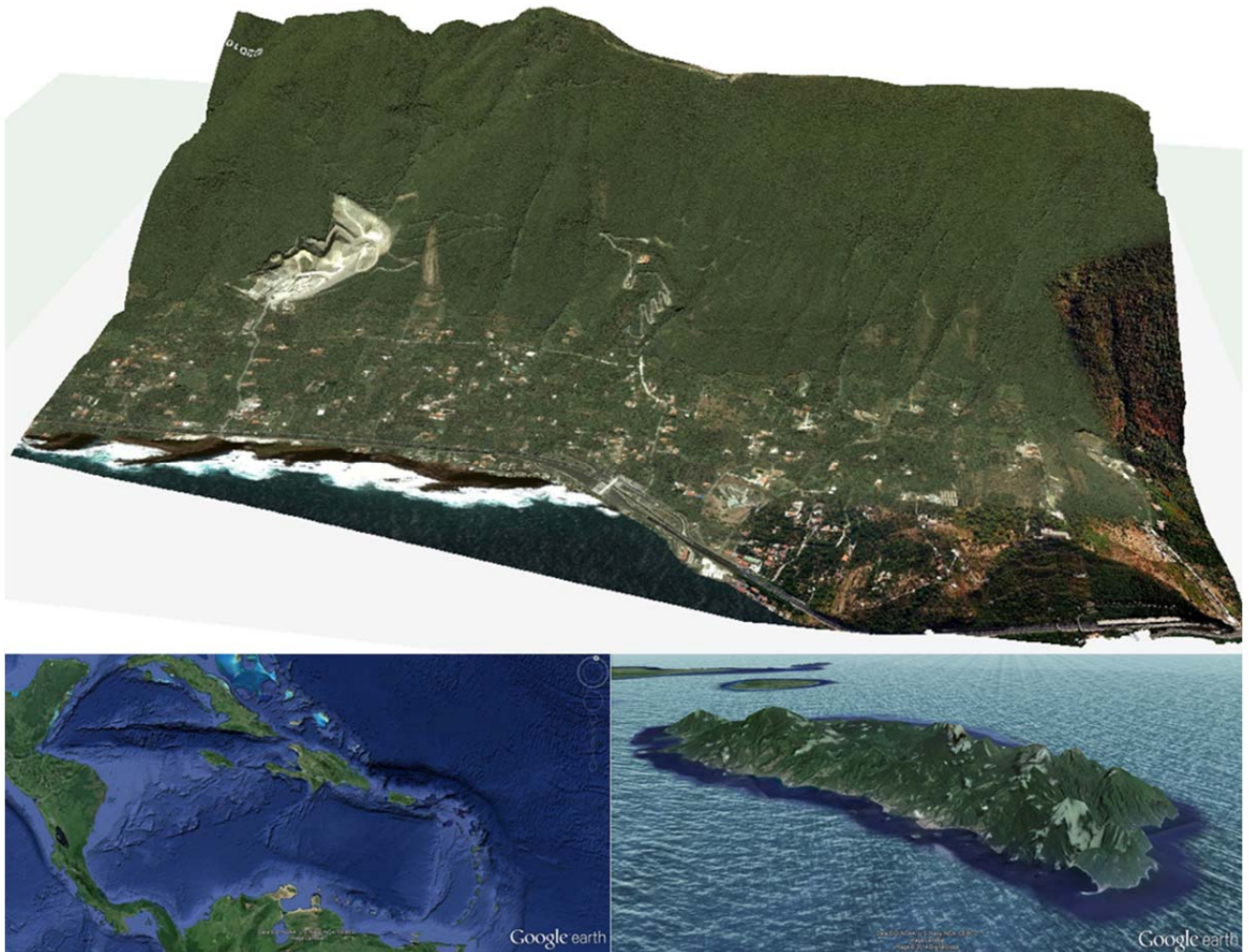


# ANALYZING CHANGING RISK AND PLANNING ALTERNATIVES : A CASE STUDY OF A SMALL ISLAND COUNTRY.



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# 1. Objectives

The overall aim of the use cases in this chapter is to evaluate possible changes in risk to different natural hazards, in an area along the coast of a small Caribbean island state. These changes may be related to possible risk reduction measures, but also to possible future scenarios related to land use change, population change, and climate change, and the effect of possible intervention alternatives on top of these possible future scenarios.

The case study has a number of components:

## **Part A: Analyse the input data required for such an analysis:**

- Hazard intensity and probability maps
- Elements-at-risk maps in the form of land parcels and their attributes (land use type, economic value and number of people)
- Vulnerability curves
- Planning alternatives: in order to reduce the current risk three alternatives have been defined (engineering solutions, ecological solutions, and relocation)
- Possible future scenarios: four possible future scenarios have been developed for this area: business as usual (rapid unplanned growth), risk informed planning (growth that follows the chosen alternative), worst case scenario (rapid unplanned growth combined with climate change) and climate change adaptation scenario (planned growth in a changing climatic situation)

## **Part B: Analyse the current risk to different hazards:**

- Calculate the number of elements-at-risk exposed to each of the hazard types and each of the return periods
- Apply vulnerability matrices for estimating the vulnerability to the various hazard types.
- Calculate the losses for each hazard type and return period
- Integrate the losses for different return periods into annualized risk
- Calculate the risk as population risk and economic risk.

## **Part C: Analyse the effect of possible risk reduction alternatives:**

- Re-calculate the risk after implementation of the risk reduction alternatives;
- Determine the annual risk reduction;
- Calculate the costs for implementing the risk reduction alternatives: investment costs, period of investment, maintenance costs, project lifetime;
- Carry out a cost-benefit analysis to identify the optimal alternative in terms of NPV (Net Present Value) and IRR (Internal Rate of Return)
- Evaluate other factors (indicators) that are relevant in the final selection of the optimal alternative using a multi-criteria evaluation approach.

**Part D: Evaluate the changes for the different scenarios.**

- Analyse the changes in land use for the different scenarios in a number of future years (2020, 2030 and 2040) and explain the trends and possible drivers;
- Analyse the changes in economic values for the different scenarios in a number of future years (2020, 2030 and 2040)
- Analyse the changes in population for the different scenarios in a number of future years (2020, 2030 and 2040)
- Analyse the changes in risk for the for the different scenarios in a number of future years (2020, 2030 and 2040)

**Part E: Evaluate which of the risk reduction alternatives would behave best under possible future scenarios.**

- Analyse the changes in risk for risk reduction alternatives for the different scenarios in a number of future years (2020, 2030 and 2040);
- Calculate annualized risk for each combination of risk reduction alternative and future year;
- Calculate annualized risk reduction (benefit) for each combination of risk reduction alternative and future year by subtracting the annualized risk with and without the risk reduction alternative;
- Use these different values for annualized risk reduction (benefits) in a cost-benefit analysis that compares risk reduction alternatives by taking into account their behaviour under different possible future scenarios;
- Determine the most “change proof” risk reduction alternative;

## 2. The ILWIS GIS software

In the development of the training materials one of the driving aspects was that the exercises, the data and the software should be freely available for all interested to learn about the dissemination results of the PPRD-EAST project. Therefore it was decided to base all the exercises on Open Source software. We decided to use the ILWIS software, as this is easy to learn, comprehensive and has an extensive set of tutorial material.

**ILWIS** is an acronym for the **Integrated Land and Water Information System**. It is a *Geographic Information System (GIS)* with *Image Processing* capabilities. ILWIS has been developed by the International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands up to release 3.3 in 2005. ILWIS comprises a complete package of image processing, spatial analysis and digital mapping. It is easy to learn and use; it has full on-line help, extensive tutorials for direct use in courses and 25 case studies of various disciplines (See [www.itc.nl](http://www.itc.nl))

Since July 2007, ILWIS software is freely available ('as-is' and free of charge) as open source software (binaries and source code) under the 52°North initiative (GPL license). This software version is called ILWIS Open. ILWIS software can be downloaded for free from **52 North**: <http://52north.org/>


As a GIS package, ILWIS allows you to input, manage, analyze and present geographical data. From the data you can generate information on the spatial and temporal patterns and processes on the earth surface.

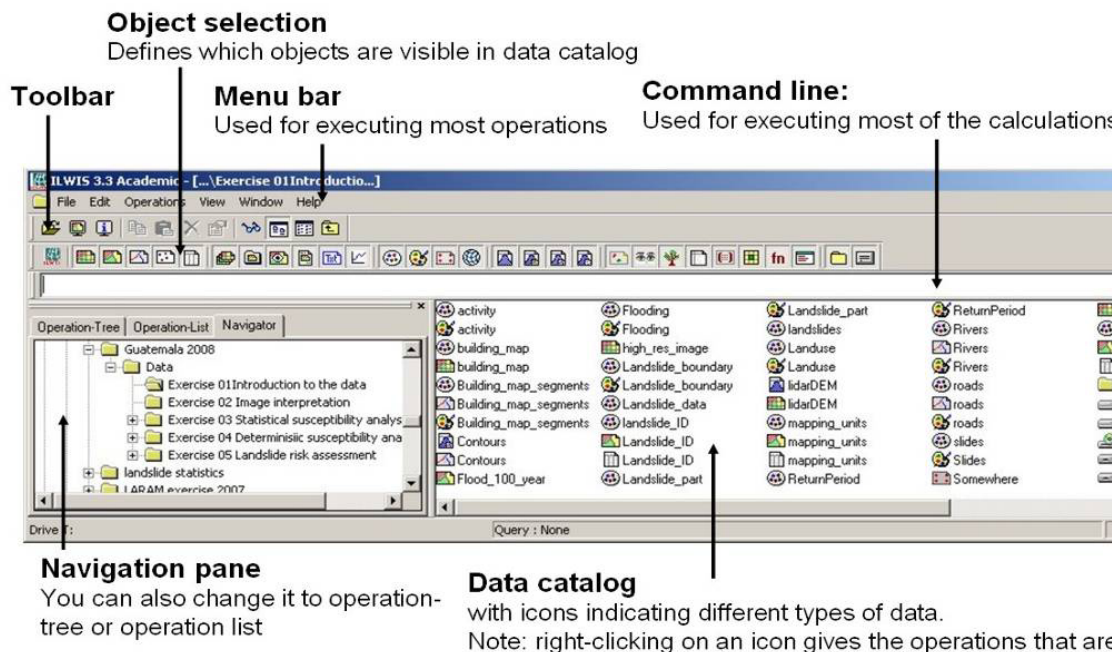


Before you can start with the exercises you will have to download the software. We have decided to use the version 3.4 which is not the most recent version of the ILWIS software, but one which is well proven stable and has all the functionalities required for carrying out the exercises. The latest versions of ILWIS have some major changes in terms of the visualisation and the exercise texts are not adapted to that.

To install the software, please follow these steps:

- Download the ILWIS software from the CHARIM website
- Copy the file: **Ilwis\_3.4\_Open.zip** to your harddisk.
- Unzip the file in a directory on the D (or C) drive. Not on the desktop.
- Run **ILWIS34Ssetup.exe** to install the software.
- The zip file also contains a directory **Users Guide\** This folder contains the complete ILWIS 3.0 User's Guide (in .pdf format). with a file describing what changed in ILWIS 3.1. ILWIS 3.4 has new functionality, but the same file describes how to use the ILWIS 3.0 User's Guide with ILWIS 3.4. Data for these basic tutorials can be downloaded from <http://www.itc.nl/ilwis/documentation/version3.asp>
- Before you use ILWIS first unzip the data of the first exercise (Exercise\_Introduction) into a directory \exercise01\ on the C or D drive.

- To start ILWIS, double-click mouse the ILWIS icon  on the desktop. After the opening screen you see the ILWIS Main window (see figure below). From this window you can manage your data and start all operations
- Use the ILWIS Navigator (Navigation pane) to go to the sub- folder of the exercise. The Navigator lists all drives and directories (i.e. folders) in a tree structure.














The ILWIS Window contains a number of features:

- Data catalog:** displays the icons and names of the objects inside the selected directory.
- Standard Toolbar:** provides shortcuts for some regularly used menu commands



The Standard toolbar has the following buttons:

	New Catalog		Properties
	Open Map		Customize Catalog
	Open Pixel Information		List
	Copy		Details
	Paste		cd..
	Delete		

- Navigation pane:** allows for fast navigation, and can also be changed to display all operations
- Menu bar:** this is the main starting point for doing most of the operations in ILWIS. Check especially the options under Operations. The ILWIS Main window has six menus: **File, Edit, Operations, View, Window** and **Help**.

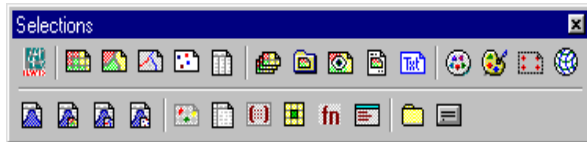
File Edit Operations View Window Help

- Command line:** this is a central facility in ILWIS. Here you type calculation

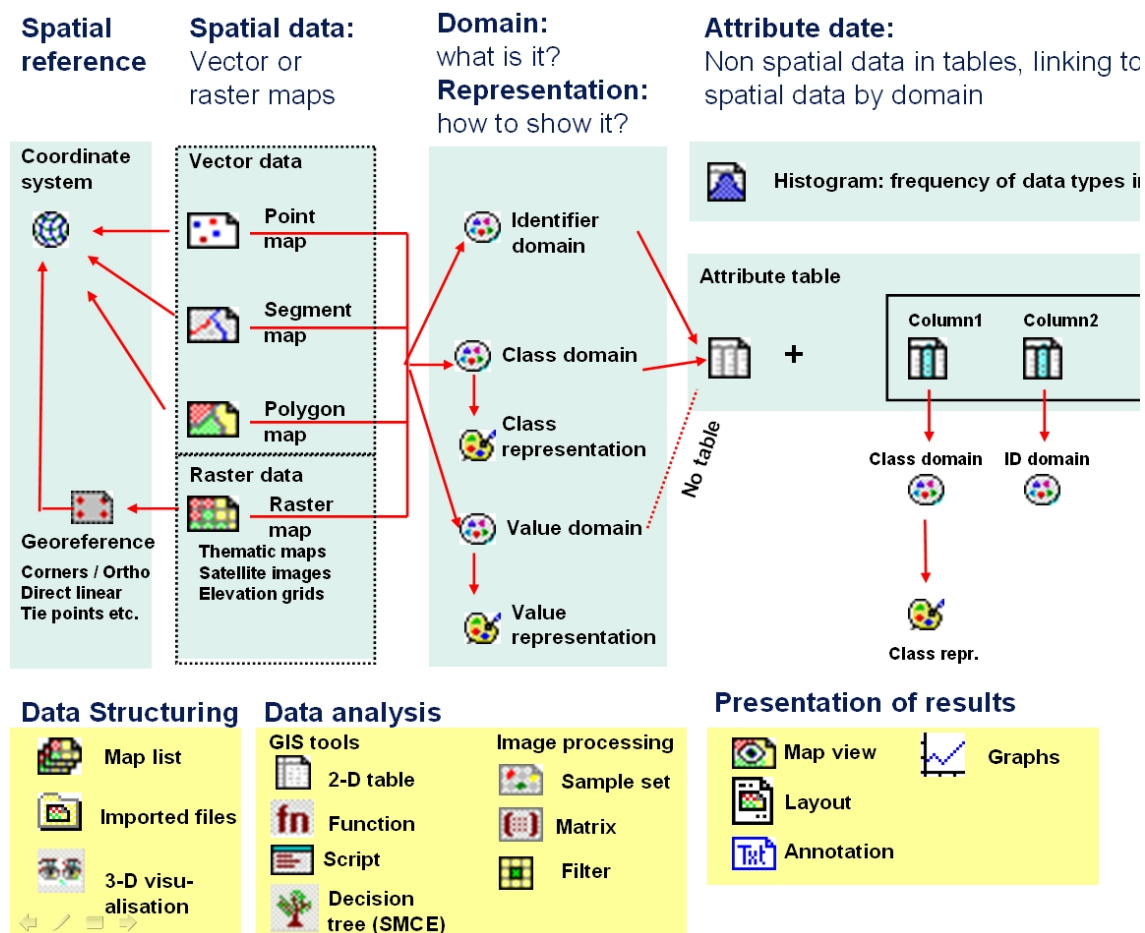
statements (called **MapCalc**) which allows you to do a lot of analysis steps with raster maps. If you do an operation, the related ILWIS command is also displayed.



- **Object selection:** this allows you to select which objects are displayed in the data catalog



- **Getting HELP :** allows you to obtain information from any point within the program. The Help menu differs per window.



ILWIS uses different types of objects.

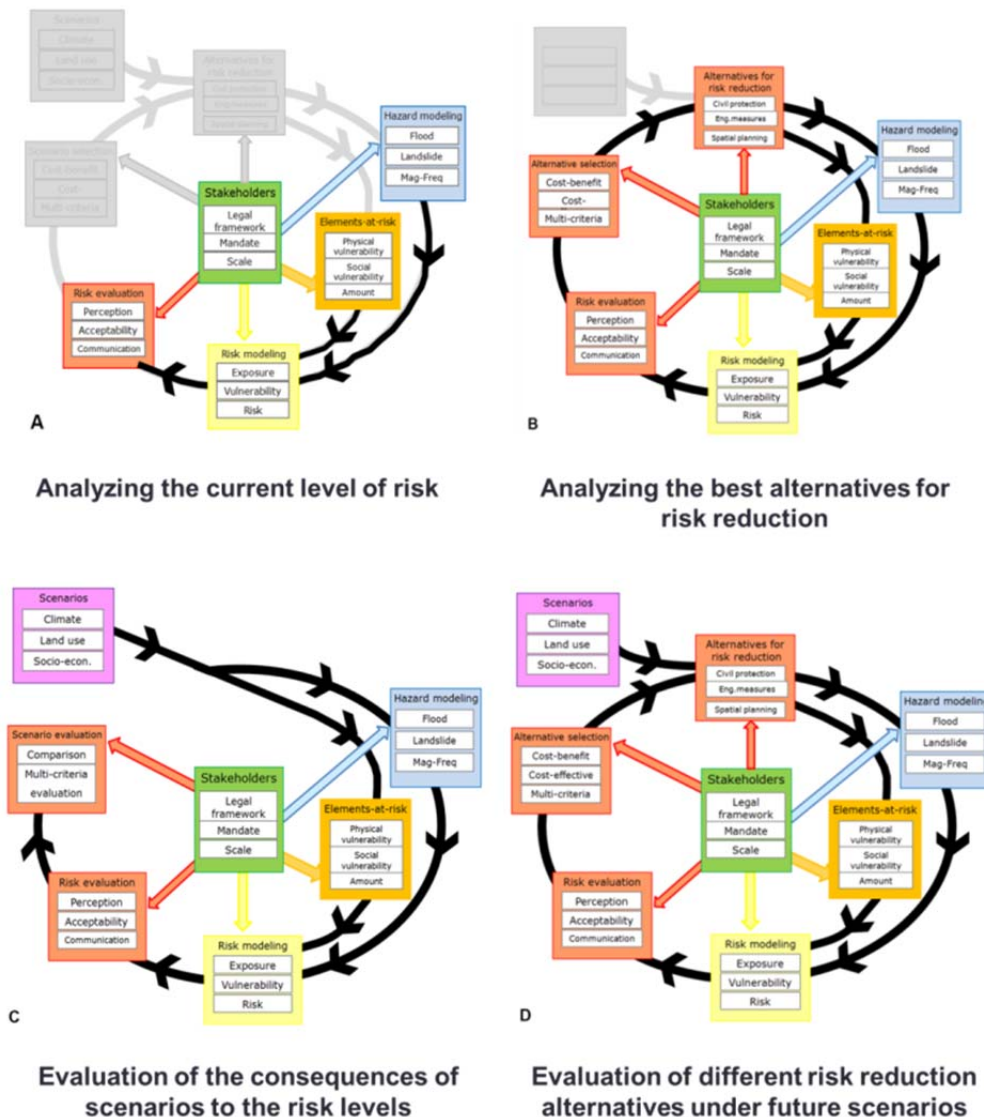
- **Data objects.** Raster maps, polygon maps, segment maps, point maps, tables and columns are called data objects. They contain the actual data.
- **Service objects.** Service objects are used by data objects; they contain accessories that data objects need besides the data itself. Domains, representations, coordinate systems and georeferences are called service objects.

