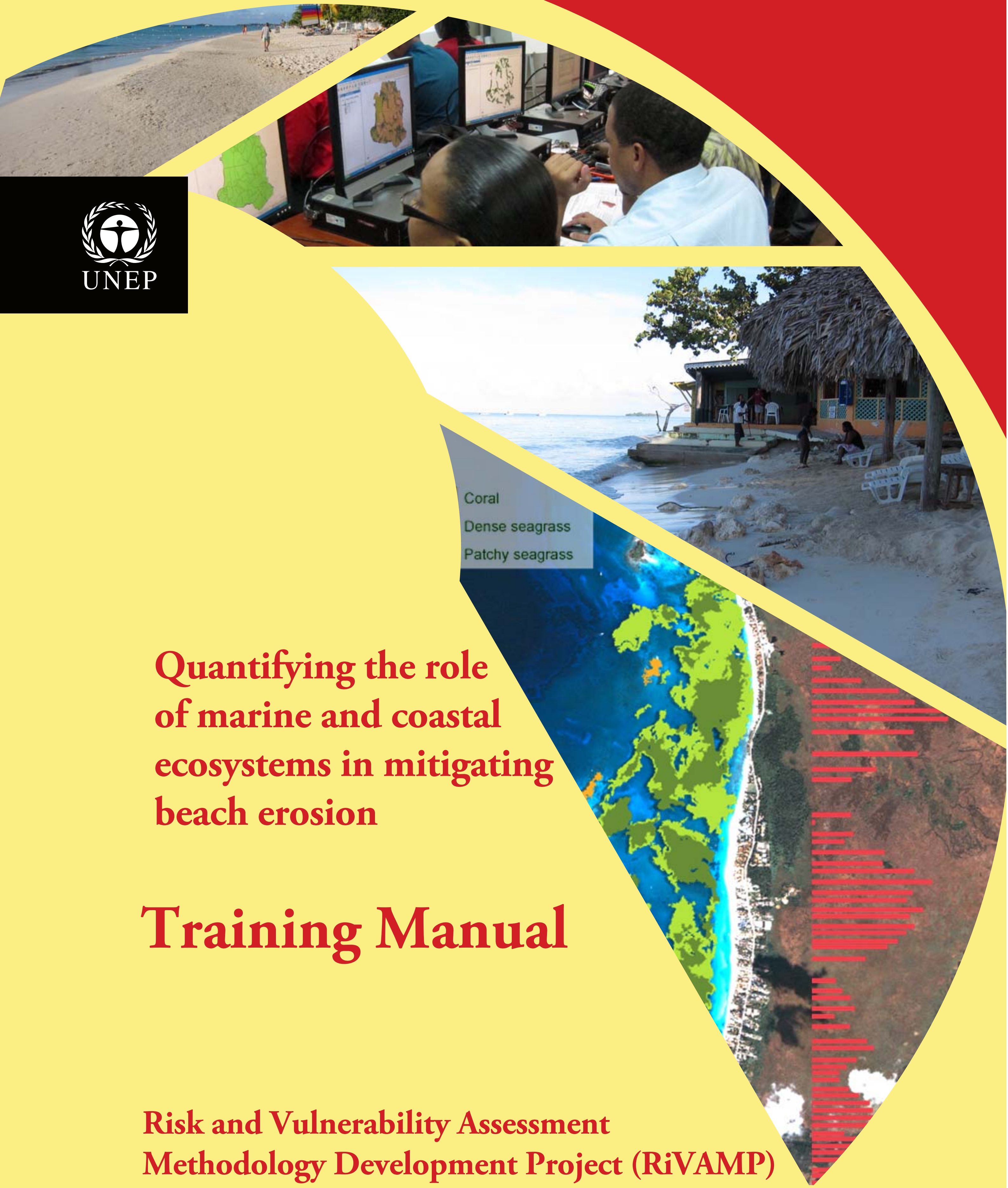

UNEP

Quantifying the role of marine and coastal ecosystems in mitigating beach erosion

Training Manual

Risk and Vulnerability Assessment Methodology Development Project (RiVAMP)

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Introduction

The Risk and Vulnerability Assessment Methodology Development Project (RiVAMP) is a collaboration between the United Nations Environment Programme Division of Early Warning and Assessment (DEWA) and Division of Environmental Policy Implementation (DEPI) and aims to identify and quantify the role of ecosystems in Disaster Risk Reduction (DRR) and climate change adaptation (CCA).

Such methodology can be applied in different ecosystems, this one is tailored to the role of coastal and marine ecosystems in mitigating beach erosion, thus reducing impacts from storm surges generated by tropical cyclones and the impacts from sea level rise. This is more specifically targeting for Small Islands Developing States (SIDS).

The pilot study was carried out in Jamaica and concentrate on beach erosion in Negril area (at the request of the Jamaican government). The methodology includes local experts and community consultations integrated with spatial analysis (GIS and remote sensing), erosion modelling and statistical analysis.

The assessment tool was pilot tested in Jamaica, as a small island developing state. The national partner was the Planning Institute of Jamaica (PIOJ). According to the IPCC's Fourth Assessment Report, global climate change will particularly impact on small island developing states (SIDS), such as Jamaica, which have a high coastal population density and existing vulnerability to natural hazards. The importance of nature-based tourism and climate sensitive livelihoods (agriculture and fisheries) in Jamaica make it critical to understand changing patterns of risk and develop effective response.

Following the release of the RiVAMP study results, the government of Jamaica, through PIOJ, requested UNEP to get a transfer of this methodology to Jamaican scientists. DEWA financed the creation of the training manual, including the transfer of the methodology on free OpenSource software (to avoid creating dependencies) and DEPI/PCDMB financed the mission itself.

In agreement with the Jamaican government, we are pleased to provide access to this training on-line, so that anybody who is interested in quantifying the role of ecosystems can access such training and related tools (GIS, statistics and beach erosion modelling software).

This training document has been created by Bruno Chatenoux (UNEP/DEWA/GRID-Geneva) – GIS chapter, Pascal Peduzzi (UNEP/DEWA/GRID-Geneva) – Statistical analysis chapter and Adonis Velegrakis (University of the Aegean) – Hydrology chapter.

RiVAMP GIS Training

In brief

The aim of this training is to introduce you to the potential of open source applications in the context of a study such as RiVAMP GIS analysis. To do so the training has been divided into sessions during which you will learn how to practically apply the RiVAMP methodology step by step.

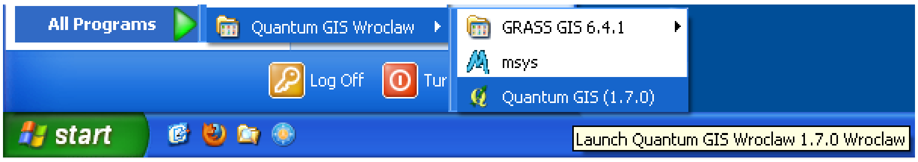
The open source GIS software Quantum GIS 1.7.0 (QGIS) will be used (without using GRASS 6.4.1 even if it will be installed jointly) and the worksheet editor of LibreOffice (fork of OpenOffice).

The training documentation has been prepared under a Windows XP environment, but is easily reproducible in any other OS after a few adjustments (installation, paths). Administrator privileges are required.

Typographic convention

In a general manner the text you have to focus because it figures in the applications or you have to type has been highlighted with ***Bold Italic*** format. They constitute the technical skeleton of the process

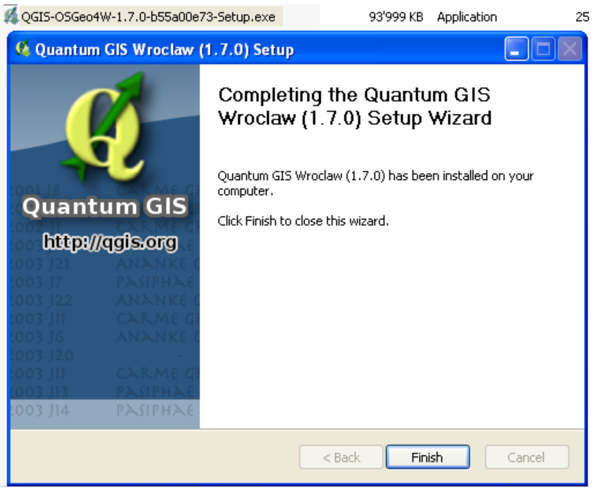
Menu > Item Instructs you to select the named *item* from the named *menu*. Note that some menus contains *sub-menus*. For example ***Start > All programs > Quantum GIS Wroclaw > Quantum GIS (1.7.0)*** is equivalent to the figure below:



>> instructs you to look on the figure on the right for the parameters to be applied.

QGIS and GRASS installation

QGIS and GRASS can be installed at once, including a plugin that will connect them. To do so simply download and install the Windows ***Standalone Installer*** from http://www.qgis.org/wiki/Download (also available in the ***Software*** folder of the training DVD) using the default options and without adding components. Shortcuts will be created on the Desktop and Windows main menu.


QGIS-OSGeo4W-1.7.0-b55a00e73-Setup.exe 93'999 KB Application 25

Quantum GIS Wroclaw (1.7.0) Setup

Completing the Quantum GIS Wroclaw (1.7.0) Setup Wizard

Quantum GIS Wroclaw (1.7.0) has been installed on your computer.

Click Finish to close this wizard.

Before to start

Copy locally (in you computer) the content of the training DVD and look at the way the data are organised.

In the ***Documents*** folder you will find the digital version of this documents as well as other relevant documentation.

In the ***Software*** folder you will find the installation files for QGIS and LibreOffice, as well as some files potentially useful.

In the ***GIS*** folder are located the data you will need during the training. The subfolders are organised by session, Coordinate Reference System (CRS, equivalent to projection) and data type.

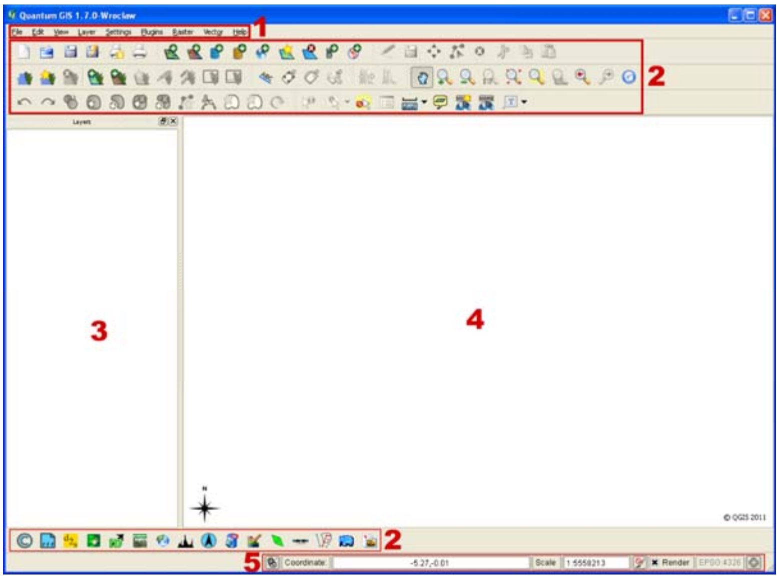
The folder ***GIS_correction*** is equivalent to the GIS folder but once the training has been completed in the case you missed one session or would like to compare your results.

Customizing QGIS

Start QGIS, by default you get a *QGIS Tips!* window every time you start the application. Even if it is a good source of information you can switch it off by checking the ***I've had enough tips,…*** checkbox to remove it from the start up.

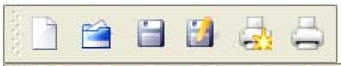
The QGIS graphical interface is divided in 5 zones:

1 Menu bar,
2 Toolbars facilitate the access to the different functions (also available in the menu bar),
3 Table of Content (ToC) to manage the layers,
4 View, where you can interact with the map,
5 Status bar where you can see information such as coordinates of the pointer, extent, scale, coordinate system; start/stop rendering or define how the view is displayed.

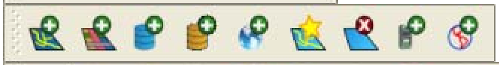


Toolbars are divided by thematic (greyed icons means they are inactive because the appropriate conditions to use them are not fulfilled). Some of them are included by default in QGIS, some others can be added/removed from the interface:

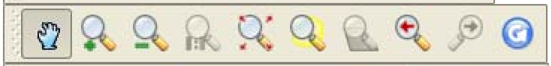
File



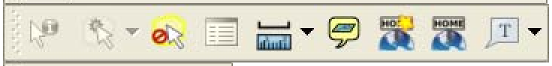
Manage Layers



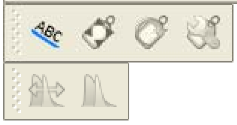
Map Navigation



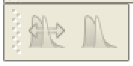
Attributes



Label



Raster

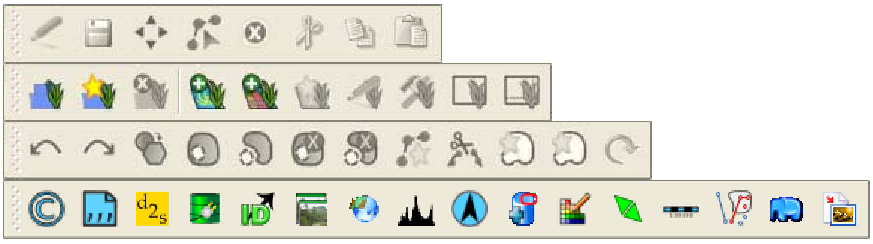


Digitizing

GRASS plugin

Advanced Digitization

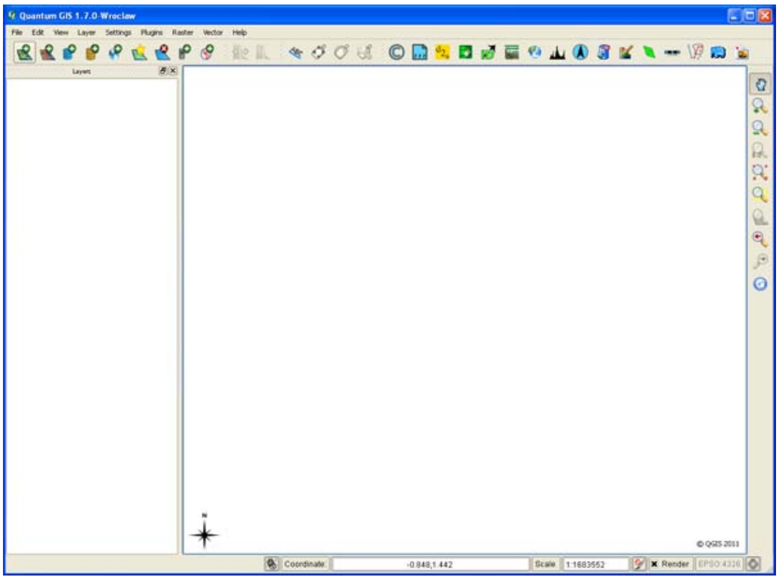
Plugins



We will not describe here the functionalities of each function, some of them will be used during this training, and you will discover the remaining one on your own as long as you practice.

The toolbars can be added/removed from the interface by *right clicking* in any empty area of any toolbar or menu and enable/disable them. They can also be moved using *drag and drop*. The Figure on the right shows the way I generally organize my interface in order too keep it functional. Even if it fits my personal needs, try to get something similar and you will improve it little by little.

Once you get something satisfying, close QGIS and start it again, as you can see the interface remains as you arranged it.



You can see the plugin toolbar remains quite overcrowded, let's remove the plugins that we will not need frequently:

- ***Plugins*** > ***Manage Plugins…***,
- Uncheck the unnecessary plugins (see the following list with the plugins I generally keep): ***Add Delimited Text Layer***, ***CopyrightLabel***, ***NorthArrow***, ***Plugin Installer***, ***ScaleBar***, ***fTools***.

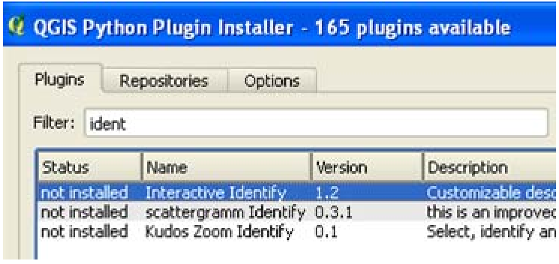
The disabled plugins will remain installed in QGIS, where they can be activated when needed (do not hesitate to use the ***Filter*** function to find more easily the plugin you are looking for). The enabled plugins will be available through the *Plugins* menu or specific menu some other through the *Plugin* toolbar.

<u>Take some time to discover the various functions available through the interface.</u>

We just saw how to enable or disable the plugins installed by default in QGIS, lets see now how we can add more functionalities:

- ***Plugins*** > ***Fetch Python Plugins…***,
- Have a quick look at the official plugins available (6 at the time of writing this document),
- Move to the ***Repositories*** tab, click the ***Add 3rd party repositories*** button, and accept the disclaimer window (do not worry if you can not fetch all repositories, it happens some times).

- Move to the ***Options*** tab, and check the ***Show all plugins, even those marked as experimental*** radio button (even if “unsecure” this option is necessary at the time of writing this document to get all the functionalities for the *Raster* menu),
- Move back to the ***Plugins*** tab and notice you have now more than 170 plugins available and the ***GdalTools*** is now upgradable,
- You can upgrade it simply by selecting it and clicking the ***Upgrade plugin*** button (you do not need to restart QGIS yet as requested).
- Have a quick look at the plugins available and try to install the ***Interactive Identify*** plugin using the ***Filter***,
- ***Close*** the window.

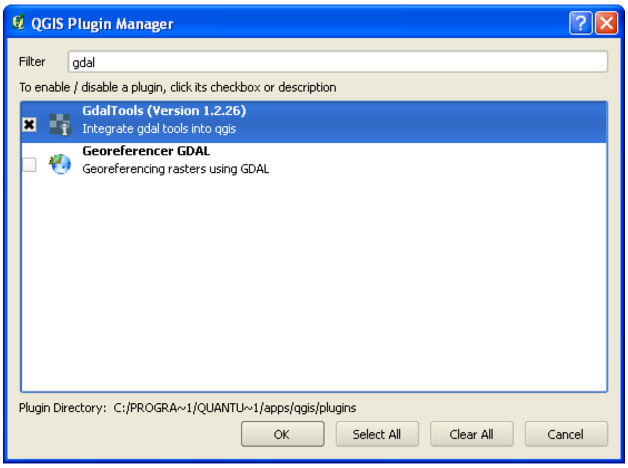


Filter: ident

Status	Name	Version	Description
not installed	Interactive Identify	1.2	Customizable desc
not installed	scattergramm Identify	0.3.1	this is an improvec
not installed	Kudos Zoom Identify	0.1	Select, identify an

Before to go further we need to complete the *Raster* menu, by enabling the ***GdalTools*** plugin!!!

Notice how the plugins have been installed on the *Plugins* menu and toolbar. Each plugin displays differently in QGIS interface, then sometime you will have to search for them!



Filter gdal

To enable / disable a plugin, click its checkbox or description

☒ GdalTools (Version 1.2.26)
Integrate gdal tools into qgis

□ Georeferencer GDAL
Georeferencing rasters using GDAL

Plugin Directory: C:/PROGRA~1/QUANTU~1/apps/qgis/plugins

To complete this chapter let’s customize a bit the QGIS *Options* the way (in my personal opinion) they should be by default:

- ***Settings*** > ***Options…***,
- ***General*** tab: check ***Display classification attribute names in legend***,
- ***Map tools*** tab: set the *Mouse wheel action* to ***Zoom to mouse cursor***,
- ***Digitizing*** tab: check ***Show markers only for selected features***,
- ***CRS*** tab: select ***EPSG:3448 - JAD2001 / Jamaica Metric Grid*** (supposing you are mainly working in Jamaica) as the ***Default Coordinate System for new projects***,
  check the ***Enable ‘on the fly’ reprojection by default***,
  and set the ***Prompt for CRS*** radio button,
- In the case the default interface language is not the appropriate one, you can ***Override system local*** (in other words change the interface language) in the ***Locale*** tab (this change will be applied the next time you start the application).
- Finally press the ***OK*** button and close QGIS.

Introduction to QGIS

This session will quickly present the QGIS interface and functionalities. Do not hesitate to explore the interface and discover by yourself the different menus and tools available.

Start QGIS again and notice how the default coordinate system has been set to EPSG:3448 (on the right of the status bar). In the case you need to change the coordinate system, you can press the button (or ***Settings*** > ***Project Properties***).

Now let's open some layers:

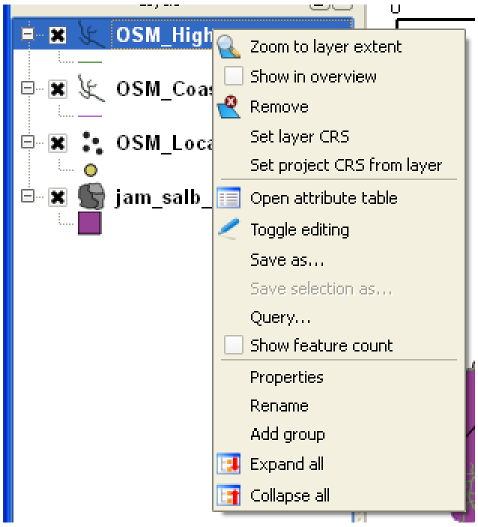
- ***Layer*** > ***Add Vector Layer…*** (or),
- Click the ***Browse*** button,
- Set the *Files of type* to ***ESRI Shapefiles [OGR]***,
- Select the 3 ***OSM_*.shp*** files (using the ***Shift*** button) in ***…\GIS\1_Introduction\JAD2001\Vector*** and click the ***Open*** button twice.

The 3 layers your added are issued from OpenStreetMap project (http://www.openstreetmap.org/) and have been downloaded for the all Jamaica from http://downloads.cloudmade.com/americas/caribbean/jamaica (*jamaica.shapefiles.zip*).

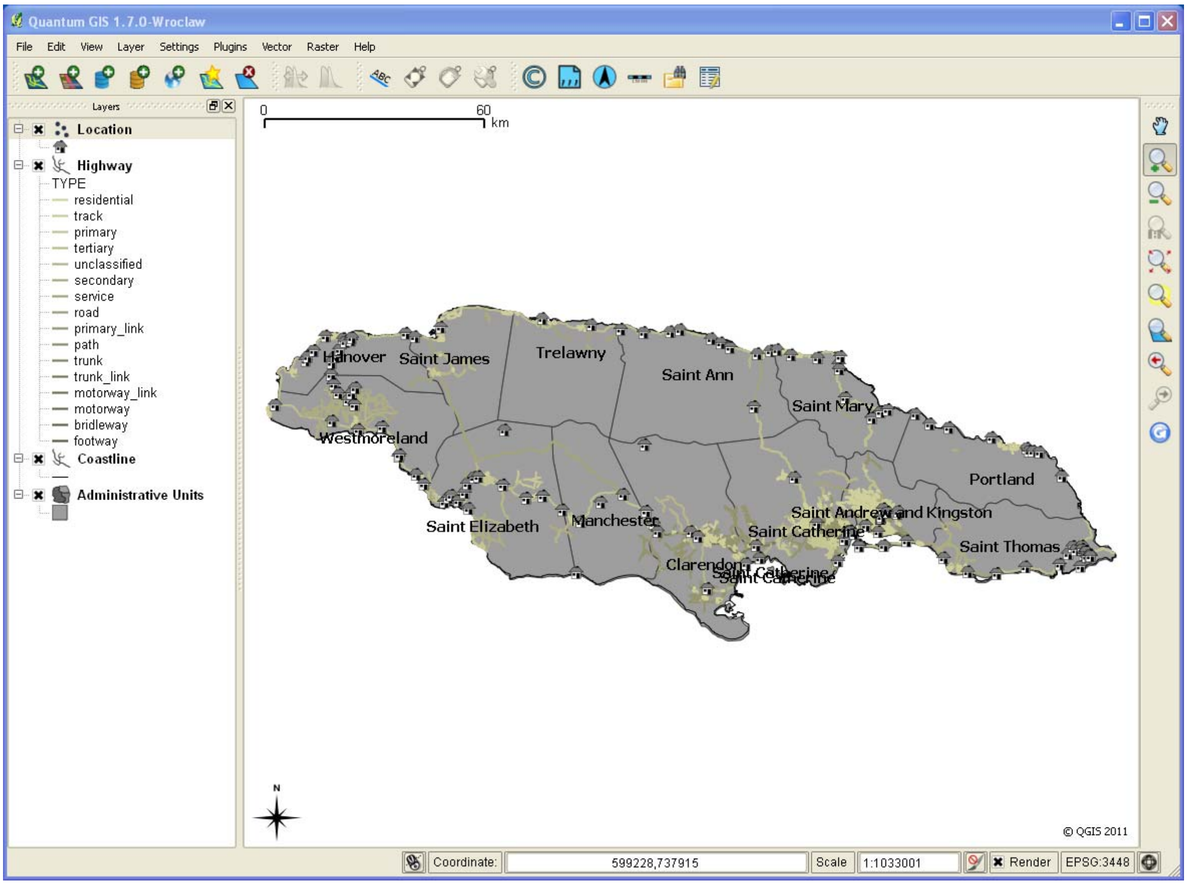
Add now a polygon layers containing the 2nd level administrative extent of Jamaica (http://www.unsalb.org/): ***…\GIS\1_Introduction\WGS84\Vector\jam_salb_jan00-aug09.shp***.

As the polygon layer hide the others layers, *drag and drop* it to the bottom of the Table of Content (ToC).

Explore for a while the *context menu* of the layers in the ToC (*right click*), visualizing the *attribute table* and customizing the way the layers are displayed through the *Properties*.

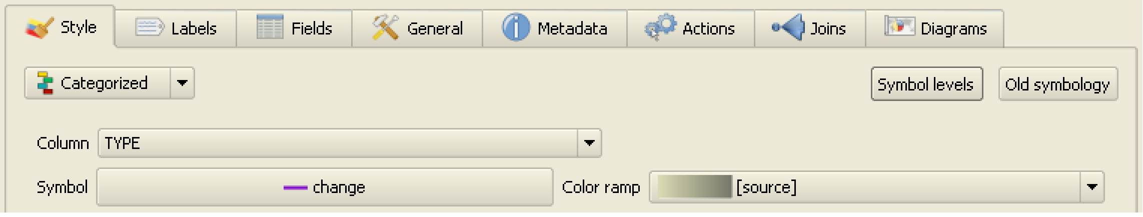


Try to get something similar to the figure below.



Here are some guidelines:

- Open the ***Properties*** of a layer (*double click* in the ToC), you can rename it in the General tab. While you are here look at the CRS of each layer and notice the efficiency of the "on the fly" reprojection.
- You can change the way the layers display with the Style tab.
- In the same tab you can ***Categorize*** the ***Highway*** layer per ***TYPE***, and create a ***New color ramp*** (do not forget to press the ***Classify*** button each time you change a *Style* parameter!).



Categorized

Column TYPE

Symbol change

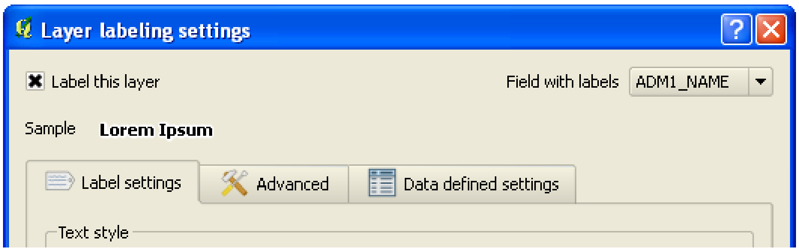
Color ramp [source]

- You can use ***SVG*** marker (or fill) through the ***Change*** buttons.
- As an exercise you can display the ***Administrative Units*** labels through the Labels tab (do not forget to check the ***Display labels*** checkbox.

What do you think about the result? I personally get frustrated by the way the labels are displayed. For this reason I prefer to use the ***Label*** toolbar:

- Uncheck the ***Display labels*** box in the ***Administrative Units Properties*** if necessary,
- Then click on the ABC button on the *plugin toolbar* (enable the plugin if necessary) when the *Administrative Units* layer is selected,

- Set the label parameters.


