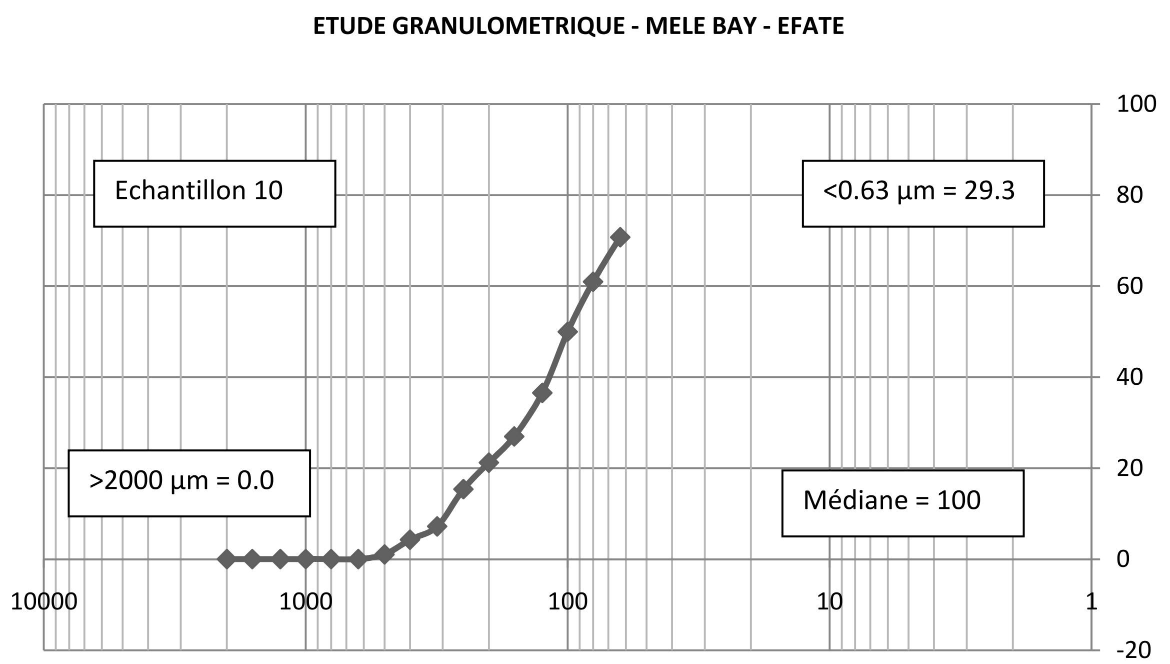
The *file* ***slopes.xls***: For each station, 10 points of slope will be measured to create the accurate profiles of slopes. It will generate 6 graphs, one for each station and two for comparison (general slope and accurate slope) of the four stations. This file will serve to know the morphology of the stations but will not be used during the monitoring.