- **Container objects.** Container objects are collections of data objects and/or annotation: map lists, object collections, map views, layouts and annotation text.
- **Special objects.** Special objects are histograms, sample sets, two-dimensional tables, matrices, filters, user-defined functions and scripts.

A vector map needs a coordinate system, a domain and a representation. These service objects are also needed for raster maps, together with another type of service object: a georeference. In this chapter we will focus our view on data and service objects.

### 3. Background

The use cases in this chapter can be used in different ways (see also the flow chart below):



- A. **Analyzing the current level of risk.** In this workflow the stakeholders (e.g. local authorities) are interested to know the current level of risk in their municipality. They request expert organizations to provide them with hazard maps, asset maps, and vulnerability information, and use this information in risk modelling. They use the results in order to carry out a risk evaluation.
- B. **Analyzing the best alternatives for risk reduction.** In this workflow the stakeholders want to analyse the best risk reduction alternative, or combination of alternatives. They define the alternatives, and request the expert organizations to provide them with updated hazard maps, assets information and vulnerability information reflecting the consequences of these alternatives. Once these hazard and asset maps are available for the scenarios, the new risk level is analysed, and compared with the existing risk level to estimate the level of risk reduction. This is then evaluated against the costs (both in terms of finances as well as in terms of other constraints) and the best risk reduction scenario is selected.

- C. **The evaluation of the consequences of scenarios to the risk levels.** The scenarios are related to possible changes related to climate, land use change or population change due to global and regional changes, and which are only partially under the control of the local planning organizations. The systems will be evaluated how these trends have an effect on the hazard and assets (again here the updated maps should be provided by expert organizations) and how these would translate into different risk levels.
- D. **The evaluation how different risk reduction alternatives will lead to risk reduction under different future scenarios** (trends of climate change, land use change and population change). This is the most complicated workflow in the SDSS, as it requires to calculate the present risk level, the effect of different risk reduction alternatives, and the overprinting of these on the scenarios. For each of these combinations of alternatives & scenarios new hazard, assets and risk maps need to be made.

If we would put the combinations in a matrix the result would look like this:

Scenario: Possible Future trends	Alternative: risk reduction options	Now 2014	Future years		
			2020	2030	2040
S0 (Without including any future trends)	A0 (no risk reduction)	2014_A0_S0	No future trends are taking into account, and all hazards, elements at risk and vulnerabilities are considered constant in future.		
	A1 Engineering	2014_A0_S1			
	A2 Ecological	2014_A0_S2			
	A3 Relocation	2014_A0_S3			
S1 Business as usual	A0 (no risk reduction)	Does not exist: use existing situation	2020_A0_S1	2030_A0_S1	2040_A0_S1
	A1 Engineering		2020_A1_S1	2030_A1_S1	2040_A1_S1
	A2 Ecological		2020_A2_S1	2030_A2_S1	2040_A2_S1
	A3 Relocation		2020_A3_S1	2030_A3_S1	2040_A3_S1
S2 Risk informed planning	A0 (no risk reduction)	Does not exist: use existing situation	2020_A0_S2	2030_A0_S2	2040_A0_S2
	A1 Engineering		2020_A1_S2	2030_A1_S2	2040_A1_S2
	A2 Ecological		2020_A2_S2	2030_A2_S2	2040_A2_S2
	A3 Relocation		2020_A3_S2	2030_A3_S2	2040_A3_S2
S3 Worst case (Rapid growth + climate change)	A0 (no risk reduction)	Does not exist: use existing situation	2020_A0_S3	2030_A0_S3	2040_A0_S3
	A1 Engineering		2020_A1_S3	2030_A1_S3	2040_A1_S3
	A2 Ecological		2020_A2_S3	2030_A2_S3	2040_A2_S3
	A3 Relocation		2020_A3_S3	2030_A3_S3	2040_A3_S3
S4 Climate resilience (informed planning under climate change)	A0 (no risk reduction)	Does not exist: use existing situation	2020_A0_S4	2030_A0_S4	2040_A0_S4
	A1 Engineering		2020_A1_S4	2030_A1_S4	2040_A1_S4
	A2 Ecological		2020_A2_S4	2030_A2_S4	2040_A2_S4
	A3 Relocation		2020_A3_S4	2030_A3_S4	2040_A3_S4

The table above indicates the combination of the four scenarios (S1,S2,S3,S4) and the 3 risk reduction alternatives (A1,A2,A3) in 3 future years (2020, 2030, 2040). In the case study we will use the coding of the files in a similar way: future\_year\_Alternative\_Scenario. So for example: LP\_2020\_A1\_S2 refers to the land parcels for future year 2020 under alternative A1 (Engineering solutions) and for scenario S2 (risk informed planning).

## 4. Information sources

The data set is based on original data that was prepared for an EU FP7 project SAFELAND (<http://www.safeland-fp7.eu/>) by the University of Salerno, Italy. The following persons have developed the original hazard maps: Leonardo Cascini, Settimio Ferlisi and Sabatino Cuomo. They also supplied the high resolution image, the DEM, building footprints, roads etc. The original hazard maps have been modified in order to reflect the situation for the various alternatives. The land parcel maps have all been generated by ourselves based on available high resolution images. The whole dataset was modified to make it a generic case study reflecting a situation in an island country.








We also would like to thank Anna Scolobig from IIASA for her work on the risk reduction alternatives (which we have taken as they were) the stakeholder involvement and the stakeholder roleplay exercise.

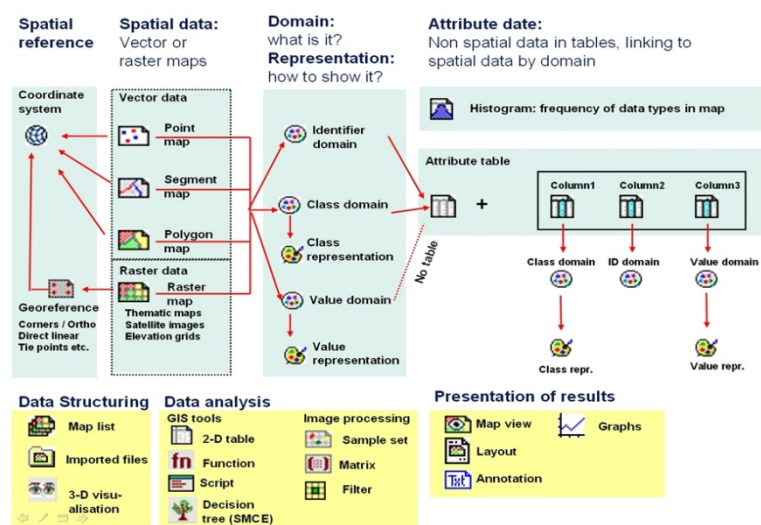
Hari Narasimhan (ETH) and Emile Dopheide are thanked for their input in the cost-benefit analysis. Also we would like to thank Andrea Tripodi for his work in the development of the case study. Luc Boerboom and Ziga Malek are thanked for their input in the thinking about possible future scenarios. Kaixi Zhang is thanked for her feedback on the risk calculation method.

## 5. Part A: Visualization of the input data

The input data will be made available through a ZIP file: [Case\\_study\\_Changing\\_Risk.zip](#)

- Unzip the data in a directory on the harddisk (C or D drive, and not on desktop)
- Open the ILWIS program and navigate to the directory where you unzipped the data
- Display the raster map **IMAGE** and analyse what the current situation is.
- (For showing in 3D in ILWIS 3.8, first select right-click on Display Tools, select 3D properties, expand the Display Tools, expand 3D properties, double click Data Source, and select DTM.)
- You can also display the hillshading image **DTMShadow** to get a better impression of the study area
- You can also use Google Maps, Google Earth or Google Street View to navigate to the Nocera Inferiore area in Italy to check the situation yourself in more detail.

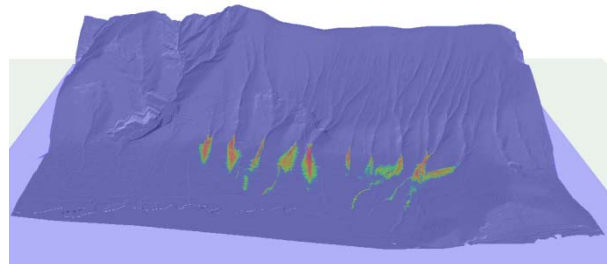
In the data window you can see the various input data which are either raster maps (  ), polygons maps (  ), or segment maps (  ). Tables (  ) contain attribute information related to the maps. Domains (  ) are datafiles that explain what is in the maps, and can be compared to legends. Representations (  ) show how domains should be displayed. Scripts (  ) are a sequenced list of ILWIS commands and expressions. By creating a script, we have combined many intermediate steps in the analysis so that you can do the exercise without knowing about GIS and ILWIS.



The study area has been affected some years ago by a landslide (in the vicinity of the quarry area, that has destroyed several buildings, and killed a number of people. The authorities in the area have become very worried because in a nearby area, a large number of debrisflows and landslides occurred some years ago. The authorities of the study area are now considering the need to carry out mitigation measures in the area as well. However, they are not sure of the type of measures and the effect of them on risk reduction, that is why they have ordered the hazard and risk study to be carried out.

### 5.1 Input data: hazard maps

We have made hazard maps for landslides, debrisflows, mudflows and floods. For the work the mudflows could be skipped if that is too much work. The debrisflow, mudflow and flood maps have intensity data (impact pressure for mudflows and debrisflows, and depth for flood). The landslide hazard maps do not have intensity maps, but only spatial probability maps indicating the chance that a particular area will be affected by a landslide.



The available maps are illustrated in the table below and in the figure below.

Map	Hazard	Return Period	Intensity	Spatial probability
LS_SP_20_A0	Landslide	20	Not available	yes
LS_SP_50_A0	Landslide	50	Not available	yes
LS_SP_100_A0	Landslide	100	Not available	yes
DF_IP_20_A0	Debrisflow	20	Impact pressure	1
DF_IP_50_A0	Debrisflow	50	Impact pressure	1
DF_IP_100_A0	Debrisflow	100	Impact pressure	1
FL_DE_20_A0	Flood	20	Waterdepth	1
FL_DE_50_A0	Flood	50	Waterdepth	1
FL_DE_100_A0	Flood	100	Waterdepth	1

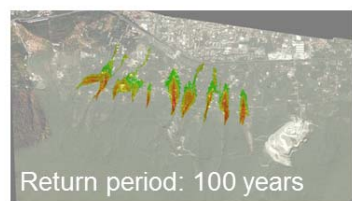
**Debrisflow (DF) hazard**  
Impact pressure (IP)



DF\_IP\_20\_A0

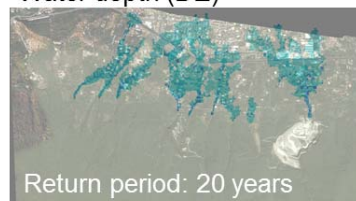


DF\_IP\_50\_A0

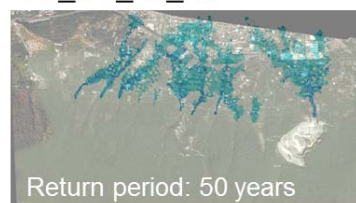


DF\_IP\_100\_A0

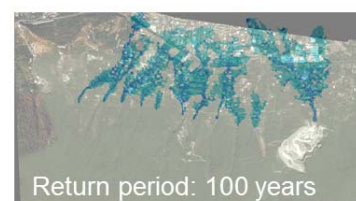
**Flashflood (FL) hazard**  
Water depth (DE)



FL\_DE\_20\_A0



FL\_DE\_50\_A0

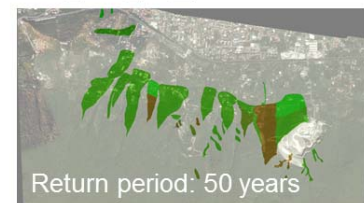


FL\_DE\_100\_A0

**Landslide (LS) hazard**  
Spatial probability (SP)



LS\_SP\_20\_A0



LS\_SP\_50\_A0



LS\_SP\_100\_A0

The hazard data consists of the following components:
























- **Hazard type:** LS= landslides, MF= mudflow, FL=Flood, DF=Debrisflows
- **Return Period:** this is the average frequency with which the events is expected to occur. This is based on the analysis of the magnitude and frequency of the triggering rainfall , or of the events themselves (e.g. flood discharge, or the number of landslides occurring in a particular period)
- **Intensity:** the intensity indicates the spatially distributed effect of the hazard event. This can be water depth for flooding, or impact pressure for debrisflows. These have been modelled using specific hazard modelling software. These models require quite a lot of input data and assumptions. In this exercise we will not deal with the methods how these were created. For some types of hazards it may also not be possible to generate intensity maps, as data or models are lacking. This is the case for landslide runout in our exercise.

- **Spatial probability:** the spatial probability indicates the chance that a particular location would actually be affected by the hazard. This could be the result of uncertainty in the flood modelling or runout modelling. Or it could also represent (in the absence of an intensity map) the likelihood that a particular area will be affected by landslides based on the area of the units, divided by the area of landslides that have occurred in the past. In this way we can use it to reclassify so-called landslide susceptibility maps into spatial probability maps.
- **Alternatives:** this indicates whether the hazard map is made for the current situation or for a planned risk reduction alternative (A1, A2, A3)
- Analyse the available hazard maps using ILWIS, by displaying them , creating histograms and by comparing the intensity and spatial probability values for the different return periods and hazard types.
- You can also consult all the other maps at the same time using the Pixel Information window.

## 5.2 Input data: Elements-at-risk

We can use four types of elements-at-risk: building footprints, land parcels, line elements and point elements. In the case study you will work only with **land parcels**. Each of them have information on:

- The **use:** indicating the land use type.
- **The types:** this is type of element-at-risk. Different types of elements-at-risk can be affected differently by hazard events. For the risk analysis this is important as this is linked to the vulnerability curves, which will be explained later. The table below gives the different types that have been used in this exercise for buildings and for land parcels.
- **The value:** this is the replacement value of the elements-at-risk in monetary units (Euros, US dollars etc).
- The **people:** the number of people that might be present in the element-at-risk. Here you can decide to take the maximum number of people or the people present at a given time (in case when we are dealing with rapid events, the time of day/year is also important for the population loss estimation). In this exercise (we take here the maximum number of people.

Legend	
	AG: Agricultural_fields
	AF: Animal_Farm
	BA: Bare
	CO: Commercial
	CH: Cultural_heritage
	FA: Farm
	FN: Forest_natural
	FP: Forest_Planted_protective
	GR: Grassland
	HW: Highway
	IN: Industry
	OS: Open_slope_soil_removed
	OC: Orchard
	PA: Parking_lot
	PL: Parkland
	QU: Quarry
	RE: Residential
	SH: Shrubs
	SB: Storage_Basin
	TA: Toll_area
	TR: Tourist_resort
	VI: Vineyard
	SP: Water_tank

- Display the polygon map for the Land\_Parcels of the current situation: **LP\_2014\_A0\_S0**. Use the attriute Type to display the map. Observe the information that is available for each of the buildings. Check also the attribute table.
- Display the land parcel maps for the other alternatives : **LP\_2014\_A0** .
- Compare the information of the buildings and the land parcels with respect to their attribute information on values and number of people.

We have made the data so that the building map and the land parcel maps have the same number of people for the parcels in which buildings are located. For the other parcels we are using values per m<sup>2</sup> and multiplied these with the area of the land parcel, so that we can have an estimate of the total maximum number of people. The same we did for the population. We took the values of the buildings from the building footprint map, and used these for the value of the land parcels. For the parcels without buildings we made an estimation based on the value per m<sup>2</sup> and multiplied this with the area.

- See the Excel sheet for the detailed information, and also for calculation procedures.
- We also provided some background documents that contains information on the replacement costs for the different land use types.
- Displaying the hazard and elements at risk maps together. What can you conclude on the possible exposure? (We will actually calculate the exposure a bit later)

### 5.3 Input data: Vulnerability curves

Another very important component in the analysis are the vulnerability curves. A vulnerability curve expresses the relation between the hazard intensity (e.g. water depth) and the degree of damage which is expressed between 0 and 1 for a specific type of element-at-risk. Vulnerability curves are derived from past disaster events by correlating observed intensities with observed damage and deriving average regression lines from these. Vulnerability curves may also be derived through computer modelling (e.g. finite element models where a particular uilding is exposed to a particular intensity and the effect is calculated) or through expert opinion.

For this exercise we have made a number of vulnerability curves for all the combinations of the hazard intensity types and the elements-at-risk types. We have used existing curves for the literature, but needed to make a lot of changes as I didn't have the curves for all of the units. The vulnerability curves are stored in an Excel sheet. For the analysis these curves should be implemented in the GIS (for the check analysis). I have made curves for buildings, and land parcels, and separate curves for the physical losses (required for the economic risk analysis) and for the population losses (people killed).

- See Excel sheet: Vulnerability curves. The excel sheet contains the following vulnerability curves

Hazard type	Intensity type	Buildings (BU)	Land parcels (LP)
Flood (FL)	Waterdepth (in cm) (DE)	Physical vulnerability (PH) Population vulnerability (PO)	Physical vulnerability (PH) Population vulnerability (PO)
Debris flows and mudflows (DF)	Impact pressure (in KPa) (IP)	Physical vulnerability (PH) Population vulnerability (PO)	Physical vulnerability (PH) Population vulnerability (PO)
Landslides (LS)	No intensity	Single vulnerability value per type	Single vulnerability value per type

The codes in the table above indicate the various aspects of the vulnerability curves. For instance the naming of the vulnerability curves should be as follows:

VUL\_01\_02\_03\_04:

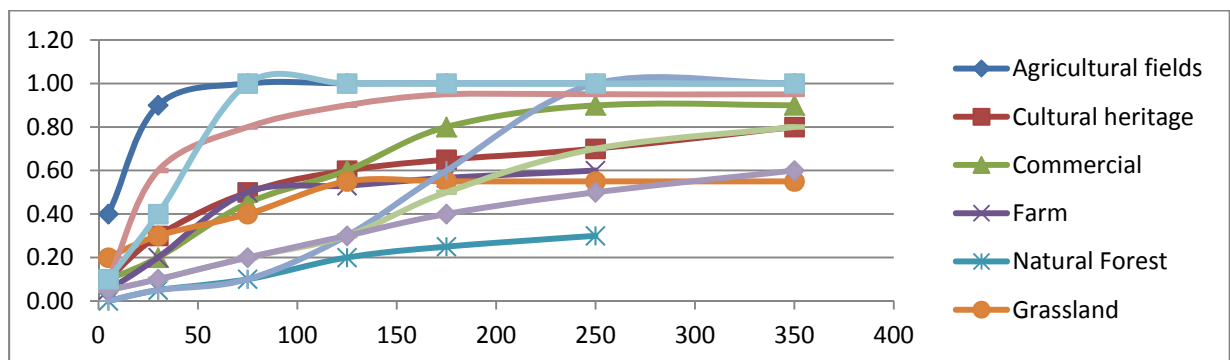
- 01 refers to the hazard type (FL, DF, LS)
- 02 refers to the intensity measurement (WD, IP etc)

- 03 refers to the type of element at risk (BU, LP)
- 04 refers to the type of vulnerability (PH, PO)

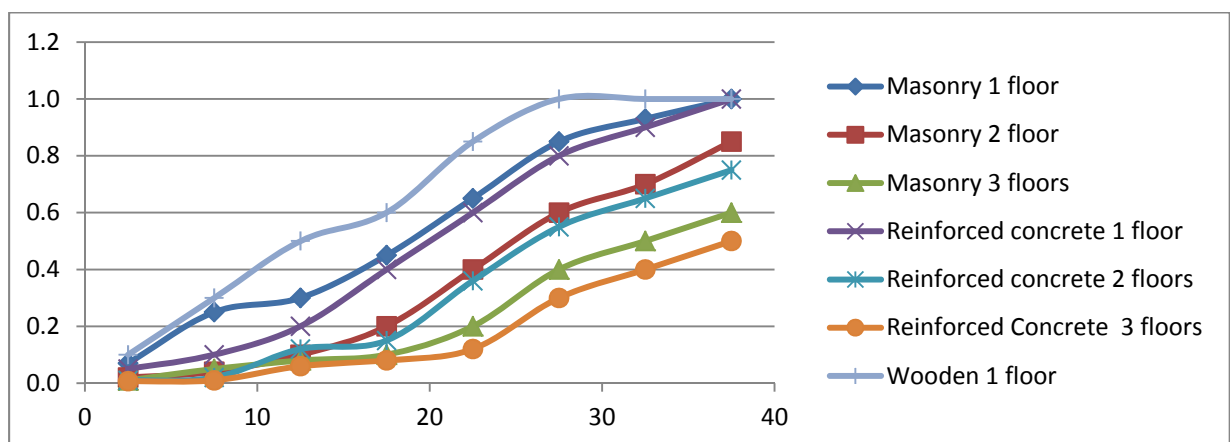
For example:

- VUL\_FL\_DE\_LP\_PH: Vulnerability curves for flooding, expressed in water depth, for land parcels, and showing the physical vulnerability.
- VUL\_DF\_IP\_LP\_PO: Vulnerability curves for debris flows, expressed in impact pressure, for land parcels, and showing the population vulnerability.