Layer labeling settings

☒ Label this layer

Field with labels: ADM1_NAME

Sample: Lorem Ipsum

Do not forget to save you project very often!

Let's add a raster layer now (Digital Elevation Model from SRTM):

- ***Layer*** > ***Add Raster Layer…*** (or 🖼),
- Try to locate ESRI GRID or similar *type of File*. You will not find it, then set this parameter to ***[GDAL] All files***,
- Select ***...\GIS\1_Introduction\WGS84\Raster\srtm_jam\w001001.adf*** and click the ***Open*** button.

It is important to remark two things:

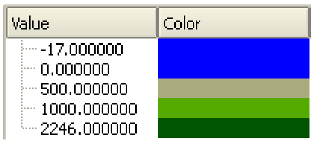
- the name of the layer in the ToC is *w001001*, then it will be difficult to find the right layer in the case you add several ESRI grid (as they all will be named by default *w001001*),
- As the raster is provided in the WGS84 coordinate system (see the ***General*** or ***Metadata*** tab of the properties of the layer), the layer is transformed 'on the fly'.

Consequently it is wise to convert the raster in a more "open" format (e.g. GeoTiff), and in the project projection (JAD2001) as "on the fly reprojection" requires a lot of processing power:

- ***Raster*** > ***Warp (Reproject)***,
- *Input file*: ***w001001***,
  Output file: ***...\GIS\1_Introduction\JAD2001\Raster\SRTM_JAM.tif***,
  Target SRS: ***EPSG:3448*** (notice how useful is the *Recently used coordinate references systems* section!),
  check the ***Load into canvas when finished box***,
- Then press the ***OK*** button, and ***Close*** all windows,
- Remove ***w001001*** from the ToC, move the new raster at the bottom of the ToC and set the ***Administrative Units*** invisible to see the raster.

Let's customize this layer with the common ***Layer Properties*** function:

- ***Style*** tab: Set the *Color map* to ***Colormap***,
- Move to the ***Colormap*** tab: Set the *Number of entries* to **5** and click the ***Classify*** button.
- Change the ***Value*** and the ***Color*** of each category by double clicking them.

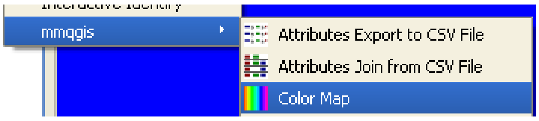


Value	Color
-17.000000	🟦
0.000000	🟦
500.000000	🟫
1000.000000	🟩
2246.000000	🟩

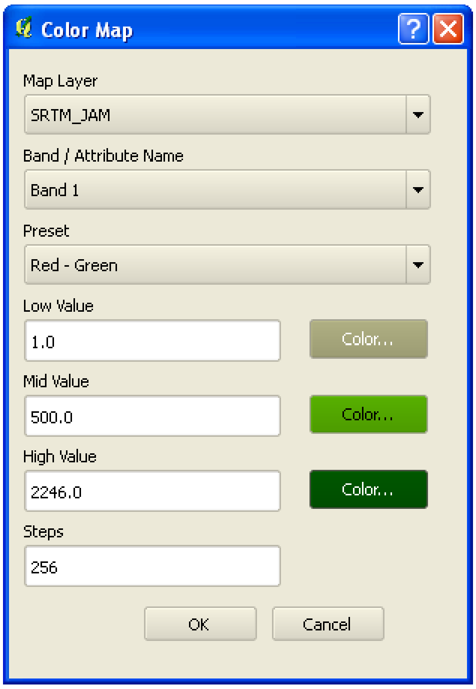
If this way is convenient when you need to display a few categories, it would be too long to set up a nice elevation color map with tens of categories. Then we have to use a plugin named ***mmqgis*** (to be installed with the ***Fetch Python Plugins…*** function). Once installed this plugin is available through the ***Plugin*** menu.

On Windows this plugin need a folder named *c:\tmp*, then create it if you get an error message.

The ***Color Map*** function of ***mmqgis*** allows to apply a blend of 3 colours legend, and to fix manually the threshold values for rasters AND vectors.



Unfortunately the plugin does not automatically detect the minimum and maximum values to render, then you will have to get them yourself through the ***Metadata*** tab of the layer ***Properties***. Try to generate a legend such at the one in the next figure.



Map Layer: SRTM_JAM

Band / Attribute Name: Band 1

Preset: Red - Green

Low Value: 1.0

Mid Value: 500.0

High Value: 2246.0

Steps: 256

To avoid displaying the ocean, set the ***No data value*** to 0 in the ***Transparency*** tab of the layer ***Properties***.

<u>In the case the new display is not updated in the *View*, you need to click on the *Apply* button, of the *Colormap* tab (layer Properties).</u>

To complete this session we will consolidate the QGIS project by reprojecting the only layer who displays through the ***'on the fly' CRS transformation*** function:

- Right click on ***Administrative Units***,
- ***Save as…***,
- *Save as*: ***...\GIS\1_Introduction\JAD2001\Vector\SALB.shp***, *CRS*: ***JAD2001 / Jamaica Metric Grid***,
- Click twice the ***OK*** button and replace the ***Administrative units*** layer by the new one.

Before to close this session let's have a look at how QGIS store projects. In a text editor (e.g. notepad) open the .qgs file you just created and look at the structure of the file in general and the way it store the data in particular.

The projects are stored using common XML format, absolute paths to the layers are stored with the ***datasource*** tag. It means several things:

- The layers are not included in the .qgs file,
- When you share a project you need to copy the .qgs file AND ALL the layers in the project and store them <u>in the same location</u> in the host computer.

In order to facilitate things, you can save QGIS projects with <u>relative paths</u>. This way the project and the data can be moved to any location or any computer as long as the structure of all files remains the same. To do so:

- Close the notepad and open your project in QGIS,
- ***Settings*** > ***Project Properties***, set the *Save paths* options (***General*** tab) to ***relative***,
- Close all windows, save and close again your project,
- Open the .qgs file in the notepad and check the difference in the ***datasource*** tags.

Unfortunately the option to use relative paths can not be set as a default parameter, then <u>it has to be changed every time you create a new project</u>.

A rescue solution in the case you receive one project with absolute paths who do not fit your computer structure is in a text editor to ***replace*** automatically the wrong path by the appropriate one in the .qgs file (do not forget to save a copy before to do so).

Population distribution

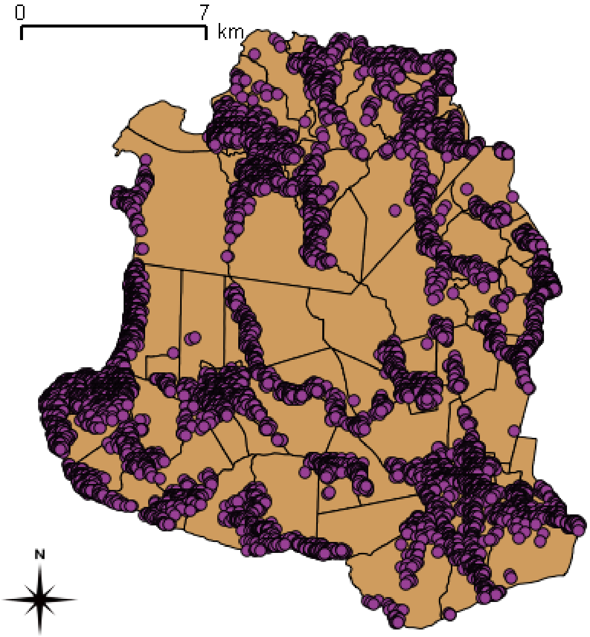
One basic data need when analysing physical exposure is to know precisely where the population is located. Unfortunately, global population distribution model remains too coarse for an analysis at the scale of the RiVAMP project. Then we need to process a population distribution grid by combining the census data with the location of the buildings in the Area of Interest (AOI).

Load and explore the data

Load all the ***.shp*** data in ***...\GIS\2_Population_Distribution\JAD2001\Vector***. As the *Negril_Census_2001* layer does not contain any projection information QGIS should ask you to define one (*JAD2001*).

Now you should have in your project:

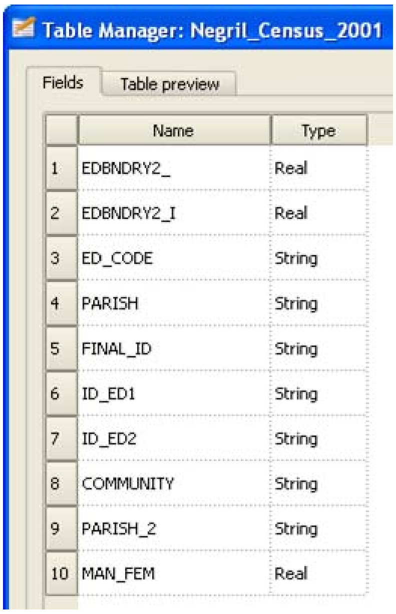
- *Negril_Census_2001*: Unofficial population 2001 data,
- *Negril_random_buildings*: Building locations randomly relocated within a 200 meter resolution grid for copyright reasons.



Generate the population distribution raster

As a preliminary step we need to remove the unnecessary information from *Negril_Census_2001* attribute table (lighter process and easier to control). To do so we need to install the ***Table Manager*** plugin (available from the ***Plugins*** menu or):

- Select ***Negril_Census_2001*** in the ToC, then start the plugin,
- Select all fields except the few visible in the figure on the right, press the ***Delete*** button and accept the deletion,
- Save as…: ***...\GIS\2_Population_Distribution\JAD2001\Vector\Census_2001.shp***,
- Set up the ***JAD2001*** projection and ***Close*** the window.



	Name	Type
1	EDBNDRY2_	Real
2	EDBNDRY2_I	Real
3	ED_CODE	String
4	PARISH	String
5	FINAL_ID	String
6	ID_ED1	String
7	ID_ED2	String
8	COMMUNITY	String
9	PARISH_2	String
10	MAN_FEM	Real

The new layer is automatically added to the project, then you can remove *Negril_Census_2001* as it will no be needed anymore.

Now we will count the number of building in each census unit:

- ***Vector*** > ***Analysis Tools*** > ***Points in polygon***,
- If you have only the two necessary layers loaded, just define the Output Shapefile as ***…\GIS\2_Population_Distribution\JAD2001\Vector\Census_2001_cnt.shp***,
- ***OK*** > ***OK*** > ***Yes*** > ***JAD2001*** > ***OK*** > ***Close*** (optionally you can remove *Census_2001)*,

Do not worry about the warning message saying the CRS are different, it is simply because JAD2001 projection is quite rare and QGIS attributes a custom CRS instead of an "official" one.

- Open the ***Attribute table*** of the new layer and check the validity of the values (minimum, maximum and visually) you just generated.

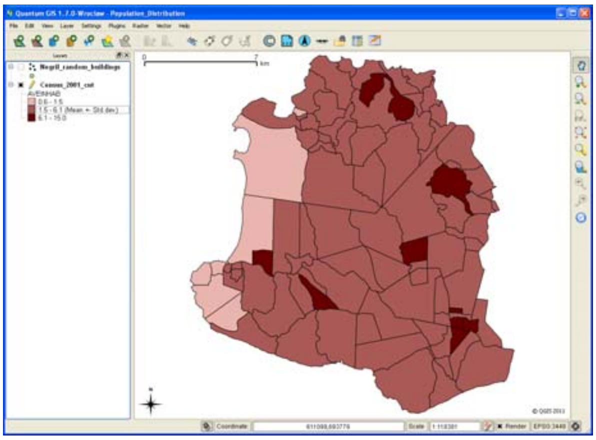
Let's calculate the average number of inhabitant per building and census unit:

- Open ***Census_2001_cnt*** attribute table,
- Switch to the Editing mode using ✎ button,
- Start the ***Field calculator*** with the 🖩 button,
- Create a *New field*: ***AVEINHAB***, ***Decimal number***, ***5***, ***1***,
- Apply the following formula: ***MAN_FEM / PNTCNT*** > ***OK***,
- Switch off the Editing mode (✎) > ***Save*** and close the attribute table.

This time let's have a deeper look at the data we generated (in order to avoid surprises coming from erroneous values further in the process):

- ***Vector*** > ***Analysis Tools*** > ***Basic statistics***,
- ***Census_2001_cnt***, ***AVEINHAB*** > ***OK***,

Values vary between 0,6 and 15,0 with a mean around 3,8 and a standard deviation of 2,3. Without surprise the figure in the right shows that the beach has the lowest values when the populated places have the highest values (as the census data does not include tourists).

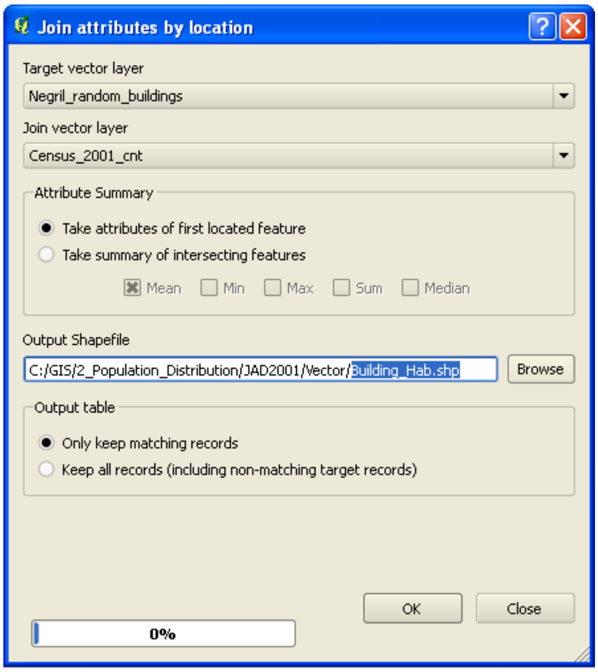

Quantum GIS 1.7.0-Wroclaw - Population_Distribution
Layers
Negril_random_buildings
Census_2001_cnt
AVEINHAB
0.6 - 1.5
1.5 - 6.1 (Mean +- Std dev)
6.1 - 15.0

Now transfer the average number of people leaving in habitations to the building layer through a spatial link:

- ***Vector*** > ***Data Management Tools*** > ***Join attributes by location >>***,

Add the layer to the display and optionally remove ***Negril_random_buildings***.

Using the ***Table Manager*** plugin, remove all fields except ***AVEINHAB*** then ***Rename*** the remaining field as ***HAB*** (otherwise the field name will become too long in the next join action) and ***Save***.



Join attributes by location

Target vector layer
Negril_random_buildings

Join vector layer
Census_2001_cnt

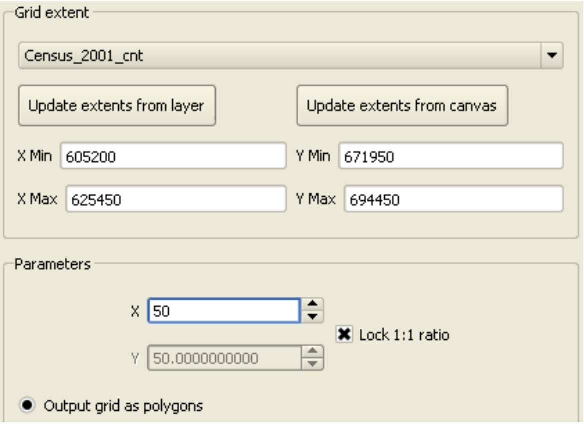
Attribute Summary
● Take attributes of first located feature
○ Take summary of intersecting features
☒ Mean □ Min □ Max □ Sum □ Median

Output Shapefile
C:/GIS/2_Population_Distribution/JAD2001/Vector/Building_Hab.shp

Output table
● Only keep matching records
○ Keep all records (including non-matching target records)

We need now to create a vector grid of 50 meter resolution to aggregate the information by "cell" (even if we are still in vector format):

- ***Vector*** > ***Research Tools*** > ***Vector grid***, *Grid extent*: ***Census_2001_cnt,*** ***Update extents from layer*** button, Round the X and Y values to 50 meter and set a 50 meter resolution (but this value can be increased if your computer is a little weak) Save the Output shapefile as ***…\GIS\2_Population_Distribution\JAD2001\Vector\VGrid_50m.shp***, ***OK*** > ***Yes*** > ***Close***.
- Check visually the vector grid covers fully the Census layer.



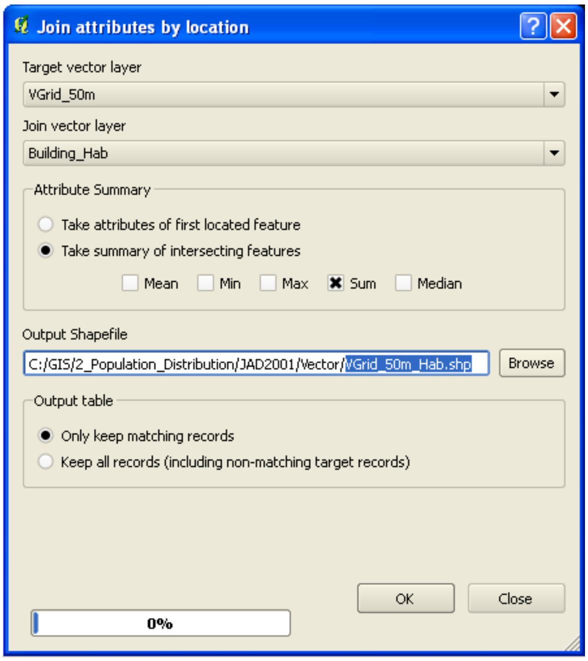
Grid extent
Census_2001_cnt

X Min 605200 Y Min 671950
X Max 625450 Y Max 694450

Parameters
X 50
Y 50.0000000000
☒ Lock 1:1 ratio
● Output grid as polygons

Finally let's combine the virtual grid with the number of inhabitant through a spatial link:

- ***Vector*** > ***Data Management Tools*** > ***Join attributes by location >>***,



Join attributes by location

Target vector layer
VGrid_50m

Join vector layer
Building_Hab

Attribute Summary
○ Take attributes of first located feature
● Take summary of intersecting features
□ Mean □ Min □ Max ☒ Sum □ Median

Output Shapefile
C:/GIS/2_Population_Distribution/JAD2001/Vector/VGrid_50m_Hab.shp

Output table
● Only keep matching records
○ Keep all records (including non-matching target records)

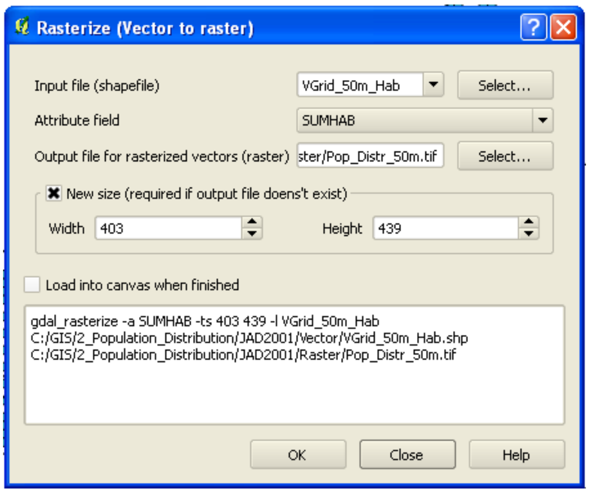
The number of people leaving in each “cell” will be automatically stored in a field named ***SUMHAB***.

As we are at the end of the process we need to estimate the error of our model, a simple way to do it is simply to sum and compare the fields ***MAN_FEM*** and ***SUMHAB*** in the layers ***Census_2001_cnt*** and ***VGrid_50m_Hab*** respectively (Using ***Vector*** > ***Analysis Tools*** > ***Basic statistics***). That makes an error of 33 inhabitants in a total of 40,215!

To conclude we will convert the virtual grid into a true raster but because the rasterization function in QGIS will ask the number of columns and rows we need to calculate them before to start:

- Get the metadata of ***VGrid_50m_Hab*** and divide the difference of extensions by 50 meter in X and Y (in my case X: (625400-605250)/50 = ***403***, Y: (694150-672200)/50 = ***439***

- ***Raster*** > ***Rasterize (Vector to raster) >>***
- Check the output raster overlays perfectly with the vector as well as the higher and lower values seem logically located.



Input file (shapefile) VGrid_50m_Hab

Attribute field SUMHAB

Output file for rasterized vectors (raster) ster/Pop_Distr_50m.tif

☒ New size (required if output file doens't exist)

Width 403 Height 439

□ Load into canvas when finished

```
gdal_rasterize -a SUMHAB -ts 403 439 -l VGrid_50m_Hab
C:/GIS/2_Population_Distribution/JAD2001/Vector/VGrid_50m_Hab.shp
C:/GIS/2_Population_Distribution/JAD2001/Raster/Pop_Distr_50m.tif
```

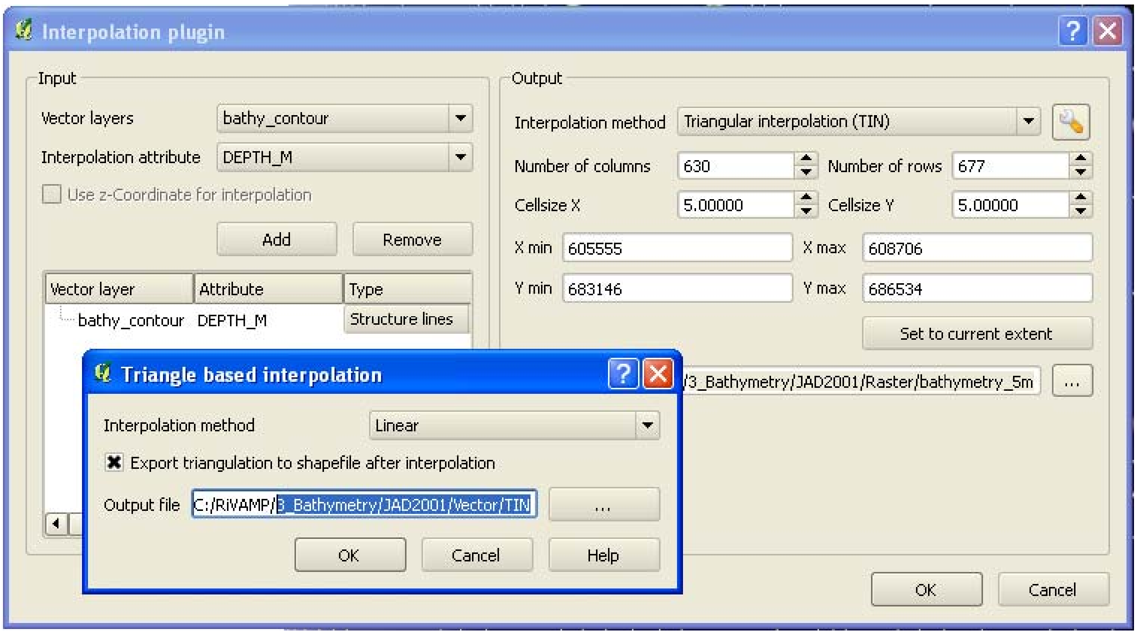
Bathymetry

QGIS offers several functions to interpolate a raster from vectors. The most easily accessible is located in the ***Raster*** menu and is called ***Grid (Interpolation)***. Unfortunately this function can process only point layers. As we have bathymetric contour lines (sample dataset extracted from a dataset provided by Smith and Warner International) we prefer to use a plugin available by default in QGIS and named ***Interpolation plugin*** that allows to use polylines as input, as well as combining *Points*, *Structures lines* and *Break lines*.

Interpolate a raster from contour lines

Start a new QGIS project, check it is in the appropriate CRS (EPSG:3448) load the shapefile available in ***...\GIS\3_Bathymetry\JAD2001\Vector*** and save the project.

Then enable the ***Interpolation plugin*** and start it from the ***Plugins*** toolbar or menu and set it up as in the figure below (using a 5 meter resolution)



Interpolation plugin

Input

Vector layers: bathy_contour

Interpolation attribute: DEPTH_M

☐ Use z-Coordinate for interpolation

Vector layer	Attribute	Type
bathy_contour	DEPTH_M	Structure lines

Output

Interpolation method: Triangular interpolation (TIN)

Number of columns: 630 Number of rows: 677

Cellsize X: 5.00000 Cellsize Y: 5.00000

X min: 605555 X max: 608706

Y min: 683146 Y max: 686534

Output file: /3_Bathymetry/JAD2001/Raster/bathymetry_5m

Triangle based interpolation

Interpolation method: Linear

☒ Export triangulation to shapefile after interpolation

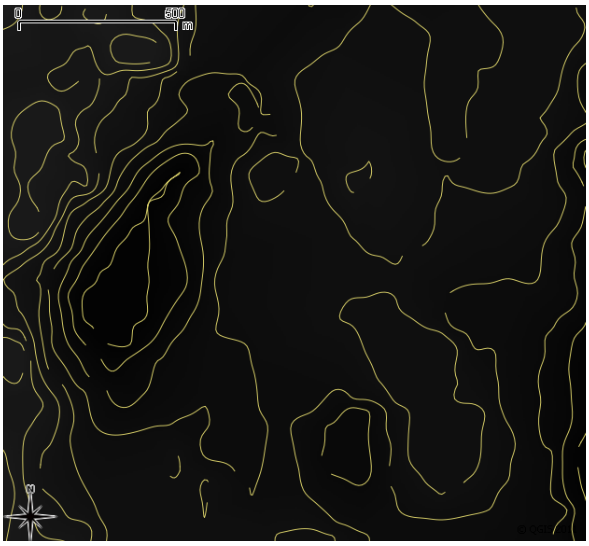
Output file: C:/RiVAMP/3_Bathymetry/JAD2001/Vector/TIN

You could also use the second ***Interpolation method*** available (***IDW***) but after several tests, it appears it a several negative points:

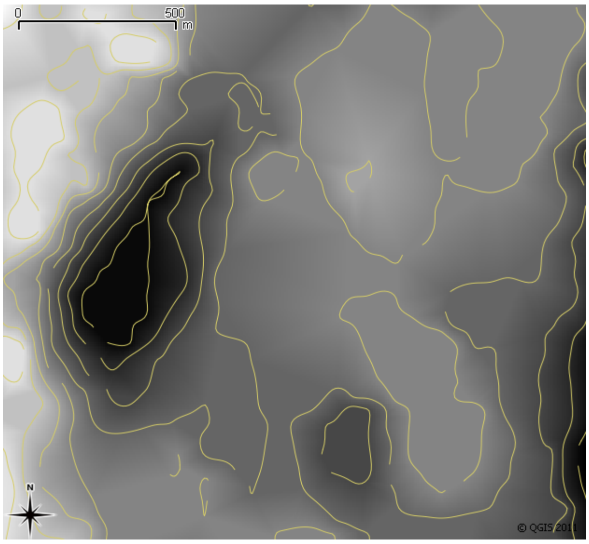
- The processing is much longer (3 min 30 sec, instead of a few seconds with the *TIN* method),
- With the default parameters, artefacts appear along the contour lines. They can be reduced by increasing the ***Distance coefficient P***, but a “stairs” artefact persist,
- The raster extent is rectangular.

The output raster is automatically added to the project with the name ***Interpolation***. I personally prefer to remove it and add it manually with its proper name (***bathymetry_5m***) in order to keep a clear relation between the ToC and the data.

You probably get a uniform grey raster. To solve this issue, select the raster in the ToC and use the or buttons from the ***Raster*** toolbar to ***Stretch*** the histogram (the first one on the full dataset, the second on the visible part, see figures below).



Full stretch

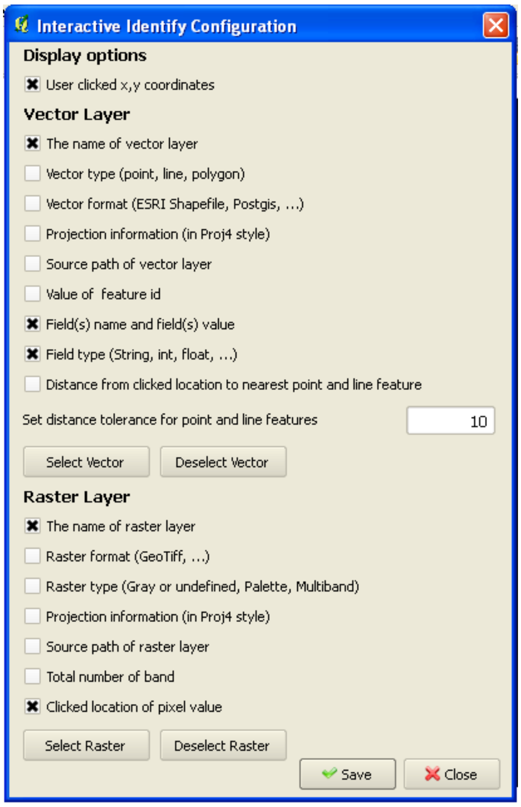


Local strech

Optionally you can add the TIN shapefile to the project to visualize the way the TIN algorithm works.