**Appendix 10 : Samples treatment organization chart.**

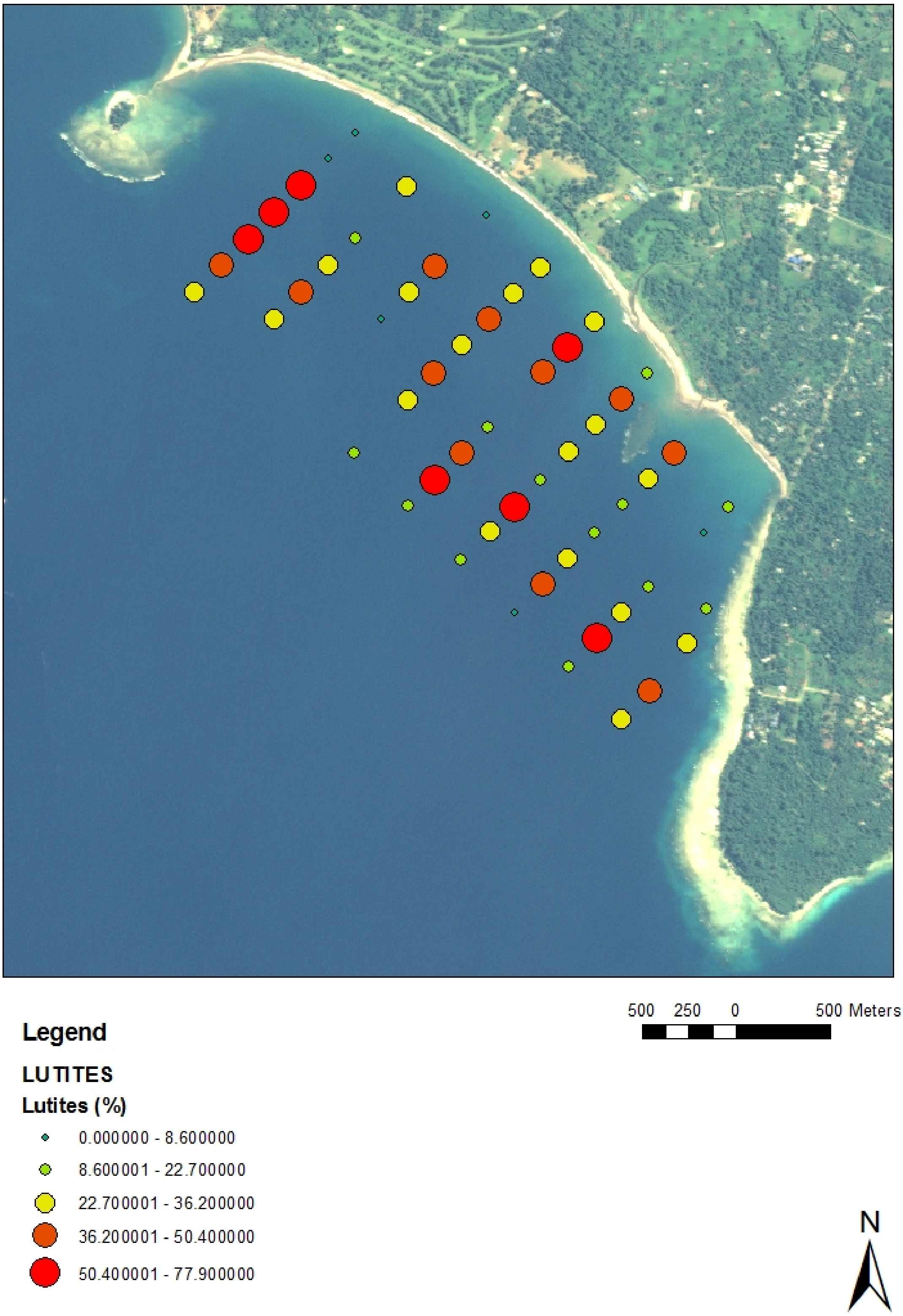


**Appendix 11 : Histogram and cumulative chart of sample 10 of Mele bay.