#### Physical vulnerability curves for land parcels (for waterdepth in cm)

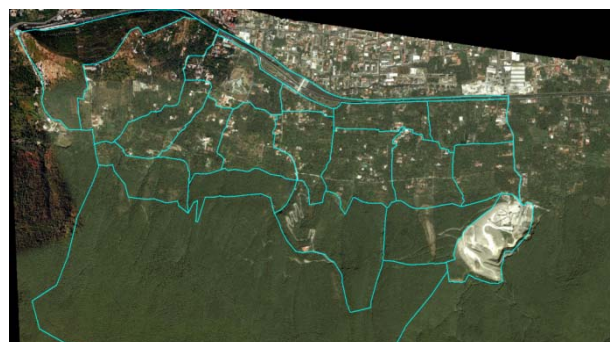


#### Physical vulnerability for debris flows (based on impact pressure in KPa )



## 5.4 Input data: administrative units

For the calculation of risk we also need an administrative unit map, as we are going to aggregate the losses eventually for particular units, and the decision making is based on the risk within these units. The administrative unit map contains 19 administrative units..



- Display the administrative unit map on top of the image and/or the hillshading image.

## 5.5 Input data: Risk reduction alternatives

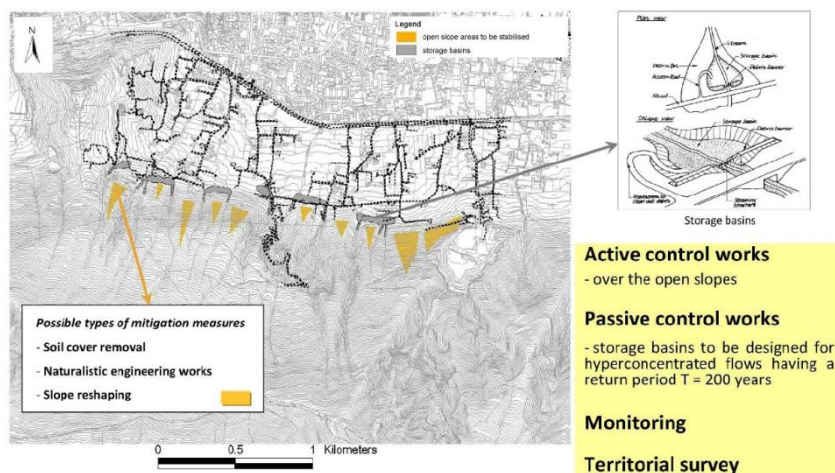
In this case study we are also evaluating three risk reduction alternatives:

- Alternative 1: engineering solutions
- Alternative 2: ecological solutions
- Alternative 3: relocation

### 5.5.1 Alternative 01: Engineering measures

This alternative aims at constructing active and passive control works using engineering measures:

- Take out the soil in the landslide prone areas
- Create storage basins that will retain the floods and debrisflows
- Create water channels to guide the water
- Create a monitoring and early warning system



We have made new land parcel maps for the alternative, and new hazard intensity maps. For the alternative 1 we assume that the engineering works will block all debris flows and floods for return periods up to 100 year. For return period of 200 years the engineering solutions might not be sufficient, and the storage basins will overflow.

- Display the maps related to this alternative. The map Alternative 1 shows the overall setting
- The maps in the table below are the new hazard and elements-at-risk maps for this alternative.
- 

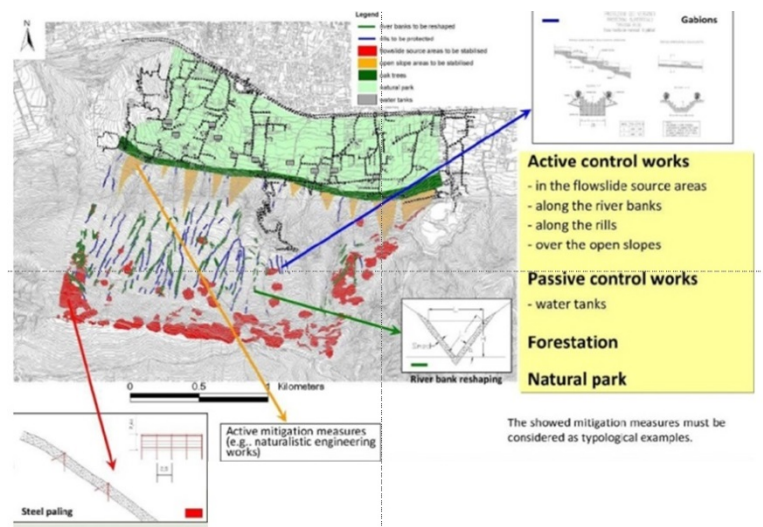
Hazard type	Return period	Intensity measure or spatial probability	Present situation:	Alternative 1: Engineering measures	Alternative 2: Ecological solutions	Alternative 3: Relocation
Landslide	20	Spatial Probability	LS_SP_20_A0	LS_SP_20_A1	LS_SP_20_A2	LS_SP_20_A3
Landslide	50	Spatial Probability	LS_SP_50_A0	LS_SP_50_A1	LS_SP_50_A2	LS_SP_50_A3
Landslide	100	Spatial Probability	LS_SP_100_A0	LS_SP_100_A1	LS_SP_100_A2	LS_SP_100_A3
Landslide	200	Spatial Probability	LS_SP_200_A0	LS_SP_200_A1	LS_SP_200_A2	LS_SP_200_A3
Debrisflow	20	Impact pressure	DF_IP_020_A0	DF_IP_20_A1	DF_IP_20_A2	DF_IP_20_A3
Debrisflow	50	Impact pressure	DF_IP_050_A0	DF_IP_50_A1	DF_IP_50_A2	DF_IP_50_A3
Debrisflow	100	Impact pressure	DF_IP_100_A0	DF_IP_100_A1	DF_IP_100_A2	DF_IP_100_A3
Debrisflow	200	Impact pressure		DF_IP_200_A1	DF_IP_200_A2	
Flood	20	Water depth	FL_DE_020_A0	FL_DE_20_A1	FL_DE_20_A2	FL_DE_20_A3
Flood	50	Water depth	FL_DE_050_A0	FL_DE_50_A1	FL_DE_50_A2	FL_DE_50_A3
Flood	100	Water depth	FL_DE_100_A0	FL_DE_100_A1	FL_DE_100_A2	FL_DE_100_A3
Flood	200	Water depth		FL_DE_200_A1	FL_DE_200_A2	
Land Parcel maps			LP_2014_A0_S0	LP_2014_A1_S0	LP_2014_A2_S0	LP_2014_A3_S0

*Table indicating the files names for the hazard maps and the elements-at-risk maps for the present situation and for the three risk reduction alternatives.*

### 5.5.2 Alternative 02: Ecological measures

This alternative aims at constructing active and passive control works using ecological solutions:

- Take out the soil in the landslide prone areas
- Use soil nailing in the upper slope to reduce the landslide susceptibility
- Create water tanks that will retain some of the the floods
- Create water channels to guide the water
- A barrier of oak trees that will retain some of the debrisflows and mudflows
- Create a natural park which will stop further development

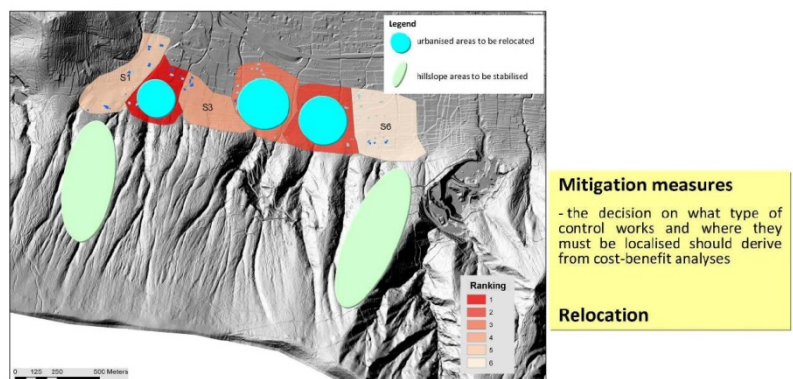


- Display the maps related to this alternative. The map Alternative 2 shows the overall setting
- The maps in the table above are the new hazard and elements-at-risk maps for this alternative.

### 5.5.3 Alternative 03: Relocation.

This alternative aims at relocation the residential population from the most endangered administrative units indicated as blue spots in the figure :

- Evacuation of the people requires that they have to be financially compensated, and that they are willing to collaborate, otherwise lengthy procedures and lawsuits are required which may take a lot of time.



- Display the maps related to this alternative. The map Alternative 3 shows the overall setting
- The maps in the table above are the new hazard and elements-at-risk maps for this alternative.

## 5.6 Input data: Possible future scenarios

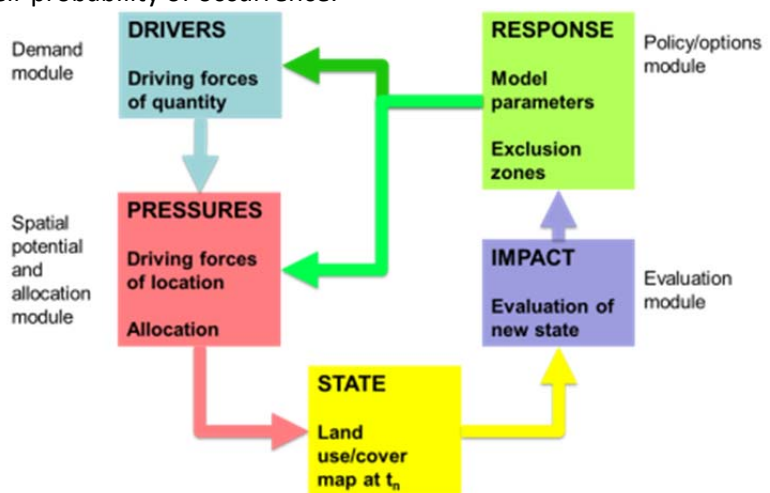
The analysis of changes involves the definition of a number of **scenarios**, which can be seen as trends, on which the users don't have a direct influence. These can be in terms of:

- **Climate change:** involving changes in the magnitude-frequency of precipitation extremes and other relevant climatic stimuli (such as evaporation, days with snow cover) and in the occurrence in the time of the year of these extremes (e.g. related to changes in springtime temperature changes).
- **Land use change:** long term land use changes relate to socio-economic developments that might occur in an area.
- **Population change:** also related to political and socio-economic developments within a country.

The scenarios are possible developments, and several scenarios are possible for which it will be difficult or impossible to indicate their probability of occurrence.

Scenarios of land use /land cover change can be developed using the so-called DPSIR (European Environmental Agency, , which identify the Drivers of change (e.g. economic growth, economic crisis, changes in macro-economic /political constellation, climate change) leading the certain pressures (e.g. increasing demand for land for residential purposes, increasing demand for natural resources), which will alter the

existing state, and lead to an impact (e.g. increasing land prices, increasing risk to natural hazards, which may elicit societal response and will feedback on the drivers again (for more information, see : [http://www.epa.gov/ged/tutorial/docs/DPSIR\\_Module\\_2.pdf](http://www.epa.gov/ged/tutorial/docs/DPSIR_Module_2.pdf))



We would like to use four scenarios:

	Name	Land use change	Climate change
<b>Scenario 1</b>	Business as usual	Rapid growth without taking into account the risk information	No major change in climate expected
<b>Scenario 2</b>	Risk informed planning	Rapid growth that takes into account the risk information and extends the alternatives in the planning	No major change in climate expected
<b>Scenario 3</b>	Worst case	Rapid growth without taking into account the risk information	Climate change expected, leading to more frequent extreme events
<b>Scenario 4</b>	Most realistic	Rapid growth that takes into account the risk information and extends the alternatives in the planning	Climate change expected, leading to more frequent extreme events

	Scenario 1 (and 3)	Scenario 2 (and 4)
Drivers		
Pressure		
State		
Impact		
Response		

If we would put the combinations of scenarios and alternatives in a matrix the result would look like this. The names of the elements-at-risk maps are given for each combination. Not that:

- for scenario 3 and 4 we are using the same element-at-risk maps as for scenario 1 and 2, but we change the frequency of the hazard events (the return periods);
- The actual hazard maps used for the scenarios are the same as those for the alternatives. We do not consider that the intensity will change. Only the return periods of the hazards will change.

Possible future scenario:	Now 2014	Elements_at_risk maps : land_parcel		
		2020	2030	2040
S1 Business as usual	LP_2014_A0_S0	LP_2020_A0_S1	LP_2030_A0_S1	LP_2040_A0_S1
S2 Risk informed planning	LP_2014_A0_S0	LP_2020_A0_S2	LP_2030_A0_S2	LP_2040_A0_S2
S3 Worst case (Rapid growth + climate change)	LP_2014_A0_S0	LP_2020_A0_S1	LP_2030_A0_S1	LP_2040_A0_S1
S4 Climate resilience (informed planning under climate change)	LP_2014_A0_S0	LP_2020_A0_S2	LP_2030_A0_S2	LP_2040_A0_S2

The change in return periods due to climate change effects for scenario 3 and 4 are indicated below:

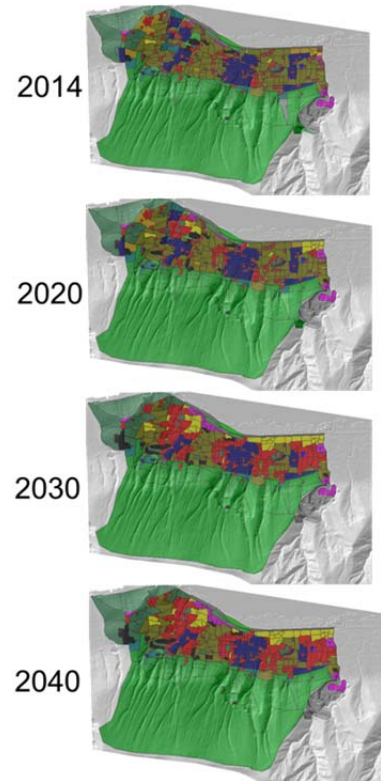
	New Return Period in Future Year		
Old Return Period	2020	2030	2040
20 ( $\pm 5$ )	17 ( $\pm 6$ )	14 ( $\pm 7$ )	11 ( $\pm 8$ )
50 ( $\pm 10$ )	45 ( $\pm 12$ )	35 ( $\pm 14$ )	25 ( $\pm 16$ )
100 ( $\pm 20$ )	90 ( $\pm 23$ )	75 ( $\pm 26$ )	55 ( $\pm 30$ )
200 ( $\pm 40$ )	180 ( $\pm 44$ )	150 ( $\pm 49$ )	110 ( $\pm 53$ )

### 5.6.1 Scenario 01: Business as usual

This scenario is a land use change scenario only. We do not expect a major climate change in this scenario. However the land use is expected to change dramatically in this scenario. Land use change will be in the form of a rapid urbanization of the study area, occupying the flat areas from North to South. This occurs in combination with a high demand for land leading to increasing land prices and also to higher population densities.

The changes in land use are reflected in the land parcel map.

- We use 3 future years : 2020, 2030 and 2040.
- With respect to **hazard types**, we are considering flooding (FL), debrisflows (DF) and landslides (LS) (and possibly coastal hazards CO as well). We assume that the hazard intensities and modelled areas stay the same, and the return periods are also the same. **So we can use the same hazard maps as for the current situation.**
- With respect to **elements-at-risk** we are only considering Land\_Parcel. Now we take into account changes in population density and in the value of elements-at-risk. We also take into account land-use developments in the period until 2040.



For seeing the results of the modelling of values and population for the scenarios, see the Excel sheet (Estimation of values and people for different scenarios). Also the calculation procedure is explained there. Check this excel sheet.