Try to use the ***Interactive Identify*** plugin (the plugin you should have installed during the introduction session) by clicking the button and then clicking on the *View*.

You should get an error message. Close the Python error window and access the ***Interactive identify configuration*** window through the button. By default this tool gives a lot of information and it seems some of them are bugged. I am personally just interested in getting the value of the selected layers in a given position, then I configure it like in the figure on the right. This way you should not get an error anymore.



Interactive Identify Configuration

Display options

☒ User clicked x,y coordinates

Vector Layer

☒ The name of vector layer
☐ Vector type (point, line, polygon)
☐ Vector format (ESRI Shapefile, Postgis, ...)
☐ Projection information (in Proj4 style)
☐ Source path of vector layer
☐ Value of feature id
☒ Field(s) name and field(s) value
☒ Field type (String, int, float, ...)
☐ Distance from clicked location to nearest point and line feature

Set distance tolerance for point and line features: 10

Raster Layer

☒ The name of raster layer
☐ Raster format (GeoTiff, ...)
☐ Raster type (Gray or undefined, Palette, Multiband)
☐ Projection information (in Proj4 style)
☐ Source path of raster layer
☐ Total number of band
☒ Clicked location of pixel value

Let’s imagine a partner ask you to provide you with a bathymetric data at 10 meter resolution in a “rustic” format such has xyz:

- ***Raster*** > ***Translate (Convert format)***,
  Output file: ***bathy_pts_10m.xyz***,
  Outsize: ***50%*** (this way the raster will be aggregated from 5 to 10 meter resolution)
- By default the no data pixels have a value of -9999, then to correctly display this layer you have to set up the ***No data value*** to ***-9999*** in the ***Transparency*** tab of the ***Properties*** of the layer.

Flooded area exposure

The aim of this session is firstly to define the land areas potentially exposed to floods due to tropical cyclones and secondly to estimates the population and assets that will be affected.

To do so, we will first use an aggregated version (for copyright reason) of the Digital Elevation Model (DEM) provided by Jamaican Government, and the maximum elevation of wave height calculated during the wave modelling for two return period (10 and 50 years). Then we will use the population distribution raster we created in a previous session, as well as an assets location layer provided by Jamaican Government.

Identify the flooded areas

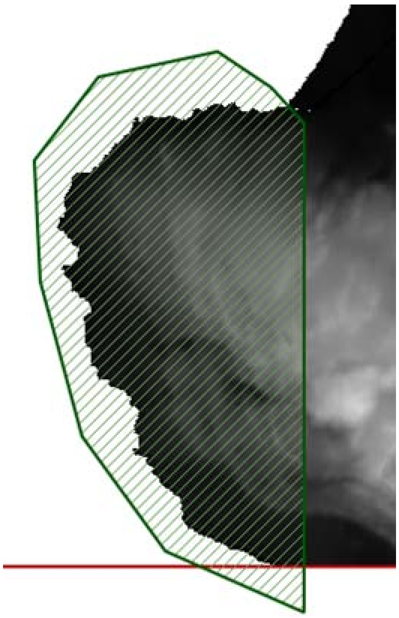
To delineate the flooded area we will reclassify the DEM on the base of the values in the table below (corresponding to the maximum simulated wave height).

	10 yrp	**50 yrp**
Beach	3.6 m	6.7 m
Cliff	7.5 m	8.0 m

Create a new project, add it the DEM (***...\GIS\4_Flood_Exposure\JAD2001\Raster\DEM_12m.tif***) and save the project.

As the elevation of the wave vary between the beach and cliff shoreline we need to create a mask that will delineate both areas:

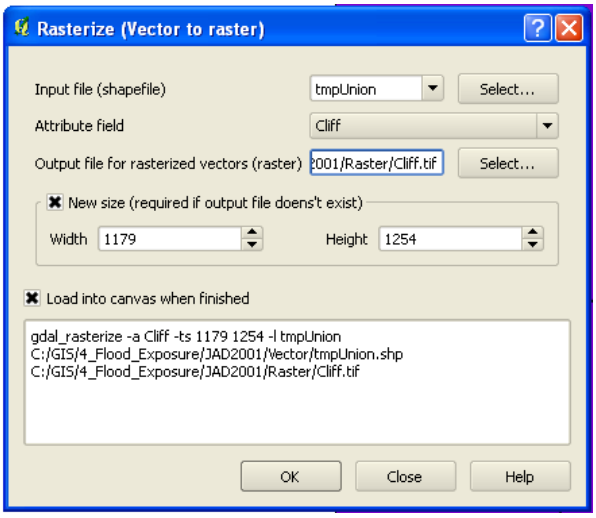
- ***Vector*** > ***Research Tools*** > ***Polygon from layer extent***,
- Save the Output polygon shapefile as: ***...\GIS\4_Flood_Exposure\JAD2001\Vector\tmpAOI.shp*** and add it to the project,
- Zoom to the cliff area, create a new ***Polygon*** shapefile (named ***tmpCliff***) with the ☆ button,
- Edit the layer (✎) and draw (⬠) the cliff area according to the figure on the right (right click to close the polygon), stop editing and save,
- Then Union the two vector layers (***Vector*** > ***Geoprocessing Tools*** > ***Union***), save the layer as ***tmpUnion***, and add it to the project (optionally you can remove the two other vector layers),
- Open the Attribute table, edit it, remove the record containing the little polygon outside the Area Of Interest (AOI),



- With the ***Field calculator***, create a new field (***Cliff***, ***Whole number***, ***2***), set the value to ***1*** in the cliff area and to ***0*** in the remaining area, ***Save*** the changes and ***Close*** the attribute table.

- Open the ***Metadata*** tab of the raster and write down on a paper the number of columns and rows (it should be X: 1179 Y: 1254),
- Then Rasterize the vector layer (***Raster*** > ***Rasterize***) **>>**
  and display it with ***pseudocolors***.

  This way you will have a perfect overlay of both rasters.



Input file (shapefile) tmpUnion Select...

Attribute field Cliff

Output file for rasterized vectors (raster) 2001/Raster/Cliff.tif Select...

☒ New size (required if output file doesn't exist)

Width 1179 Height 1254

☒ Load into canvas when finished

```
gdal_rasterize -a Cliff -ts 1179 1254 -l tmpUnion
C:/GIS/4_Flood_Exposure/JAD2001/Vector/tmpUnion.shp
C:/GIS/4_Flood_Exposure/JAD2001/Raster/Cliff.tif
```

Now let's reclassify the DEM using also the Cliff raster. To do so we will use the *Raster calculator*:

- ***Raster*** > ***Raster calculator***…,
- Apply the following formula: ***(DEM_12m@1 <= 3.6 AND Cliff@1 = 0) * 10***, save the Output layer as ***test.tif*** and apply a ***pseudocolors*** or ***freakout*** colormap to visualize the result.

  The formula can be split in two parts, the first one (*DEM_12m@1 <= 3.6 AND Cliff@1 = 0*) is a conditional statement and will return 1 if the condition is true and 0 if it is false. Then if the elevation is lower or equal to 3.6 meter in the beach area, the result will be 1. The second part corresponds to the factor to be applied on the condition result (1 ** 10* = 10 or 0 ** 10* = 0) in our case 10 correspond to the return period in years. Consequently the output raster should have 3 values: 10 in the flooded area, 0 in other land areas and NULL in ocean where the DEM and/or the cliff raster are also NULL.

- To check the validity of your classification you can use the button, but a better option consist in installing and using the ***ValueTool*** plugin, who will give you the value of each visible raster instantaneously on a Panel.
- The 4 conditions of the table given in the introduction of this session can be combined in a single formula to do the reclassification at once. Apply the next formula in the ***Raster calculator***:
  ((DEM_12m@1 <= 6.7 AND Cliff@1 = 0) * 50) + ((DEM_12m@1 <= 8 AND Cliff@1 = 1) * 50) + ((DEM_12m@1 <= 3.6 AND Cliff@1 = 0) * -40) + ((DEM_12m@1 <= 7.5 AND Cliff@1 = 1) * -40)
- Save it as ***Flooded_Area.tif***:

  What we are doing here is applying first a value of 50 in areas affected by a 50 years return period (yrp) and then subtracting 40 to areas affected by a 10 yrp that will make a 10 value (50-40 = 10). We could also have used a double conditional on the DEM (e.g. > 3.6 AND <= 6.7), but I preferred to keep the equation as short as possible.

- Check the output raster values with the *ValueTool*,
- Create a nice 2 categories ***colormap***, setting the 0 values to transparent.
- Let's vectorize the Flooded_area raster:
  Raster > ***Polygonize*** > ***Flooded_Area.shp***,
  Edit the new vector layer and remove the polygons with a value (*DN*) of 0 (using the *Attribute table* ***Look for*** function and the button), as well as the little patches far inland

that obviously will not be flooded (to make things easier you can install and use the ***selectplus*** plugin).

Compute the exposure

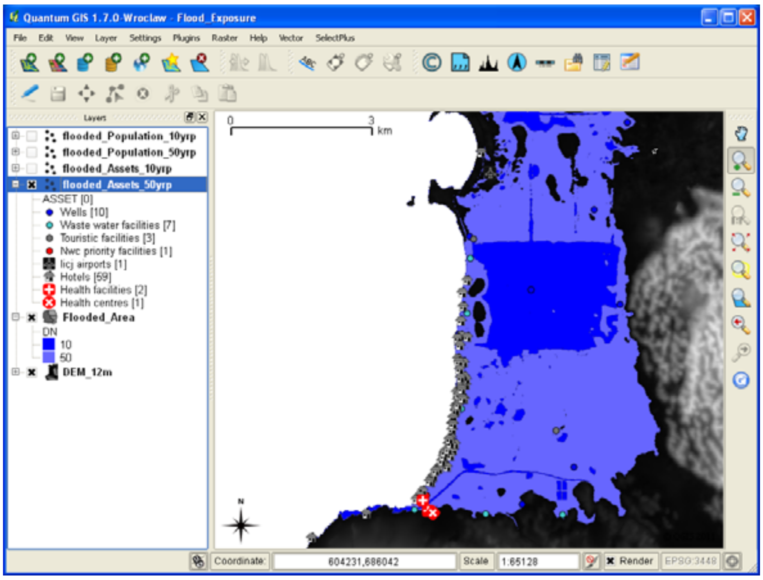
Add to the project the assets and population layers that will be processed. The first one is available at ***...\GIS\4_Flood_Exposure\JAD2001\Vector\assets_pts.shp***. You processed the second one during the Population distribution session (***Buildings_Hab.shp***), you can use you own or a version clipped to the AOI (***...\GIS\4_Flood_Exposure\JAD2001\Vector\Buildings_Hab_clip.shp***).

Using the *Attribute table* ***Look for*** function select all polygons with a value of ***10*** in *Flooded_Area*.

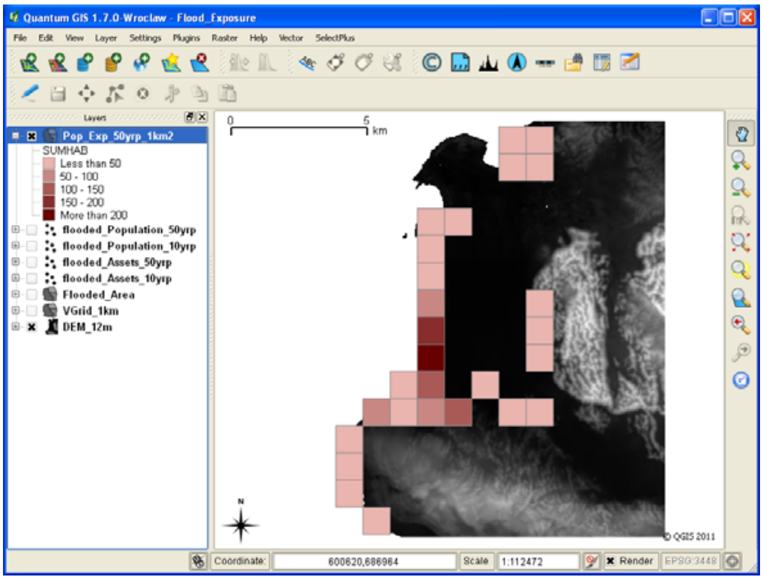
Then clip the two point layers (***Vector*** > ***Geoprocessing Tools*** > ***Clip***) with the flooded area (use *all features* for the 50 yrp, and ***only the selected features*** in *Flooded_area* for the 10 yrp). You will get 4 layers:

- ***flooded_assets_10yrp***
- ***flooded_assets_50yrp***
- ***flooded_population_10yrp***
- ***flooded_population_50yrp***

Assets exposure can be easily synthesized through a map such as on the right showing the number of assets exposed (use the ***Show feature count*** option of the context menu) and their location, but we still need to process a little bit the population exposure.



As we did during the Population distribution session, create a ***Vector grid of 1 km*** and then ***sum*** the exposed population for both return periods for each “cell” of Vector grid and you will get a map such the one below (notice I used the excellent ***Pretty breaks*** *mode* for my classification.



Profile extraction

The aim of this session is to draw profiles perpendicular to the shoreline and extract the environmental and bathymetric parameters that will be used during the *Statistical analysis* training.

Draw the profiles

Create a new project, add it the beach profile layer (***...\GIS\5_Profile_Extraction\JAD2001\Vector\Beach_Profiles.shp***) and save the project.

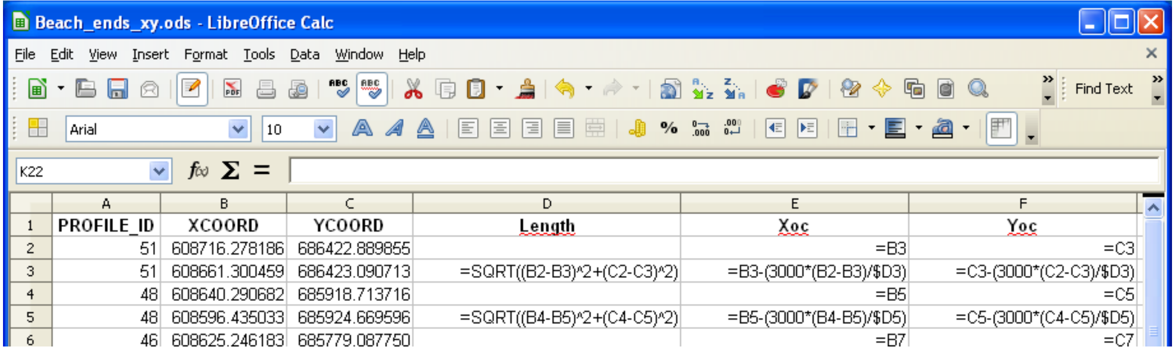
To locate yourself add ***land_classif_negril.shp*** and ***bathy_4m.tif*** in the same folder. As you will notice the style of the land classification layer is already defined as a .qml file with the same name exist, it is automatically used (notice the partial transparency of some categories).

The beach profiles have been acquired and kindly provided by Smith and Warner International (in fact the layer we are using only contains a sample of the full dataset). The eastern ends correspond to the inland limit of the beach, the western ends to the shoreline at the time of the profile acquisition.

First we need to extend the profile toward the ocean but it can not be done completely within QGIS:

- Convert the beach profiles layer to points with the ***Extract nodes*** function of the ***Vector*** menu > ***Beach_ends.shp***,
- Then add the nodes coordinates to the attribute table with the ***Export/Add geometry columns*** of the same menu > ***Beach_ends_xy.shp***,
- Do not forget to save your project before to start a spreadsheet editor (in our case with LibreOffice Calc (installation file available in the ***Software*** folder of the training DVD, you need to close QGIS during the installation)),
- Within LibreOffice Calc open the attribute table of the last layer > ***...\GIS\5_Profile_Extraction\JAD2001\Vector\Beach_ends_xy.dbf***,
  and save the table as ***Beach_ends_xy.ods***
- In order to facilitate the reading of the table Rename the 3 headers in row #1 to ***PROFILE_ID***, ***XCOORD***,***YCOORD***,
- Each profile fit in two rows, in general the second one corresponds to the shoreline end, but we need to make sure of that.
  Write the following formula in cell ***D3*** and copy it until the bottom of the dataset.
  =IF(A3=A2,IF(B2>B3,0,1),0)
  This formula will return a "***1***" in the case the X coordinate value of the second point of a profile is higher than the first one (meaning the ends are inversed),
  Check if you have any ***1*** value (in this case you should inverse the rows of a given profile,
  When it is done you can delete the ***D*** column,
- Let's use Pythagoras theorem to calculate the oceanic end for ***3 kilometres*** (3000 metres) extension of each profile into the ocean,
  Add three headers in the column D, E and F (respectively ***Length***, ***Xoc***, ***Yoc***,
  In cell ***E2*** add the formula: ***=B3***,
  In cell ***F2*** add: ***=C3***,
  In cell ***D3*** add: ***=SQRT((B2-B3)^2+(C2-C3)^2)***,
  In cell ***E3*** add: ***=B3-(3000*(B2-B3)/$D3)***,
  In cell ***F3*** add: ***=C3-(3000*(C2-C3)/$D3)***,

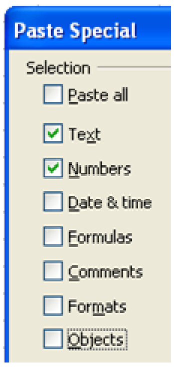
Copy the 6 cells to the bottom of the dataset using the drag and drop functionality,


Beach_ends_xy.ods - LibreOffice Calc
File Edit View Insert Format Tools Data Window Help
Find Text
Arial
10
K22

	A	B	C	D	E	F
1	PROFILE_ID	XCOORD	YCOORD	Length	Xoc	Yoc
2	51	608716.278186	686422.889855		=B3	=C3
3	51	608661.300459	686423.090713	=SQRT((B2-B3)^2+(C2-C3)^2)	=B3-(3000*(B2-B3)/$D3)	=C3-(3000*(C2-C3)/$D3)
4	48	608640.290682	685918.713716		=B5	=C5
5	48	608596.435033	685924.669596	=SQRT((B4-B5)^2+(C4-C5)^2)	=B5-(3000*(B4-B5)/$D5)	=C5-(3000*(C4-C5)/$D5)
6	46	608625.246183	685779.087750		=B7	=C7

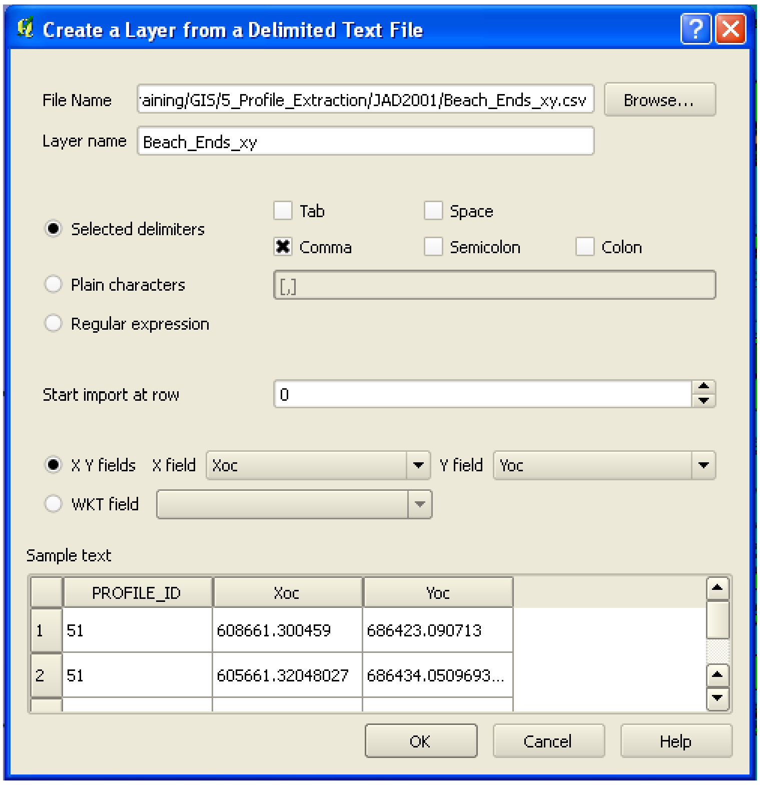
Copy the values (see figure on the right) of the all dataset into a new sheet and remove the column ***B***, ***C*** and ***D***,

Finally save the file as usual, and save it again as .csv (only the active sheet will be saved), before to close LibreOffice.


Paste Special

Selection
☐ Paste all
☑ Text
☑ Numbers
☐ Date & time
☐ Formulas
☐ Comments
☐ Formats
☐ Objects

- Move back to QGIS and import the .csv file with the ***Add Delimited Text Layer*** plugin (), ***Save*** the layer ***as*** a shapefile > ***Oceanic_ends.shp*** add it to the project and remove the .csv layer.


Create a Layer from a Delimited Text File

File Name: aining/GIS/5_Profile_Extraction/JAD2001/Beach_Ends_xy.csv
Layer name: Beach_Ends_xy

● Selected delimiters ☐ Tab ☐ Space ☒ Comma ☐ Semicolon ☐ Colon
○ Plain characters [,]
○ Regular expression

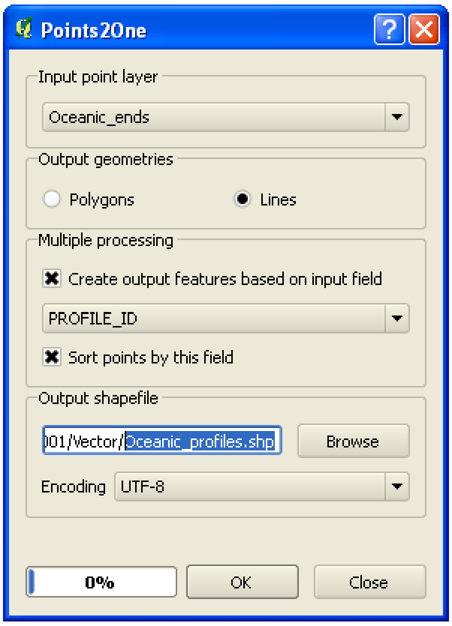
Start import at row: 0

● X Y fields X field: Xoc Y field: Yoc
○ WKT field

Sample text

	PROFILE_ID	Xoc	Yoc
1	51	608661.300459	686423.090713
2	51	605661.32048027	686434.0509693...

- Now add the plugin ***Points2One*** (see the left figure below) and use it to convert the point to a line and check all oceanic profiles are in the prolongation of the beach profiles,


Points2One

Input point layer

Oceanic_ends

Output geometries

○ Polygons ● Lines

Multiple processing

☒ Create output features based on input field

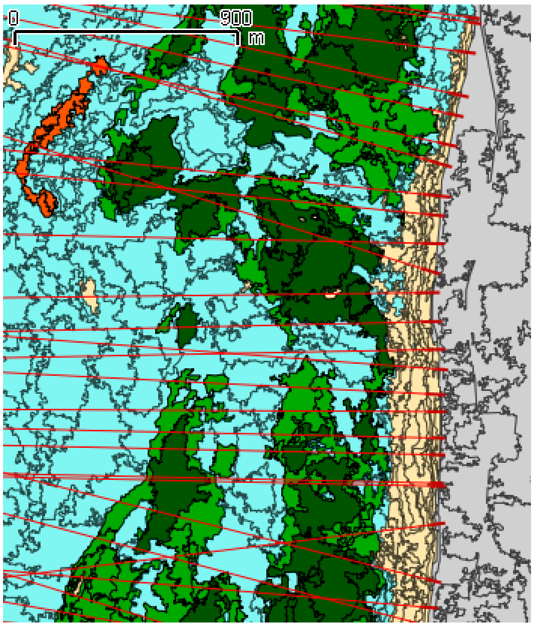
PROFILE_ID

☒ Sort points by this field

Output shapefile

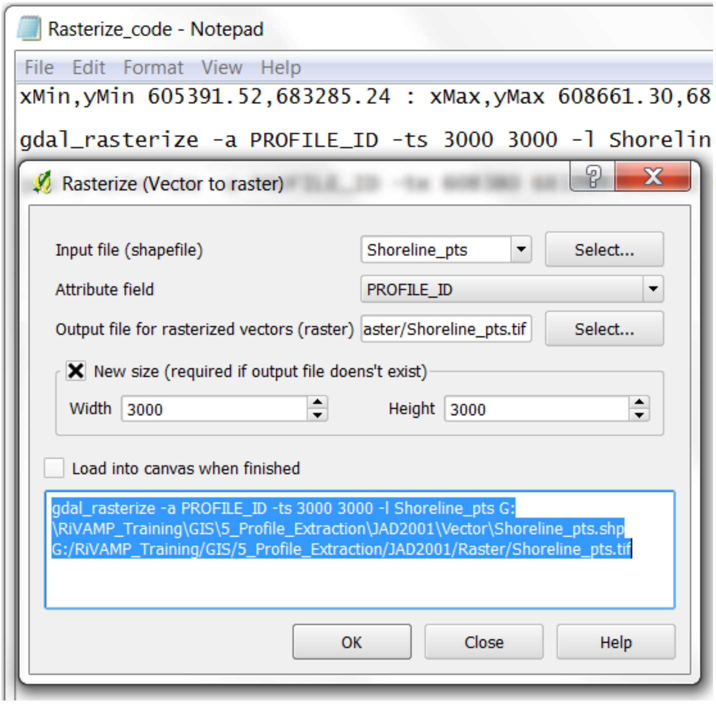
)01/Vector/Oceanic_profiles.shp

Encoding UTF-8



Now we need to convert the line profiles into series of points to be used for sampling land use and bathymetry layers. But unfortunately this task is not as easy at it seems (here is suggested a simplified methodology):

- Use the ***SelectPlus*** plugin to select all the points located on the shoreline of ***Oceanic_ends***, ***save*** the ***selection as Shoreline_pts.shp*** and add the layer to the project,
- Open a text editor (in our case the *notepad*) and copy/paste the Extents of Oceanic_ends you get from the ***Metadata*** (probably "*xMin,yMin 605391.52,683285.24 : xMax,yMax 608661.30,686731.19*"),
- Then convert the point layer into a raster with the extent of ***Oceanic_ends*** and a resolution of ***1 meter***: ***Raster*** > ***Rasterize*** >>, copy/paste the preview code (selected in the figure) into the *notepad* and ***Close*** the *Rasterize* windows without running it,


Rasterize_code - Notepad

```
xMin,yMin 605391.52,683285.24 : xMax,yMax 608661.30,68
gdal_rasterize -a PROFILE_ID -ts 3000 3000 -l Shorelin
```

Rasterize (Vector to raster)

Input file (shapefile) Shoreline_pts

Attribute field PROFILE_ID

Output file for rasterized vectors (raster) aster/Shoreline_pts.tif

☒ New size (required if output file doesn't exist)

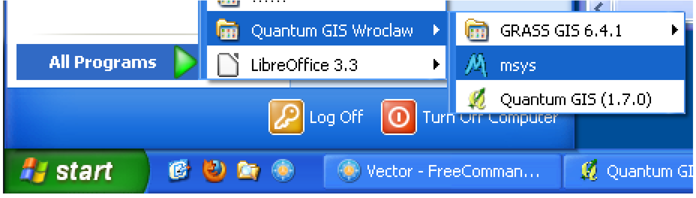
Width 3000 Height 3000

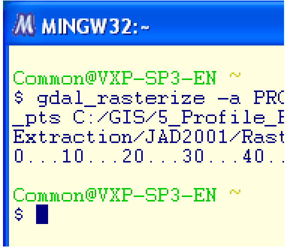
□ Load into canvas when finished

```
gdal_rasterize -a PROFILE_ID -ts 3000 3000 -l Shoreline_pts G:
\RiVAMP_Training\GIS\5_Profile_Extraction\JAD2001\Vector\Shoreline_pts.shp
G:/RiVAMP_Training/GIS/5_Profile_Extraction/JAD2001/Raster/Shoreline_pts.tif
```

In the *notepad* replace "*-ts 3000 3000*" by "***-te 605391 683285 608662 686732 -tr 1 1 -ot Int16***"
-te correspond to the rounded values plus or minus 1 resolution unit,
-tr correspond to the resolution unit,
-ot correspond to the data type (set as Integer to keep a small file size).