**

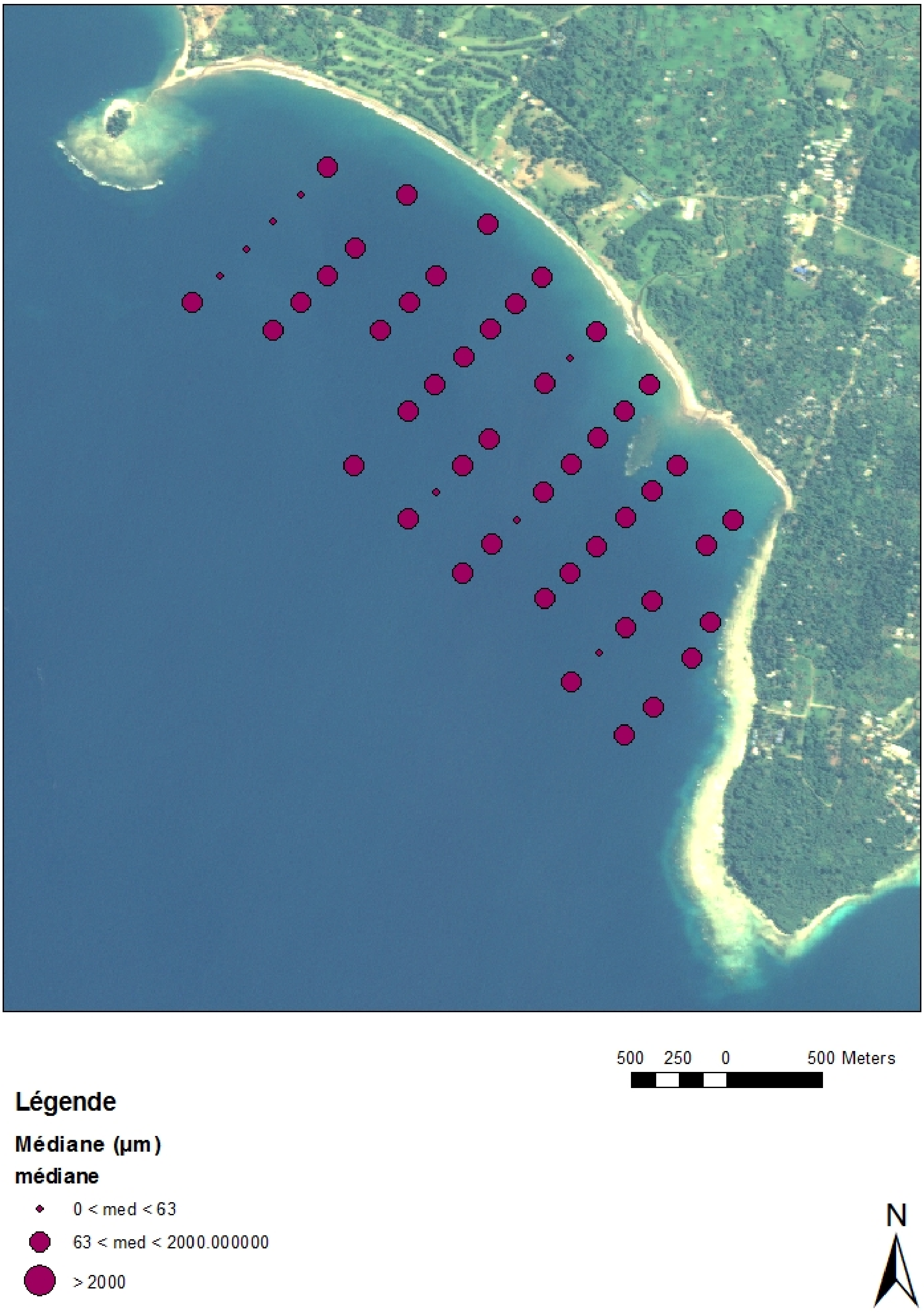


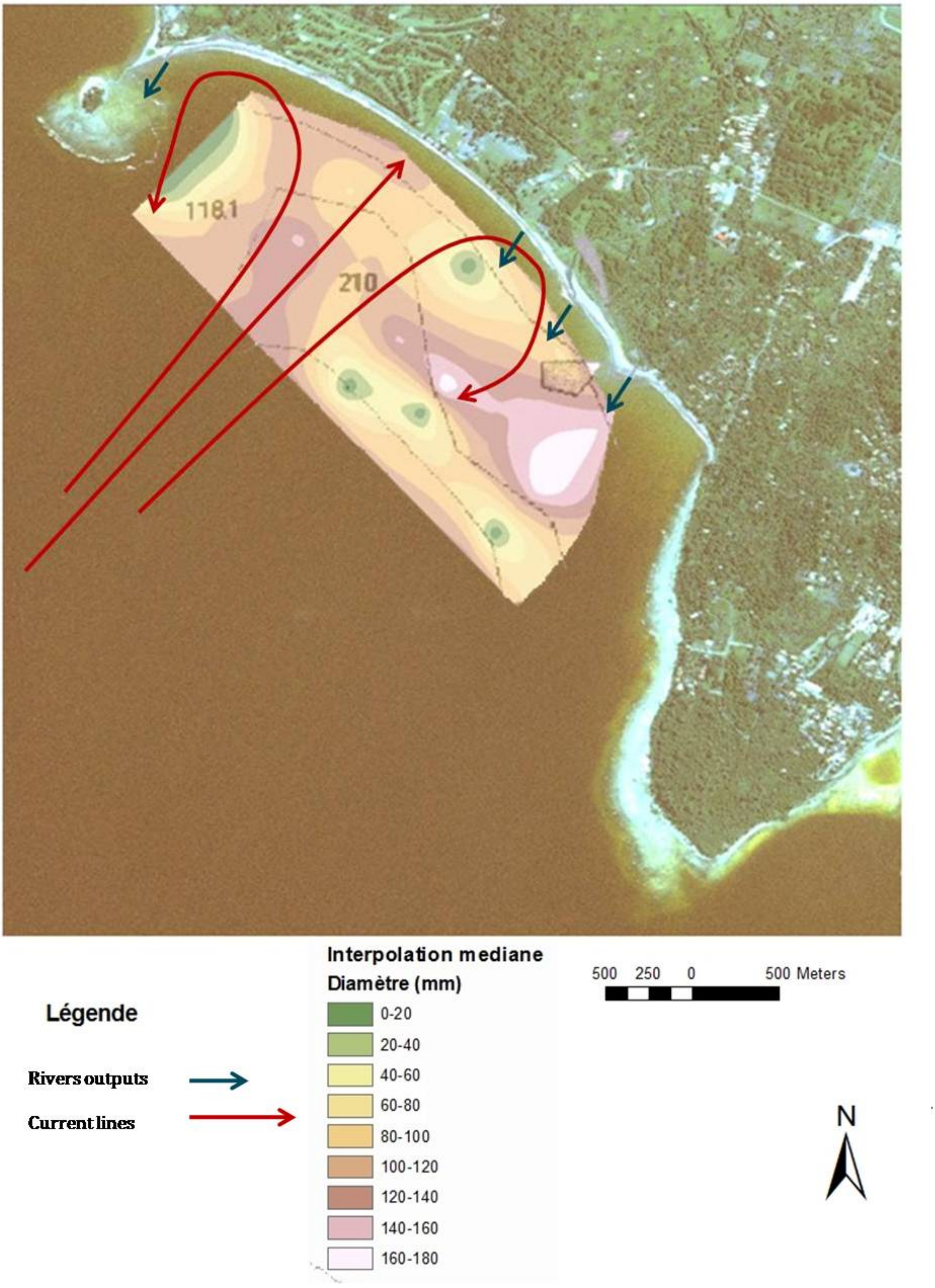
**Appendix 12 : Distribution map of Lutites on the study area.**