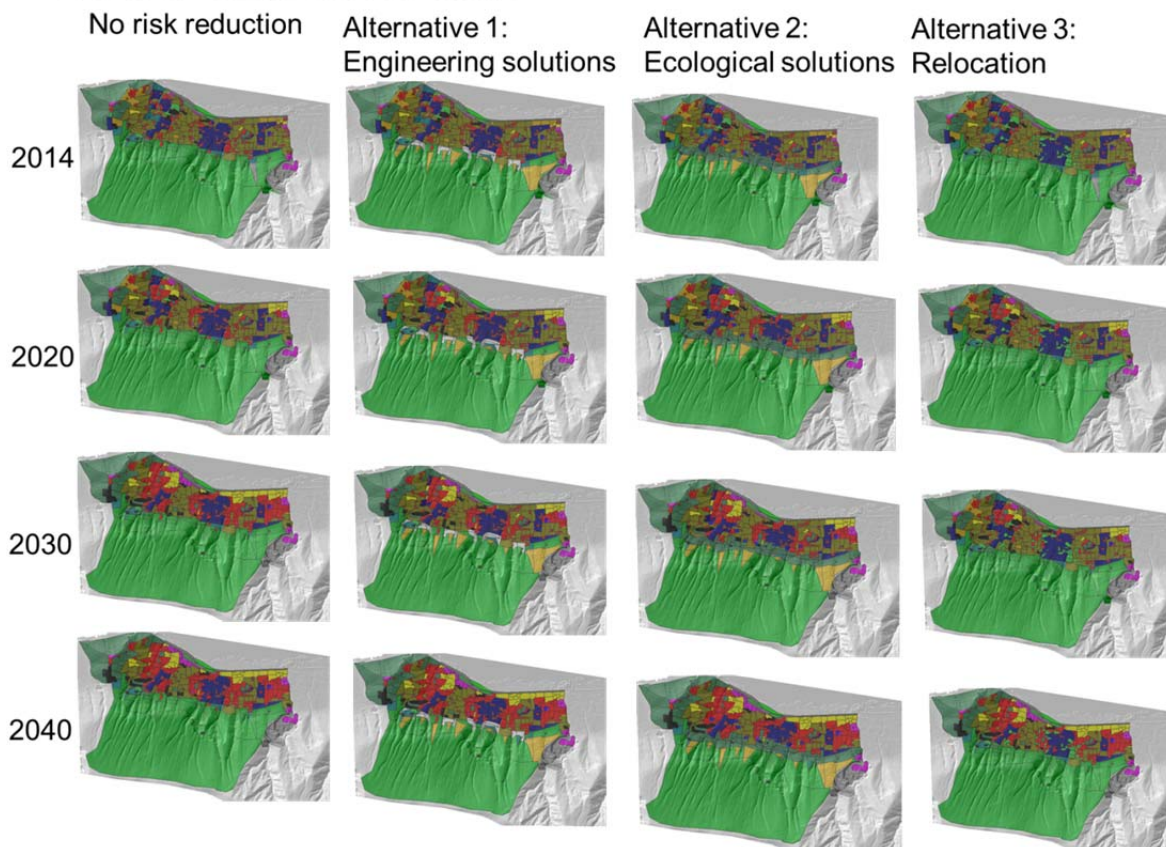
We also incorporate the following four situations with respect to the design of alternatives:

- No risk reduction measures
- Engineering measures (Alternative 1)
- Ecological measures (Alternative 2)
- Relocation (Alternative 3)

If we would put the combinations in a matrix the result would look like this:

Possible future scenario:	Alternative: risk reduction options	Elements_at_risk maps : land_parcels		
		2020	2030	2040
S1 Business as usual	A0 (no risk reduction)	LP_2020_A0_S1	LP_2030_A0_S1	LP_2040_A0_S1
	A1 Engineering	LP_2020_A1_S1	LP_2030_A1_S1	LP_2040_A1_S1
	A2 Ecological	LP_2020_A2_S1	LP_2030_A2_S1	LP_2040_A2_S1
	A3 Relocation	LP_2020_A3_S1	LP_2030_A3_S1	LP_2040_A3_S1

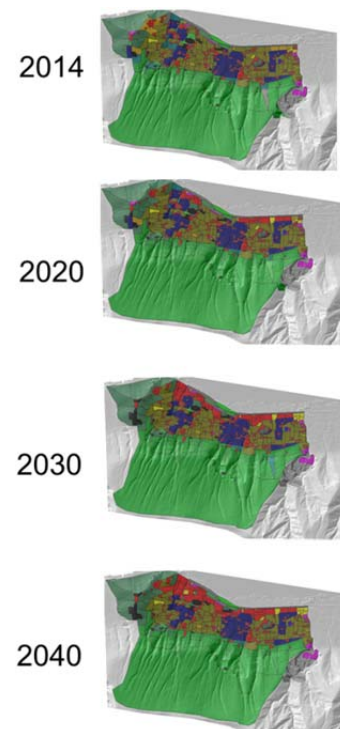
## Scenario 1: Business as usual



### 5.6.2 Scenario 02: Risk Informed planning

In this scenario we have also rapid growth , however in the development of the area, the risk information is taken into consideration, and the development follows the alternatives that have been defined. E.g. relocation will eventually lead to relocation of all dangerous areas. Ecological alternatives will lead to a park land area without much economic activities. In this scenario there are no climate change effects taken into account.

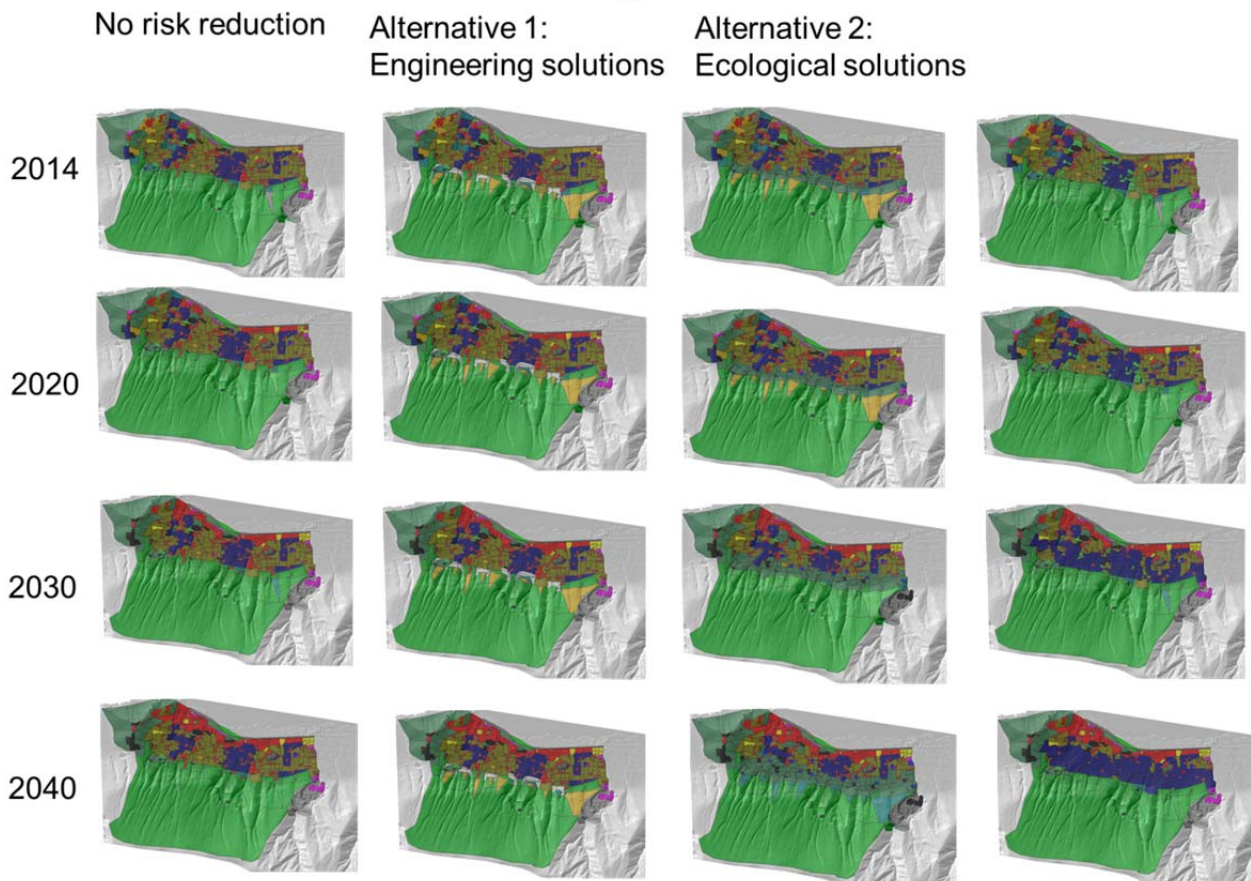
- We use 3 future years : 2020, 2030 and 2040.
- With respect to **hazard types**, we are considering flooding, debrisflows and landslides. We assume that the hazard intensities and modelled areas stay the same, and also the return period. So we use the same hazard maps as for the present situation
- With respect to **elements-at-risk** we are only considering Land\_Parcel. We also take into account changes in population density and in the value of elements-at-risk. We also do not take into account land-use developments in the period until 2040. Therefore we use the land parcel maps for the present situation
- We also incorporate the following four situations with respect to the design of alternatives:



- No risk reduction measures
- Engineering measures (Alternative 1)
- Ecological measures (Alternative 2)
- Relocation (Alternative 3)
- Since this scenario uses existing maps in the database, we will indicate in the table below which maps are used for which combination of Alternative-Scenario-Future-Year.
- In the database there is no need to actually upload new maps for the specific combinations of Alternative-Scenario-FutureYear. The real difference is only to assign new Return Periods in the Hazard Data Sets. New maps are indicated in red, and new values in Orange.
- We use the following maps:

Possible future scenario:	Alternative: risk reduction options	Now 2014	Elements_at_risk maps : land_parcel		
			2020	2030	2040
S2 Risk informed planning	A0 (no risk reduction)	Does not exist: use existing situation	LP_2020_A0_S2	LP_2030_A0_S2	LP_2040_A0_S2
	A1 Engineering		LP_2020_A1_S2	LP_2030_A1_S2	LP_2040_A1_S2
	A2 Ecological		LP_2020_A2_S2	LP_2030_A2_S2	LP_2040_A2_S2
	A3 Relocation		LP_2020_A3_S2	LP_2030_A3_S2	LP_2040_A3_S2

## Scenario 2: Risk-Informed Planning



### 5.6.3 Scenario 03: Worst case

This scenario is a climate change and land use change scenario. Both land use change and climate change are expected to change dramatically in this scenario. Land use change will be in the form of a rapid urbanization of the study area, occupying the flat areas from North to South. This occurs in combination with a high demand for land leading to increasing land prices and also to higher population densities. With respect to climate change, the drastic change results in an almost 50% reduction of the return periods for the same triggering events.

The changes in land use are reflected in the land parcel map.

- We use 3 future years : 2020, 2030 and 2040.
- With respect to **hazard types**, we are considering flooding, debrisflows and landslides. We assume that the hazard intensities and modelled areas stay the same, but that the return periods become smaller.

Old Return Period	New Return Period in Future Year		
	2020	2030	2040
20 (± 5)	17 (± 6)	14 (± 7)	11 (± 8)
50 (± 10)	45 (± 12)	35 (± 14)	25 (± 16)
100 (± 20)	90 (± 23)	75 (± 26)	55 (± 30)
200 (± 40)	180 (± 44)	150 (± 49)	110 (± 53)

- With respect to **elements-at-risk** we are only considering Land\_Parcels. Now we take into account changes in population density and in the value of elements-at-risk. We also take into account land-use developments in the period until 2040.
- We also incorporate the following four situations with respect to the design of alternatives:
  - No risk reduction measures
  - Engineering measures (Alternative 1)
  - Ecological measures (Alternative 2)
  - Relocation (Alternative 3)
- We use the following maps:

Possible future scenario:	Alternative: risk reduction options	Now 2014	Elements_at_risk maps : land_parcels		
			2020	2030	2040
S3 Worst case (Rapid growth + climate change)	A0 (no risk reduction)	Does not exist: use existing situation	LP_2020_A0_S1	LP_2030_A0_S1	LP_2040_A0_S1
	A1 Engineering		LP_2020_A1_S1	LP_2030_A1_S1	LP_2040_A1_S1
	A2 Ecological		LP_2020_A2_S1	LP_2030_A2_S1	LP_2040_A2_S1
	A3 Relocation		LP_2020_A3_S1	LP_2030_A3_S1	LP_2040_A3_S1

### 5.6.4 Scenario 04: Realistic case

This scenario is a climate change and land use change scenario. Both land use change and climate change are expected to change dramatically in this scenario. In this scenario we have also rapid growth, however in the development of the area, the risk information is taken into consideration, and the development follows the alternatives that have been defined. E.g. relocation will eventually lead to relocation of all dangerous areas. Ecological alternatives will lead to a park land area without

much economic activities. With respect to climate change, the drastic change results in an almost 50% reduction of the return periods for the same triggering events.

The changes in land use are reflected in the land parcel map.

- We use 3 future years : 2020, 2030 and 2040.
- With respect to **hazard types**, we are considering flooding, debrisflows and landslides. We assume that the hazard intensities and modelled areas stay the same, but that the return periods become smaller.

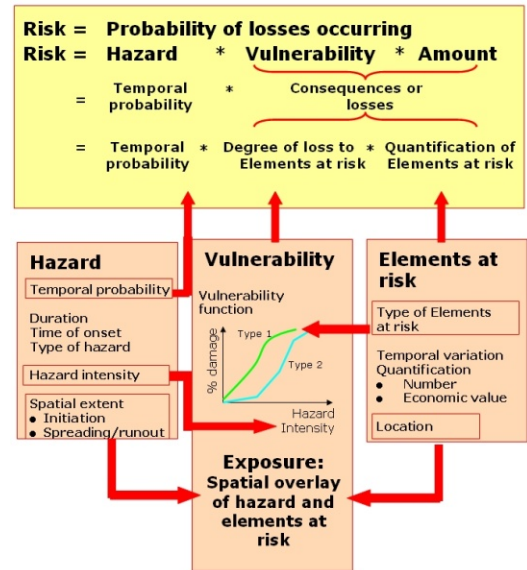
	New Return Period in Future Year		
Old Return Period	2020	2030	2040
20 (± 5)	17 (± 6)	14 (± 7)	11 (± 8)
50 (± 10)	45 (± 12)	35 (± 14)	25 (± 16)
100 (± 20)	90 (± 23)	75 (± 26)	55 (± 30)
200 (± 40)	180 (± 44)	150 (± 49)	110 (± 53)

- With respect to **elements-at-risk** we are only considering Land\_Parcels. Now we take into account changes in population density and in the value of elements-at-risk. We also take into account land-use developments in the period until 2040.
- We also incorporate the following four situations with respect to the design of alternatives:
  - No risk reduction measures
  - Engineering measures (Alternative 1)
  - Ecological measures (Alternative 2)
  - Relocation (Alternative 3)
- We use the following maps:

Possible future scenario:	Alternative: risk reduction options	Now 2014	Elements_at_risk maps : land_parcels		
			2020	2030	2040
S4 Climate resilience (informed planning under climate change)	A0 (no risk reduction)	Does not exist: use existing situation	LP_2020_A0_S2	LP_2030_A0_S2	LP_2040_A0_S2
	A1 Engineering		LP_2020_A1_S2	LP_2030_A1_S2	LP_2040_A1_S2
	A2 Ecological		LP_2020_A2_S2	LP_2030_A2_S2	LP_2040_A2_S2
	A3 Relocation		LP_2020_A3_S2	LP_2030_A3_S2	LP_2040_A3_S2

## 6. Part B: Risk analysis

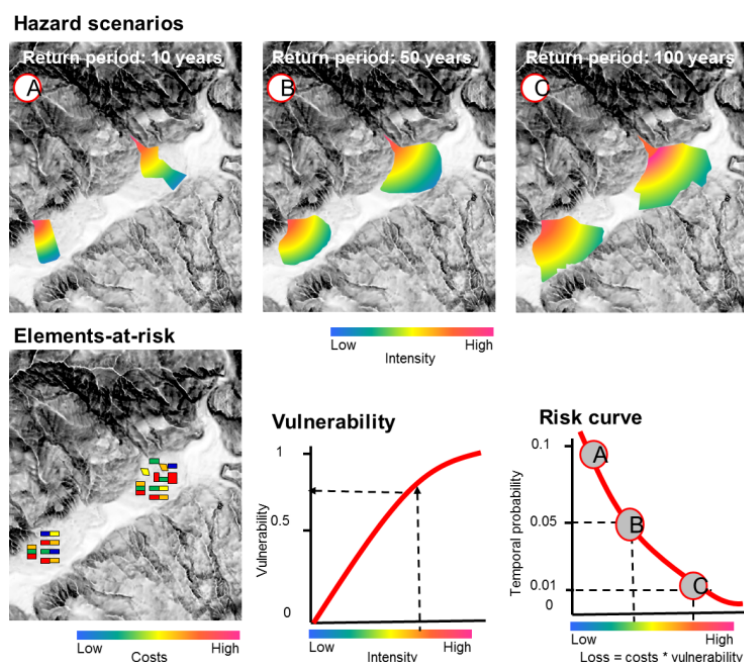
Risk is the probability of losses that may occur in the future due to different types of hazards. Hazards, such as floods, landslides, earthquakes, tsunami's have a relation between the frequency of occurrence and the magnitude of the event. The intensity is the spatially distributed effect of a hazard event (e.g. water depth during a flood varies over an area based on the topography and other factors). Intensity maps for different return periods are obtained through hazard modelling. In this case study these data are provided for three types of hazards (floods, debrisflows, landslides). Also coastal hazards may be considered in this case study. Elements-at-risk are all objects, people, activities that may be affected by a hazardous event, and cause losses. The spatial overlay of hazard intensity maps and elements-at-risk maps is called exposure. Elements-at-risk exposed to a certain hazard intensity may be damaged to a certain degree. This is defined by vulnerability curves.



**Loss analysis** for each combination of a hazard map (for a given return period) and an elements-at-risk map. This done using the following steps:

- Cross the intensity map with the elements-at-risk map. For land parcels and line elements these are subdivided into smaller units with the same intensity. For building footprints and points the maximum intensity is taken.
- For each of the combination units of hazard intensity and elements-at-risk type, the intensity value is used in the lookup table of the vulnerability and the vulnerability value is then used. This is done separately for physical vulnerability and population vulnerability.
- Then the loss is calculated:
  - Physical vulnerability \* value \* spatial probability (for economic losses)
  - Population vulnerability \* people \* spatial probability (for population losses)

**Risk analysis** is done after that: based on an administrative unit map, this map is crossed with the results of the loss estimation, and the losses are aggregated for the unit. When losses are calculated for at least three different hazard intensity maps with different return periods, the losses are plotted on the X-Axis of a graph and the annual probabilities of these on the Y-axis. The points are connected with a graph: so-called risk curve. The area under the curve is calculated, and is define as the annual risk. The annual risk is used in the cost-benefit analysis, where the difference in annual risk before and after the implementation of risk reduction measures (benefit) is compared with the costs of implementation.



## 6.1 Loss estimation

The **Loss analysis** has to be done for each combination of a hazard map (for a given return period) and an elements-at-risk map. Each loss estimation requires a number of steps, which make that doing this type of analysis manually is very time consuming. Therefore we are using an automated script, which combines a number of calculations and operations, and uses parameters.

The script is called “**Loss\_calculation**”. It does the following steps:

1. Rasterize the element-at-risk map (e.g. LP\_2014\_A0\_S0)
  2. Overlay the element at risk map with the hazard intensity map. This is done with the Cross operation. For example the element-at-risk map LP\_2014\_A0\_S0 is crossed with the hazard intensity map, e.g. FL\_DE\_20\_A0
  3. The resulting cross table (joint frequency table) contains all combinations of the land parcel code and the intensity values (e.g. water depths). Classify the results, according to the classification of the hazard intensity (e.g. domain class group FL\_DE), so that the result is in the form of classes, which can be used to join with the vulnerability tables.
  4. As land parcels are sometimes large and only part of them might be actually exposed to hazard intensity the script calculates the losses first for the parts of the land parcels with the same intensity.
  5. In order to know which fraction of each land parcel has a certain intensity, the script reads in in the area of the whole land parcel from the attribute table of the land parcel map.
  6. Then the script calculates the fraction of the land parcel (Area of the unit in the joint frequency table / the area of the entire land parcel).
  7. Then the script joins with the attribute table of the land parcels and reads in the amount column either value or people, depending on the input provided by the user.)
  8. The script uses this then to calculate the amount for each combination of land parcel and intensity class
  9. The script joins with the attribute table of the land parcels and reads in the land use types.
  10. The script joins with the vulnerability table (of the hazard type indicated) and reads in the vulnerability values for all lands use types. The script needs to joint all 23 vulnerability types.
  11. The vulnerability for each record is calculated by taking the vulnerability value of the column that has the same land use code as in the record .
  12. The script calculates a column that has an indication whether we are dealing with a spatial probability map. This is done by creating a column SPCheck and then checking if the entered value is SP (Spatial Probability) or not.
  13. If this is the case, we use the spatial probability, otherwise a value of 1.
  14. **The script then calculates the loss by multiplying the amount \* vulnerability \* spatial probability.**
  15. In order to bring back the information at the level of the land parcels, the script aggregates the loss for the land parcels and put the results in the table **Results\_LP**
  16. The script also aggregates the loss for the administrative units and stores the results in the Table **Results\_Admin\_units**
  17. The script aggregates the losses for the whole area and stores the results in the Table **Result\_Total\_area**
  18. The script then deletes all the intermediate files
- [Open the script Loss\\_calculation and have a look at the codes. We don't ask you now to understand it.](#)

The script stores the results in three tables:

- Results\_LP : the results for each land parcel. Generally this is too detailed.
- Results\_Admin\_Unit: the results are stored per administrative unit. This is the level for which we want to calculate the risk.
- Results\_Total\_Area: the results aggregated for the entire area. If you do a cost-benefit analysis, using single values for the entire area could be used.