From the start button start *msys* ***copy/paste*** (pressing the scroll button of your mouse) the modified code and press ***Enter*** (you might have to convert “\” into “/”),





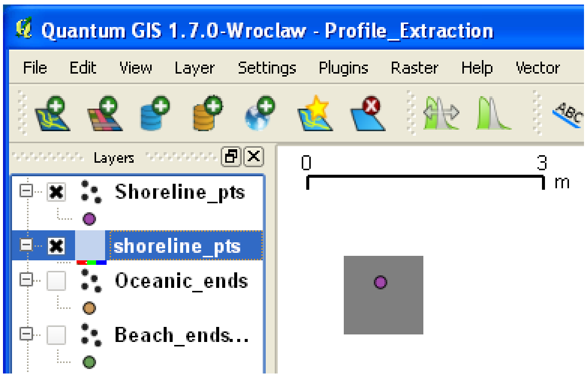
```
MINGW32:~

Common@VXP-SP3-EN ~
$ gdal_rasterize -a PRO
_pts C:/GIS/5_Profile_E
Extraction/JAD2001/Rast
0...10...20...30...40..

Common@VXP-SP3-EN ~
$
```

We have to do that because by default the *Rasterize* function of QGIS does not allows the user to define the extent and resolution of the output raster, but these options exist in gdal.

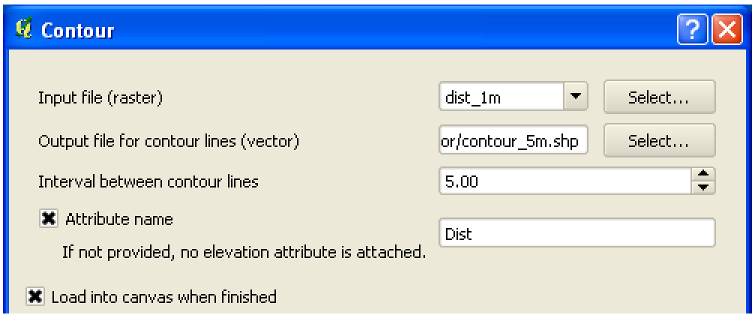
Close *msys* and the *notepad* and add the raster you just created to your QGIS project,
check the raster covers totally the *Oceanic_profiles* layer,
set the ***No data value*** to “***0***” in the ***Transparency*** tab),



- Using this raster compute a distance raster with the ***Proximity*** function of the ***Raster*** menu > ***dist_1m.tif***, and add it to your project,

  As you can see this function covers the raster to process extent, this is the reason why we had to force this parameter by using *msys* in the previous step.

- Convert the raster into a contour layer with ***5 meter*** interval (to keep processing time short) and intersect it with the profiles:
  Raster > ***Contour >>***,



Contour

Input file (raster): dist_1m

Output file for contour lines (vector): or/contour_5m.shp

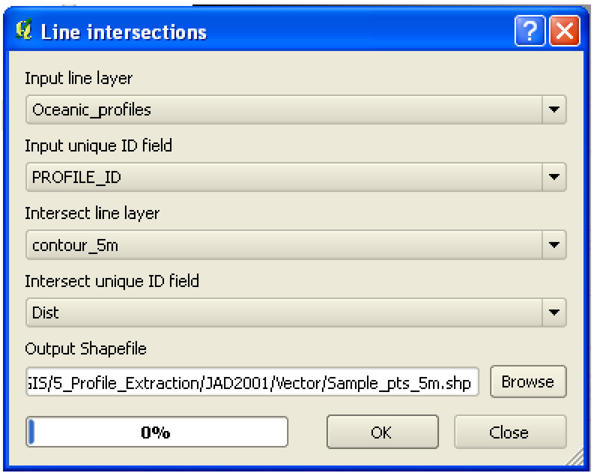
Interval between contour lines: 5.00

☒ Attribute name: Dist

If not provided, no elevation attribute is attached.

☒ Load into canvas when finished

Intersect the contour lines with the profiles to create the sampling points:
Vector > ***Analysis Tools*** > ***Line intersections >>***,



Line intersections

Input line layer: Oceanic_profiles

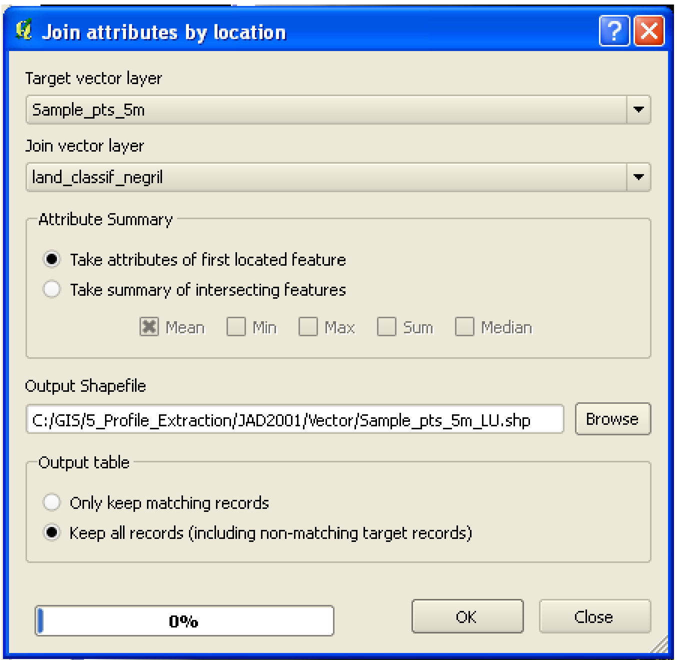
Input unique ID field: PROFILE_ID

Intersect line layer: contour_5m

Intersect unique ID field: Dist

Output Shapefile: GIS/5_Profile_Extraction/JAD2001/Vector/Sample_pts_5m.shp

- Then gather the land use information at the location of sampling points: ***Vector*** > ***Data Management Tools*** > ***Join Attributes by location >>***,



Join attributes by location

Target vector layer: Sample_pts_5m

Join vector layer: land_classif_negril

Attribute Summary

● Take attributes of first located feature

○ Take summary of intersecting features

☒ Mean ☐ Min ☐ Max ☐ Sum ☐ Median

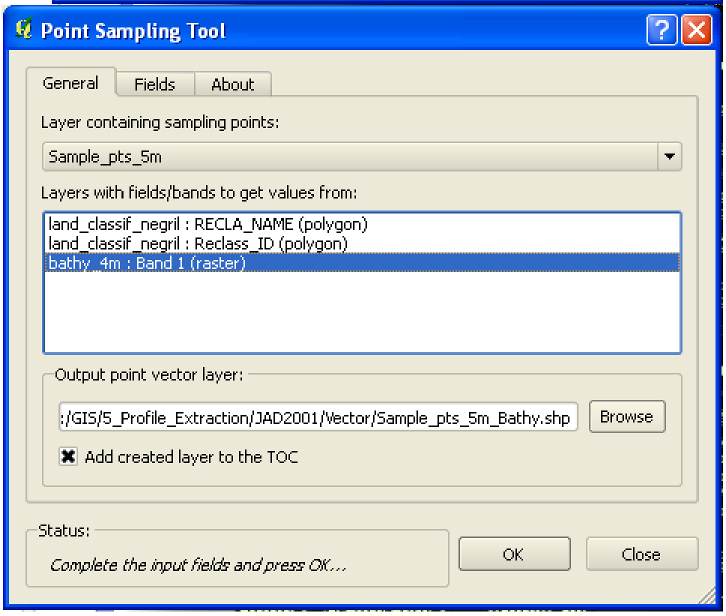
Output Shapefile: C:/GIS/5_Profile_Extraction/JAD2001/Vector/Sample_pts_5m_LU.shp

Output table

○ Only keep matching records

● Keep all records (including non-matching target records)

- Install the ***Point sampling tool*** plugin ( ) to extract the bathymetric information (only the visible layers will be selectable),



Point Sampling Tool

Layer containing sampling points: Sample_pts_5m

Layers with fields/bands to get values from:

land_classif_negril : RECLA_NAME (polygon)
land_classif_negril : Reclass_ID (polygon)
bathy_4m : Band 1 (raster)

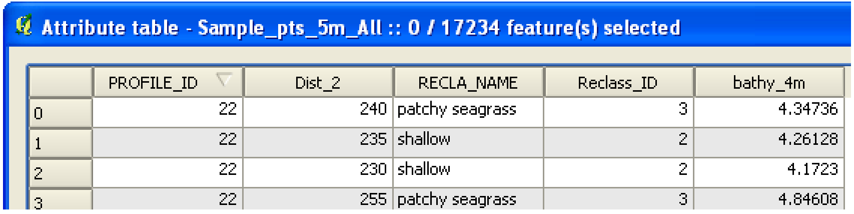
Output point vector layer: :/GIS/5_Profile_Extraction/JAD2001/Vector/Sample_pts_5m_Bathy.shp

☒ Add created layer to the TOC

Status: *Complete the input fields and press OK...*

As you can see in the above figure, we could have done the previous step with this plugin, but as it is extremely slow with vectors, it is better to use the *Join Attributes by location* function when possible.

- Open the attribute table of the layer you just created. The attribute table from the input layer has been lost and only remains a single column with the bathymetric information! Then use the ***Join Attributes by location*** once again to join the two last layers into one. You should get a table like the next one > ***Sample_pts_5m_All.shp***.



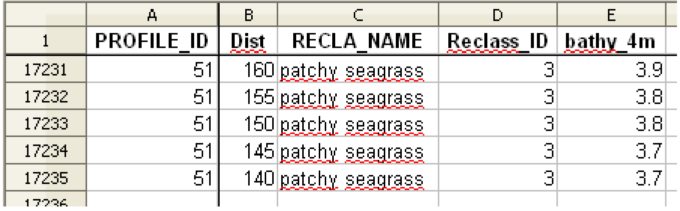
Attribute table - Sample_pts_5m_All :: 0 / 17234 feature(s) selected

	PROFILE_ID	Dist_2	RECLA_NAME	Reclass_ID	bathy_4m
0	22	240	patchy seagrass	3	4.34736
1	22	235	shallow	2	4.26128
2	22	230	shallow	2	4.1723
3	22	255	patchy seagrass	3	4.84608

The GIS works is done, save your project and close QGIS.

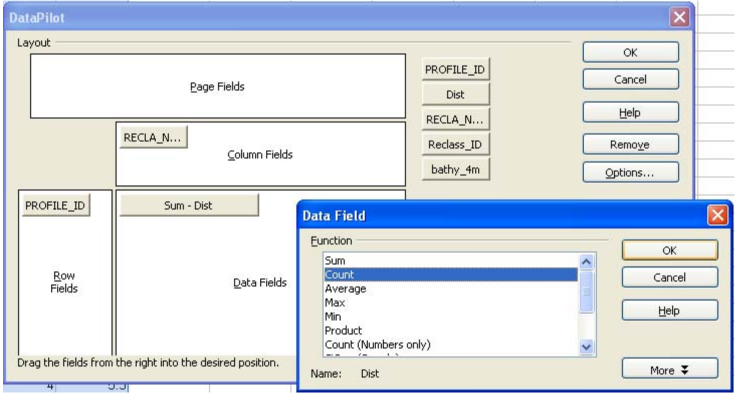
From this table we will be able to calculate the various parameters to be used in the statistical analysis. To do so we will use again LibreOffice Calc:

- Open ***Sample_pts_5m_All.dbf*** in ***LibreOffice Calc*** and ***Save*** the file as and ***.ods***,
- ***Rename*** the column headers in the first raw and ***Format*** the cells to improve the readability of the table,



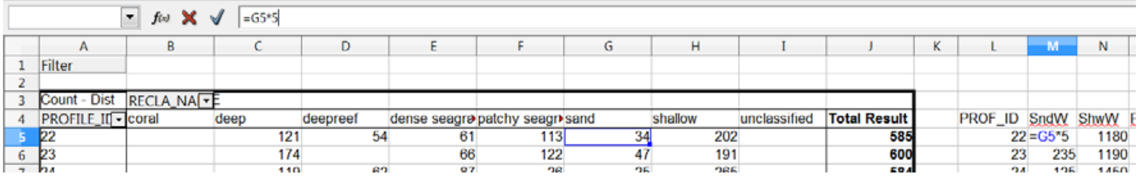
	A	B	C	D	E
1	PROFILE_ID	Dist	RECLA_NAME	Reclass_ID	bathy_4m
17231	51	160	patchy seagrass	3	3.9
17232	51	155	patchy seagrass	3	3.8
17233	51	150	patchy seagrass	3	3.8
17234	51	145	patchy seagrass	3	3.7
17235	51	140	patchy seagrass	3	3.7

- Calculate the Total width of each land use:
  Data > ***Pivot Table*** (*DataPilot* in older versions of LibreOffice) > ***Create…***,
  Current selection (in the case the full dataset has been automatically selected) > ***OK***,
  Drag and drop ***Profile_ID*** in the ***Row Fields*** area, ***Reclass_Name*** in the ***Column Fields*** area and ***Dist*** in the ***Data Fields*** area, then double click on ***Dist*** and select the ***Count Function***, > ***OK*** > ***OK***,



- Add the following columns (names in bold) and calculate their value for each profile (do not forget to multiply the values from the attribute table by 5 (spacing of the sampling points)

Prof_ID	Profile ID
SndW	Total width of sand on the profile (meter)
ShwW	Total width of mix of sand and vegetation on the profile (meter)
PSgW	Total width of patchy seagrass on the profile (meter)
DSgW	Total width of dense seagrass on the profile (meter)
SwRfW	Total width of shallow coral reef on the profile (meter)
DpRfW	Total width of supposed deep coral reef on the profile (meter)
TotSgW	Total width of patchy and dense seagrass on the profile (meter)



=G5*5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Filter													
2														
3	Count - Dist	RECLA_NA E												
4	PROFILE_II	coral	deep	deepreef	dense seagra	patchy seagr	sand	shallow	unclassified	**Total Result**		PROF_ID	SndW	ShwW
5	22		121	54	61	113	34	202		**585**		22	=G5*5	1180
6	23		174		66	122	47	191		**600**		23	235	1190

Add a new sheet named ***Data synthesis*** and ***paste*** it the values of the column you just created and then delete them from the Pivot table sheet,

- Calculate the minimum distance from shoreline to each land use:
  Right click any cell of the pivot table > ***Edit Layout…***,
  Replace the count function of the Data Fields by ***Min*** > ***OK***,
  Add the following columns (names in bold) and calculate their value for each profile

Prof_ID	Profile ID
SndD	Minimum distance from shoreline to sand (meter)
ShwD	Minimum distance from shoreline to mix of sand and vegetation (meter)
PSgD	Minimum distance from shoreline to patchy seagrass (meter)
DSgD	Minimum distance from shoreline to dense seagrass (meter)

SwRfD	Minimum distance from shoreline to shallow coral reef (meter)
DpRfD	Minimum distance from shoreline to supposed deep coral reef (meter)
MinSgD	Minimum distance from shoreline to patchy or dense seagrass (meter)

Paste the values of the column you just created in the ***Data synthesis*** sheet and then delete them from the Pivot table sheet (check the Profile_IDs coincide between the two tables),
As the 0 values correspond to no data in these columns, ***replace 0 by 9999*** to symbolize the difference.

- Calculate the average depth in a given distance (within a 50 meter radius) from the shoreline:
Copy the original sheet (containing the sampled data) to a new sheet named ***Bathymetry***,
Keep only the columns relative to the *Profile_ID*, *Dist* and the bathy_4m,
Sort the table with the ***Dist*** column,
In a new column named ***Dist2Shore***, write down ***500*** in all rows with a ***Dist*** value ***between 450 and 550***, do the same with ***Dist*** values of ***1000***, ***1500***, ***2000***, ***2500***, ***3000*** (keeping a ***+- 50*** meter tolerance),
Create a ***Pivot table*** (this time you will have to select the cells first) with ***Profile_ID***, ***Dist2Shore*** and the ***Average*** of ***bathy_4m*** as *Data Field*,
Copy the relevant values of the content table (without the empty columns and Total values) into the ***Data synthesis*** sheet and rename the columns into

Dpt500	Average depth (50 meter radius) around 500 m from shoreline (meter)
Dpt1000	Average depth (50 meter radius) around 1000 m from shoreline (meter)
Dpt1500	Average depth (50 meter radius) around 1500 m from shoreline (meter)
Dpt2000	Average depth (50 meter radius) around 2000 m from shoreline (meter)
Dpt2500	Average depth (50 meter radius) around 2500 m from shoreline (meter)
Dpt3000	Average depth (50 meter radius) around 3000 m from shoreline (meter)

Keep 1 digit format and replace the empty cells by ***9999***.

- Calculate the maximum distance from the shoreline to reach a given depth:
Sort the table in ***Bathymetry*** sheet with the ***bathy_4m*** column,
Add a new column named ***DepthCat*** and fill it with the rounded value of ***bathy_4m***,
Right click in any cell of the pivot table of the bathymetry sheet > Edit Layout… > More > extend the selection until the E column,
then change the layout with ***Profile_ID***, ***DepthCat*** and the ***Min*** of ***Dist***,
Copy the relevant values of the content table (without the Total values) into the ***Data synthesis*** sheet, remove the columns that are not ***4***, ***5***, ***6***, ***7***, ***8***, ***9***, ***10***, ***12***, ***14***, ***16***, ***20*** and rename the columns into

Prof4	Maximal distance to reach the 4 meter depth (meter)
Prof5	Maximal distance to reach the 5 meter depth (meter)
Prof6	Maximal distance to reach the 6 meter depth (meter)
Prof7	Maximal distance to reach the 7 meter depth (meter)
Prof8	Maximal distance to reach the 8 meter depth (meter)
Prof9	Maximal distance to reach the 9 meter depth (meter)
Prof10	Maximal distance to reach the 10 meter depth (meter)
Prof12	Maximal distance to reach the 12 meter depth (meter)
Prof14	Maximal distance to reach the 14 meter depth (meter)
Prof16	Maximal distance to reach the 16 meter depth (meter)
Prof20	Maximal distance to reach the 20 meter depth (meter)

That’s it you are now ready to perform the statistical analysis

Plugins selection

GdalTools: Need to be upgraded at the time of writing this document AND enabled to access all functionalities of the *Raster* menu.
Interactive identify: Query several layers at once with extended configuration settings.
mmqgis: Various helpful GIS functions.
Point sampling tool: Collect values from multiple layers (vector AND raster).
Points2One: Create polygon or polyline from points.
SelectPlus: Menu with selection options.
Table manager: Manage attribute table structures
Value tool: Instantaneous display of raster values.

References

Quantum GIS website: http://qgis.org/
Python plugins repositories: http://www.qgis.org/wiki/Python_Plugin_Repositories
GRASS GIS website: http://grass.fbk.eu/
GDAL: http://www.gdal.org/index.html
LibreOffice: http://www.libreoffice.org/

Index

RiVAMP statistical analysis Training

Some theory

Statistical concepts

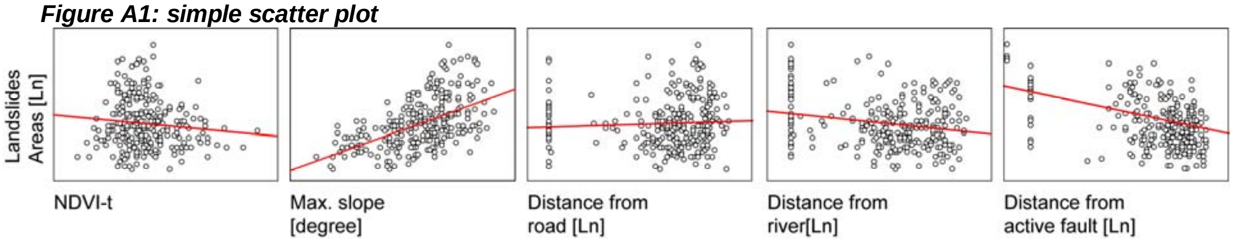
For readers who are not familiar with some of the statistical concepts used in this training, here is a small summary. This section is adapted from the on-line help of StatSoft Electronic Statistics Textbooks (http://www.statsoft.com/textbook/statistics-glossary/).

This example was made for a research on links between deforestation and landslides in North Pakistan (see Peduzzi, P., Landslides and vegetation cover in the 2005 North Pakistan earthquake: a GIS and statistical quantitative approach, Nat. Hazards Earth Syst. Sci., 10, 623-640, 2010. http://www.nat-hazards-earth-syst-sci.net/10/623/2010/nhess-10-623-2010.html).

Multiple regression analysis

When addressing the potential link between one variable (e.g. slope) and a dependant variable (e.g. landslide areas) simple scatter plots provide useful information (See figure A1).

Figure A1: simple scatter plot



Some variables can directly be linked with landslide areas (e.g. slope), however, one variable is usually not enough to model the behaviour of a dependent variable. Variables can have a multiplicative effect when associated one to another.

To understand what the best combinations of susceptibility factors are and how they contribute to landslide area, a multiple regression analysis can be made. Such statistical process aims to highlight the relationship between a dependent variable (e.g. landslide area) and several independent variables (potential susceptibility factors, e.g. slopes, distance from active fault, presence of vegetation,...).

The aim is to obtain an equation such as:

$$LA = \alpha X_1 + \beta \cdot X_2 + \ldots + \theta \cdot X_n + I$$

Where
LA = Landslide area
X_1 = first susceptibility factor (e.g. slope)
X_2 = second suscpeptibility factor (e.g. distance from active fault)
X_n = last susceptibility factors (e.g. vegetation density)
α, β and θ = weights which multiplies the factors.
I = Intercept

The purpose is double, first it allows a better understanding of the underlying processes leading to landslides, secondly, it provides the weights associated with each susceptibility factors, allowing creating maps of landslides susceptibility. The main limitation being that although it shows potential link, it cannot ensure causality (see causality below).

Pearson coefficient, r

The independent variables in the model should not have influence between them. To produce group of independent variables a correlation matrix is computed and variables that are too correlated should not be tested in the same hypothesis. Thus group of uncorrelated variables should be created (see appendix C). The r is the pearson coefficient (or correlation coefficient), it is computed as follows:

$$r = \frac{\sum(x-\overline{x})\cdot\sum(y-\overline{y})}{\sqrt{\sum(x-\overline{x})^2\cdot\sum(y-\overline{y})^2}}$$

where

$\overline{x}$ is the average for a observed dependant variable

$\overline{y}$ is the average for the modelled variable

In this study, two independent variables could be placed in the same group if |r| < 0.5.

R^2 and Adjusted R^2

R^2 is the square of r, it provides an indication of the percentage of variance explained. Adjusted R^2 is a modification of R^2 that adjusts for the number of explanatory terms in a model. Meaning that by adding more explanatory variables you might increase the R^2, but it could also be by chance (over fitting models). The Adjusted R^2 is particularly useful in the selection of potential susceptibility factors as it takes into account the number of explanatory variables and only increase if the added explanatory variable explains more than as a result of a coincidence.

$$adj.R^2 = 1-(1-R^2)\cdot\frac{n-1}{n-p-1}$$

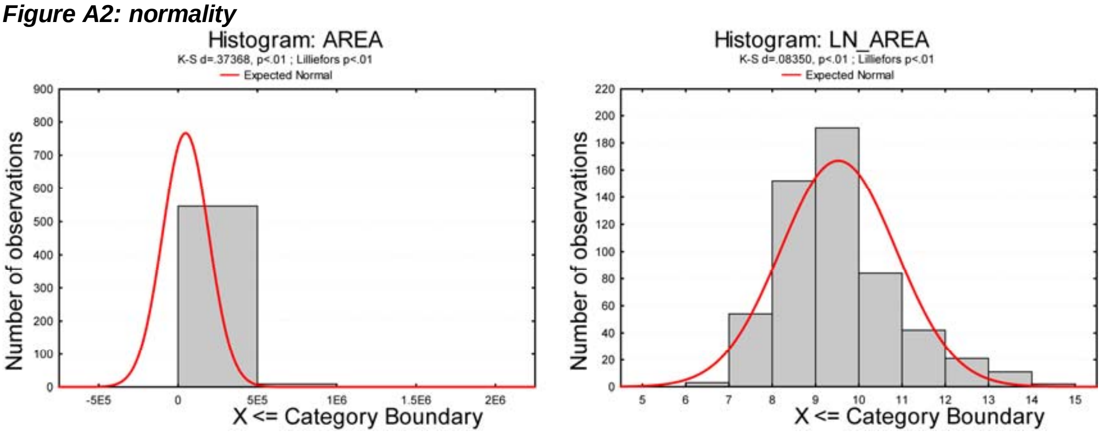
Where n is the sample size, p is the number of independent variables in the model.

In general terms, the more explanatory variables you have the less the R^2, because by introducing more independent variables, you increase the risk that the results is obtained by random. This is often called “overfitting”.

Normal distribution

The variables should follow a normal distribution. This can be done by looking at histograms and by applying some statistical normality tests (e.g. Normal expected frequencies, Kolmogorov-Smirnov & Lilliefors test for normality, Shapiro-Wilk’s W test.). If a variable do not follow a normal distribution, it needs to be transformed so that it does (e.g. computing the Ln, or using transformation formula). The figure below shows the distribution of landslide areas. Taking the Ln greatly improve the normality.

Figure A2: normality



Other functions can be used as specified in the article.

Correlation matrix

A sound statistical multiple regression analysis do not include dependant variables which are correlated between them. Compute the correlation between parameters and do not use two dependant variables which are correlated (e.g. r > 0.5).

This test can also be done after you find the model, however, this would help to reduce the amount of tests.

VARIABLES	GEO_CLAS	EPI7_LN	DFPC2001	AFPC2001	DFPC1979	AFPC1979	D_DF_N	FAU_E_LN	RIV_E_LN	ROAD_ELN	AS_SLMAX
GEO_CLAS	1										
EPI7_LN	-0.61054494	1									
DFPC2001	0.030173617	0.064267123	1								
AFPC2001	0.151408464	-0.02053886	0.681399181	1							
DFPC1979	-0.157253167	0.150427599	0.511186591	0.407626633	1						
AFPC1979	-0.306262486	0.263142132	0.397172862	0.29143195	0.660796501	1					
D_DF_N	-0.189837925	0.159892844	-0.054033713	0.009781408	0.557353372	0.379014984	1				
FAU_E_LN	-0.574314739	0.509284177	-0.018360254	-0.059362492	0.132283622	0.194093629	0.126551334	1			
RIV_E_LN	-0.027317046	-0.047358484	0.072998129	0.025901471	0.085597576	0.137044457	0.039028676	-0.109581934	1		
ROAD_ELN	0.245954832	-0.180364857	0.163845352	0.240070041	0.115202886	-0.03391631	-0.001611524	-0.191126149	0.006302733	1	
AS_SLMAX	-0.083784927	0.069787184	0.01342266	-0.000396599	0.069191982	0.244110713	0.064153034	0.037619704	-0.030041463	-0.035268997	1
LN_AREA	0.322441637	-0.329124405	0.022722721	0.069425912	-0.110669497	0.004488764	-0.077697417	-0.357883868	-0.217723769	0.084802057	0.546452847

Outliers

Outliers are cases that do not follow the general assumption. In the real environment, it is difficult to take all the parameters reflecting the complexity of the situations. Some isolated cases, might have specific settings, and they don't follow the general trends. These outliers are easy to identify as they are distant to the rest of the data. They should be identified and removed so that the general rule can be better identified. However, an analysis of these outliers should be performed to ensure that they don't follow another rule. If this is the case, then the dataset might need to be split so that two (or more) models can be generated. For example, we differentiated landslides close to rivers and landslides away from rivers as it seems that these two groups follow different rules.