**Appendix 13 : Distribution of medians on the study area.**

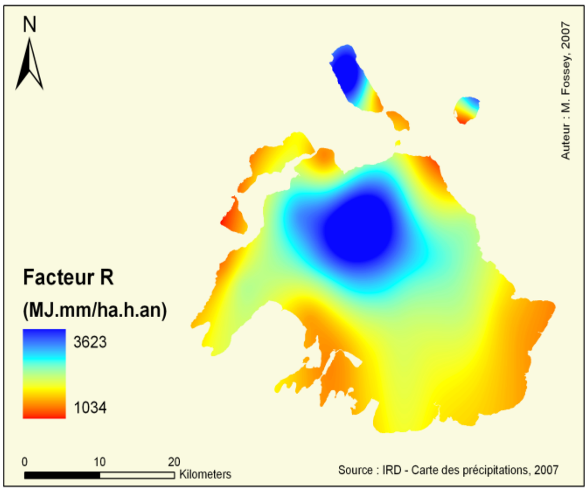


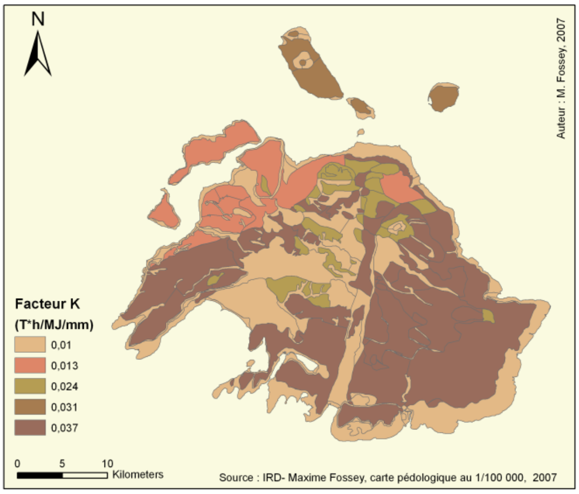
**Appendix 14 : Medians interpolation and sedimentary dynamic interpretation.**



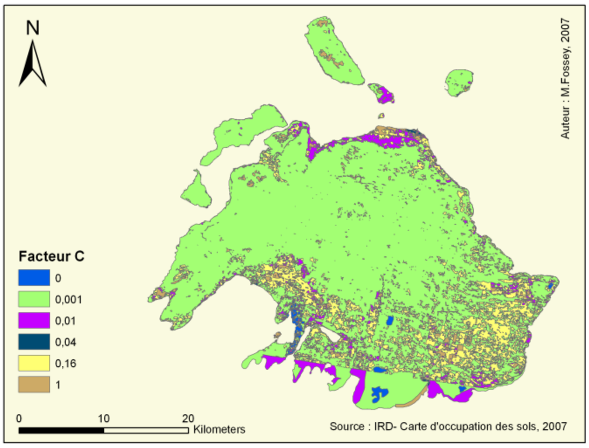
**Appendix 15 : Cartography of distribution of USLE Equation factors (Fossey, 2007)**