It is not really required that you understand each individual step of the analysis, because we have combined them into one file, called a script file that contains all above calculation steps. You can run the total analysis in one go. the only thing you need to specify is: for which combinations of hazard type, return period, and element-at-risk map do I make the loss assessment. This is done by indicating the variables in a script. the **Loss\_calculation** script has the following variables.

The script uses nine parameters, which you can change everytime, so you can use the script for all possible combinations:

- %1 = Hazard Type (e.g. FL, DF, LS)
- %2 = Intensity measure (e.g. DE, IP)
- %3 = Return period (e.g. 020)
- %4 = Future Year (2014, 2020, 2030, 2040)
- %5 = Risk reduction alternative (A0, A1, A2,A3)
- %6 = Scenario (S1, S2, S3, S4)
- %7 = Physical or population Risk (PH or PO)
- %8 = Value or People (If you select PH for %5 you should select Value, otherwise People)
- %9 = Spatial Probability (either 1 or the letters SP)

- You can run the script in various ways. On the command line type:

**Run Loss\_calculation**

- Open the script and press the run button.

Then the following input screen shows .

Fill in the right values. Make sure for the return period to fill in values without decimals (so 20 and not 20.000) and also for the future year.

## Automate the loss calculation for many combinations

You can also run the script bypassing the input screen. You can do that by typing the parameters behind the script name, separated by spaces.

For instance, on the command line:

- **Run Loss\_calculation FL DE 20 2014 A0 S0 PH value**

You can also prepare an input script where you write all the combinations for which you want to calculate losses.

- Open the script **Loss\_Input** where you can adjust all the input lines, and after that run the input script. The script contains all the combinations of hazard maps , return periods, and alternatives for the current situation.
- Make sure the input script contains the following lines:

```
Run Loss_calculation FL DE 20 2014 A0 S0 PH value
Run Loss_calculation FL DE 50 2014 A0 S0 PH value
Run Loss_calculation FL DE 100 2014 A0 S0 PH value
```

Run **Loss\_calculation** DF IP 20 2014 A0 S0 PH value  
 Run **Loss\_calculation** DF IP 50 2014 A0 S0 PH value  
 Run **Loss\_calculation** DF IP 100 2014 A0 S0 PH value  
 Run **Loss\_calculation** LS SP 20 2014 A0 S0 PH value  
 Run **Loss\_calculation** LS SP 50 2014 A0 S0 PH value  
 Run **Loss\_calculation** LS SP 100 2014 A0 S0 PH value

- When you type : **Run Loss\_input** and all the loss calculations are done in one go (it will take some minutes).
- Check the results in the tables: Results\_LP, Results\_admin\_units and Results\_total\_area.

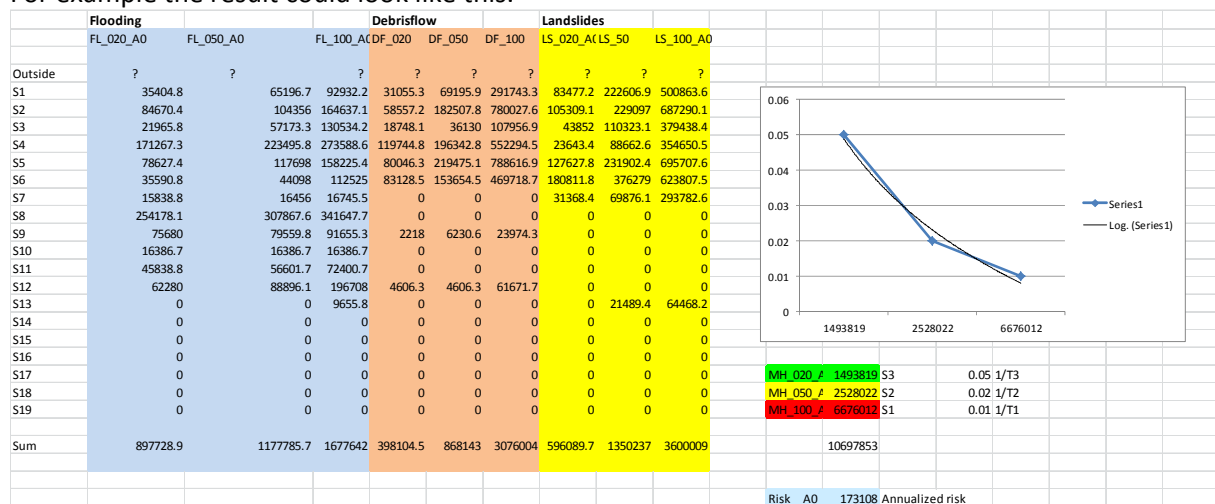
## 6.2 Risk analysis

The risk analysis can be carried out if you have done the loss estimation for three return periods of the hazard type(s) that were selected, and for the land parcel map that was selected, and the risk type (physical or population)

For the risk analysis, the losses have already been aggregated for a given administrative unit. We therefore use the map Admin\_units.

- Copy the relevant columns for risk into an Excel sheet.
- As a result you get for each administrative unit the losses related to three return periods.

For example the result could look like this.



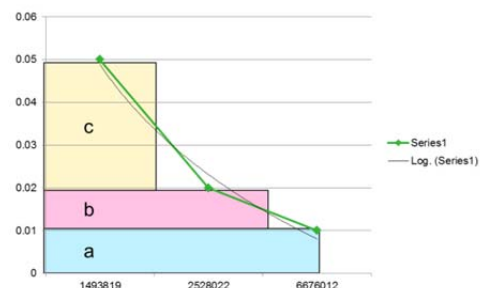
- In order to calculate the annualized risk use the following equation:

$$risico = \frac{1}{T_1} \cdot S_1 + \left( \frac{1}{T_2} - \frac{1}{T_1} \right) \cdot \frac{S_1 + S_2}{2} + \left( \frac{1}{T_3} - \frac{1}{T_2} \right) \cdot \frac{S_2 + S_3}{2} + \left( \frac{1}{T_4} - \frac{1}{T_3} \right) \cdot \frac{S_3 + S_4}{2} + \left( \frac{1}{T_5} - \frac{1}{T_4} \right) \cdot \frac{S_4 + S_5}{2}$$

Where T1, T2 etc are the return periods used, and S1, S2 etc are the losses.

For example:

Loss	Return Period	Annual probability
1493819	20	0.05
2528022	50	0.02
6676012	200	0.01



Annual risk: =

$$0.01 * 6676012 + (0.02 - 0.01) * (6676012 + 2528022) / 2 + (0.05 - 0.02) * (2528022 + 1493819) / 2 = 173108$$

When you are doing this for different hazard types it is also important to decide if the hazard types are dependent or not. This means if they are related to the same triggering event. In our case the hazards are all related to the same triggering: rainfall. This is important for the estimation of the risk, where we take the maximum loss per administrative unit of the various hazards, and do not add them up. We would therefore not add the losses for different hazards, but would take the maximum losses for each of the hazards.

The risk analysis can also be done using a script: **Risk\_calculation**. It can only be executed after you have calculated the losses using the script **Loss\_calculation**. The data should be available in the table: Results\_LP. It requires the individual losses for Floods (FL), Debrisflow (DF) and Landslides (LS) for three return periods. This script does the following:

- For each land parcel it will calculate the maximum loss for the same return period resulting either from flooding, landslides or debrisflows, as these events are caused by the same trigger.
- Then the resulting losses are aggregated by the administrative units;
- Then the annual risk is calculated using the equation indicated above;

The script uses the following parameters:

%1 = Year

%2 = Alternative

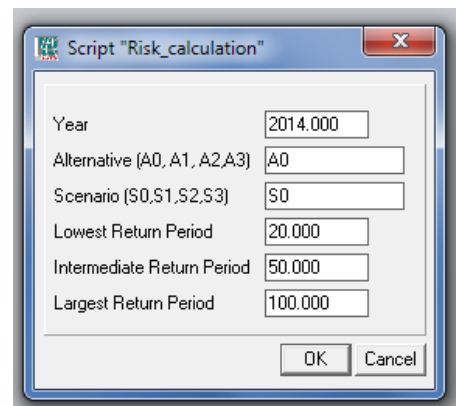
%3 = Scenario

%4 = First return period

%5 = Second return period

%6 = Third return period

The three return periods %4 , %5 and %6 allow us later to change the return periods in scenarios 3 and 4 where we assume that due to climate change the frequency of the hazard events will increase.



We will run the risk analysis for the current situation:

Year = 2014

Alternative = A0

Scenario = S0

First return period = 20

Second return period = 50

Third return period = 100

- Run the script **Risk\_Calculation** and fill in these parameters. Make sure to delete the decimals for year, and return periods.
- When the calculation is finished, open the table **Risk\_Results**, and find out:
- The administrative units with the highest risk
- The total annualized risk for the entire area.

## 7.Part C: Analyse the effect of possible risk reduction alternatives

After knowing how you calculate the loss using the script Loss\_calculation and how to generate the risk curve using the script Risk\_calculation, as was explained in the previous exercise, we will now evaluate the possibilities for risk reduction. The results of the previous exercise show the resulting loss values for the three hazard types (flooding, debrisflows and landslides) for different return periods (1 in 20 years, 1 in 50 years and 1 in 100 years). The results show the losses for the 19 administrative units in the study area. As you can see (see resulting table from the previous exercise) the results show that in some of the administrative units the risk is higher than in others. For instance administrative units 4,5 and 6 have high potential losses for all three hazards. Unit 8 has only flood losses. Unit 13 has predominantly landslide losses. You can also see that the average annual losses for the entire area, based on the three hazards are high: 173 thousand Dollars per year. Therefore it is important to take action and plan for risk reduction measures to reduce the risk

A similar calculation can be done for population losses. The results for that also show that in some of the administrative units the population losses are high. This is the basis for evaluating which risk reduction alternatives would be the best to implement.

In this exercise we will identify three risk reduction alternatives and reanalyse the risk, the calculate the risk reduction (which is the average annual risk after the implementation minus the current average annual risk). We will later also make an estimation of the costs for the alternatives and carry out a cost-benefit analysis.

Scenario: Possible Future trends	Alternative: risk reduction options	Now 2014	Average Annual risk	Risk reduction
S0 (Without including any future trends)	A0 (no risk reduction)	2014_A0_S0		
	A1 Engineering	2014_A0_S1		
	A2 Ecological	2014_A0_S2		
	A3 Relocation	2014_A0_S3		

### 7.1 Loss analysis of the alternatives

The first step to do is to reanalyse the losses , but now for the new situations that would exist if the risk reduction alternatives would be implemented. In the animation above you have seen the various input maps that are required for each of the three alternatives. They are also summarized in the three table below, whihc gives the example for alternative 1. As you can see from the animation, depending on the proposed risk reduction alternative, both hazard maps and elements-and-risk maps should be updated.

For alternative 1: both hazard maps and elements-at-risk maps should be updated. Constructing the engineering measures will greatly reduce the flood, debrisflow and landslide hazards. However, as the most eastern watershed is not considered in the plans, there the flood and debris flow hazard will remain the same. The engineering works have been designed for a return period of 100 years. Therefore we have also modelled the 1 in 200 year event, and for this situation the engineering works will be partly overtopped. The construction of the storage basins requires to change the land

use and relocate some of the houses which are in the location of the storage basins. Therefore also a new elements-at-risk map is needed.

For alternative 2: also both hazard maps and elements-at-risk maps should be remade, as they both will change as a consequence of the risk reduction alternative. The plantation of the protective forest will greatly reduce the hazards, however, not as much as the construction of the engineering works. It will also take a number of years before the trees in the protective forest are tall enough to have their full protection function. Also for the plantation of the protective forest some land parcels will have to change their land use and some buildings have to be relocated.

For alternative 3 (relocation) only the elements will change. This alternative doesn't involve the reduction of hazards, but only the reduction of the exposed elements-at-risk (buildings). therefore the same hazard maps can be used as for the current situation.

Similarly as the analysis which was done for the current risk we are doing this analysis in two steps:

- Loss analysis for each individual combination of hazard set (for a given date, hazard type and return period) and elements-at-risk (the land parcel map for the given scenario and future year).
- Risk analysis by combining the loss results for different hazards and return periods.

#### Loss analysis.

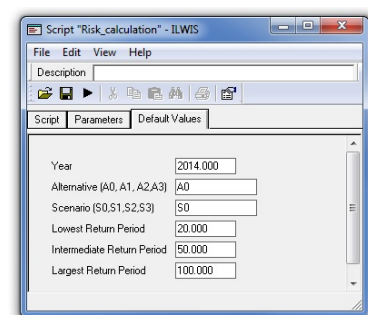
We will use the script **Loss\_calculation** for that.

- Adapt the script **Loss\_input** and add the specific combinations of alternatives, hazard types and elements-at-risk
- The best is to copy the text in a text editor and adjust the parameters like the alternative.
- The example on the right side show the situation for alternative 1
- After generating the input script, you can run it and one by one the actual loss estimation script (**Loss\_calculation**) is calculated, everytime with another set of input data.
- Each time the results of the analysis are written in three tables with the results: **Results\_LP** (for each landparcel the results are stored), **Result\_Admin\_Units** (results aggregated per administrative units) and **Results\_Total** (Aggregated values for the entire area).
- The calculation might take some time (probably about 15 minutes)
- When the calculation is completed, check the results from the tables indicated above.

## 7.2 Risk analysis of the alternatives

The risk analysis which was done using a scrip **Risk\_calculation** (see previous exercises) can now also be done for the different scenarios. Remember that the script has the following vairables:

- %1 = Year
- %2 = Alternative
- %3 = Scenario
- %4 = First return period
- %5 = Second return period
- %6 = Third return period



We assume that flooding, landslides and debrisflows are depending on the same trigger, so we take the maximum losses for a given area from one of the three hazards. We assume that if a triggering events occurs it may trigger either landslides, flashfloods or debrisflows, and the area affected by

one would lead to a certain amount of losses. If another event also happens it will not cause twice the same damage.

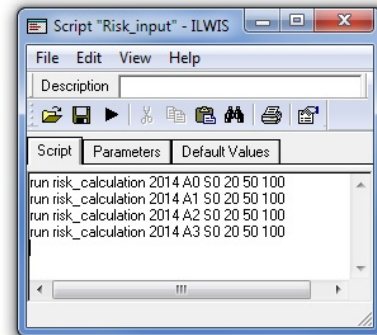
The input data for the risk analysis is handled through the scrip **Risk\_calculation\_input**. For running the alternatives 1 to 3 the following information should be available:

Note that we first calculate the current risk, and then calculate the risk for the three alternatives.

- Adapt the **Risk\_calculation\_input** script so that it represents the same situation as the one shown above.
- Then run the script by typing on the command line:  
**Run Risk\_calculation\_input**
- Next you use the script **Risk\_calculation** with the input script **Risk\_calculation\_input**, which should contain the following lines:

```
run risk_calculation 2014 A0 S0 20 50 100
run risk_calculation 2014 A1 S0 20 50 100
run risk_calculation 2014 A2 S0 20 50 100
run risk_calculation 2014 A3 S0 20 50 100
```

- Run the script.
- Copy to the results to an Excel table, and present them in a graph in which you show the average annual risk before and after the implementation of the alternative, and calculate the difference, which is the annual risk reduction or benefit;



## 7.3 Cost benefit analysis of the alternatives

After calculating the risk curves and annual risk for the current situation and for one or more of the three alternatives, you can analyse which of the alternatives leads to the highest risk reduction (the largest benefit). However, the costs for the alternative might be much higher. Therefore it is important to also analyse the cost-benefit relation.

### 7.3.1 Calculating the costs

In order to do that you need to estimate the costs for each of the alternatives. For that you need to analyse:

- The initial investment costs
- The period over which these investment costs are made
- In which year after the start of the construction are the benefits achieved.
- The annual maintenance costs
- The total duration of the project. In our case we will use a project lifetime of 50 years.

The initial investment costs are composed of all the costs needed to carry out the alternative. The implementation of each alternative will have a number of components that each costs money. The first part of the analysis is to identify all the individual cost options. The table below shows an example of these.

Item	Alternative 1: Engineering solutions	Alternative 2: Ecological solutions	Alternative 3: Relocation.
Item related to construction costs	Expropriating existing houses where green belt is constructed	Expropriating existing houses where green belt is constructed	Expropriating existing houses

	Expropriating land where green belt is constructed	Expropriating land where green belt is constructed	Lawsuits
	Construction of retention basins	Planting trees	Construction of new buildings (or)
	Slope stabilization	Constructing water tanks	Giving compensation to expropriated owners
		Slope stabilization	
How long does the construction take?			
In which year does the benefit start?			
Annual maintenance costs			
Project lifetime	50 years		

The following aspects should be considered:

	Items related to construction cost	Time of construction	Benefit starts	Annual Maintenance
Alternative 1: engineering solutions	<ul style="list-style-type: none"> <li>Storage basins</li> <li>Slope stabilization</li> <li>Expropriation of land and existing buildings where construction will take place</li> </ul>	3 years	4 <sup>th</sup> year	From year 4
Alternative 2: Ecological solutions	<ul style="list-style-type: none"> <li>Expropriation of land and existing buildings where construction will take place</li> <li>Slope stabilization</li> <li>Water tank construction</li> </ul>	3 years	From 4 <sup>th</sup> year with 100% benefit in 10 <sup>th</sup> year	From year 2
Alternative 3: Relocation	<ul style="list-style-type: none"> <li>Compensation of owners of buildings</li> <li>Expropriation of existing buildings</li> <li>Lawsuits</li> </ul>	10 years	100% benefit starts from 11 <sup>th</sup> year	From year 11

For each of these items you need to make an estimation. The costs estimation can be done in the following ways:

- Calculating the area of land that will change. You can do that using the building maps or the land parcel maps of the present situation and of the alternatives (e.g. LP\_2014\_A0 as land parcel map of the current situation). This map also has value information and information on the number of people. When you overlay these with the land parcel map for the alternative (e.g. LP\_2014\_A1 for the parcel map of the first alternative) you can calculate how much area of land will change and their values.
- You can also calculate the area of the land that is converted from the current situation to for example the tree belt under Alternative 2, or the number of retention basin under Alternative 1. You can then use values per m<sup>2</sup> in the calculation.
- Make an estimation of the unit costs per m2 that you are using in the analysis, or ask the staff for these values. See also the suggested values on the right side
- Prepare an Excel sheet in which you make a line for each year, and a column for each of the components of the cost analysis. See example below:

Alternative 1	Engineering solutions
Storage basins	
nr	6
Per basin	250000
Years construction	3
Maintenance	25000
Slope stabilization	
Area (m2)	92052
Soil removal (per m2)	1
Years construction	3
Maintenance	5000
Expropriation	60000 m2 * 5
When does benefit start:	year 4

Alternative 2	Ecological solutions
Tree planting	
Area (m2)	153526
Cost per m2	1
Years	1
Maintenance/year	0.1
Expropriation	Protective forest area
Watertanks	302229
Number	3668
Construction	
Years	10
Maintenance	5000
Slope stabilization	
Area (m2)	92052
Soil removal (per m2)	25
Years construction	3
Maintenance	5000
When does benefit start:	year 10

Alternative 3	Relocation
How many houses	95
Value of buildings	14041177
Lawsuits	50
Value per lawsuit	10000
Years this takes	10
Compensation per building	150000

Year	Alternative 1: Engineering solutions				Alternative 2: Ecological solutions					Alternative 3: Relocation				
	Storage basin construction	Slope stabilization	Maintenance	Total	Expropriation	Tree planting	Slope stabilization	Maintenance	Total	Expropriating existing houses	New buildings	Financial compensation	Maintenance	Total
2014														
2015														
2016														
2017														
2018														
2019														
2020														
2021														
2022														
2023														
etc														
2030														
Etc														
2040														
etc														

- After filling in the values in the Excel sheet you can also calculate the overall costs per year for each of the alternatives (the columns: Total)

### 7.3.2 Entering the benefit values.

In the previous part of the exercise the benefits in terms of risk reduction have been calculated. The table below gives a summary of the calculated reduction in annual risk reduction. The calculation on the following pages gives the results of these calculation:

	Current situation	Alternative 1	Alternative 2	Alternative 3
Annualized risk				
Risk Reduction	-			

- Calculate the Risk Reduction (as the annualized risk for the current situation minus the annualized risk for the alternative) for the 3 alternatives.
- Decide in which year the Risk Reduction will actually start. It may be possible that in the first years you have investments, but no risk reduction yet, as the alternative to reduce the risk is not finished.
- Think about this for the 3 alternatives and decide in which year we will actually reach the risk reduction.
- In the Excel sheet add for each of the alternatives a column, called Risk Reduction for each of the scenarios.
- In the Excel sheet calculate the Incremental Benefits, by Calculating the difference between the Risk Reduction and the total of the costs per year. For the first years these values might be negative.