Causality

Correlation between two variables (e.g. A & B) do not imply that variation of A is the origin of the variation of B.

If multiple regression can shows potential link, it cannot ensure causality.

What we aim to do is to say that factor A (e.g. vegetation density) influence B (landslide area). Now having a correlation between factors A & B can have several origins:

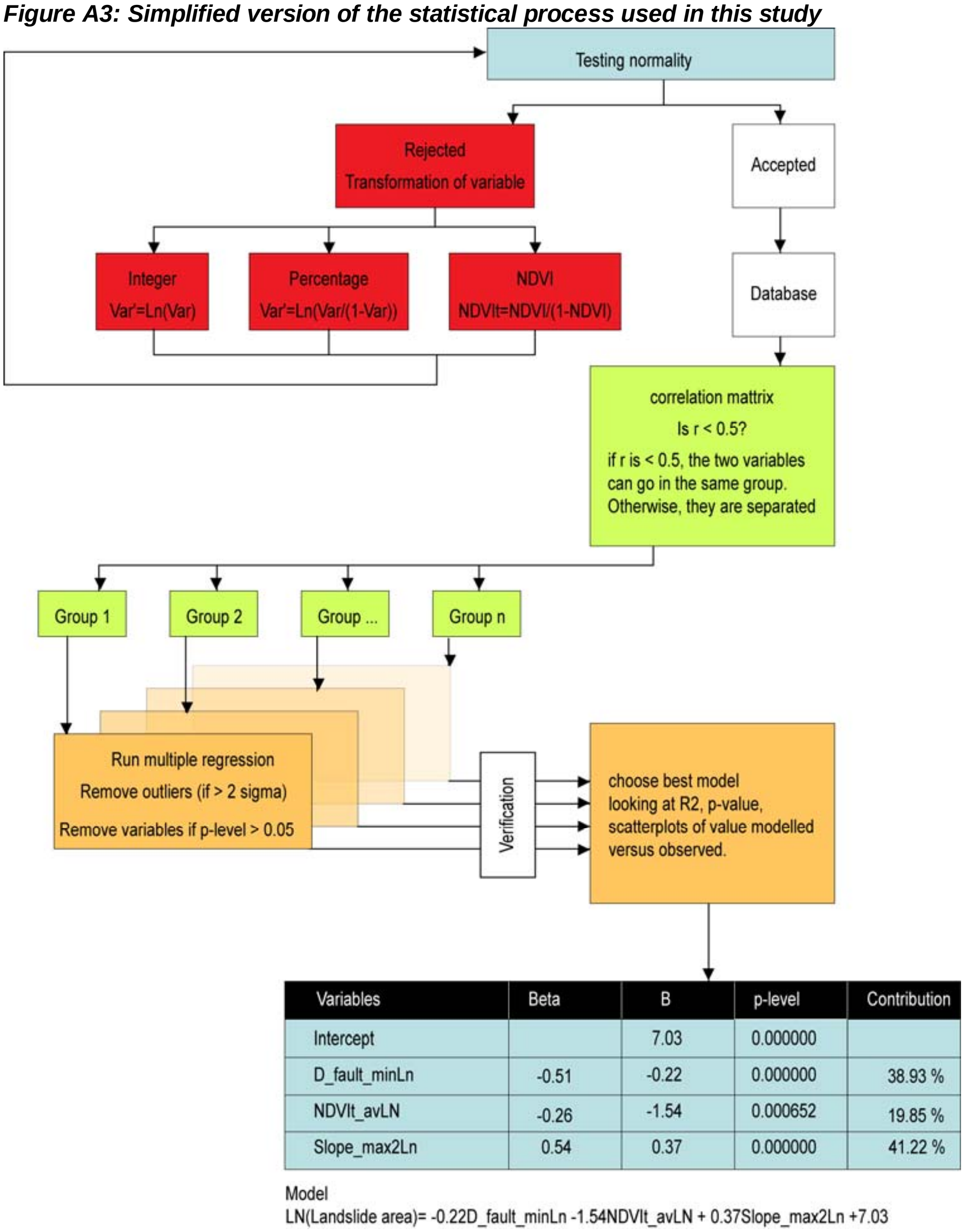
A is indeed having an influence on B or

B is influencing A or

C is influencing A & B.

The p-level provide good insight on the probability that the link is due to a coincidence. However, addressing causality is always the main challenge (see discussion under "verification of causality").

Figure A3: Simplified version of the statistical process used in this study


Testing normality
Rejected
Transformation of variable
Accepted
Integer
Var'=Ln(Var)
Percentage
Var'=Ln(Var/(1-Var))
NDVI
NDVIt=NDVI/(1-NDVI)
Database
correlation mattrix
Is r < 0.5?
if r is < 0.5, the two variables can go in the same group. Otherwise, they are separated
Group 1
Group 2
Group ...
Group n
Run multiple regression
Remove outliers (if > 2 sigma)
Remove variables if p-level > 0.05
Verification
choose best model looking at R2, p-value, scatterplots of value modelled versus observed.

Variables	Beta	B	p-level	Contribution
Intercept		7.03	0.000000	
D_fault_minLn	-0.51	-0.22	0.000000	38.93 %
NDVIt_avLN	-0.26	-1.54	0.000652	19.85 %
Slope_max2Ln	0.54	0.37	0.000000	41.22 %

Model
LN(Landslide area)= -0.22D_fault_minLn -1.54NDVIt_avLN + 0.37Slope_max2Ln +7.03

In the final table (in blue), the coefficient "Beta" provides information on the relative contribution of each susceptibility factor to landslides area. Slopes is the main one (0.54) and has a positive sign, hence the steeper the slope the bigger the landslide area; distance from active fault is the second contributor (-0.51) and has a negative sign, hence the further away from active fault line, the smaller the landslide areas and finally NDVI has a negative sign, hence denser vegetation (high NDVI) relates to smaller landslide areas.

One can even compute the percentage of contribution from each factor. For this we need to sum the absolute value of the Beta coefficient (0.51 + 0.26 + 0.54 = 1.31), then the ratio of each absolute value of the Beta coefficient provides the percentage of contribution for each variable: slope contributes for 41.22% (0.54/1.31), distance from active fault for 38.93% and NDVI for 19.85%. These percentage are provided in the last column (contribution).

The coefficient B (third column) provide the weights which can be used to model the landslide area (see equation of the model below the table).

The p-level indicates the probability that the variable was selected by coincidence. For example a p-level of 0.05 indicates that there is 5% of chance that the selected variable is a "fluke". This level is customarily treated as a "border-line acceptable" error level. So the lowest the p-level the highest the confidence in the selection. In this study the highest p-level was 0.0018, meaning all the selected variables have less than 0.18% chance of being selected by coincidence.

What is a good model?

Models are not the reality, they try to approximate it based on a simplification. A good model is a model which :

1) Explains a significant part of the differences observed (look at R^2 values, they represent the percentage of variance explained).
2) If you have a good R^2, this is not enough, the distribution should be along a line. Observe the distribution between observed versus modelled, ideally, your points on the scatterplot should be representing a line.
3) The number of independant variables is not too high (e.g. between 2 and 4), if you have too many independant variables, your model may be data driven. To test this, look at the adj. R^2 as well as test your model on one part of your data (e.g. 2/3) and keep the other part (1/3) for validating your model. You can also do this in an iterative way (e.g. bootstrap process).
4) Look at the p-value of your independant variables, they should be < 0.05.
5) Test if the independant variables are not auto-correlated, run a correlation matrix between the independant variables and look if all the r are < 0.5.
6) Make sure you have enough records, the more you have the higher the confidence in your model.

In brief

The aim of this training is to introduce you to statistical analysis in the context of a study such as RiVAMP.

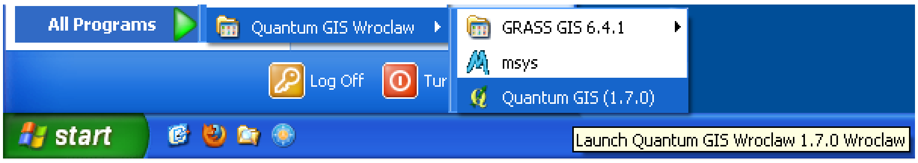
The open source statistical analysis software TANAGRA will be used.

The training documentation has been prepared under a Windows XP environment, but is easily reproducible in any other OS after a few adjustments.

Typographic convention

In a general manner the text you have to focus because it figures in the applications has been highlighted with ***Bold Italic*** format.

Menu > Item Instructs you to select the named *item* from the named *menu*. Note that some menus contains *sub-menus*. For example ***Start > All programs > Quantum GIS Wroclaw > Quantum GIS (1.7.0)*** in Windows XP means:



Reference instructs you to look this string/value or type it into a field within the user interface.

>> instructs you to look on the figure on the right for the parameters to be applied.

TANAGRA installation (if necessary)

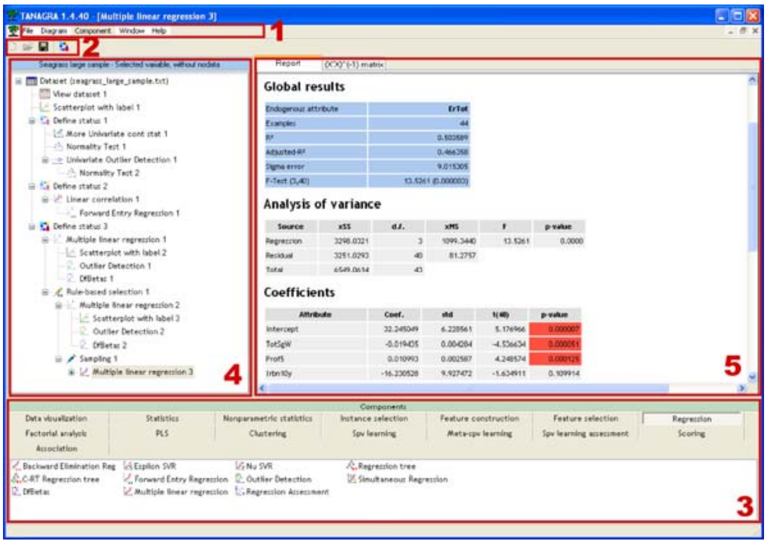
Download the installation file from http://eric.univ-lyon2.fr/~ricco/tanagra/en/tanagra.html or from the Software folder in the DVD of the training (***setup.tanagra.exe***) and install it with the default options.

Introduction to TANAGRA

During the statistical software selection the user friendliness of the interface was an important parameter. Many open source of free statistical exist but very often with a command line interface not easy to apprehend for beginners in statistics. Even if TANAGRA potential as limited functionalities compared to these software, the way it has been conceived (to introduce data mining to students) and its important documentation (http://eric.univ-lyon2.fr/~ricco/tanagra/en/tanagra.html, http://eric.univ-lyon2.fr/~ricco/publications.html) made it the perfect candidate for our training.

Start TANAGRA and explore its interface. It is divided in 5 zones:

1 Menu bar,
2 Toolbar to manage the project and define variables,
3 Components (or operators) library divided into sub-categories,
4 Data mining diagram,
5 Results view of each components.



Global results

Endogenous attribute	ErTot
Examples	44
R²	0.503589
Adjusted-R²	0.466358
Sigma error	9.015305
F-Test (3,40)	13.5261 (0.000003)

Analysis of variance

Source	xSS	d.f.	xMS	F	p-value
Regression	3298.0321	3	1099.3440	13.5261	0.0000
Residual	3251.0293	40	81.2757		
Total	6549.0614	43			

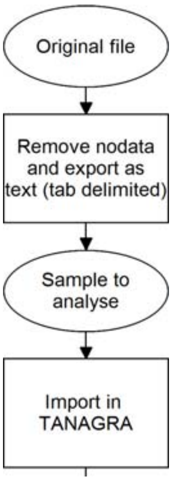
Coefficients

Attribute	Coef.	std	t(40)	p-value
Intercept	32.245049	6.228561	5.176966	0.000007
TotSgW	-0.019435	0.004284	-4.536634	0.000051
Prof5	0.010993	0.002587	4.248574	0.000125
Irbn10y	-16.230528	9.927472	-1.634911	0.109914

Data preparation and importation in TANAGRA

Because TANAGRA do not work well with records containing nodata, some work on raw data is necessary:

- Open the file ***...\Statistic\RiVAMP_Negril_Erosion.xls*** in LibreOffice Calc (a description of the different variables is available in the ReadMe sheet).
- Copy the ***Data*** sheet in first position and rename it ***Seagrass_small_sample***.
- As the aim of RiVAMP project in Negril is to quantify the amount of shoreline protection provided by bathymetry, seagrass meadows and shallow coral reef, we need to split the dataset in two. In our case we will analyse the protection provided by seagrass then we will remove the record containing shallow coral reef.
  Sort the copied table by ***SwRfW*** and remove the records with values higher than 0 (61 records are remaining).
  Remove the columns related to shallow coral reef (***SwRfW*** and ***SwRfD***).
  Sort back the table by ***Prof_ID***, find empty cells and remove the related records (47 records are remaining).
- Save the xls file and save again the first table as ***Text CSV*** with ***Tab field delimiter*** > ***seagrass_small_sample.csv***.
- ***Rename*** the file from ***.csv*** to ***.txt***.


Original file
Remove nodata and export as text (tab delimited)
Sample to analyse
Import in TANAGRA

Then import the data in TANAGRA:

- Start TANAGRA,
- File > New…
- Fill the windows as in the Figure >>

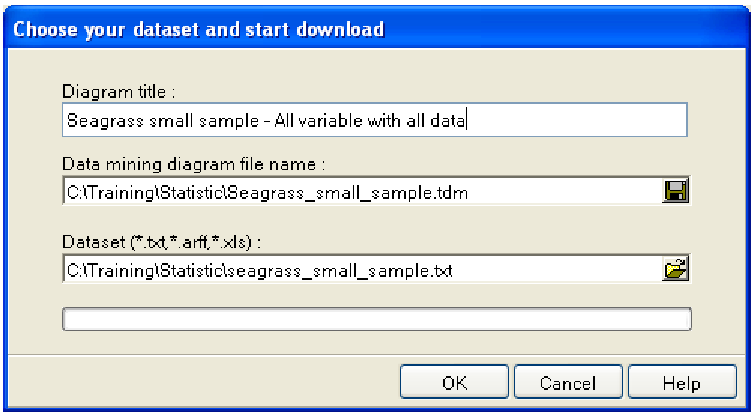


Diagram title : Seagrass small sample - All variable with all data

Data mining diagram file name : C:\Training\Statistic\Seagrass_small_sample.tdm

Dataset (*.txt,*.arff,*.xls) : C:\Training\Statistic\seagrass_small_sample.txt

- Check that 40 attributes and 47 examples (records) have been imported. In the case you have missed any nodata value, an error message will figure in front of the related attribute in the ***Dataset description*** table.

Explore the dataset

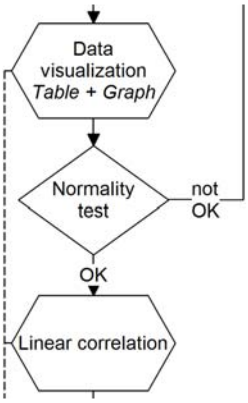
Visualize the table by drag and dropping the ***Data visualization*** / ***View dataset*** component in ***Dataset*** (in the diagram). And double click it to display it.

Add also some graph functionalities by adding the ***Scatterplot with label*** component.

Take some notes with the information you can see and could be helpful during the manual linear regression.

Test the normality of the dependant variable (in our case ErTot (Maximum erosion 1968-2008 based on 2006 shoreline (meter)):

- In the diagram select ***Dataset*** and click on the button,
  Add ***ErTot*** to the ***Input*** list > ***OK***.
- Drag ***Statistics*** / ***More univariate cont*** stat to ***Define status 1***,
  Have a look at the Histogram and decide if fits a Gaussian distribution:
  Is the ***Average*** more or less equivalent to the ***Median***?
  Is the ***MAD/STDDEV*** ratio near 0.7979?
  Are the ***Skewness*** and ***Kurtosis*** values near 0?



In the case of a perfect Gaussian distribution the average and the median values are the same, the Skewness and Kurtosis values equal 0, and the ratio MAD/STDDEV = 0.7979.

But all these parameters are only informative and do not imply at 100% the distribution is not normal.

We can go further with a normality test:

- Drag ***Statistics*** / ***Normality Test*** stat to ***Define status 1.***

The normality test includes 4 tests, in the case the normality is verified the cells appears in green, if they are not they display in red. In case of doubt they appear in grey.

In our case, no test is either positive or negative then we can continue the analysis without transforming the dataset before to start again the process.

Let's now visualize the correlation between the variables:

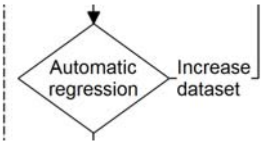
- Add a new ***Define status*** to the ***Dataset*** with ***ErTot*** as ***Target*** variable and all other variables as ***Input***.
- Drag ***Statistics*** / ***Linear correlation*** stat to ***Define status 2***,
  Parameters… > check the ***sort results*** checkbox, select the ***¦r¦-value*** as well as the ***Target and Input*** options.

The maximum r^2 is quite low (0.24) and show no high correlation between the dependant variable and one of the independent variables. Without surprise ***Er08*** shows of the best correlation with ***ErTot*** as they are both representative of the erosion rate. ***TotSgW***, ***PSgW***, ***ShwW*** and a few bathymetric parameters appears as potentially interesting.

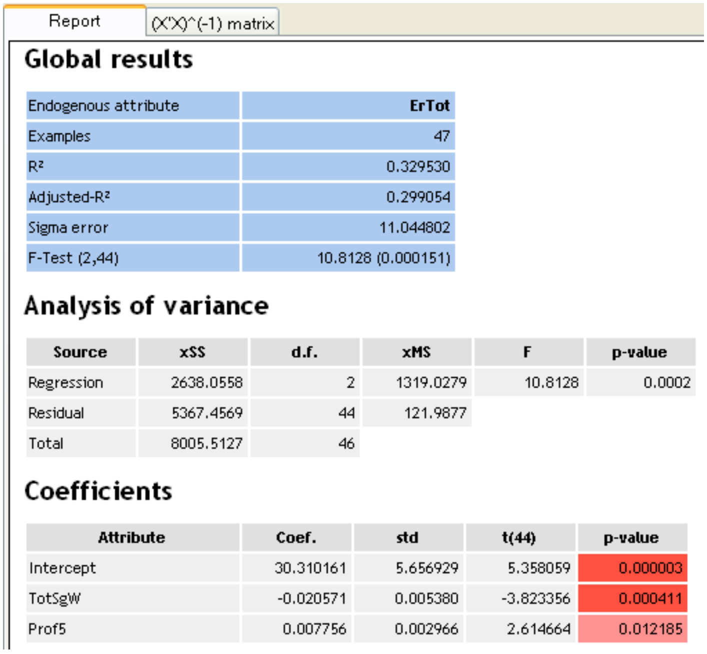
Clarify ideas through automatic regression

Let’s TANAGRA suggest a reasonable regression model:

- Drag ***Regression*** / ***Forward entry regression*** stat to ***Define status 2***,



R^2 remains similar to the values obtained from one by one linear correlation. The 2 suggested variables are significant (the deeper the red, the better) even if Prof5 as limited significance.



Global results

Endogenous attribute	ErTot
Examples	47
R²	0.329530
Adjusted-R²	0.299054
Sigma error	11.044802
F-Test (2,44)	10.8128 (0.000151)

Analysis of variance

Source	xSS	d.f.	xMS	F	p-value
Regression	2638.0558	2	1319.0279	10.8128	0.0002
Residual	5367.4569	44	121.9877		
Total	8005.5127	46			

Coefficients

Attribute	Coef.	std	t(44)	p-value
Intercept	30.310161	5.656929	5.358059	0.000003
TotSgW	-0.020571	0.005380	-3.823356	0.000411
Prof5	0.007756	0.002966	2.614664	0.012185

Let’s increase the number of variable in the model by increasing significantly the ***Sig***. level to ***0.3*** in the ***Parameters***.

TotSgW remains the main parameters followed by ***Prof6***, then ***Dpt2000***, ***Prof10***, ***PSgW***, ***Prof 5*** and ***Irbn5y***.

Following this first analysis we can conclude, TotSgW is THE main explicative variable, with one bathymetric variable to define. Then we can increase the dataset with a limited number of variables and start again the analysis with a more complete dataset.

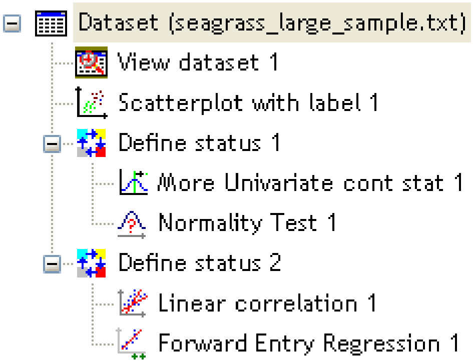
Save your project and close TANAGRA before to do so.

Increase the dataset

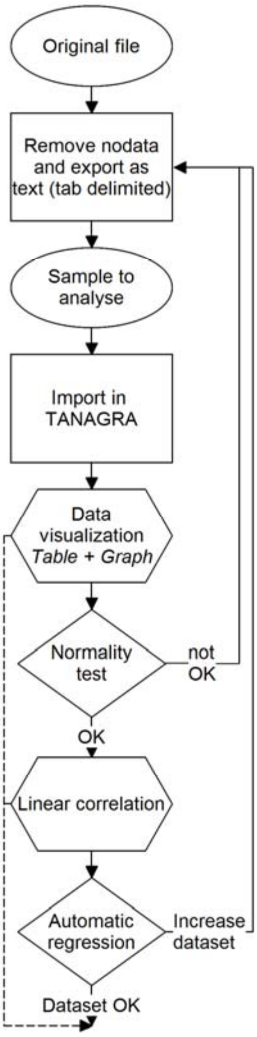
Open again the file ***RiVAMP_Negril_Erosion.xls*** and create a new table with a maximum of records without nodata (by limiting the number of variables) to be imported in TANAGRA > ***Seagrass_large_sample.tdm***.

I personally removed all the minimum distance as well as the Dpt3000 variables who seems to be not significant and reduced the dataset, that give me 33 attributes and 61 examples.

Repeat the data exploration and automatic regression



- Dataset (seagrass_large_sample.txt)
  - View dataset 1
  - Scatterplot with label 1
  - Define status 1
    - More Univariate cont stat 1
    - Normality Test 1
  - Define status 2
    - Linear correlation 1
    - Forward Entry Regression 1



Data visualization / View dataset
Data visualization / Scatterplot with label

Statistics / More univariate cont stat *(dependant variable)*
Statistics / Normality test

Statistics / Linear correlation

Regression / Forward entry regression

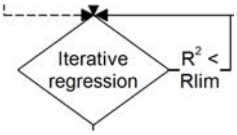
This time the normality test give worse values but as they are not 100% sure let's continue the analysis.

The automatic regression confirms the strong significance of TotSgW, followed by bathymetric indicators, and potentially Iribarren number.

Precise manually the model through manual iterations

Add a new ***Define status*** with ***ErTot*** as ***Target***, ***TotSgW*** and ***Dpt2000*** as Input and add it the ***Regression*** / ***Multiple linear regression*** component > R^2 = 0.177 and Dpt2000 is not significant.

Try to find the best model by testing each bathymetric variable. When it is done try to add a third variable (not representative of the bathymetry) and see if it increase R^2 and is significant.



Prof5 seems to give the best model (significant with a R^2 = 0.315), but ***Prof6***, ***Dpt1000*** and ***Dpt1500*** also seems interesting.

The best third variable seems to be one of the Irribaren numbers, as they all increase R^2 to 0.341, but remains no significant.

The combination of ***PSgW***, ***DsgW*** and ***Prof5*** is also one potential model (R^2 = 0.319 (0.349 with one Irribaren variable (not significant)).

Improve the model by removing outliers

Let's find and remove outliers of a model with ***TotSgW***, ***Prof5*** and ***Irbn5y***:

- Set the appropriate ***Parameters*** of ***Define status 3***,
- Add a ***Regression*** / ***Outlier detection*** component to ***Multiple linear regression 1***. Move to the ***Values*** tab and list the potential outliers (based on 6 test, they are highlighted in orange).

- Add also a ***Regression*** / ***DfBetas*** component (it will highlight the records that have the bigger influence on the model). Move to the ***DfBetas*** tab and list the potential outliers (highlighted in orange).

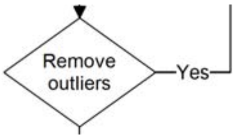
Create a synthesis table such as

		Outlier detection				
		0	**1**	**2**	**3**	**4**
DfBetas	**0**		33, 34	60, 61	**39**	
	1	25, 35		4		**38**
	2	28				44

The record 44 is showed 4 times as an outlier and has an important impact on the model. The records 38 is tested 4 times as an outlier with a smaller impact on the model. The records 25, 28 and 35 seems to have a greta impact but are not detected as outliers.

- Add a ***Data visualization*** / ***Scatterplot with label*** component to ***Multiple linear regression 1*** and graph ***ErTot*** vs ***Pred_lmreg_1*** and/or ***Err_Pred_lmreg1***.

Records 38 and 39 have a ErTot values of 0, that could correspond to artificial beach nourishment. On the other side record 44 could correspond to an exceptional erosion rate. Then in a first time we will remove the records 38 and 39 from the analysis.



As we cannot remove records from the dataset simply by using their ID, we have to find the Prof_ID of the 2 records to remove with View dataset 1> Prof_ID = 44 and 45. Then we can create 2 conditions filters:

- Add an ***Instance selection*** / ***Rule-based selection*** component to ***Define status 3***, ***Parameters***: Add the 2 following conditions ***Prof_ID<>44 And Prof_ID<>45*** (we could have instead used the less generic single condition (ErTot<>0).
- Move ***Multiple linear regression 1*** into ***Rule-based selection1***.

Notice how the ***Examples*** values decreased from 61 to 59. R^2 increased to 0.443 and Irbn5y became more significant.

Play a while with the model by removing other outliers and replacing variables in order to attempt to improve the model.

The model ***TotSgW***, ***Prof5*** and ***Irbn5y*** (or any other Iribarren number) gives the best results (R^2 = 0.443, with Irbn5y partially significant).

The model PSgW, DSgW, Prof5 and Irbn5y gives also good results (R^2 = 0.445), but DSgW is not significant and Irbn5y is only partially significant, then this model will not be continued.

Database of Beach Retreat Projections and Beach Retreat Estimators

Introduction

The Database of Beach Retreat Projections and the *Beach Retreat Estimator* comprise a *tool* that can estimate the range of beach retreat for different morphologically beaches, under different scenarios of long-term and short-term sea level rise and different conditions/forcing (in terms of sedimentology and hydrodynamics). The incorporated database has resulted though the construction/application of ensembles (a short-term and a long-term ensemble) of different 1-D analytical and numerical morphodynamic models of varied complexity. It must be noted that this tool does not intend to replace detailed studies, which are based upon the 2-D/3-D morphodynamic modles calibrated/validated through the collection of comprehensive sets of field observations (see McLeod et al., 2010 for a review); rather, it aims to provide an easily deployed methodology that can provide a rapid first assessment of beach erosion/inundation risk under sea level rise.

Beach retreat morphodynamic models

Beaches are among the most morphologically dynamic environments, being controlled by complex process-response mechanisms that operate in several temporal and spatial scales (Van Rijn, 2003). Beach erosion can be differentiated into: (i) long-term erosion, i.e. irreversible retreat of the shoreline position, due to sea level rise and/or negative coastal sedimentary budgets (Nicholls *et al*., 2007) that force either landward migration of the beaches or drowning; and (ii) short-term erosion, caused by storms and storm surges, which may not necessarily result in permanent shoreline retreats, but may create large-scale devastation (Niedoroda *et al*., 2009).

Sea level rise can have significant impacts on beach geomorhology, as beaches will be forced to retreat (Fig. 1). The extent and rate of the beach retreat depend on several parameters, e.g. the beach slope, the type/supply of beach sediments and the hydrodynamic conditions (Dean, 2002).