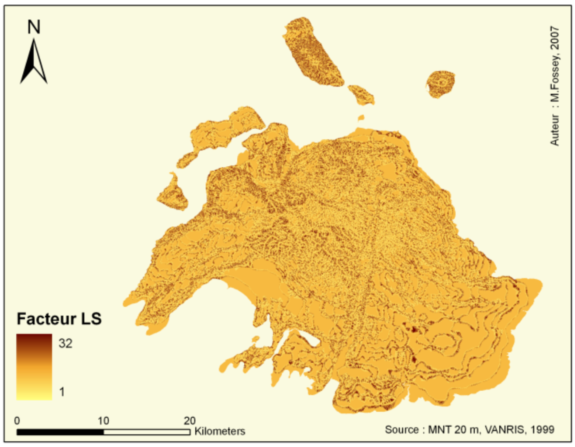
Spatialisation des facteurs R et K :



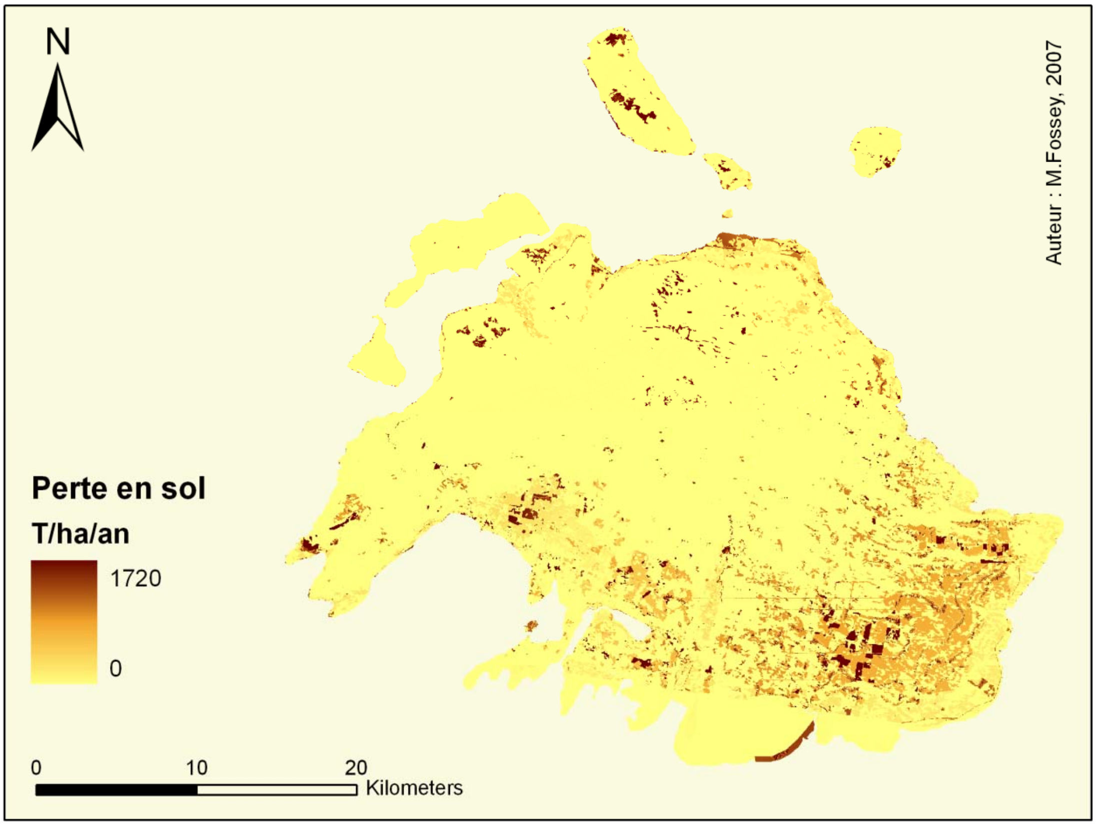




Spatialisation des facteurs C et LC :