### 7.3.3 Net Present Value

We need to take into account that the same amount of money in the future will be less valuable today. We will need therefore to calculate the so-called net present value (NPV).

The Net Present Value (NPV) calculates the net present value of an investment by using a discount rate and a series of future payments (negative values) and income (positive values).

$$NPV = \sum_{i=1}^n \frac{values_i}{(1+rate)^i}$$

Rate: is the rate of discount over the length of one period

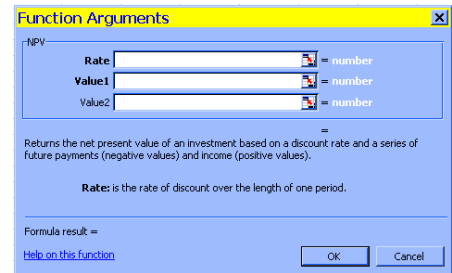
Value 1 value 2 ... are the "arguments" representing the payments and income.

NPV = the discounted benefits and costs at a given discount rate.

An example is given below:

A	B
<b>1 Data</b>	<b>Description</b>
2 8%	Annual discount rate. This might represent the rate of inflation or the interest rate of a competing investment.
3 -40,000	Initial cost of investment
4 8,000	Return from first year
5 9,200	Return from second year
6 10,000	Return from third year
7 12,000	Return from fourth year
8 14,500	Return from fifth year
<b>Formula</b>	<b>Description (Result)</b>
=NPV(A2, A4:A8)+A3	Net present value of this investment (1,922.06)
=NPV(A2, A4:A8, -9000)+A3	Net present value of this investment, with a loss in the sixth year of 9000 (-3,749.47)

- In the Excel worksheet to the right of the table make a cell NPV ( Net Present Value) ;
- In the cell next to it insert the name Interest rate (which is the same as discount rate) and enter the value of : 10 %.
- In Excel: Click in your “NPV” cell and Insert Function; select Financial Functions.
- Select: NPV
- The Function Arguments Box opens ( see figure below);
- Select for Interest Rate 6%
- For value 1: select the whole column down all the incremental benefits; starting at year 1 up to year 40.
- Click OK



Alternative 1				Alternative 2				Alternative 3			
Year	Costs	Risk Reduction	Incremental benefit	Year	Costs	Risk Reduction	Incremental benefit	Year	Costs	Risk Reduction	Incremental benefit
1	630684	0	-630684	1	1738695	0	-1738695	1	1475000	0	-1475000
2	630684	0	-630684	2	63360	0	-63360	2	1475000	10000	-1465000
3	630684	0	-630684	3	38860	0	-38860	3	1475000	20000	-1455000
4	30000	150214	120214	4	13176	50000	36824	4	1475000	30000	-1445000
5	30000	150214	120214	5	13176	60000	46824	5	1475000	40000	-1435000
6	30000	150214	120214	6	13176	70000	56824	6	1475000	50000	-1425000
7	30000	150214	120214	7	13176	80000	66824	7	1475000	60000	-1415000
8	30000	150214	120214	8	13176	90000	76824	8	1475000	70000	-1405000

- Repeat the NPV calculation, but now with different discount rates

### 7.3.4 Internal Rate of Return

Now we are going to calculate the Internal rate of return. The Internal Rate of Return is the discount rate/interest rate at which the NPV=0

- In Excel: Click Insert Function and select Financial Functions.
- Select: IRR
- The Function Arguments Box opens;
- Read the HELP file
- For values: select the whole column down all the incremental benefits; starting at year 1 up to year 40.
- Click OK.

### 7.3.5 Comparing the alternatives and select the best one

Now we will compare the NPV and IRR values for the various risk reduction alternatives.

- Calculate the NPV and IRR for the three alternatives. Calculate the NPV for 3 interest rates
- Compare the results.
- Decide which of the three alternatives is the best based on the cost-benefit evaluation.

	NPV at 5 % interest rate	NPV at 10 % interest rate	NPV at 20 % interest rate	IRR
Alternative 1				
Alternative 2				
Alternative 3				

## 8.Part D: Evaluate the changes for the different scenarios.

The aim of this component is to analyse the changes in land use, values and population over time due to the different scenarios and the alternatives, and to describe the drivers, pressures , and changes. We do this using the land parcel maps for the different combinations.

We have generated the various land parcel maps in such a way that they have the same polygon boundaries, but the contents (attributes: type, value and population) change from one situation to another.

- Check that the polygon boundaries are the same by comparing different land parcel maps.
- Use the PixelInfo programme and load in the series of land parcels maps that you would like to compare. Moving over the map with the mouse will show you how land use types change from period to another.

### 8.1 Analysing the changes in land use

For analysing the changes in landuse we are going to calculate the area per land use type for the various land parcel maps of the scenarios, future years and alternatives.

- Create a new table **Results\_landuse\_change**, using the domain **landuse**
- In this table join with the table **LP\_2014\_A0\_S0** and aggregate the **Area** , grouping by **Type**.
- Check the results in the table **Results\_landuse\_change**

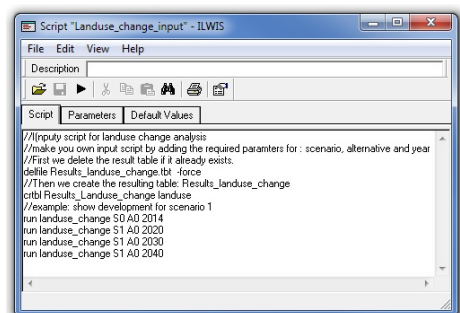
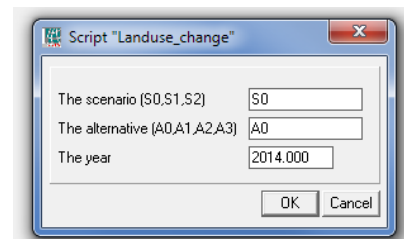
You can also automate this procedure using the script Landuse\_change. This script uses three parameters:

%1 = The scenario (S0,S1,S2)

%2 = The alternative (A0,A1,A2,A3)

%3 = The year

- Open the script and check the statement.
- Run the script for a particular combination of alternative, scenario and year. Best is to do that for the combination marked red in the table on the next page.
- Adjust the script **Landuse\_change\_input** by entering the combinations that you want to analyse.
- The example to the right shows how the **Landuse\_change\_input** script could be for analysing the changes in senario1
- You can run this script by typing on the command line:  
**Run landuse\_change\_input**
- Present the results in a table, and in a graph in which you show the change in area per land use through time for the different scenarios and alternative combinations.



Discuss the results of the land use change given the particular scenario and alternative, and indicate:

- Which developments in land use type do you observe?

- Can you explain these given the scenario / alternative descriptions given earlier?
- What are the main drivers for landuse change?
- Are there un logical development?

Land use type	Current situation	Land use according to scenario 1 and 3 (both have same landuse situation, but different climate change effect)			Landuse according to scenario 2 and 4 (both have same landuse situation, but different climate change effect)		
	Hectares 2014	2020	2030	2040	2020	2030	2040
Agricultural_fields Animal_Farm Bare Commercial Cultural_heritage Farm Forest_natural Forest_Planted_protective Grassland Highway Industry Open_slope_soil_removed Orchard Parking_lot Parkland Quarry Residential Shrubs Storage_Basin Toll_area Tourist_resort Vineyard Water_tank							

## 8.2 Analysing the changes in land values

Land values are indicated per land parcel for each of the future scenarios and future years. The land values were estimated based on the land use. The values include the objects on the land and the values represent the replacement costs. In the value estimation the effect of inflation is not considered so that it is better to compare the situation of the different years.

The following table gives the changes in land value per land use type:

Estimated values for scenarios 1 and 3.

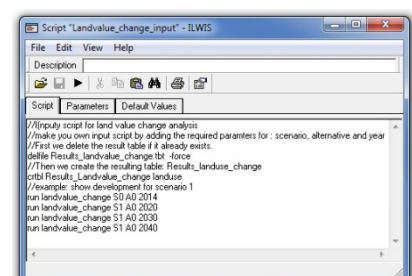
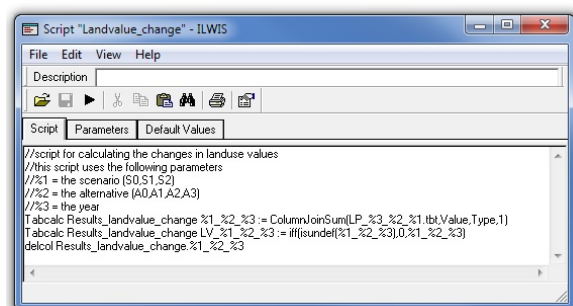
Land use type	Value per m2 2014	Value per hectare 2014	Increase per year	Value per m2 2020	Increase per year	Value per m2 2030	increase per year	Value per m2 2040
Agricultural_fields	0.2	2000	0.01	0.2	0.01	0.2	0.01	0.3
Animal_Farm	300.0	3000000	0	300.0	0	300.0	0	300.0
Bare	0.0	0	0	0.0	0	0.0	0	0.0
Commercial	237.0	2370000	0.01	251.6	0.01	277.9	0.01	307.0
Cultural_heritage	396.0	3960000	0.02	446.0	0.02	543.6	0.02	662.7
Farm	211.0	2110000	0	211.0	0	211.0	0	211.0
Forest_natural	11.0	110000	0	11.0	0	11.0	0	11.0
Forest_Planted_protective	13.0	130000	0	13.0	0	13.0	0	13.0
Grassland	0.1	1000	0	0.1	0	0.1	0	0.1
Highway	250.0	2500000	0	250.0	0	250.0	0	250.0
Industry	300.0	3000000	0	300.0	0	300.0	0	300.0
Open_slope_soil_removed	0.0	0	0	0.0	0	0.0	0	0.0
Orchard	2.5	25000	0.01	2.7	0.01	2.9	0.03	3.9
Parking_lot	150.0	1500000	0	150.0	0.01	165.7	0.03	222.7
Parkland	15.0	150000	0	15.0	0	15.0	0	15.0
Quarry	0.1	1000	0	0.1	0	0.1	0	0.1
Residential	300.0	3000000	0.01	318.5	0.02	388.2	0.03	521.7
Shrubs	0.0	100	0	0.0	0	0.0	0	0.0
Storage_Basin	50.0	500000	0	50.0	0	50.0	0	50.0
Toll_area	350.0	3500000	0	350.0	0	350.0	0	350.0
Tourist_resort	266.0	2660000	0.02	299.6	0.03	402.6	0.04	595.9
Vineyard	12.0	120000	0.03	14.3	0.04	21.2	0.06	38.0
Water_tank	30.0	300000	0	30.0	0	30.0	0	30.0

Estimated values for scenarios 2 and 4.

Land use type	Value per m2 2014	Value per hectare 2014	Increase per year	Value per m2 2020	Increase per year	Value per m2 2030	increase per year	Value per m2 2040
Agricultural_fields	0.2	2000	0.01	0.2	0.01	0.2	0.01	0.3
Animal_Farm	300.0	3000000	0	300.0	0	300.0	0	300.0
Bare	0.0	0	0	0.0	0	0.0	0	0.0
Commercial	237.0	2370000	0.04	299.9	0.06	537.0	0.07	1056.4
Cultural_heritage	396.0	3960000	0.02	446.0	0.02	543.6	0.02	662.7
Farm	211.0	2110000	0	211.0	0	211.0	0	211.0
Forest_natural	11.0	110000	0	11.0	0	11.0	0	11.0
Forest_Planted_protective	13.0	130000	0	13.0	0	13.0	0	13.0
Grassland	0.1	1000	0	0.1	0	0.1	0	0.1
Highway	250.0	2500000	0	250.0	0	250.0	0	250.0
Industry	300.0	3000000	0.04	379.6	0.06	679.8	0.07	1337.3
Open_slope_soil_removed	0.0	0	0	0.0	0	0.0	0	0.0
Orchard	2.5	25000	0.01	2.7	0.01	2.9	0.03	3.9
Parking_lot	150.0	1500000	0	150.0	0.01	165.7	0.03	222.7
Parkland	15.0	150000	0	15.0	0	15.0	0	15.0
Quarry	0.1	1000	0	0.1	0	0.1	0	0.1
Residential	300.0	3000000	0.05	402.0	0.07	790.9	0.1	2051.3
Shrubs	0.0	100	0	0.0	0	0.0	0	0.0
Storage_Basin	50.0	500000	0	50.0	0	50.0	0	50.0
Toll_area	350.0	3500000	0	350.0	0	350.0	0	350.0
Tourist_resort	266.0	2660000	0.04	336.6	0.05	548.2	0.06	981.8
Vineyard	12.0	120000	0.03	14.3	0.04	21.2	0.06	38.0

Land value change can be analysed in different ways. You could do this for administrative units, for land use types, or for the entire area. The easiest method is to do this for the whole area. You can directly get the total land values from the attribute tables.

- Open the table **LP\_2014\_A0\_S0**. Check whether the statistics pane is visible. You can read the total value for this combination.
- For the analysis of land value changes we use a script: **Landvalue\_change** See right)
- This script has the following variables:  
 %1 = the scenario (S0,S1,S2)  
 %2 = the alternative (A0,A1,A2,A3)  
 %3 = the year
- The actual analysis of land value changes is done using an input script: **Landvalue\_change\_input**. An example of this is given here for analysing the land value changes for scenario 1.



- Run this script by typing: Run Landvalue\_change\_input
- Adjust the **Landvalue\_change\_input** script so that also the other scenarios are included. Do this by copying the content in a text editor and changing them.
- Then run the input script and after the calculation is done, investigate the results and write them in a table like the one below.
- Note that the results for scenario 1 and 3 and for scenario 2 and 4 are the same as the land use for scenario 3 is the same as for scenario 1 and the ones from scenario 4 the same as scenario 2 (only the frequency of hazard events changes due to climate change effects).

Scenario: Possible Future trends	Current situation	Future years		
		2020	2030	2040
S1 Business as usual				
S2 Risk informed planning				
S3 Worst case (Rapid growth + climate change)				
S4 Climate resilience (informed planning under climate change)				

- Present the results in a table, and in a graph in which you show the change in area per land use through time for the different scenarios and alternative combinations.

### 8.3 Analysing the changes in population

Also population densities and number of people are indicated per land parcel for each of the future scenarios and future years. The population data were estimated based on the land use. The number of people are considered maximum values, and not specific population scenarios (e.g. daytime night-time, summer / winter etc.) have been considered. The tables below show the data on the basis of which the estimations were made:

Scenario 1 and 3: Population data

Land use type	People per m2 2014	People per hectare 2014	Increase per year	People per m2 2020	Increase per year	People per m2 2030	increase per year	People per m2 2040	People per hectare 2014
Agricultural_fields	0.00001	1	0	0.00001	0	0.00001	0	0.00001	1
Animal_Farm	0.00005	5	0	0.00005	0	0.00005	0	0.00005	5
Bare	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0
Commercial	0.00500	500	0	0.00500	0	0.00500	0	0.00500	500
Cultural_heritage	0.00100	100	0	0.00100	0	0.00100	0	0.00100	100
Farm	0.00005	5	0	0.00005	0	0.00005	0	0.00005	5
Forest_natural	0.00001	1	0	0.00001	0	0.00001	0	0.00001	1
Forest_Planted_protective	0.00002	2	0	0.00002	0	0.00002	0	0.00002	2
Grassland	0.00000	0.1	0	0.00000	0	0.00000	0	0.00000	0
Highway	0.00500	500	0	0.00500	0	0.00500	0	0.00500	500
Industry	0.00100	100	0	0.00100	0	0.00100	0	0.00100	100
Open_slope_soil_removed	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0

Orchard	0.00003	2.5	0	0.00003	0	0.00003	0	0.00003	3
Parking_lot	0.00100	100	0	0.00100	0	0.00100	0	0.00100	100
Parkland	0.00020	20	0	0.00020	0	0.00020	0	0.00020	20
Quarry	0.00005	5	0	0.00005	0	0.00005	0	0.00005	5
Residential	0.00040	40	0.01	0.00042	0.02	0.00052	0.03	0.00070	70
Shrubs	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0
Storage_Basin	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0
Toll_area	0.00500	500	0	0.00500	0	0.00500	0	0.00500	500
Tourist_resort	0.00150	150	0	0.00150	0	0.00150	0	0.00150	150
Vineyard	0.00020	20	0	0.00020	0	0.00020	0	0.00020	20
Water_tank	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0

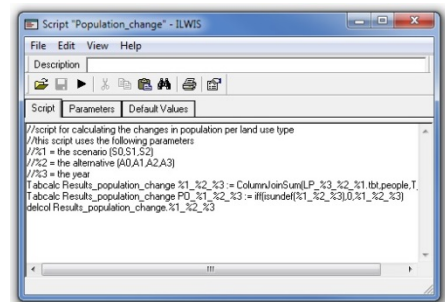
#### Scenario 2 and 4: Population data

Land use type	People per m2 2014	People per hectare 2014	Increase per year	People per m2 2020	Increase per year	People per m2 2030	increase per year	People per m2 2040	People per hectare 2014
Agricultural_fields	0.00001	1	0	0.00001	0	0.00001	0	0.00001	1
Animal_Farm	0.00005	5	0	0.00005	0	0.00005	0	0.00005	5
Bare	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0
Commercial	0.00500	500	0	0.00500	0	0.00500	0	0.00500	500
Cultural_heritage	0.00100	100	0	0.00100	0	0.00100	0	0.00100	100
Farm	0.00005	5	0	0.00005	0	0.00005	0	0.00005	5
Forest_natural	0.00001	1	0	0.00001	0	0.00001	0	0.00001	1
Forest_Planted_protective	0.00002	2	0	0.00002	0	0.00002	0	0.00002	2
Grassland	0.00000	0.1	0	0.00000	0	0.00000	0	0.00000	0
Highway	0.00500	500	0	0.00500	0	0.00500	0	0.00500	500
Industry	0.00100	100	0	0.00100	0	0.00100	0	0.00100	100
Open_slope_soil_removed	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0
Orchard	0.00003	2.5	0	0.00003	0	0.00003	0	0.00003	3
Parking_lot	0.00100	100	0	0.00100	0	0.00100	0	0.00100	100
Parkland	0.00020	20	0	0.00020	0	0.00020	0	0.00020	20
Quarry	0.00005	5	0	0.00005	0	0.00005	0	0.00005	5
Residential	0.00040	40	0.05	0.00054	0.1	0.00139	0.1	0.00361	361
Shrubs	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0
Storage_Basin	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0

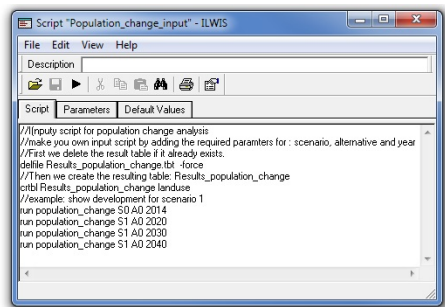
Toll_area	0.00500	500	0	<b>0.00500</b>	0	<b>0.00500</b>	0	<b>0.00500</b>	500
Tourist_resort	0.00150	150	0	<b>0.00150</b>	0	<b>0.00150</b>	0	<b>0.00150</b>	150
Vineyard	0.00020	20	0	<b>0.00020</b>	0	<b>0.00020</b>	0	<b>0.00020</b>	20
Water_tank	0.00000	0	0	<b>0.00000</b>	0	<b>0.00000</b>	0	<b>0.00000</b>	0

Population change can be analysed in different ways. You could do this for administrative units, for land use types, or for the entire area. The easiest method is to do this for the whole area. You can directly get the total population values from the attribute tables.