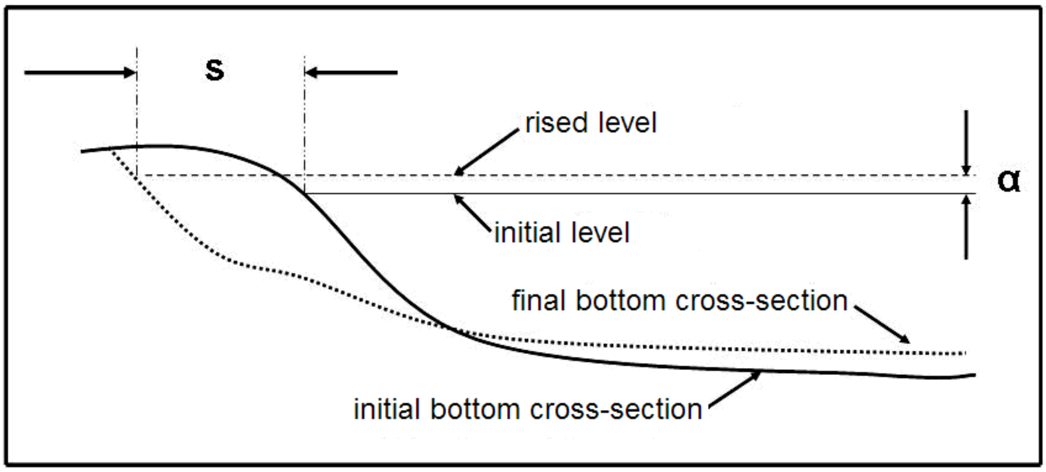


Fig. 1. *Sketch of beach response to sea level rise. A rise α produces erosion of the beach face sediment, which is transferred to the adjacent sea bed, resulting in a coastal retreat S.*

In order to predict the response of the beach coastline to sea level rise, several static and dynamic models have been developed. The basic principle on which such models are based is that sea level or/and different wave conditions result in changes of the beach profile which is forced to adapt (Komar, 1998).

Static models

Several static (analytical) models have been developed to assess beach retreat under sea level rise. In the present work, the following models are considered:

1. The Bruun model (e.g. Bruun, 1988), which is based on the concept of the equilibrium profile (Zhang *et al.*, 2004). The major expression used in the model is:

$$S = \frac{l \cdot a}{h_c + B} \qquad \textbf{[1]}$$

where S the beach retreat, B the height of the beachface, h_c the closure depth and l the distance between the coastline and the closure depth (Komar, 1998).

2. Edelman's (1972) model, which can deal with more realistic beach profiles and temporally-variable sea level changes. Beach retreat according to this model is given by:

$$S(t) = w_b \ln\left[\frac{h_b + B_o}{h_b + B - a(t)}\right] \qquad \textbf{[2]}$$

where the B_o is the initial height of the beachface, w_b, is the surf zone width and h_b is the water depth at wave breaking.

3. The Dean (1991) model, which was developed for the diagnosis/prediction of storm-driven beach retreat, is also based on the equilibrium profile concept, with the beach retreat controlled by the water depth at wave breaking, the height of breaking waves H_b, the surf zone width, according to the following expression:

$$S = (a + 0.068H_b)\frac{w_b}{B + h_b} \qquad \textbf{[3]}$$

Dynamic models

The dynamic (numerical) models used in the present tool are:

4. The SBEACH model (Larson and Kraus, 1989), which is a 'bottom-up' morphodynamic model, consisting of combined hydrodynamic, sediment transport and morphological development modules. The hydrodynamic module contains detailed descriptions of the wave transformation, with its basic expression being:

$$\frac{dE_F}{dx} = -\frac{k}{h}(E_F - E_{Fs}) \qquad \textbf{[4]}$$

where *k* is an empirical wave decay coefficient, E_F is the wave energy flux and E_{Fs} is the stable wave energy flux. The sediment transport is controlled by the wave energy flux and the beach slope according to the equations below:

$$q = \mathrm{K}(D - D_{eq} + \frac{\varepsilon}{\mathrm{K}}\frac{dh}{dx}),\ D > D_{eq} - \frac{\varepsilon}{\mathrm{K}}\frac{dh}{dx} \qquad \textbf{[5]}$$

$$q = 0,\ D < D_{eq} - \frac{\varepsilon}{\mathrm{K}}\frac{dh}{dx} \qquad \textbf{[6]}$$

where K is an empirical transport rate coefficient, *D* is the wave energy dissipation per unit volume, D_{eq} is equilibrium energy dissipation per unit volume and *ε* is a transport rate coefficient for the slope-dependent term. Finally, the sediment continuity equation on which the morphological development model is based upon, is addressed by finite differences and a 'stair – step' beach profile discretisation.

5. The model based on the Leont'yev (1996) algorithm uses the energetics approach (Battjes and Janssen, 1978), with the wave energy balance in the cross-shore direction controlled by the wave propagation angle ϕ, the group velocity c_g the wave energy *E* and its dissipation due to breaking *D*:

$$\frac{\partial\left(\overline{E}\cdot c_g\cdot\cos\phi\right)}{\partial x}=-D \qquad \textbf{[7]}$$

Sediment transport rates are predicted separately for the surf and swash zones. The transport rate q_W due to wave/current interaction is determined following Leont'yev (1996):

$$q_W=\frac{\varepsilon_b}{2\tan\phi}f_W\rho\left(\overline{\tilde{u}^3}\cos\phi+3\overline{\tilde{u}^2}U_d\right)+\varepsilon_s\left(F+B\right)\left(\frac{W_s}{U_d}-\frac{\partial d}{\partial x}\right)^{-1} \qquad \textbf{[8]}$$

where f_W is the bed friction coefficient for wave orbital velocities *u* (Nielsen, 1992), U_d is the wave undertow velocity, W_s is the sediment fall velocity and ε_s is the efficiency factor of suspended load transport. *F* and *B* express power 'expenditure' due to bed friction (*F*) and excess turbulence at the bottom layer (Roelvink and Stive, 1989). On the surf zone, run up sediment transport is estimated using Leont'yev (1996):

$$\widehat{q}_R=c_1\rho\left(2gR\right)^{3/2}\left(\tan\beta_{eq}-\tan\beta\right) \qquad \textbf{[9]}$$

where c_1 is a dimensionless proportionality coefficient and tanβ_e is the equilibrium beach slope (Bascom, 1964). For the swash zone, run up transport rate is given by:

$$q_R=\widehat{q}_R\left(\frac{1-x/x_M}{1-x_R/x_M}\right)^{3/2} \quad x_R\le x\le x_M \qquad \textbf{[10]}$$

where x_R, x_M are the lower and upper limit of the swash zone. The run-up induced transport rate q_R decays away from the swash zone towards the outer boundary of the surf zone according to:

$$q_R = \widehat{q}_R \exp\left(c_3\left(x - x_R\right)/ H_o\right) \qquad x \leq x_R \qquad \textbf{[11]}$$

The suspended and bed load transport rates are assumed to decay linearly to zero from the breaking point to the beach border. Finally, the beach profile evolution is estimated by solving the sediment continuity equation through a forward finite differences scheme.

Introduction to Matlab GUI

A graphical user interface (GUI) provides the user with a familiar environment. This environment contains familiar to the user push-buttons, toggle-buttons, lists, menus, text boxes etc, so that he or she can concentrate on using the application rather than on the mechanics involved. The 3 principal elements required to create a MATLAB Graphical User Interface are:

1. Components. Each item of a MATLAB GUI (push-buttons, labels, edit boxes, etc) is a graphical component. The types of components include graphical controls (push-buttons, edit boxes, lists, sliders, etc.), static elements (frames and text strings), menus, and axes. Graphical controls and static elements are created by the function *uicontrol*, and menus are created by the functions *uimenu* and *uicontextmenu*. Axes, which are used to display graphical data, are created by the function axes.

2 Figures. The components of a GUI must be arranged within a figure, which is a window on the computer screen. In the past, figures have been created automatically whenever there were data to be plotted. However, empty figures can be created through he function figure and can be used to hold any combination of components.

3 Callbacks. Finally, there must be some way to perform an action if a user clicks a mouse on a button or types information on a keyboard. A mouse click or a key press is an event, and the MATLAB program must respond to each event if the program is to perform its function. For example, if a user clicks on a button, that event must cause the MATLAB code that implements the button function to be executed. The code that is executed in response to an event is known as a call back. There must be a callback to implement the function of each graphical component on the GUI. MATLAB GUIs are created using a tool called guide, the GUI Development Environment. This tool allows a programmer to layout the GUI, selecting and aligning the GUI components to be placed within it.

Once the components are in place, the programmer can edit their properties: name, colour, size, font, text to display etc. In addition, the programmer may want to modify the *Tag* parameters of the components. The *Tag* parameter is basically the variable name of a component, and it is used as identifier in the programming code. When the Guide saves the GUI, it creates a working program including skeleton functions (as m-file) that the programmer can modify to implement the behaviour of the GUI. The m-file is where the programmer attaches the appropriate code to the callback of each component. So a Matlab GUI consists of (i) a figure which is the platform that the programmer has created and (ii) an m-file created by Matlab guide and modified by the programmer.

Database of Beach Retreat Projections

Introduction

The models that were used to create this database are: 3 analytical (Edelman, Bruun, Dean) (Edelman, 1972; Bruun, 1988; Dean, 1991) and 2 numerical models (SBEACH and Leont'yev) (Larson and Kraus, 1989; Leont'yev, 1996). The models Leont'yev, SBEACH and Edelman can estimate (mainly) short-term changes of beaches and the models Bruun and Dean long-term changes. All models were applied for the case of beaches (low coasts consisted of unconsolidated sediments) using linear profiles with slopes of 1/10, 1/15, 1/20, 1/25 and 1/30. Experiments were carried out using varying wave conditions, i.e. wave heights (H) of 0.5, 1, 1.5, 2, 3, 4, 5 and 6 m and periods (T) 3- 12 s and 7 different sediment grain sizes (d_{50} of 0.2, 0.33, 0.50, 0.80, 1, 2 and 5 mm). For all cases (totally 465), 14 sea level rise scenarios (0.038, 0.05, 0.10, 0.15, 0.22, 0.30, 0.40, 0.50, 0.75, 1, 1.25, 1.50, 2 and 3 m) were tested.

In order for this volume of data to be manageable, a simplified platform was created using the Matlab Guide. The users of this platform can search in the database for the environmental conditions (beach slope, wave height, wave period, sediment size) of their interest. They can use specific conditions (viz. one value for each parameter) and obtain (if these conditions are found in the database) the beach retreat (for small spatial scale e.g. one beach) given by the five models (Leont'yev, SBEACH, Edelman, Bruun and Dean) for 14 sea level scenarios (0.038, 0.05, 0.10, 0.15, 0.22, 0.30, 0.40, 0.50, 0.75, 1, 1.25, 1.50, 2 and 3 m) and the polynomial equation that describes the relation between sea level rise and beach retreat. Users can select all, or some of these models to create an ensemble and then they can obtain the mean values (by selected models) of beach retreat and the polynomial equation that fits in the mean values of the retreat. For large (spatial) scale applications, users can enter a range of environmental conditions in the platform and obtain the lower and upper limit of the beach retreat, projected by the models. They can also select models to create an ensemble and obtain the mean (by selected models) lower and mean upper limits of the projected retreat. A criterion for the selection of models can be the classification of the models to short-term and long-term for short-term and long-term projections respectively.

The database used by this platform is consisted from the files:

Leont.txt: is a table with 465 rows and 14 columns and contains the results (beach retreat projections) of the Leont'yev model. Each row corresponds to a different case viz. a combination of conditions (beach slope, wave height, wave period and sediment size). Each column corresponds to a different sea level rise scenario.

Sbeach.txt: is also a matrix with 465 rows and 14 columns, containing the results (beach retreat projections) of the SBEACH model.

Edelman.txt: is also a table with 465 rows and 14 columns, containings the results (beach retreat projections) of the Edelman model.

Bruun.txt*:* is also a table with 465 rows and 14 columns and contains the results (beach retreat projections) of the Bruun model.

Dean.txt: is also a table with 465 rows and 14 columns and contains the results (beach retreat projections) of the Dean model.

slc.txt: is a one column table and contains the 14 sea level rise scenarios.

dic.txt: is a table with 465 rows and 4 columns and contains the combinations of conditions for which the models were applied. The first column is the beach slope (viz. 10 for a beach slope 1/10), the second is the wave height in meters, the third is the wave period in sec and the fourth is the sediment size (viz. d_{50}) in millimeters.

These files should be in the same folder with the Figure file (B_retreat1.fig) and the m-file (B_retreat1.m) of this GUI program.

How to use this program

First, open up MATLAB. Go to the command window and type in guide, or use the icon (GUIDE) below of the main menu. You should see the following screen appear (Figure 2), choose Open Existing GUI and then choose or browse the file you want to open e.g. for this GUI the file B_retreat1.

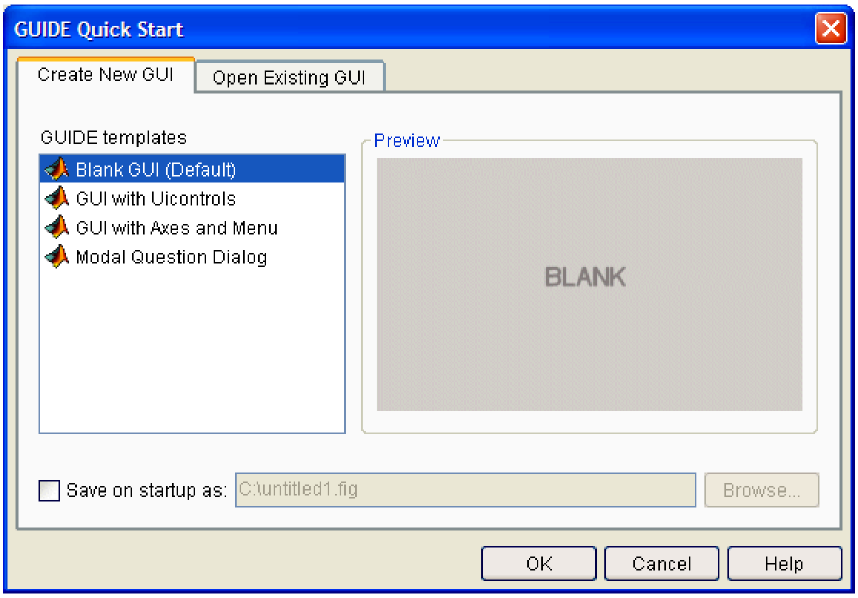
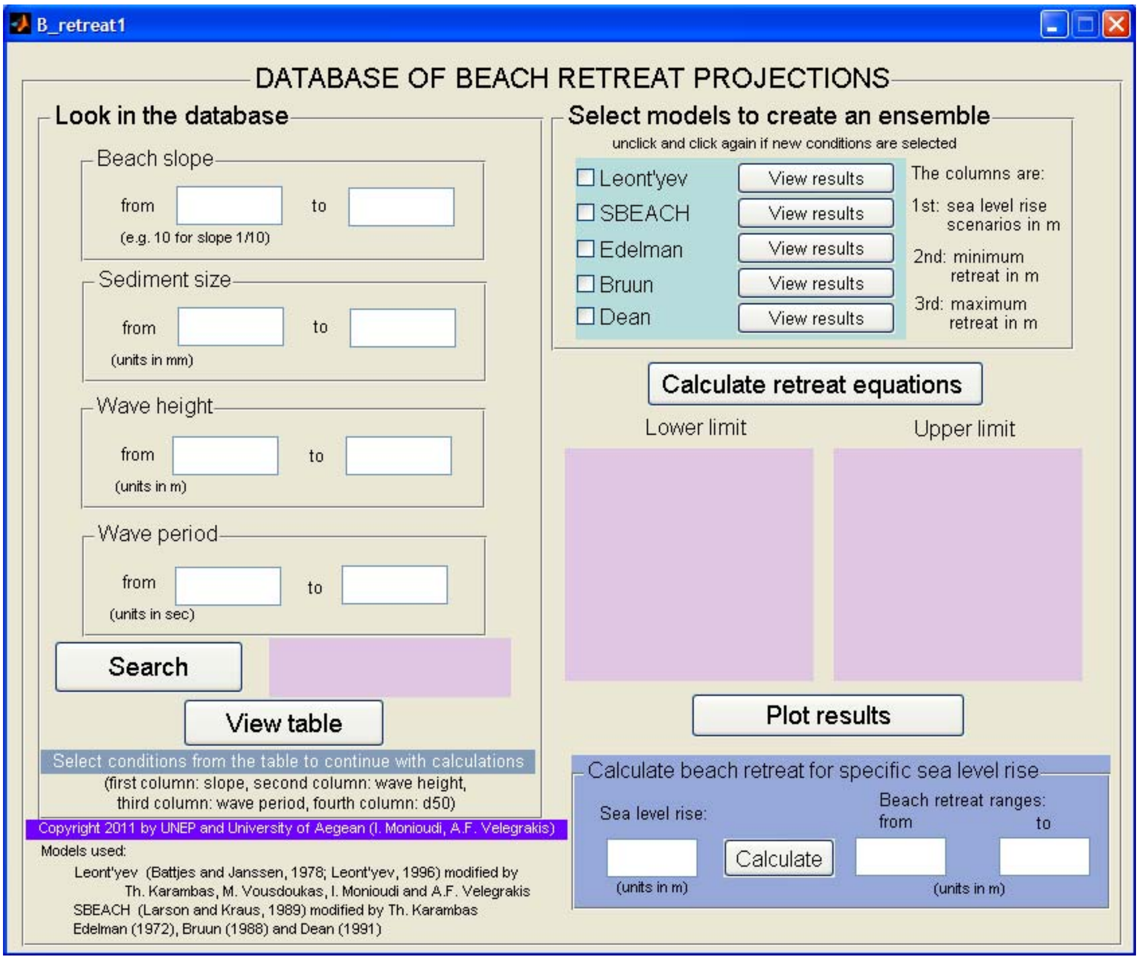


Figure 2. *Open files window.*

You should now see the following screen (or something similar depending on what version of MATLAB you are using):



The columns are:
1st: sea level rise scenarios in m
2nd: minimum retreat in m
3rd: maximum retreat in m

Select conditions from the table to continue with calculations
(first column: slope, second column: wave height,
third column: wave period, fourth column: d50)

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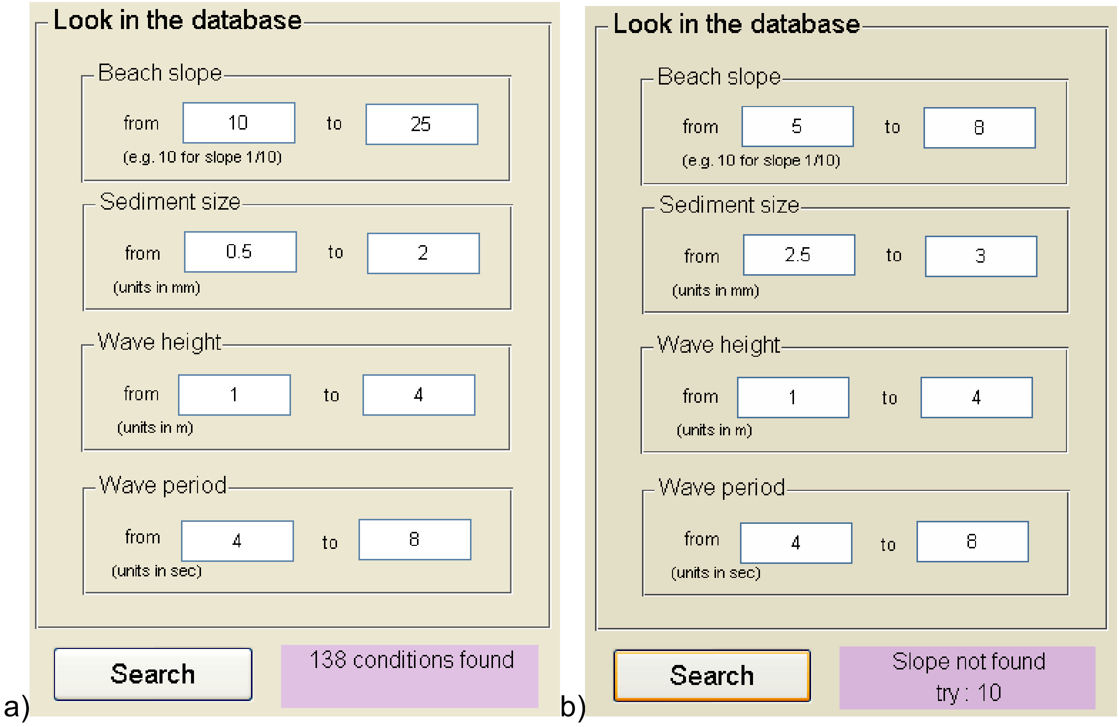
Models used:
Leont'yev (Battjes and Janssen, 1978; Leont'yev, 1996) modified by Th. Karambas, M. Vousdoukas, I. Monioudi and A.F. Velegrakis
SBEACH (Larson and Kraus, 1989) modified by Th. Karambas
Edelman (1972), Bruun (1988) and Dean (1991)

Figure 3. The B_retreat1 GUI figure.

To run the program press the button ▶ and to view the m-file file press the button 📄.

This GUI is consisted of a big panel named ‘Database of beach retreat projections’ which contains all the components of the GUI. In the panel named ‘Look in the database’, the user enters information about the beach slope, the sediment size, the wave height, and the wave period. For each parameter 2 edit boxes exist. In the first box, the user enters the smaller value of the parameter and in the second box the larger value in order to insert a range of values, or he/she can enter the same value in the 2 boxes in order to insert a specific value; examples of input values are shown in Figure 4. Once all edit boxes are filled the user can push the button ‘Search’ and a text appears in text field next to the pushbutton.



a)

Look in the database

Beach slope: from 10 to 25 (e.g. 10 for slope 1/10)

Sediment size: from 0.5 to 2 (units in mm)

Wave height: from 1 to 4 (units in m)

Wave period: from 4 to 8 (units in sec)

138 conditions found

b)

Look in the database

Beach slope: from 5 to 8 (e.g. 10 for slope 1/10)

Sediment size: from 2.5 to 3 (units in mm)

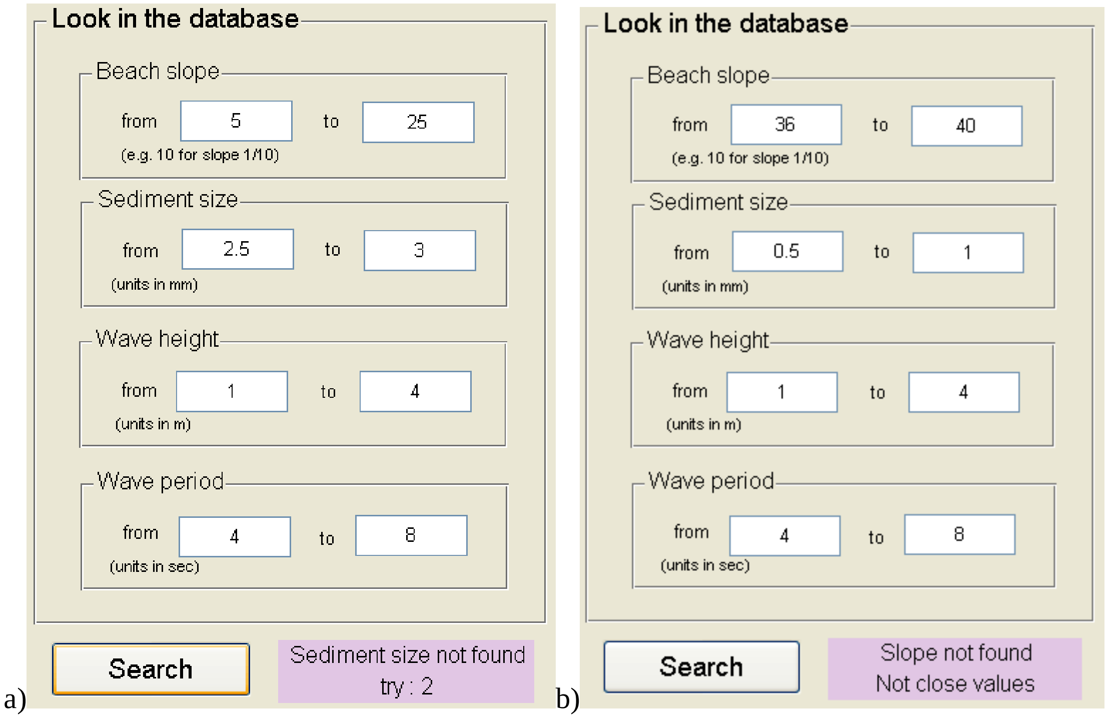
Wave height: from 1 to 4 (units in m)

Wave period: from 4 to 8 (units in sec)

Slope not found
try : 10

Figure 4. *Examples of input values.*

If the conditions inserted by the user are found in the database the number of conditions is written in the text field next to the button ‘Search’ (Figure 4a). The program is first searching for the beach slope, if beach slope is not found then, the program stops the quest for the others parameters and informs the user that the slope is not found and suggests close values, if there are any in the data base (Figure 4b). If the inserted beach slope is found, but not the sediment size, then the program stops the quest for the other parameters and informs the user that the sediment size is not found and suggests close values, if there are any in the data base (Figure 5a). The same procedure is also applied for the other parameters.



a)

Look in the database

Beach slope
from 5 to 25
(e.g. 10 for slope 1/10)

Sediment size
from 2.5 to 3
(units in mm)

Wave height
from 1 to 4
(units in m)

Wave period
from 4 to 8
(units in sec)

Sediment size not found
try : 2

b)

Look in the database

Beach slope
from 36 to 40
(e.g. 10 for slope 1/10)

Sediment size
from 0.5 to 1
(units in mm)

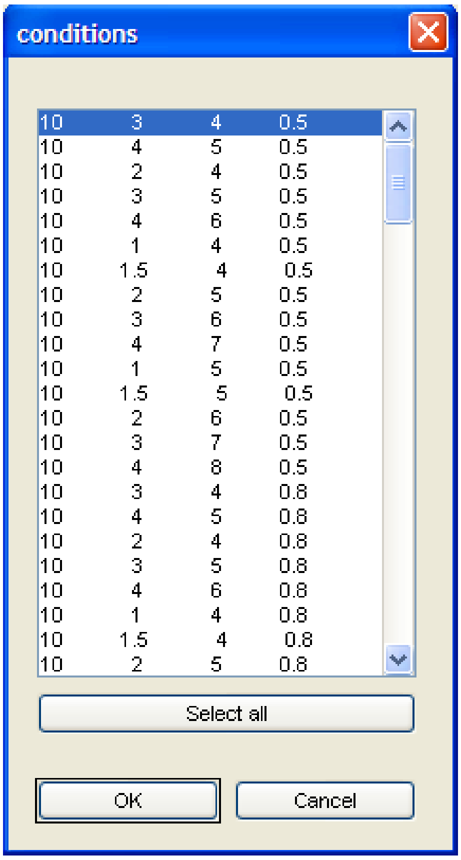
Wave height
from 1 to 4
(units in m)

Wave period
from 4 to 8
(units in sec)