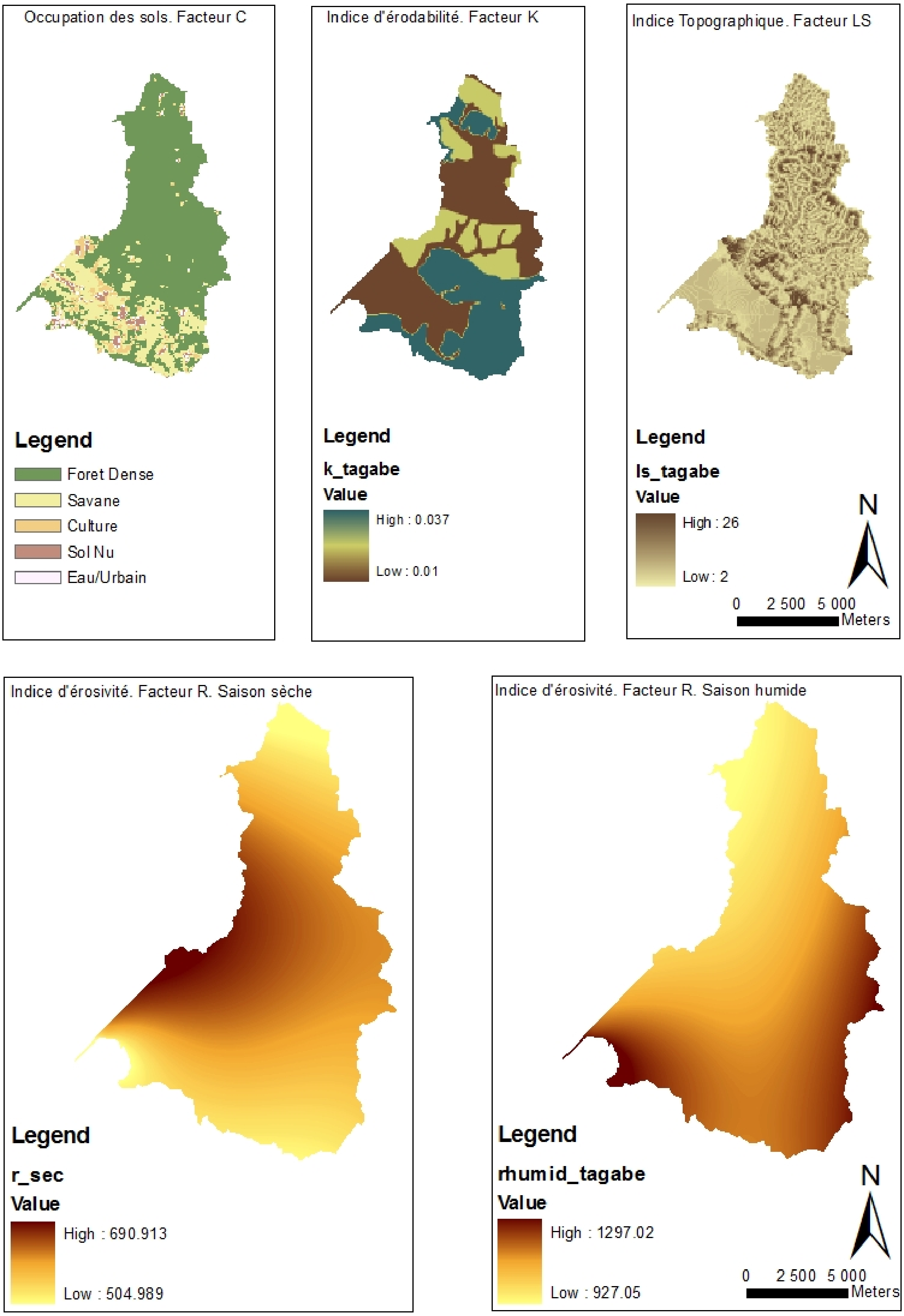


**Appendix 16 : Cartography of erosion hazard (Fossey, 2007).**



**Appendix 17 : Factors and erosion hazard for the dry and humid season for Tagabe catchment.**



COMPONENT 1A - Project 1A4

Integrated Coastal Management - GERSA Project
Hydrology

December 2008

CRISP

Composante 1
sous-composante 1A

# Sedimentary contribution of catchments on Efate Island, Vanuatu - Instrumentation and modelling -

Abstract

Sedimentary processes are complex, they interfere at the geological scale in the relief formation and at the human scale on the land degradation and water quality. These processes are still badly known on the archipelago of Vanuatu, where few data are available concerning the catchments behaviour. A modelling of the soil loss based on USLE equation was used for Efaté Island, Vanuatu, in order to estimate the zones with high potential of erosion. To validate the model it is necessary to implement on field experiments to get data on the real catchment behaviour. This works includes the three aspects of erosion processes: wrenching, transport and sedimentation. From one hand, transport and sedimentation will be measured and experimental station will be build to monitor wrenching. On the other hand, the model will be used to determine the erosion hazard on the Tagabe catchment.

IRD
Institut de recherche pour le développement
unité espace S140