- Open the table **LP\_2014\_A0\_S0**. Check whether the statistics pane is visible. You can read the population information for this combination.
- For the analysis of land value changes we use a script: **Population\_change** See right)
- This script has the following variables:  
%1 = the scenario (S0,S1,S2)  
%2 = the alternative (A0,A1,A2,A3)  
%3 = the year



- The actual analysis of population changes is done using an input script: **Population\_change\_input**. An example of this is given here for analysing the population changes for scenario 1.
- Run this script by typing:
- **Run Population\_change\_input**
- Adjust the **Population\_change\_input** script so that also the other scenarios are included. Do this by copying the content in a text editor and changing them.
- Then run the input script and after the calculation is done, investigate the results and write them in a table like the one below.
- Note that the results for scenario 1 and 3 and for scenario 2 and 4 are the same as the land use for scenario 3 is the same as for scenario 1 and the ones from scenario 4 the same as scenario 2 (only the frequency of hazard events changes due to climate change effects).



Scenario: Possible Future trends	Current situation	Future years		
		2020	2030	2040
<b>S1 Business as usual</b>				
<b>S2 Risk informed planning</b>				
<b>S3 Worst case (Rapid growth + climate change)</b>				
<b>S4 Climate resilience (informed planning under climate change)</b>				

## 8.4 Analysing the changes in risk for the different scenarios

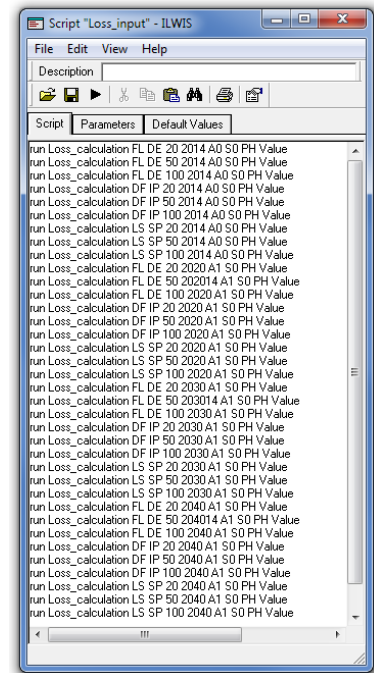
Similarly as the analysis which was done for the current risk and for the evaluation of the best risk reduction alternative, we are doing this analysis in two steps:

- Loss analysis for each individual combination of hazard set (for a given date, hazard type and return period) and elements-at-risk (the land parcel map for the given scenario and future year).
- Risk analysis by combining the loss results for different hazards and return periods.

### Loss analysis.

You can also analyse the changes in risk for the different scenarios. This will take more time, but you can use the script **Loss\_calculation** for that.

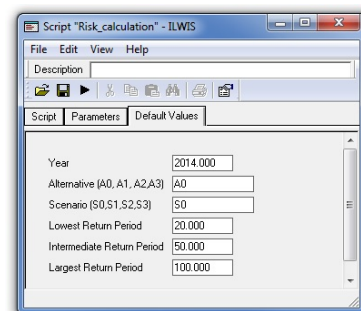
- Adapt the script **Loss\_input** and add the specific combinations of scenarios, and future years
- The best is to copy the text in a text editor and adjust the parameters like the future year and the scenario number.
- The example on the right side show the situation for the scenario 1 for the current situation and for 3 future years: 2020, 2030 and 2040.
- After generating the input script, you can run it and one by one the actual loss estimation script (Loss\_calculation) is calculated, everytime with another set of input data.
- Each time the results of the analysis are written in three tables with the results: **Results\_LP** (for each landparcel the results are stored), **Result\_Admin\_Units** (results aggregated per administrative units) and **Results\_Total** (Aggregated values for the entire area).
- The calculation might take quite some time (probably at least one hour, since many calculations have to be made)
- When the calculation is completed, check the results from the tables indicated above.



### Risk analysis

The risk analysis which was done using a scrip **Risk\_calculation** (see previous exercises) can now also be done for the different scenarios. Remember that the script has the following variables:

- %1 = Year
- %2 = Alternative
- %3 = Scenario
- %4 = First return period
- %5 = Second return period
- %6 = Third return period



We assume that flooding, landslides and debrisflows are depending on the same trigger, so we take the maximum losses for a given area from one of the three hazards. We assume that if a triggering events occurs it may trigger either landslides, flashfloods or debrisflows, and the area affected by one would lead to a certain amount of losses. If another event also happens it will not cause twice the same damage.

The input data for the risk analysis is handled through the scrip **Risk\_calculation\_input**. For running the scenarios 1 to 4 the following information should be available:

Note that we first calculate the current risk, and then calculate the risk for the four different scenarios.

- Scenario 1 and 2 use the same return periods as the current situation, as both of these scenarios only consider land use changes, and the losses for these were calculated in the loss calculation. There is no climate change effect considered, so therefore we use the same return periods as for the current situation.
- However for scenarios 2 and 4 we adjust the return periods based on the change in expected frequencies that are coming from the climate change analysis. The table with these values was presented in the beginning in the section dealing with the input data.

```
//Input script for the risk analysis
define Risk_Results.tbl -force
setbl Risk_Results admin_units
//now define the risk calculation combinations
//%1 = Year
//%2 = Alternative
//%3 = Scenario
//%4 = First return period
//%5 = Second return period
//%6 = Third return period
//Risk calculation for current situation and for scenario 1
run risk_calculation 2014 A0 S0 20 50 100
run risk_calculation 2020 A1 S0 20 50 100
run risk_calculation 2030 A1 S0 20 50 100
run risk_calculation 2040 A1 S0 20 50 100
run risk_calculation 2020 A2 S0 20 50 100
run risk_calculation 2030 A2 S0 20 50 100
run risk_calculation 2040 A2 S0 20 50 100
run risk_calculation 2020 A3 S0 17 45 90
run risk_calculation 2030 A3 S0 14 35 75
run risk_calculation 2040 A3 S0 11 25 55
run risk_calculation 2020 A4 S0 17 45 90
run risk_calculation 2030 A4 S0 14 35 75
run risk_calculation 2040 A4 S0 11 25 55
```

- Adapt the **Risk\_calculation\_input** script so that it represents the same situation as the one shown above.
- Then run the script by typing on the command line:  
**Run Risk\_calculation\_input**
- Calculate the annualized risk for the combinations indicated and put these in the table
- Present the results in a table, and in a graph in which you show the change in area per land use through time for the different scenarios and alternative combinations.

Scenario: Possible Future trends	Alternative: risk reduction options	Future years		
		2020	2030	2040
S1 Business as usual	A0 (no risk reduction)			
S2 Risk informed planning	A0 (no risk reduction)			
S3 Worst case (Rapid growth + climate change)	A0 (no risk reduction)			
S4 Climate resilience (informed planning under climate change)	A0 (no risk reduction)			

## 8.5 Create your own scenario

Optionally it would also be nice if you could also make your own scenario, and change the land use types for the different future years based on your own assumptions. We are not going to use any land use change model, but use logical reasoning instead. The idea is that future land use developments should also take into account:

- Avoid hazardous areas as much as possible;
- Possible coastal hazards (storm surges and tsunamis) which would prohibit constructions close to the coast;

- Incorporate for population increase of 10% per decade;

You can do this using the following approach:

- In the table LP\_2014\_A0\_S0 create a new column Type\_2020\_A0\_S5 which has the same landuse as 2014 by using the following equation in the table:  
Type\_2020\_A0\_S5:=Type
- Overlay with the largest return periods of the hazard maps (DF\_IP\_100\_A0, FL\_DE\_100\_A0 and LS\_IP\_100\_A0) using transparencies. Use pixelinfo and load in these maps.
- Double click on a polygon of the map LP\_2014\_A0\_S0 and change the land use type for 2020, and continue to do so for all relevant polygons.
- Create a column Type\_2030\_A0\_S5:= Type\_2020\_A0\_S5 and edit the new changes.
- Create a column Type\_2040\_A0\_S5:= Type\_2030\_A0\_S5 and edit the new changes.
- Calculate the population changes, using the data from the Excel sheet (Estimation of values and people for different scenarios).
- Analyse the changes in land use for the new scenario in the future years (2020, 2030 and 2040) and explain the trends and possible drivers;

	Value_m			Value_m		Value_m		Value_m	
People	2_2014			2_2020		2_2030		2_2040	
	People_m	hectare	Increase		Increase		increase		
			per year		per year		per year		
Agricultur	0.00001	1	0	0.00001	0	0.00001	0	0.00001	1
Animal_Fe	0.00005	5	0	0.00005	0	0.00005	0	0.00005	5
Bare	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0
Commerci	0.00500	500	0	0.00500	0	0.00500	0	0.00500	500
Cultural_h	0.00100	100	0	0.00100	0	0.00100	0	0.00100	100
Farm	0.00005	5	0	0.00005	0	0.00005	0	0.00005	5
Forest_na	0.00001	1	0	0.00001	0	0.00001	0	0.00001	1
Forest_Pla	0.00002	2	0	0.00002	0	0.00002	0	0.00002	2
Grassland	0.00000	0.1	0	0.00000	0	0.00000	0	0.00000	0
Highway	0.00500	500	0	0.00500	0	0.00500	0	0.00500	500
Industry	0.00100	100	0	0.00100	0	0.00100	0	0.00100	100
Open_slo	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0
Orchard	0.00003	2.5	0	0.00003	0	0.00003	0	0.00003	3
Parking_lc	0.00100	100	0	0.00100	0	0.00100	0	0.00100	100
Parkland	0.00020	20	0	0.00020	0	0.00020	0	0.00020	20
Quarry	0.00005	5	0	0.00005	0	0.00005	0	0.00005	5
Residenti	0.00040	40	0.01	0.00042	0.02	0.00052	0.03	0.00070	70
Shrubs	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0
Storage_B	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0
Toll_area	0.00500	500	0	0.00500	0	0.00500	0	0.00500	500
Tourist_re	0.00150	150	0	0.00150	0	0.00150	0	0.00150	150
Vineyard	0.00020	20	0	0.00020	0	0.00020	0	0.00020	20
Water_tar	0.00000	0	0	0.00000	0	0.00000	0	0.00000	0

## 8.6 Summary of your analysis

After analysing the land use change, land value change and population change, you can now give a more thorough evaluation of the changes and the drivers.

- Analyse the changes in land use for the different scenarios in a number of future years (2020, 2030 and 2040) and explain the trends and possible drivers;
- Analyse the changes in economic values for the different scenarios in a number of future years (2020, 2030 and 2040)
- Analyse the changes in population for the different scenarios in a number of future years (2020, 2030 and 2040)
- Analyse the changes in risk for the for the different scenarios in a number of future years (2020, 2030 and 2040)

## 9.Part E: Evaluate which of the risk reduction alternatives would behave best under possible future scenarios.

This part integrates the previous components. It will allow you to analyse which risk reduction alternative is the best change-proof. The analysis follows the following steps:

- Analyse the changes in risk for risk reduction alternatives for the different scenarios in a number of future years (2020, 2030 and 2040);
- Calculate annualized risk for each combination of risk reduction alternative and future year;
- Calculate annualized risk reduction (benefit) for each combination of risk reduction alternative and future year by subtracting the annualized risk with and without the risk reduction alternative;
- Use these different values for annualized risk reduction (benefits) in a cost-benefit analysis that compares risk reduction alternatives by taking into account their behaviour under different possible future scenarios;
- Determine the most “change proof” risk reduction alternative;

### 9.1 Loss calculation

The table below shows all combinations for scenario S1, the no risk reduction situation, and the three risk reduction alternatives, for 4 future years. For each combination there are 3 loss maps for flooding (for 20, 50 and 100 year return period), 4 for debrisflows and 3 for landslides.

Scenario: Possible Future trends	Alternative: risk reduction options	Now 2014	Future years		
			2020	2030	2040
<b>S0 (Without including any future trends)</b>	A0 (no risk reduction)	2014_A0_S0	No future trends are taking into account, and all hazards, elements at risk and vulnerabilities are considered constant in future.		
	A1 Engineering	2014_A0_S1			
	A2 Ecological	2014_A0_S2			
	A3 Relocation	2014_A0_S3			
<b>S1 Business as usual</b>	A0 (no risk reduction)	Does not exist: use existing situation	2020_A0_S1	2030_A0_S1	2040_A0_S1
	A1 Engineering		2020_A1_S1	2030_A1_S1	2040_A1_S1
	A2 Ecological		2020_A2_S1	2030_A2_S1	2040_A2_S1
	A3 Relocation		2020_A3_S1	2030_A3_S1	2040_A3_S1
<b>S2 Risk informed planning</b>	A0 (no risk reduction)	Does not exist: use existing situation	2020_A0_S2	2030_A0_S2	2040_A0_S2
	A1 Engineering		2020_A1_S2	2030_A1_S2	2040_A1_S2
	A2 Ecological		2020_A2_S2	2030_A2_S2	2040_A2_S2
	A3 Relocation		2020_A3_S2	2030_A3_S2	2040_A3_S2
<b>S3 Worst case (Rapid growth + climate change)</b>	A0 (no risk reduction)	Does not exist: use existing situation	2020_A0_S3	2030_A0_S2	2040_A0_S3
	A1 Engineering		2020_A1_S3	2030_A1_S3	2040_A1_S3
	A2 Ecological		2020_A2_S3	2030_A2_S3	2040_A2_S3
	A3 Relocation		2020_A3_S3	2030_A3_S3	2040_A3_S3
<b>S4 Climate resilience (informed planning under</b>	A0 (no risk reduction)	Does not exist: use existing situation	2020_A0_S4	2030_A0_S3	2040_A0_S4
	A1 Engineering		2020_A1_S4	2030_A1_S3	2040_A1_S4

climate change)	A2 Ecological		2020_A2_S4	2030_A2_S3	2040_A2_S4
	A3 Relocation		2020_A3_S4	2030_A3_S3	2040_A3_S4

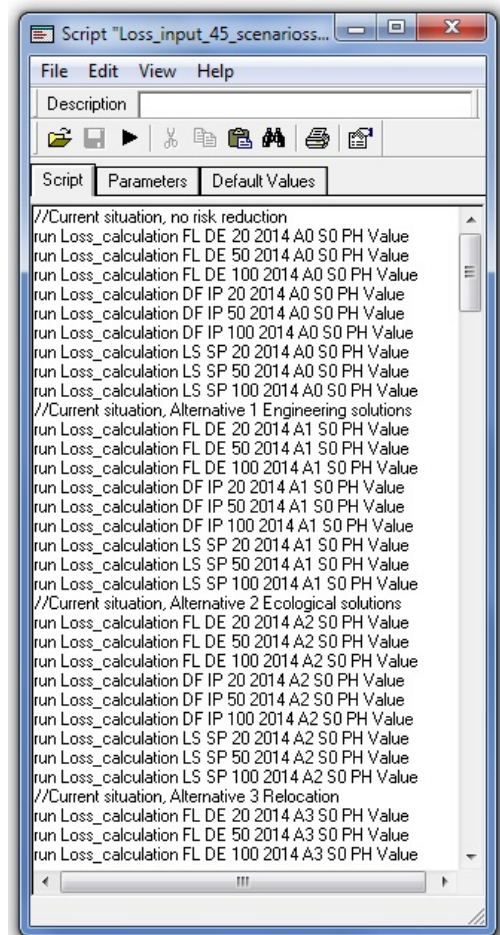
The cells in the table above all have a specific combination of elements-at-risk and hazard maps. For instance for the first two scenarios the following maps are needed. Red (e.g. LP\_2020\_A0\_S1) = elements-at-risk maps. Green (e.g. FL\_DE\_020\_A1) = hazard maps

Scenario	Alternative	2020	2030	2040
S1 Business as usual	A0 (no risk reduction)	LP_2020_A0_S1	LP_2030_A0_S1	LP_2040_A0_S1
		Landslides: LS_SP_020_A0, LS_SP_050_A0, LS_SP_100_A0 Floods: FL_DE_020_A0, FL_DE_050_A0, FL_DE_100_A0 Debrisflow: DF_IP_020_A0, DF_IP_050_A0, DF_IP_100_A0		
	A1 Engineering	LP_2020_A1_S1	LP_2020_A1_S1	LP_2020_A1_S1
		Landslides: LS_SP_020_A1, LS_SP_050_A1, LS_SP_100_A1 Floods: FL_DE_020_A1, FL_DE_050_A1, FL_DE_100_A1 Debrisflow: DF_IP_020_A1, DF_IP_050_A1, DF_IP_100_A1		
	A2 Ecological	LP_2020_A2_S1	LP_2020_A2_S1	LP_2020_A2_S1
		Landslides: LS_SP_020_A2, LS_SP_050_A2, LS_SP_100_A2 Floods: FL_DE_020_A2, FL_DE_050_A2, FL_DE_100_A2 Debrisflow: DF_IP_020_A2, DF_IP_050_A2, DF_IP_100_A2		
	A3 Relocation	LP_2020_A3_S1	LP_2020_A3_S1	LP_2020_A3_S1
		Landslides: LS_SP_020_A3, LS_SP_050_A3, LS_SP_100_A3 Floods: FL_DE_020_A3, FL_DE_050_A3, FL_DE_100_A3 Debrisflow: DF_IP_020_A3, DF_IP_050_A3, DF_IP_100_A3		
S2 Risk informed planning	A0 (no risk reduction)	LP_2020_A0_S2	LP_2020_A0_S2	LP_2020_A0_S2
		Landslides: LS_SP_020_A0, LS_SP_050_A0, LS_SP_100_A0 Floods: FL_DE_020_A0, FL_DE_050_A0, FL_DE_100_A0 Debrisflow: DF_IP_020_A0, DF_IP_050_A0, DF_IP_100_A0		
	A1 Engineering	LP_2020_A1_S2	LP_2020_A1_S2	LP_2020_A1_S2
		Landslides: LS_SP_020_A1, LS_SP_050_A1, LS_SP_100_A1 Floods: FL_DE_020_A1, FL_DE_050_A1, FL_DE_100_A1 Debrisflow: DF_IP_020_A1, DF_IP_050_A1, DF_IP_100_A1		
	A2 Ecological	LP_2020_A2_S2	LP_2020_A2_S2	LP_2020_A2_S2
		Landslides: LS_SP_020_A2, LS_SP_050_A2, LS_SP_100_A2 Floods: FL_DE_020_A2, FL_DE_050_A2, FL_DE_100_A2 Debrisflow: DF_IP_020_A2, DF_IP_050_A2, DF_IP_100_A2		
	A3 Relocation	LP_2020_A3_S2	LP_2020_A3_S2	LP_2020_A3_S2
		Landslides: LS_SP_020_A1, LS_SP_050_A1, LS_SP_100_A1 Floods: FL_DE_020_A1, FL_DE_050_A1, FL_DE_100_A1 Debrisflow: DF_IP_020_A1, DF_IP_050_A1, DF_IP_100_A1		

For these combinations the loss assessment needs to be done. The script Loss\_Calculation has the following variables:

- %1 = Hazard Type (e.g. FL, DF, LS)
- %2 = Intensity measure (e.g. DE, IP)
- %3 = Return period (e.g. 020)
- %4 = Future Year (2014, 2020, 2030, 2040)
- %5 = Risk reduction alternative (A0, A1, A2,A3)
- %6 = Scenario (S1, S2, S3, S4)
- %7 = Physical or population Risk (PH or PO)
- %8 = Value or People (If you select PH for %5 you should select Value, otherwise People)

- Adapt the script **Loss\_input** and add the specific combinations of scenarios, alternatives and future years that you want to analyse.
- The table on the next page shows all the loss combinations that should be calculated for scenario 1 in order to be able to calculate the multi-hazard risk. So for each combination of scenario, future year and alternative we have loss for three hazard types (floods, landslides and debrisflow) and each of these for three return periods (20 , 50 and 100 years). For scenario 2 this would look similarly.
- For scenario 3 the losses are basically the same as for scenario 1, because we are using the same land use scenario, and the same hazard maps. Only the frequency of the hazard events will differ, but this has not effect on the individual losses, but only on the risk .
- The Loss\_input script might need many lines, with different combinations of scenario, year, alternative, hazard type and return period. You can use a text editor to copy and past, and find&replace text easier.
- Once the Loss\_input script is completed, run it. It will take a considerable amount of time, so a coffee break might be useful
- After completion it might be good to copy the result file: **Result\_LP** to another directory as a back-up.