Slope not found
Not close values

Figure 5. *Examples of input values not found.*

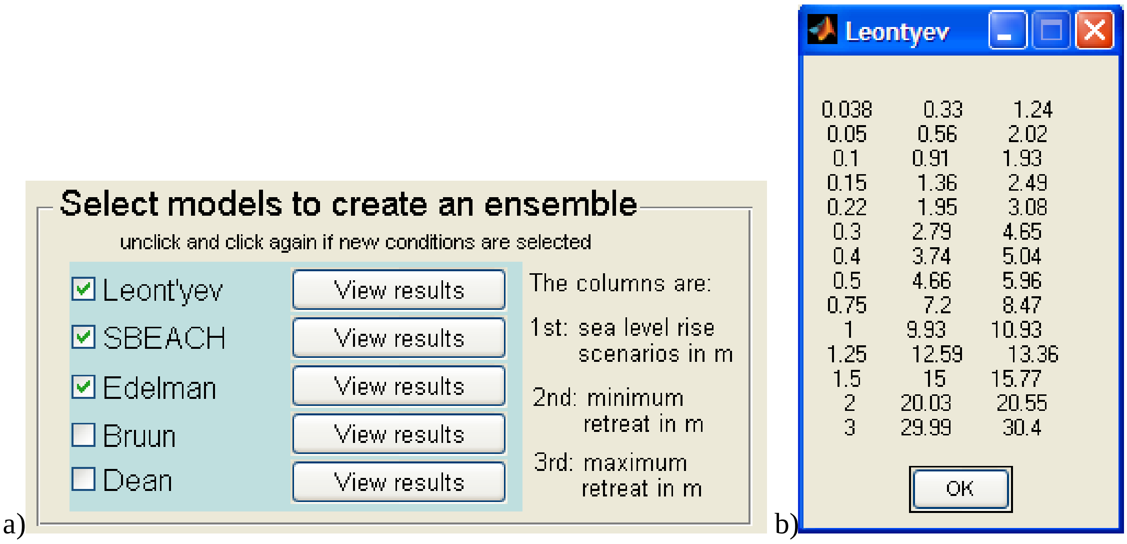
Once the desired conditions are found, the user can use the button ‘View table’, which prompts a list box to appear (Figure 6) with all the condition combinations found in the database, enabling the user to view the results of his/her quest and make a new selection from the list. Now that the environmental conditions are determined, the user can select models to create an ensemble, by clicking in the corresponding checkboxes (Figure 7a). The user has the option to view the lower and upper limit of beach retreat estimations made by each model individually by pushing the button ‘View results’ next to the model (the checkbox of the model should be clicked on) (Figure 7b). When the ‘View results’ button is pressed a message box opens with a table consisted by 3 columns. The first column is the sea level rise scenarios (in m), the second is the lower limit of beach retreat estimations (in m) made by the model and the third column is the upper limit. If new conditions are selected, the checkboxes should be un-clicked and clicked again, otherwise zero values appears in the table in the message box.



conditions

```
10     3     4     0.5
10     4     5     0.5
10     2     4     0.5
10     3     5     0.5
10     4     6     0.5
10     1     4     0.5
10     1.5    4     0.5
10     2     5     0.5
10     3     6     0.5
10     4     7     0.5
10     1     5     0.5
10     1.5    5     0.5
10     2     6     0.5
10     3     7     0.5
10     4     8     0.5
10     3     4     0.8
10     4     5     0.8
10     2     4     0.8
10     3     5     0.8
10     4     6     0.8
10     1     4     0.8
10     1.5    4     0.8
10     2     5     0.8
```

Figure 6. *The list box of the environmental conditions, 1st column: beach slope (m), 2nd column: wave height (m), 3rd column: wave period (sec), 4th column: sediment size (mm).*



a)

Select models to create an ensemble

unclick and click again if new conditions are selected

☑ Leont'yev
☑ SBEACH
☑ Edelman
☐ Bruun
☐ Dean

The columns are:

1st: sea level rise scenarios in m

2nd: minimum retreat in m

3rd: maximum retreat in m

b)

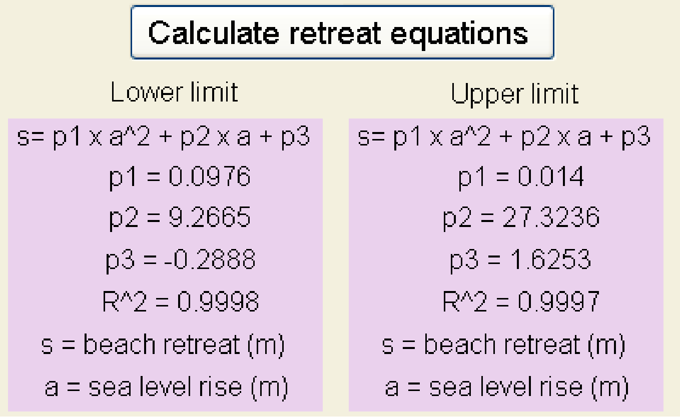
Leontyev

```
0.038     0.33      1.24
0.05      0.56      2.02
0.1       0.91      1.93
0.15      1.36      2.49
0.22      1.95      3.08
0.3       2.79      4.65
0.4       3.74      5.04
0.5       4.66      5.96
0.75      7.2       8.47
1         9.93      10.93
1.25      12.59     13.36
1.5       15        15.77
2         20.03     20.55
3         29.99     30.4
```

Figure 7. *a) An example of model selection. b) An example of message box with the results of Leont'yev model.*

Once the models that comprise the ensemble are selected, the user can use the button 'Calculate retreat equations'; then the polynomial equations describing the mean lower and mean upper limits of beach retreat estimations appear in the text fields below the texts

'Lower limit' and 'Upper limit', respectively (see e.g. Figure 8). These equations have the form: $s = p_1a^2 + p_2a + p_3$, where s: is the beach retreat, p_1, p_2 and p_3: are the polynomial coefficients and a: is the sea level rise. The value of R^2 is also given in the text field.



Calculate retreat equations

Lower limit	Upper limit
s= p1 x a^2 + p2 x a + p3	s= p1 x a^2 + p2 x a + p3
p1 = 0.0976	p1 = 0.014
p2 = 9.2665	p2 = 27.3236
p3 = -0.2888	p3 = 1.6253
R^2 = 0.9998	R^2 = 0.9997
s = beach retreat (m)	s = beach retreat (m)
a = sea level rise (m)	a = sea level rise (m)

Figure 8. *An example of the resulted equations.*

With the press of the pushbutton 'Plot results' the polynomials equations of the lower and upper limit of all selected model are calculated and plotted together with the mean (non-weighed) limits (see e.g. Figure 9).

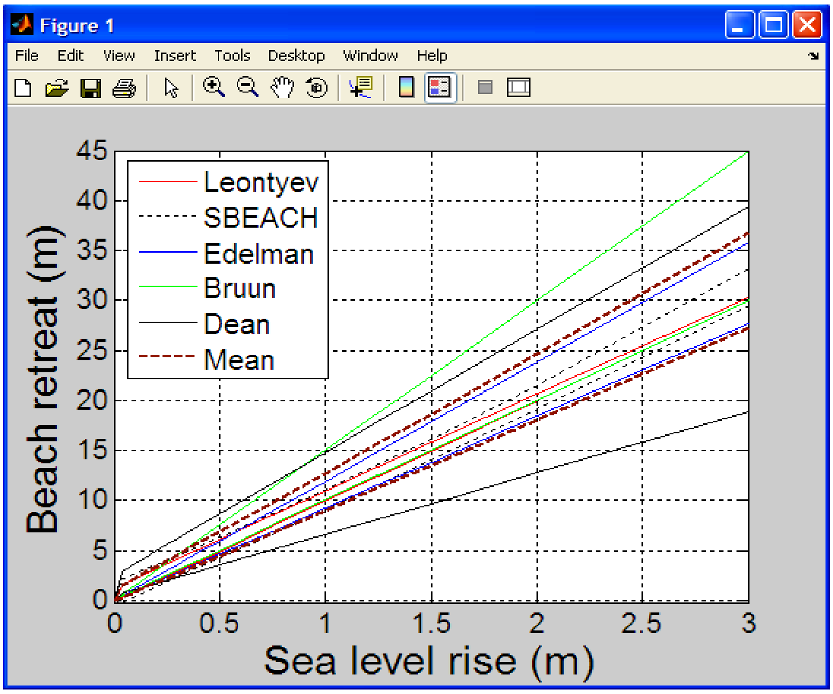
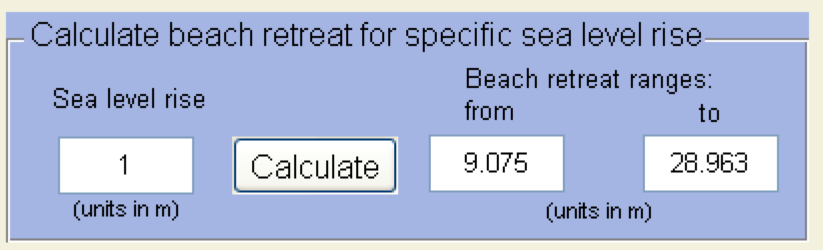


Figure 9. *An example of a plotting result.*

From the resulting equations, the range of beach retreat due to a sea level rise can be calculated. This program gives the user the option to calculate the range of retreat only with a click on the pushbutton ‘Calculate’ inside the panel ‘Calculate the retreat for a specific sea level rise’. An example is given in Figure 10.



Calculate beach retreat for specific sea level rise

Sea level rise: 1 (units in m)

Beach retreat ranges: from 9.075 to 28.963 (units in m)

Figure 10. An example of beach retreat range calculation for a specific sea level rise scenario.

The call-back functions of the program

In this section the call-back functions of the components of this GUI program are presented and described. The call-back functions are the codes that are executed in response to a mouse click or a key press and are written in the m-file (B_retreat1.m).

The function executed with the pushbutton 'Search' :

```
% --- Executes on button press in Search.
function Search_Callback(hObject, eventdata, handles)
% hObject    handle to Search (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

These lines are created automatically when a pushbutton is drawn in the GUI. The name 'Search' has been given in the *Tag* property of the pushbutton.

```
sl1=str2num(get(handles.slope1,'String'));
sl2=str2num(get(handles.slope2,'String'));
sd1=str2num(get(handles.d50a,'String'));
sd2=str2num(get(handles.d50b,'String'));
H1=str2num(get(handles.height1,'String'));
H2=str2num(get(handles.height2,'String'));
P1=str2num(get(handles.period1,'String'));
P2=str2num(get(handles.period2,'String'));
```

These lines of the code get the values that the user enters in the edit boxes of the 'Beach slope', 'Sediment size', 'Wave height' and 'Wave period' panels

```
load dic.txt;
ind1=find(dic(:,1)>=sl1 & dic(:,1)<=sl2);
d1=dic(ind1,:);
sls=unique(dic(:,1));
if size(ind1,1)==0;
    newind1=find(abs(sls(:)-sl1)<=5 | abs(sls(:)-sl2)<=5);
    if size(newind1,1)==0;
        set(handles.res1,'String','Slope not found');
        set(handles.rres1,'String','Not close values');
    else
       aa1=sls(newind1);
       nnam1(1,:)=char(['try : ' num2str(aa1')]);
       set(handles.res1,'String','Slope not found');
       set(handles.rres1,'String',nnam1(1,:));
    end
dif_cod=0;
dlmwrite('dif_cod.txt', dif_cod, 'delimiter', '\t', 'precision', 2);
else
```

In this section the code is searching for the values of beach slope given by the user in the file 'dic.txt' and keeps the indices of the rows of the 'dic' table that contain these values. If the exact values are not found, is searching for close (±5 units) ones. If close values are found a text appears in the text field next to the button 'Search' e.g. 'Slope not found try 10   15'. If no close values are found a text appears writing: 'Slope not found not close values'.

```
ind2=find(d1(:,4)>=sd1 & d1(:,4)<=sd2);
```

In this section the code is searching for the values of sediment size given by the user in the previously indexed rows of the 'dic' table that the slope values were found and keeps the indices of rows of the 'dic' table that contain these values. If the exact values are not found is

```
    d2=d1(ind2,:);
    d50s=unique(d1(:,4));
    if size(ind2,1)==0;
       newind2=find(abs(d50s(:)-sd1)<=1 | abs(d50s(:)-sd2)<=1);
      if size(newind2,1)==0;
        set(handles.res1,'String','Sediment size not found');
        set(handles.rres1,'String','No close values');
      else
       aa2=d50s(newind2);
       nnam2(1,:)=char(['try : ' num2str(aa2')]);
       set(handles.res1,'String','Sediment size not found');
       set(handles.rres1,'String',nnam2(1,:));
     end
     dif_cod=0;
dlmwrite('dif_cod.txt', dif_cod, 'delimiter', '\t', 'precision', 2);
    else
```

```
Hs=unique(d2(:,2));
         ind3=find(d2(:,2)>=H1 & d2(:,2)<=H2);
         d3=d2(ind3,:);
     if size(ind3,1)==0;
          newind3=find(abs(Hs(:)-H1)<=1 | abs(Hs(:)-H2)<=1);
          if size(newind3,1)==0;
            set(handles.res1,'String','Wave height not found');
           set(handles.rres1,'String','No close values');
      else
           aa3=Hs(newind3);
          nnam3(1,:)=char(['try : ' num2str(aa3')]);
         set(handles.res1,'String','Wave height not found');
         set(handles.rres1,'String',nnam3(1,:));
      end
     dif_cod=0;
dlmwrite('dif_cod.txt', dif_cod, 'delimiter', '\t', 'precision', 2);
     else
```

This section of the code is searching for the values of wave height given by the user in the previously indexed rows of the 'dic' table that the sediment sizes values were found and keeps the indices of rows of the 'dic' table that contain these values. If the exact values are not found is searching for close (±1 units) ones. If close values are found a text appears in the text field next to the button 'Search' e.g. 'Wave height not found try 1 2'. If no close values are found a text appears writing 'Wave height not found not close values'.

```
      ind4=find(d3(:,3)>=P1 & d3(:,3)<=P2);
           Ts=unique(d3(:,3));
        if size(ind4,1)==0;
              dif_cod=0;
       dlmwrite('dif_cod.txt', dif_cod, 'delimiter', '\t', 'precision', 2);
              newind4=find(abs(Ts(:)-P1)<=1 | abs(Ts(:)-P2)<=1);
           if size(newind4,1)==0;
              set(handles.res1,'String','Wave period not found');
             set(handles.rres1,'String','No close values');
          else
           aa4=Ts(newind4);
           nnam4(1,:)=char(['try : ' num2str(aa4')]);
           set(handles.res1,'String','Wave period not found');
          set(handles.rres1,'String',nnam4(1,:));
         end
    else
```

This section of the code is searching for the values of wave period given by the user in the previously indexed rows of the 'dic' table that the wave periods values were found and keeps the indices of rows of the 'dic' table that contain these values. If the exact values are not found is searching for close (±1 units) ones. If close values are found a text appears in the text field next to the button 'Search' e.g. 'Wave period not found try 1   2'. If no close values are found a text appears writing 'Wave period not found not close values'.

```
              k=size(ind4,1);
              dif_cod=d3(ind4,:);
             dlmwrite('dif_cod.txt', dif_cod, 'delimiter', '\t', 'precision', 2);
             nam(1,:)=char([num2str(k) ' conditions found']);
             set(handles.res1,'String',nam(1,:));
             set(handles.rres1,'String','    ');
           end
       end
      end
    end
```

If all values are found the code creates and saves (as txt file) a new table named dif_cod with the combinations of conditions that fulfil the user's request. The number of conditions found appears as a text in the text field next to the button 'Search'.

The function executed with the pushbutton 'View table':

```
% --- Executes on button press in table.
function table_Callback(hObject, eventdata, handles)
% hObject    handle to table (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

Lines automatically created with the creation of the pushbutton 'View table'.

Opens a list box with the conditions found in the database according with the criteria given by the user and saves the new selection of conditions made by the user in a txt file named 'Selection'. It also creates and saves 2 zero table (L_limit and U_limit) in which the limits of beach retreat estimations will be saved with the press of another component.

```
load dif_cod.txt;
L_limit=zeros(5,14);
U_limit=zeros(5,14);
dlmwrite('L_limit.txt', L_limit, 'delimiter', '\t', 'precision', 6);
dlmwrite('U_limit.txt', U_limit, 'delimiter', '\t', 'precision', 6);
s=num2str(dif_cod);
[Selection,ok]=listdlg('ListString',s,'name','conditions','ListSize',[200 300]);
dlmwrite('Selection.txt', Selection, 'delimiter', '\t');
```

The call-back function executed when the checkbox e.g. ‘Leontyev’ is clicked/unclicked:

```
% --- Executes on button press in leo.
function leo_Callback(hObject, eventdata, handles)
% hObject    handle to leo (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hint: get(hObject,'Value') returns toggle state of leo
```

Lines automatically created with the creation of the checkbox ‘Leontyev’

```
    checkboxStatus = get(handles.leo,'Value');
    load dif_cod.txt;
    load Selection.txt;
    dcod=dif_cod(Selection,:);
    load dic.txt;
  for i=1:size(dcod,1);
    ind4(i)=find(dic(:,1)==dcod(i,1) & dic(:,2)==dcod(i,2) &
    dic(:,3)==dcod(i,3) & dic(:,4)==dcod(i,4));
  end
     load Leont.txt;
     load L_limit.txt;
    load U_limit.txt;
```

Finds the indices of the selected conditions, inside the dic table and loads the table with the results of Leont’yev model.

```
if checkboxStatus==1;
    if size(ind4,2)==1;
        L_limit(1,:)=Leont(ind4,:);
        U_limit(1,:)=Leont(ind4,:);
    else
        L_limit(1,:)=min(Leont(ind4,:));
        U_limit(1,:)=max(Leont(ind4,:));
    end
        else
```

If check box is clicked on the lower and upper limit of the beach retreat estimations made by Leont’yev model are calculated and saved in the first row of L_limit and U_limit tables respectively. Each row of these tables corresponds to a different model and each column to a different sea level rise scenario. If check box is not clicked zero values are given in the Leont’yev corresponding row (1st row) of the L_limit and U_limit tables.

```
        L_limit(1,:)=0;
       U_limit(1,:)=0;
end
dlmwrite('L_limit.txt', L_limit, 'delimiter', '\t', 'precision', 6);
dlmwrite('U_limit.txt', U_limit, 'delimiter', '\t', 'precision', 6);
```

A similar code is used and for the others checkboxes. The lower and upper limits of SBEACH model estimations are saved in the 2nd row of the L_limit and U_limit tables respectvely, of Edelman model in the 3rd row, of Bruun model in the 4th row and of Dean model in the 5th row. For the models checked in the checkboxes the corresponding rows shows the limits of beach retreat estimations while for the unchecked models zero values are given in the corresponding rows.

The call-back function executed with the pushbutton 'View results' e.g. for the model Leont'yev is the following:

```
% --- Executes on button press in Lmodel.
function Lmodel_Callback(hObject, eventdata, handles)
% hObject    handle to Lmodel (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
 load L_limit.txt;
   load U_limit.txt;
   load slc.txt;
   aa(:,1)=slc;
   aa(:,2)=L_limit(1,:)';
   aa(:,3)=U_limit(1,:)';
   ss=num2str(aa);
   msgbox(ss,'Leontyev');
```

Creates a table consisted of 3 columns. The 1st column shows sea level rise scenarios, the 2nd column shows the lower limit of beach retreat estimations resulted from e.g. Leont'yev model and the 3rd column shows the upper limit.

The call-back function executed with the pushbutton 'Calculate retreat equations':

```
% --- Executes on button press in CE.
function CE_Callback(hObject, eventdata, handles)
% hObject    handle to VE (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
load L_limit.txt;
load U_limit.txt;
load slc.txt;
indl=find(L_limit(:,1)~=0);
if size(indl,1)==1
    mll=L_limit(indl,:);
    mul=U_limit(indl,:);
else
   mll=mean(L_limit(indl,:));
  mul=mean(U_limit(indl,:));
end
```

Loads the L_limit and U_limit tables. The average of the non zero rows (viz. of the beach retreat estimations of the 'checked' models), is calculated.

```
pll=polyfit(slc',mll,2);
pul=polyfit(slc',mul,2);
yll=pll(1)*(slc.^2)+pll(2)*slc+pll(3);
yul=pul(1)*(slc.^2)+pul(2)*slc+pul(3);
rsssll=sum((yll-mll').^2);
sssssll=sum((mll-mean(mll)).^2);
rrll=1-rsssll/sssssll;
rsssul=sum((yul-mul').^2);
ssssul=sum((mul-mean(mul)).^2);
rrul=1-rsssul/ssssul;
pll=roundn(pll,-4);
pul=roundn(pul,-4);
rrll=roundn(rrll,-4);
rrul=roundn(rrul,-4);
```

Finds the coefficients of the second degree polynomials that fit the mean lower and the mean upper limits of beach retreat estimations of the model ensemble selected by the user.

```
cresll1(1,:)=char(['s= p1 x a^2 + p2 x a + p3 ']);
cresll2(1,:)=char(['   p1 = ' num2str(pll(1))]);
cresll3(1,:)=char(['   p2 = ' num2str(pll(2))]);
cresll4(1,:)=char(['   p3 = ' num2str(pll(3))]);
cresll5(1,:)=char(['   R^2 = ' num2str(rrll)]);
cresll6(1,:)=char(['s = beach retreat (m) ']);
cresll7(1,:)=char(['a = sea level rise (m)']);
cresul1(1,:)=char(['s= p1 x a^2 + p2 x a + p3 ']);
cresul2(1,:)=char(['   p1 = ' num2str(pul(1))]);
cresul3(1,:)=char(['   p2 = ' num2str(pul(2))]);
cresul4(1,:)=char(['   p3 = ' num2str(pul(3))]);
cresul5(1,:)=char(['   R^2 = ' num2str(rrul)]);
cresul6(1,:)=char(['s = beach retreat (m) ']);
cresul7(1,:)=char(['a = sea level rise (m)']);
```

Creates the text strings that describes the polynomial equations fitted to the lower and upper limit of the beach retreat estimations of the ensemble of the models selected by the user.

```
set(handles.ll1,'String',cresll1(1,:));
set(handles.ll2,'String',cresll2(1,:));
set(handles.ll3,'String',cresll3(1,:));
set(handles.ll4,'String',cresll4(1,:));
set(handles.ll5,'String',cresll5(1,:));
set(handles.ll6,'String',cresll6(1,:));
set(handles.ll7,'String',cresll7(1,:));
set(handles.ul1,'String',cresul1(:,:));
set(handles.ul2,'String',cresul2(:,:));
set(handles.ul3,'String',cresul3(:,:));
set(handles.ul4,'String',cresul4(:,:));
set(handles.ul5,'String',cresul5(:,:));
set(handles.ul6,'String',cresul6(:,:));
set(handles.ul7,'String',cresul7(:,:));
```

Displays the text strings created at the previous step in the fields under the texts ‘Lower limit’ and ‘Upper limit’.

The function executed with the pushbutton ‘Plot results’:

```
% --- Executes on button press in plresults.
function plresults_Callback(hObject, eventdata, handles)
% hObject    handle to plresults (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
load L_limit.txt;
load U_limit.txt;
load slc.txt;
indl=find(L_limit(:,1)~=0);
if size(indl,1)==1
    mll=L_limit(indl,:);
    mul=U_limit(indl,:);
else
   mll=mean(L_limit(indl,:));
   mul=mean(U_limit(indl,:));
end
for i=1:size(indl,1);
    ppl(i,:)=polyfit(slc',L_limit(indl(i),:),2);
    yyl(i,:)=ppl(i,1)*(slc.^2)+ppl(i,2)*slc+ppl(i,3);
    ppu(i,:)=polyfit(slc',U_limit(indl(i),:),2);
    yyu(i,:)=ppu(i,1)*(slc.^2)+ppu(i,2)*slc+ppu(i,3);
end
pll=polyfit(slc',mll,2);
pul=polyfit(slc',mul,2);
yll=pll(1)*(slc.^2)+pll(2)*slc+pll(3);
yul=pul(1)*(slc.^2)+pul(2)*slc+pul(3);
yym=[flipud(yll);0;yul];
```

Finds the coefficients of the second degree polynomials that fit the beach retreat lower and upper limit of the models selected by the user.

```
tit(1,:)=char(['Leontyev']);
tit(2,:)=char(['SBEACH  ']);
tit(3,:)=char(['Edelman ']);
tit(4,:)=char(['Bruun   ']);
tit(5,:)=char(['Dean    ']);
tit(6,:)=char(['Mean    ']);
indnl=[indl;6];
xx1=[flipud(slc);0;slc];
colo=['r','k','b',''];
   typ=['-',':','-'];
figure
for i=1:size(indl,1);
   yy1(:,i)=[flipud(yyl(i,:)');0;yyu(i,:)'];
   pl=plot(xx1,yy1(:,i),typ(i));
   set(pl,'color',colo(i));
   hold on;
end
if size(indl,1)==1;
   hold off
   indnl=indl;
else
   h=plot(xx1,yym,'--');
   set(h,'color',[0.6 0.2 0],'linewidth',2);
  indnl=[indl;6];
end
set(gca,'fontsize',15);
xlabel('Sea level rise (m)','fontsize',22);
ylabel('Beach retreat (m)','fontsize',22);
legend(tit(indnl,:),'location','northwest');
axis tight;
grid on;
```

Plots the polynomials found for the selected models together with the polynomials of the means of these

===

The function that is executed with the press of pushbutton 'Calculate':

```
% --- Executes on button press in CALCretreat.
function CALCretreat_Callback(hObject, eventdata, handles)
% hObject    handle to CALCretreat (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

===

```
slr=str2num(get(handles.SLRscenario,'String'));
load L_limit.txt;
load U_limit.txt;
load slc.txt;
indl=find(L_limit(:,1)~=0);
```

Calculates the range of retreat for a specific sea level rise scenario given by the user, in the edit box with the *Tag* name 'SLRscenario' below the text 'Sea level rise:' using the polynomial equations that describe the mean

```
if size(indl,1)==1
    mll=L_limit(indl,:);
    mul=U_limit(indl,:);
else
   mll=mean(L_limit(indl,:));
   mul=mean(U_limit(indl,:));
end
pll=polyfit(slc',mll,2);
pul=polyfit(slc',mul,2);
yll=pll(1)*(slr.^2)+pll(2)*slr+pll(3);
yul=pul(1)*(slr.^2)+pul(2)*slr+pul(3);
br1=roundn(yll,-3);
br2=roundn(yul,-3);
set(handles.Bretreat1,'String',br1);
set(handles.Bretreat2,'String',br2);
```

Beach Retreat Estimator

Introduction

The users of this GUI can estimate beach retreat according to static modles (Edelman' s, Bruun's and Dean's) for particular environmental conditions (beach slope, wave height, wave period, sediment size) and sea level rise scenarios of their interest. The users can select all or some of these models to create an ensemble and then they can obtain the mean values (by selected models) of beach retreat and the polynomial equation that fits in the mean values of the retreat. This GUI is consisted of the figure file (B_retreat2.fig) and the m-file (B_retreat2.m).

How to use the program

Open up MATLAB. Use the icon (GUIDE) below of the main menu and open the file B_retreat2. You should now see the screen shown in Figure 11. To run the program press the button ▶ and to view the m-file file press the button .

In the panel named 'Insert data', the user enters information on beach slope, wave height and wave period. He can also insert sea level rise scenarios pushing the button 'Insert sea level rise scenarios'. Then an input dialog box appears with default values been already inserted which the user can use, or he/she can erase them and enter new values. The input dialog box with default values is shown in Figure 12.

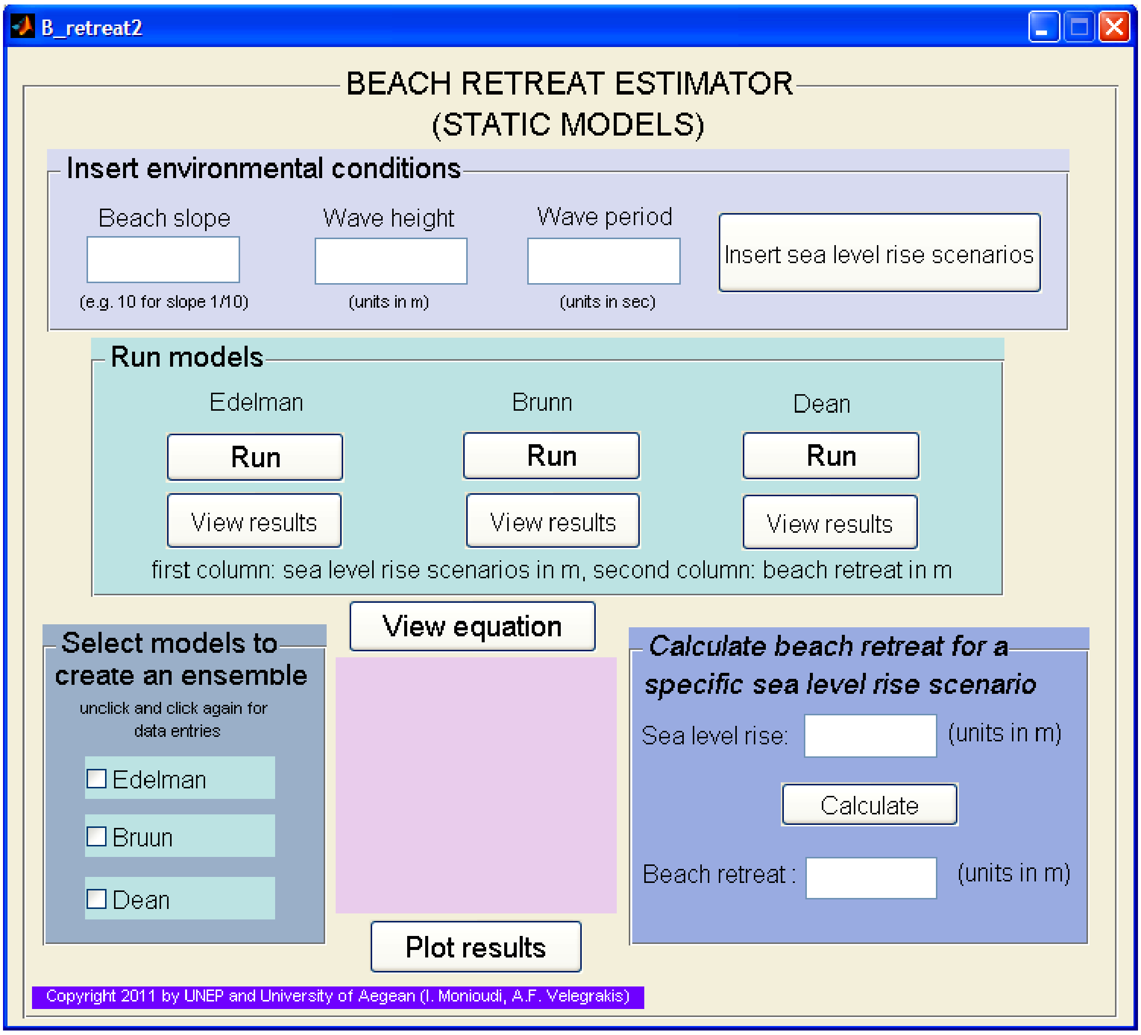
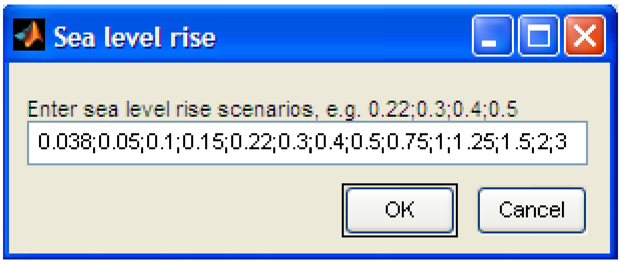

B_retreat2
BEACH RETREAT ESTIMATOR
(STATIC MODELS)
Insert environmental conditions
Beach slope
Wave height
Wave period
Insert sea level rise scenarios
(e.g. 10 for slope 1/10)
(units in m)
(units in sec)
Run models
Edelman
Brunn
Dean
Run
Run
Run
View results
View results
View results
first column: sea level rise scenarios in m, second column: beach retreat in m
Select models to create an ensemble
unclick and click again for data entries
Edelman
Bruun
Dean
View equation
Plot results
Calculate beach retreat for a specific sea level rise scenario
Sea level rise:
(units in m)
Calculate
Beach retreat :
(units in m)
Copyright 2011 by UNEP and University of Aegean (I. Monioudi, A.F. Velegrakis)

Figure 11. *The figure of the B_retreat2 GUI.*



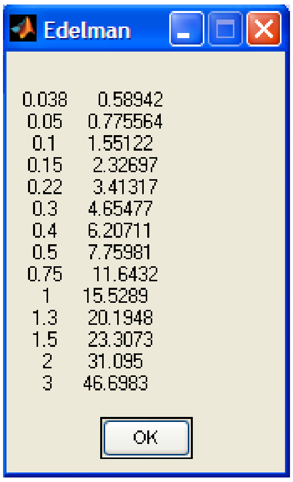
Enter sea level rise scenarios, e.g. 0.22;0.3;0.4;0.5

0.038;0.05;0.1;0.15;0.22;0.3;0.4;0.5;0.75;1;1.25;1.5;2;3

Figure 12. *Input dialog box with default sea level rise scenarios.*

Once all parameters are determined, the user can run the models by using the buttons 'Run' inside the panel named 'Run models' (Figure 11). The user has the option to view beach retreat estimations made by each model individually by pushing the button 'View results' below the pushbutton 'Run'. When the 'View results' button is pressed, a message box opens with a table consisted by 2 columns. The first column is the sea level rise scenarios (in m) and the second is the beach retreat estimations (in m) made by the model.

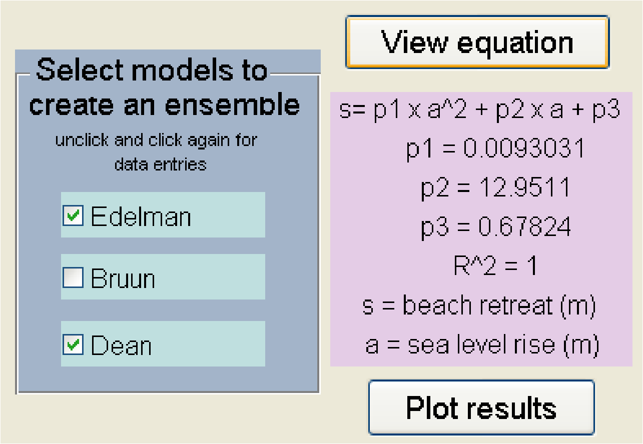
An example of this message box is shown in Figure 13. The user can select models to create an ensemble, by clicking in the corresponding checkboxes (Figure 14).



```
0.038    0.58942
0.05    0.775564
0.1     1.55122
0.15     2.32697
0.22     3.41317
0.3     4.65477
0.4     6.20711
0.5     7.75981
0.75     11.6432
1     15.5289
1.3     20.1948
1.5     23.3073
2     31.095
3     46.6983
```

Figure 13. *An example of message box with results of the Edelman model.*

Once the models comprising the ensemble are selected, the user use the button 'View equation'; then, a polynomial equation describing beach retreat estimations appears in the text fields below the button. An example is shown in Figure 14. This equation have the form: $s = p_1a^2 + p_2a + p_3$, where s: is the beach retreat, p_1, p_2 and $p_{3:}$ are the polynomial coefficients and a: is the sea level rise. The value of R^2 is also given in the text field.



Select models to create an ensemble

unclick and click again for data entries

☑ Edelman

□ Bruun

☑ Dean

```
s= p1 x a^2 + p2 x a + p3
p1 = 0.0093031
p2 = 12.9511
p3 = 0.67824
R^2 = 1
s = beach retreat (m)
a = sea level rise (m)
```

Figure 14. *An example of the resulted equation.*

With the press of the pushbutton 'Plot results', the polynomial equations of all selected models are calculated and plotted together with the polynomial equation that fits in the mean values of beach retreat. An example of a plot result is depicted in Figure 15.

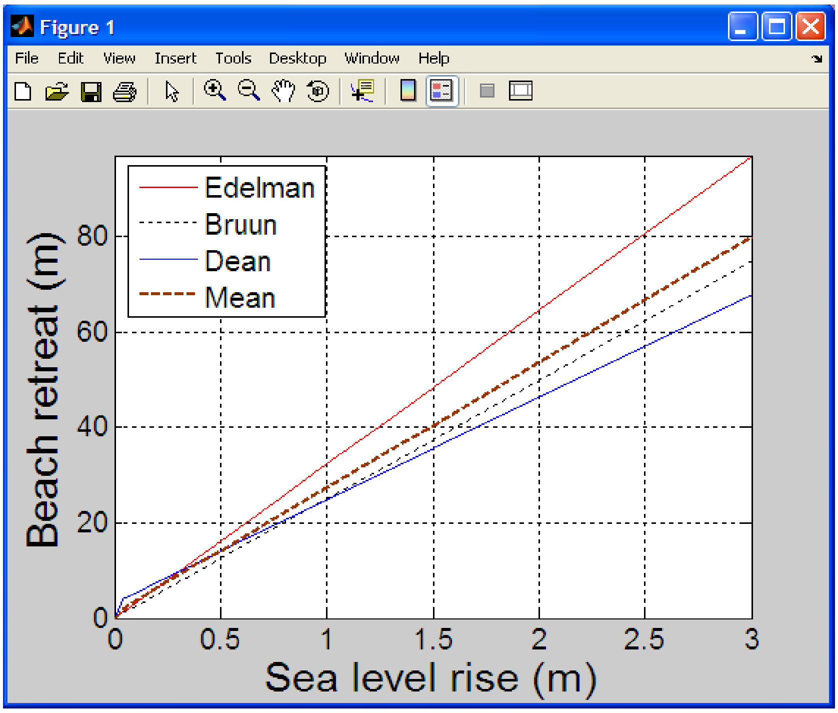
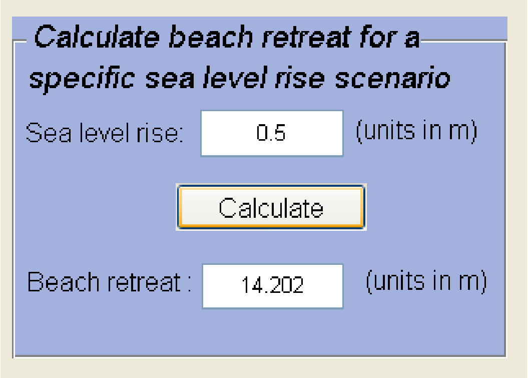


Figure 15. *An example of a plotting result.*

From the equation resulted by the program, the range of beach retreat due to a specific value of sea level rise can be easily calculated. This program gives the user the possibility to calculate the range of retreat only with a click on the pushbutton calculate inside the panel 'Calculate the retreat for a specific sea level rise scenario'. An example is given in Figure 16.


Calculate beach retreat for a specific sea level rise scenario

Sea level rise: 0.5 (units in m)

Beach retreat : 14.202 (units in m)

Figure 16. *An example of beach retreat calculation for a specific sea level rise scenario.*

The call-back functions of the program

In this section the call-back functions of the components of this GUI program are presented and described. The call-back functions are the codes that are executed in response to a mouse click or a key press and are written in the m-file (B_retreat1.m).

The function executed with the press of pushbutton 'Insert sea level rise scenarios':

```
% --- Executes on button press in slrsenario.
function slrscenario_Callback(hObject, eventdata, handles)
% hObject    handle to slrsenario (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
prompt={'Enter sea level rise scenarios, e.g. 0.22;0.3;0.4;0.5'};
name='Sea level rise';
numlines=1;
defaultanswer={'0.038;0.05;0.1;0.15;0.22;0.3;0.4;0.5;0.75;1;1.25;1.5;2;3'};
options.Resize='on';
options.WindowStyle='normal';
options.Interpreter='tex';
answer=inputdlg(prompt,name,numlines,defaultanswer,options);
if size(answer,1)==0;
    slrs=0;
else
   [slrs status] = str2num(answer{1});
end
total_table=zeros(3,size(slrs,1));
dlmwrite('slrs.txt', slrs, 'delimiter', '\t', 'precision', 2);
dlmwrite('total_table.txt', total_table, 'delimiter', '\t', 'precision', 6);
```

Opens an input dialog box, giving the user the possibility to enter the sea level scenarios that he/she wants to be tested and save them in a txt file named 'slrs'.
Also creates a zero table named total_table.txt.

The function executed with the press of pushbutton ‘Run’ under the text field ‘Edelman’:

```
% --- Executes on button press in Emodel.
function Emodel_Callback(hObject, eventdata, handles)
% hObject    handle to Emodel (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
    m=str2num(get(handles.Slope,'String'));
     Ho=str2num(get(handles.Wheight,'String'));
     T=str2num(get(handles.Wperiod,'String'));
     load slrs.txt;
     load total_table.txt;
     numa=size(slrs,1);
     tend=300;
     slope=1/m;
     do=20;
```

Gets the input values for the beach slope (*m*), wave height (*Ho*) and wave period (*T*) entered by the user. Also loads the file ‘slrs.txt’ which contains the sea level rise scenarios entered by the user.

```
     f=1/T;
     kl=calculk(do,f);
     Lo=2*pi/kl;
     ir=slope/sqrt(Ho/Lo);
     Hs=Ho;
     Hb=Hs/(3.3*(Hs/Lo)^(1/3));
     g=ir^0.17+0.08;
    db=Hb/g;
    ddd(1)=db;
 for k=2:100
       kb=calculk(ddd(k-1),f);
       Lb=2*pi/kb;
       nb=0.5*(1+2*kb*ddd(k-1)/sinh(2*kb*ddd(k-1)));
       ks=sqrt((0.5*Lo)/(nb*Lb));
       Hsn=ks*Ho;
       Hbn=Hsn/(3.3*(Hsn/Lo)^(1/3));
       dbn1=Hbn/g;
       ddd(k)=dbn1;
       if abs(ddd(k)-ddd(k-1))<=0.05
           break
        end
 end
      kk=k;
      dbf=(ddd(kk)+ddd(kk-1))/2;
      Hbf=dbf*g;
 if ir<2.3
       R=Hbf*ir;
else
```

Calculates the wave length (*Lo*) using the dispersion relation (calling the function ‘calculk’), the wave height (*Hbf*) and the water depth (*dbf*) at the wave breaking point. Also calculates run up height (*R*) and the width of the surf zone (*wb*).

```
     R=Hbf*2.3;
end
     wb=dbf/slope;
```

```
for i=1:numa;
      aa1=slrs(i)/tend;
      aa=0;
      t=0.;
     dt=0.67;
     ss2=0;
     for j=1:tend
         ss2=ss2+(aa1/dt)*(wb/(dbf+R-aa1));
    end
      sEdel(i,1)=ss2;
end
total_table(1,:)=sEdel';
dlmwrite('sEdel.txt', sEdel, 'delimiter', '\t', 'precision', 6);
dlmwrite('total_table.txt', total_table, 'delimiter', '\t', 'precision', 6);
```

Calculation of beach retreat according to the Edelman’s model, for the sea level rise scenarios entered by the user.
Also saves the results in the first row of the table named total_table.

The function executed with the press of pushbutton ‘Run’ under the text field ‘Bruun’:

```
% --- Executes on button press in Brmodel.
function Brmodel_Callback(hObject, eventdata, handles)
% hObject    handle to Brmodel (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
m=str2num(get(handles.Slope,'String'));
Ho=str2num(get(handles.Wheight,'String'));
T=str2num(get(handles.Wperiod,'String'));
load slrs.txt;
load total_table.txt;
numa=size(slrs,1);
slope=1/m;
do=20;
```

Gets the input values for the beach slope (*m*), wave height (*Ho*) and wave period (*T*) entered by the user.
Also loads the file ‘slrs.txt’ which contains the sea level rise scenarios entered by the user.

```
 f=1/T;
kl=calculk(do,f);
  Lo=2*pi/kl;
  ir=slope/sqrt(Ho/Lo);
  Hs=Ho;
  Hb=Hs/(3.3*(Hs/Lo)^(1/3));
 g=ir^0.17+0.08;
 db=Hb/g;
 ddd(1)=db;
for k=2:100
       kb=calculk(ddd(k-1),f);
       Lb=2*pi/kb;
       nb=0.5*(1+2*kb*ddd(k-1)/sinh(2*kb*ddd(k-1)));
       ks=sqrt((0.5*Lo)/(nb*Lb));
       Hsn=ks*Ho;
       Hbn=Hsn/(3.3*(Hsn/Lo)^(1/3));
       dbn1=Hbn/g;
        ddd(k)=dbn1;
      if abs(ddd(k)-ddd(k-1))<=0.05
        break
     end
 end
kk=k;
dbf=(ddd(kk)+ddd(kk-1))/2;
Hbf=dbf*g;
 if ir<2.3
      R=Hbf*ir;
 else
      R=Hbf*2.3;
End
 dc=0.75*Ho; % closure depth according to Velinga, 1983
 l=(dc+R)/slope;
```

Calculation of wave length (*Lo*) using the dispersion relation (calling the function 'calculk'), wave height (*Hbf*) and water depth (*dbf*) at the breaking point. Also calculates run up height (*R*) and closure depth (*dc*).

```
for i=1:numa;
     sBruun(i,1)=l*slrs(i,1)/(dc+R);
end
 dlmwrite('sBruun.txt', sBruun, 'delimiter', '\t', 'precision', 6);
 total_table(2,:)=sBruun';
dlmwrite('total_table.txt', total_table, 'delimiter', '\t', 'precision', 6);
```

Calculation of beach retreat according to the Bruun's model, for the sea level rise scenarios entered by the user. Also saves the results in the second row of the table named total_table.

The function executed with the press of pushbutton ‘Run’ under the text field ‘Dean’:

```
% --- Executes on button press in Dmodel.
function Dmodel_Callback(hObject, eventdata, handles)
% hObject    handle to Dmodel (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
m=str2num(get(handles.Slope,'String'));
Ho=str2num(get(handles.Wheight,'String'));
T=str2num(get(handles.Wperiod,'String'));
  load slrs.txt;
  load total_table.txt;
  numa=size(slrs,1);
  slope=1/m;
  do=20;
```

Gets the input values for the beach slope (*m*), wave height (*Ho*) and wave period (*T*) entered by the user. Also loads the file ‘slrs.txt’ which contains the sea level rise scenarios entered by the user.

```
   f=1/T;
   kl=calculk(do,f);
   Lo=2*pi/kl;
   ir=slope/sqrt(Ho/Lo);
   Hs=Ho;
   Hb=Hs/(3.3*(Hs/Lo)^(1/3));
   g=ir^0.17+0.08;
   db=Hb/g;
   ddd(1)=db;
 for k=2:100
     kb=calculk(ddd(k-1),f);
     Lb=2*pi/kb;
     nb=0.5*(1+2*kb*ddd(k-1)/sinh(2*kb*ddd(k-1)));
     ks=sqrt((0.5*Lo)/(nb*Lb));
      Hsn=ks*Ho;
      Hbn=Hsn/(3.3*(Hsn/Lo)^(1/3));
      dbn1=Hbn/g;
      ddd(k)=dbn1;
    if abs(ddd(k)-ddd(k-1))<=0.05
        break
    end
end
  kk=k;
  dbf=(ddd(kk)+ddd(kk-1))/2;
  Hbf=dbf*g;
if ir<2.3
    R=Hbf*ir;
 else
     R=Hbf*2.3;
```

Calculation of wave length (*Lo*) using the dispersion relation (calling the function ‘calculk’), wave height (*Hbf*) and water depth (*dbf*) at the breaking point. Also calculates run up height (*R*) and the width of the surf zone (*wb*).

```
 end
     Wb=dbf/slope;
```

```
for i=1:numa;
       sDean(i,1)=(slrs(i)+0.068*Hbf)*Wb/(R+dbf);
end;
save sDean sDean;
 dlmwrite('sDean.txt', sDean, 'delimiter', '\t', 'precision', 6);
 total_table(1,:)=sDean';
 dlmwrite('total_table.txt', total_table, 'delimiter', '\t', 'precision', 6);
```

Calculation of beach retreat according to the Dean's model, for the sea level rise scenarios entered by the user. Also saves the results in the third row of the table named total_table.

The function executed with the press of pushbutton 'View results' e.g. for the model Edelman:

```
% --- Executes on button press in Edeltable.
function Edeltable_Callback(hObject, eventdata, handles)
% hObject    handle to Edeltable (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
load sEdel.txt;
load slrs.txt;
    aa(:,1)=slrs;
    aa(:,2)=sEdel;
    ss=num2str(aa);
    msgbox(ss,'Edelman')
```

Creates a table consisted of 2 columns. The 1st column shows the sea level rise scenarios selected by the user, the 2nd column shows the beach retreat estimations for these scenarios resulted from e.g. Edelman model.

The function executed when the checkbox e.g. ‘Edelman’ is clicked/unclicked is the following:

```
% --- Executes on button press in Edel.
function Edel_Callback(hObject, eventdata, handles)
% hObject    handle to Edel (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hint: get(hObject,'Value') returns toggle state of Edel
```

```
checkboxStatus = get(handles.Edel,'Value');
load sEdel.txt;
load total_table.txt;
if checkboxStatus==1;
    total_table(1,:)=sEdel';
else
    total_table(1,:)=0;
end
dlmwrite('total_table.txt', total_table, 'delimiter', '\t', 'precision', 6);
```

If check box is clicked beach retreat estimations made by Edelman model are loaded and saved in the first row of table named ‘total_table’. Each row of these tables corresponds to a different model and each column to a different sea level rise scenario. If check box is not clicked zero values are given in the Edelman corresponding row (1st row) of the total_table.

The function executed with the press of pushbutton ‘View equation’:

```
% --- Executes on button press in Ve1.
function Ve1_Callback(hObject, eventdata, handles)
% hObject    handle to Ve1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
load total_table.txt;
load slrs.txt;
tt=total_table;
indl=find(tt(:,1)~=0);
if size(indl,1)==1
     mr=tt(indl,:);
else
    mr=mean(tt(indl,:));
end
```

Loads the total_table.txt and estimates the average of the non zero rows of the table (viz. of the beach retreat estimations of the ‘checked’ models).

Finds the coefficients of the second degree polynomials that fit the mean beach retreat of the model ensemble selected by the user.

```
pr=polyfit(slrs',mr,2);
yr=pr(1)*(slrs.^2)+pr(2)*slrs+pr(3);
rss_r=sum((yr-mr').^2);
sss_r=sum((mr-mean(mr)).^2);
rr_r=1-rss_r/sss_r;
```

```
cresr1(1,:)=char(['s= p1 x a^2 + p2 x a + p3 ']);
cresr2(1,:)=char(['   p1 = ' num2str(pr(1))]);
cresr3(1,:)=char(['   p2 = ' num2str(pr(2))]);
cresr4(1,:)=char(['   p3 = ' num2str(pr(3))]);
cresr5(1,:)=char(['   R^2 = ' num2str(rr_r) '']);
cresr6(1,:)=char(['s = beach retreat (m) ']);
cresr7(1,:)=char(['a = sea level rise (m)']);
```

Creates the text strings that describes the polynomial equation fitted to the mean beach retreat estimations of the ensemble of the models selected by the user.

```
set(handles.eq1,'String',cresr1(1,:));
set(handles.eq2,'String',cresr2(1,:));
set(handles.eq3,'String',cresr3(1,:));
set(handles.eq4,'String',cresr4(1,:));
set(handles.eq5,'String',cresr5(1,:));
set(handles.eq6,'String',cresr6(1,:));
set(handles.eq7,'String',cresr7(1,:));
```

Displays the text strings created at the previous step in the fields under the push button ‘View equation’.

The function executed with the press of pushbutton ‘Plot results’:

```
% --- Executes on button press in plres.
function plres_Callback(hObject, eventdata, handles)
% hObject    handle to plres (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
load total_table.txt;
load slrs.txt;
tt=total_table;
indl=find(tt(:,1)~=0);
if size(indl,1)==1
    mr=tt(indl,:);
else
   mr=mean(tt(indl,:));
end
pr=polyfit(slrs',mr,2);
yr=pr(1)*(slrs.^2)+pr(2)*slrs+pr(3);
for i=1:size(indl,1);
```

Finds the coefficients of the second degree polynomials that fit the beach retreat projections of the models selected by the user.

```
    ppr(i,:)=polyfit(slrs',tt(indl(i),:),2);
    yyr(i,:)=ppr(i,1)*(slrs.^2)+ppr(i,2)*slrs+ppr(i,3);
end
```

```
colo=['r','k','b','g','k'];
 typ=['-',':','-','-','-'];
tit(1,:)=char(['Edelman ']);
tit(2,:)=char(['Bruun   ']);
tit(3,:)=char(['Dean    ']);
tit(4,:)=char(['Mean    ']);
indnl=[indl;4];
figure
for i=1:size(indl,1);
    pl=plot([0;slrs],[0;yyr(i,:)'],typ(i));
    set(pl,'color',colo(i));
    hold on;
end
if size(indl,1)==1;
    hold off;
    indnl=indl;
else
   h=plot([0;slrs],[0;yr],'--');
   set(h,'color',[0.6 0.2 0],'linewidth',2);
  indnl=[indl;4];
end
set(gca,'fontsize',15);
xlabel('Sea level rise (m)','fontsize',22);
ylabel('Beach retreat (m)','fontsize',22);
legend(tit(indnl,:),'location','northwest');
axis tight;
grid on;
```

Plots the polynomials found for the selected models together with the polynomial of the mean of these models.

The function executed with the press of pushbutton ‘Calculate’:

```
% --- Executes on button press in calc.
function calc_Callback(hObject, eventdata, handles)
% hObject    handle to calc (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
slr=str2num(get(handles.slr1,'String'));
load total_table.txt;
load slrs.txt;
```

Calculates the beach retreat for a specific sea level rise scenario given by the user, in the edit box with the *Tag* name ‘slr1’ next to the text ‘Sea level rise:’ using the polynomial equations that describe the mean (of the selected models)

```
tt=total_table;
indl=find(tt(:,1)~=0);
if size(indl,1)==1
    mr=tt(indl,:);
else
    mr=mean(tt(indl,:));
end
pr=polyfit(slrs',mr,2);
yr=pr(1)*(slr.^2)+pr(2)*slr+pr(3);
br1=roundn(yr,-3);
set(handles.bretreat1,'String',br1);
```

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Beach Retreat under Sea Level Rise

The main objectives of this part of the Training Session are (a) to transfer ‘know how’ developed within the RiVAMP and (b) provide free platforms/software solutions to Jamaican and Caribbean’s partners with regard to a rapid assessment of beach erosion/retreat under climate change-induced sea level rise. This part of the Training forms an integral part of the overarching objective of the RiVAMP Training Session, i.e. to promote an improved understanding of the role of ecosystems in disaster risk reduction (including climate change-related risks), through integrated assessments that can support policy and land-use planning decisions.

Climate change induces several impacts pertinent to coastal areas, including mean sea level rise, warmer water temperatures, higher intensity of cyclones, storm surges and precipitation as well as changes in the wave regime (e.g. Emanuel, 2005; Allan.and Soden, 2008; and Ruggiero et al., 2010). These changes can severely affect coastal ecosystems and economic activities, such as e.g. coral reefs (e.g. Woodroffe, 2008), coastal wetlands, seagrasses and lagoons (e.g. Cruz-Palacios and van Tussenbroek, 2005; Karim and Mimura, 2008), beaches (McKee Smith et al., 2010) , tourism (e.g Bardolet and Sheldon, 2008), seaports and other coastal infrastructure (e.g. Nicholls et al., 2007; McGranahan et al., 2007; CCSP, 2008; Lenton et al., 2009), particularly in Developing Countries and SIDS (e.g. Dasgupta et al., 2009). However, although predictions of exposure to climatic changes are required at decadal scales, most of the available information/models are dealing with either long-term (century-to millennium) (e.g. Nott et al, 2009), annual (e.g. Greenwood and Orford, 2008) or even storm event (e.g. Callaghan et al., 2008) scales. There have already been attempts to develop global coastal hazards data bases (e.g. Vafeidis et al., 2008), as well as methodologies/tools to assess rapidly coastal vulnerability to sea level rise and extreme events (e.g. Hinkel and Klein, 2009), but the work is still far from concluded (McLeod et al., 2010).

Within the RiVAMP framework, a simple, rapid methodology has been applied/used (e.g. Estrella et al., 2010) to assess beach retreat/erosion under both-long- and short term sea level rise (see also Velegrakis et al., 2009). According to this method, ensembles of beach morphodynamic models of varying complexity are used in order to assess beach/erosion/retreat under varying conditions (i.e. beach slope and sediment size) and forcing (i.e. sea level rise and wave conditions). In the present RiVAMP Training Session, an especially developed tool, based on the construction/application of ensembles (a short-term and a long-term ensemble) of different 1-D analytical and numerical morphodynamic models of varied complexity, will be presented/distributed that can rapidly estimate ranges of beach retreat for different morphologically and sedimentologically beaches, under different scenarios of long-term and short-term sea level rise and different hydrodynamic forcing. It must be noted that this tool does not intend to replace detailed studies, which are based upon the 2-D/3-D morphodynamic modles calibrated/validated through the collection of comprehensive sets of field observations, but to provide an easily deployed methodology that can provide a rapid first assessment of beach erosion/inundation risks under sea level rise.

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