The results will look like the ones in the table below:

Step	Alternative: risk reduction options	Future years		
		2020	2030	2040
S1 Business as usual	A0 (no risk reduction)	Flood losses: FL_20_2020_A0_S1_PH FL_50_2020_A0_S1_PH FL_100_2020_A0_S1_PH Debris flow losses DF_20_2020_A0_S1_PH DF_50_2020_A0_S1_PH DF_100_2020_A0_S1_PH Landslide losses LS_20_2020_A0_S1_PH LS_50_2020_A0_S1_PH LS_100_2020_A0_S1_PH	Flood losses FL_20_2030_A0_S1_PH FL_50_2030_A0_S1_PH FL_100_2030_A0_S1_PH Debris flow losses DF_20_2030_A0_S1_PH DF_50_2030_A0_S1_PH DF_100_2030_A0_S1_PH Landslide losses LS_20_2030_A0_S1_PH LS_50_2030_A0_S1_PH LS_100_2030_A0_S1_PH	Flood losses FL_20_2040_A0_S1_PH FL_50_2040_A0_S1_PH FL_100_2040_A0_S1_PH Debris flow losses DF_20_2040_A0_S1_PH DF_50_2040_A0_S1_PH DF_100_2040_A0_S1_PH Landslide losses LS_20_2040_A0_S1_PH LS_50_2040_A0_S1_PH LS_100_2040_A0_S1_PH
		FL_20_2020_A1_S1_PH FL_50_2020_A1_S1_PH FL_100_2020_A1_S1_PH DF_20_2020_A1_S1_PH DF_50_2020_A1_S1_PH DF_100_2020_A1_S1_PH LS_20_2020_A1_S1_PH LS_50_2020_A1_S1_PH LS_100_2020_A1_S1_PH	FL_20_2030_A1_S1_PH FL_50_2030_A1_S1_PH FL_100_2030_A1_S1_PH DF_20_2030_A1_S1_PH DF_50_2030_A1_S1_PH DF_100_2030_A1_S1_PH LS_20_2030_A1_S1_PH LS_50_2030_A1_S1_PH LS_100_2030_A1_S1_PH	FL_20_2040_A1_S1_PH FL_50_2040_A1_S1_PH FL_100_2040_A1_S1_PH DF_20_2040_A1_S1_PH DF_50_2040_A1_S1_PH DF_100_2040_A1_S1_PH LS_20_2040_A1_S1_PH LS_50_2040_A1_S1_PH LS_100_2040_A1_S1_PH
		FL_20_2020_A2_S1_PH FL_50_2020_A2_S1_PH FL_100_2020_A2_S1_PH DF_20_2020_A2_S1_PH DF_50_2020_A2_S1_PH DF_100_2020_A2_S1_PH LS_20_2020_A2_S1_PH LS_50_2020_A2_S1_PH LS_100_2020_A2_S1_PH	FL_20_2030_A2_S1_PH FL_50_2030_A2_S1_PH FL_100_2030_A2_S1_PH DF_20_2030_A2_S1_PH DF_50_2030_A2_S1_PH DF_100_2030_A2_S1_PH LS_20_2030_A2_S1_PH LS_50_2030_A2_S1_PH LS_100_2030_A2_S1_PH	FL_20_2040_A2_S1_PH FL_50_2040_A2_S1_PH FL_100_2040_A2_S1_PH DF_20_2040_A2_S1_PH DF_50_2040_A2_S1_PH DF_100_2040_A2_S1_PH LS_20_2040_A2_S1_PH LS_50_2040_A2_S1_PH LS_100_2040_A2_S1_PH

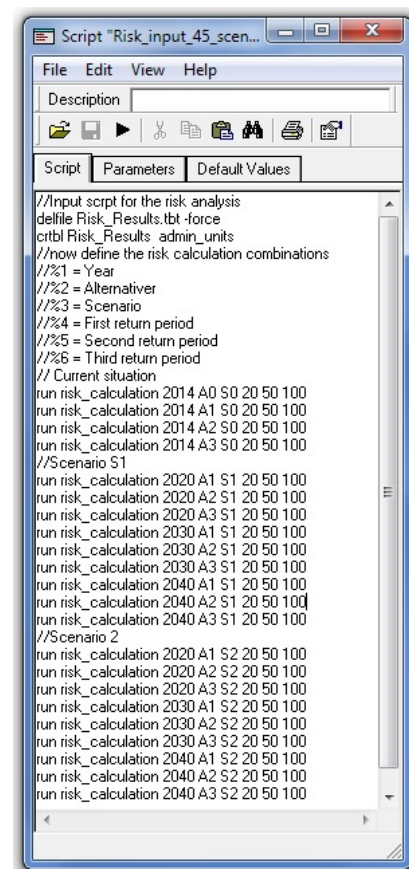
	A3 Relocation	FL_20_2020_A3_S1_PH FL_50_2020_A3_S1_PH FL_100_2020_A3_S1_PH DF_20_2020_A3_S1_PH DF_50_2020_A3_S1_PH DF_100_2020_A3_S1_PH LS_20_2020_A3_S1_PH LS_50_2020_A3_S1_PH LS_100_2020_A3_S1_PH	FL_20_2030_A3_S1_PH FL_50_2030_A3_S1_PH FL_100_2030_A3_S1_PH DFL_20_2030_A3_S1_PH DF_50_2030_A3_S1_PH DF_100_2030_A3_S1_PH LS_20_2030_A3_S1_PH LS_50_2030_A3_S1_PH LS_100_2030_A3_S1_PH	FL_20_2040_A3_S1_PH FL_50_2040_A3_S1_PH FL_100_2040_A3_S1_PH DF_20_2040_A3_S1_PH DF_50_2040_A3_S1_PH DF_100_2040_A3_S1_PH LS_20_2040_A3_S1_PH LS_50_2040_A3_S1_PH LS_100_2040_A3_S1_PH
S2 Risk informed planning	A0 (no risk reduction)	Not filled in here because of the limited space but they would be looking like the ones filled in for scenario 1.		
	A1 Engineering			
	A2 Ecological			
	A3 Relocation			
S3 Worst case (Rapid growth + climate change)	A0 (no risk reduction)	Losses same as S1 A0	Losses same as S1 A0	Losses same as S1 A0
	A1 Engineering	Losses same as S1 A1	Losses same as S1 A1	Losses same as S1 A1
	A2 Ecological	Losses same as S1 A2	Losses same as S1 A2	Losses same as S1 A2
	A3 Relocation	Losses same as S1 A3	Losses same as S1 A3	Losses same as S1 A3
S4 Climate resilience (informed planning under climate change)	A0 (no risk reduction)	Losses same as S2 A0	Losses same as S2 A0	Losses same as S2 A0
	A1 Engineering	Losses same as S2 A1	Losses same as S2 A1	Losses same as S2 A1
	A2 Ecological	Losses same as S2 A2	Losses same as S2 A2	Losses same as S2 A2
	A3 Relocation	Losses same as S2 A3	Losses same as S2 A3	Losses same as S2 A3

## 9.2 Risk calculation

Also the risk assessment script (**Risk\_calculation**) has to be run for many combinations, basically for each combination of scenario, future year and alternative. Remember that the script **Risk\_calculation** requires the following variables:

- %1 = Year
- %2 = Alternativer
- %3 = Scenario
- %4 = First return period
- %5 = Second return period
- %6 = Third return period

- Adapt the script **Risk\_input** and add the specific combinations of scenarios, alternatives and future years that you want to analyse. The example to the right shows the possible combinations for scenarios 1 and 2
- Run the script **Risk\_Input** and calculate the **Annualized risk** for the specific combinations of scenarios, alternatives and future years of scenario 1 and 2. These are the results indicated below in the green part in the table below.
- Copy the results into an Excel table , so that for each combination you have an Average Annual Risk value.



```
Script "Risk_input_45_scen...
File Edit View Help
Description
Script Parameters Default Values
//Input script for the risk analysis
del file Risk_Results.txt -force
cd \bl Risk_Results -admin_units
//now define the risk calculation combinations
//%1 = Year
//%2 = Alternativer
//%3 = Scenario
//%4 = First return period
//%5 = Second return period
//%6 = Third return period
// Current situation
run risk_calculation 2014 A0 S0 20 50 100
run risk_calculation 2014 A1 S0 20 50 100
run risk_calculation 2014 A2 S0 20 50 100
run risk_calculation 2014 A3 S0 20 50 100
//Scenario 1
run risk_calculation 2020 A1 S1 20 50 100
run risk_calculation 2020 A2 S1 20 50 100
run risk_calculation 2020 A3 S1 20 50 100
run risk_calculation 2030 A1 S1 20 50 100
run risk_calculation 2030 A2 S1 20 50 100
run risk_calculation 2030 A3 S1 20 50 100
run risk_calculation 2040 A1 S1 20 50 100
run risk_calculation 2040 A2 S1 20 50 100
run risk_calculation 2040 A3 S1 20 50 100
//Scenario 2
run risk_calculation 2020 A1 S2 20 50 100
run risk_calculation 2020 A2 S2 20 50 100
run risk_calculation 2020 A3 S2 20 50 100
run risk_calculation 2030 A1 S2 20 50 100
run risk_calculation 2030 A2 S2 20 50 100
run risk_calculation 2030 A3 S2 20 50 100
run risk_calculation 2040 A1 S2 20 50 100
run risk_calculation 2040 A2 S2 20 50 100
run risk_calculation 2040 A3 S2 20 50 100
```

Scenario: Possible Future trends	Alternative: risk reduction options	Future years		
		2020	2030	2040
S1 Business as usual	A0 (no risk reduction)	Losses AR_2020_A0_S1)	Annualized risk (AR_2030_A0_S1)	Annualized risk (AR_2040_A0_S1)
	A1 Engineering	AR_2020_A1_S1	AR_2030_A1_S1	AR_2040_A1_S1
	A2 Ecological	AR_2020_A2_S1	AR_2030_A2_S1	AR_2040_A2_S1
	A3 Relocation	AR_2020_A3_S1	AR_2030_A3_S1	AR_2040_A3_S1
S2 Risk informed planning	A0 (no risk reduction)	AR_2020_A0_S2	AR_2030_A0_S2	AR_2040_A0_S2
	A1 Engineering	AR_2020_A1_S2	AR_2030_A1_S2	AR_2040_A1_S2
	A2 Ecological	AR_2020_A2_S2	AR_2030_A2_S2	AR_2040_A2_S2
	A3 Relocation	AR_2020_A3_S2	AR_2030_A3_S2	AR_2040_A3_S2
S3 Worst case (Rapid growth + climate change)	A0 (no risk reduction)			
	A1 Engineering			
	A2 Ecological			
	A3 Relocation			
S4 Climate resilience (informed planning under climate change)	A0 (no risk reduction)			
	A1 Engineering			
	A2 Ecological			
	A3 Relocation			

- Calculate the **Risk Reduction** for the specific combinations of scenarios, alternatives and future years of scenario 1 and 2. These are the results indicated below in the green part below:

Scenario: Possible Future trends	Alternative: risk reduction options	Future years		
		2020	2030	2040
S1 Business as usual	A0 (no risk reduction)	Losses AR_2020_A0_S1)	Annualized risk (AR_2030_A0_S1)	Annualized risk (AR_2040_A0_S1)
	A1 Engineering	Risk reduction = AR_2020_A0_S1 - AR_2020_A1_S1	Risk reduction = AR_2030_A0_S1 - AR_2030_A1_S1	Risk reduction = AR_2040_A0_S1 - AR_2040_A1_S1
	A2 Ecological	Risk reduction = AR_2020_A0_S1 - AR_2020_A2_S1	Risk reduction = AR_2030_A0_S1 - AR_2030_A2_S1	Risk reduction = AR_2040_A0_S1 - AR_2040_A2_S1
	A3 Relocation	Risk reduction = AR_2020_A0_S1 - AR_2020_A3_S1	Risk reduction = AR_2030_A0_S1 - AR_2030_A3_S1	Risk reduction = AR_2040_A0_S1 - AR_2040_A3_S1
S2 Risk informed planning	A0 (no risk reduction)	Risk reduction = AR_2020_A0_S2 - AR_2020_A0_S2	Risk reduction = AR_2030_A0_S2 - AR_2030_A0_S2	Risk reduction = AR_2040_A0_S2 - AR_2040_A0_S2
	A1 Engineering	Risk reduction = AR_2020_A0_S2 - AR_2020_A1_S2	Risk reduction = AR_2030_A0_S2 - AR_2030_A1_S2	Risk reduction = AR_2040_A0_S2 - AR_2040_A1_S2
	A2 Ecological	Risk reduction = AR_2020_A0_S2 - AR_2020_A2_S2	Risk reduction = AR_2030_A0_S2 - AR_2030_A2_S2	Risk reduction = AR_2040_A0_S2 - AR_2040_A2_S2
	A3 Relocation	Risk reduction = AR_2020_A0_S2 - AR_2020_A3_S2	Risk reduction = AR_2030_A0_S2 - AR_2030_A3_S2	Risk reduction = AR_2040_A0_S2 - AR_2040_A3_S2
S3 Worst case (Rapid growth + climate change)	A0 (no risk reduction)			
	A1 Engineering			
	A2 Ecological			
	A3 Relocation			
S4 Climate resilience (informed planning under climate change)	A0 (no risk reduction)			
	A1 Engineering			
	A2 Ecological			
	A3 Relocation			

For calculating the Annualized risk for the specific combinations of scenarios, alternatives and future years of scenario 3 and 4, we can use the calculated losses of scenario 1 and 2 and change the

frequency (return periods and annual probability ) of the hazards as indicated in the table below while taken the same values for the losses as for scenario 1 and scenario 2. These are the results indicated below in the green part

Old Return Period	New Return Period in Future Year for scenarios 3 and 4		
	2020	2030	2040
20	17	14	11
50	45	35	25
100	90	75	55
200	180	150	110

In the script **Risk\_input** you can do that by adding the new return periods, for example:

Scenario 1:	Scenario 3
run risk_calculation 2020 A0 S1 20 50 100 run risk_calculation 2030 A0 S1 20 50 100 run risk_calculation 2040 A0 S1 20 50 100 etc	run risk_calculation 2020 A0 S1 17 45 90 run risk_calculation 2030 A0 S1 14 35 75 run risk_calculation 2040 A0 S1 11 25 55 etc

- Adapt the script **Risk\_input** and add the specific combinations of scenarios, alternatives and future years that you want to analyse.
- Run the script **Risk\_Input** and calculate the **Annualized risk** for the specific combinations of scenarios, alternatives and future years of scenario 3 and 4. These are the results indicated below in the yellow part.
- Calculate the annualized risk for the combinations indicated and put these in an Excel table.
- Calculate the benefits for each situation by subtracting the annualized risk after implementation of a risk reduction alternative from the one before that.

Scenario: Possible Future trends	Alternative: risk reduction options	Future years		
		2020	2030	2040
S1 Business as usual	A0 (no risk reduction)			
	A1 Engineering	Benefit S1 A1 2020	Benefit S1 A1 2030	Benefit S1 A1 2040
	A2 Ecological	Benefit S1 A2 2020	Benefit S1 A2 2030	Benefit S1 A2 2040
	A3 Relocation	Benefit S1 A3 2020	Benefit S1 A3 2030	Benefit S1 A3 2040
S2 Risk informed planning	A0 (no risk reduction)			
	A1 Engineering	Benefit S2 A1 2020	Benefit S2 A1 2030	Benefit S2 A1 2040
	A2 Ecological	Benefit S2 A2 2020	Benefit S2 A2 2030	Benefit S2 A2 2040
	A3 Relocation	Benefit S2 A3 2020	Benefit S2 A3 2030	Benefit S2 A3 2040
S3 Worst case (Rapid growth + climate change)	A0 (no risk reduction)			
	A1 Engineering	Benefit S3 A1 2020	Benefit S3 A1 2030	Benefit S3 A1 2040
	A2 Ecological	Benefit S3 A2 2020	Benefit S3 A2 2030	Benefit S3 A2 2040
	A3 Relocation	Benefit S3 A3 2020	Benefit S3 A3 2030	Benefit S3 A3 2040
S4 Climate resilience (informed planning under climate change)	A0 (no risk reduction)			
	A1 Engineering	Benefit S4 A1 2020	Benefit S4 A1 2030	Benefit S4 A1 2040
	A2 Ecological	Benefit S4 A2 2020	Benefit S4 A2 2030	Benefit S4 A2 2040
	A3 Relocation	Benefit S4 A3 2020	Benefit S4 A3 2030	Benefit S4 A3 2040

		A32020	2030	
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### 9.3 Cost-benefit analysis

Once the benefits have been calculated, the cost-benefit can be calculated. If you compare the method explained in section 6.1 , the cost calculation stays the same, but the values for risk reduction (the benefits) are now different for future years (the ones indicated in red below). These values come from the benefits (annualized risk before – annualized risk after implementation of a risk reduction alternative). The orange values inbetween are interpolated values between the calculated ones (in the red cells).

Scenario 1															
Year	Alternative 1: Engineering solutions					Alternative 2: Ecological solutions					Alternative 3: Relocation				
	Costs	Risk Reducti on	Increm ental benefit	NP V	IR R	Costs	Risk Reducti on	Increm ental benefit	NP V	IR R	Costs	Risk Reducti on	Increm ental benefit	NPV	IR R
2014															
2015															
2016															
2017															
2018															
2019															
2020		Benefit S1 A1 2020					Benefit S1 A2 2020					Benefit S1 A3 2020			
2021															
2022															
2023															
etc															
2030		Benefit S1 A1 2030					Benefit S1 A2 2030					Benefit S1 A3 2030			
Etc															
2040		Benefit S1 A1 2040					Benefit S1 A2 2040					Benefit S1 A3 2040			
etc															
2064															

- Create in Excel 4 tables with the cost-benefit calculations for the scenarios.
- Calculate the Net Present Value and Internal Rate of Return for the Scenarios

## 9.4 Conclusions

Finally , in your report and presentation for this case study, present the results of part B, C, D,E.

We hope you are able to provide an answer to the questions:

- Which risk reduction alternative is the best now?
- Which risk reduction alternative is the best for each of the 4 scenarios?
- Which is the most “change proof” risk reduction alternative?
- In which scenario does the risk increase most?
- In which scenario do we have the best development?
- What would be the added effect of coastal hazards on the results?

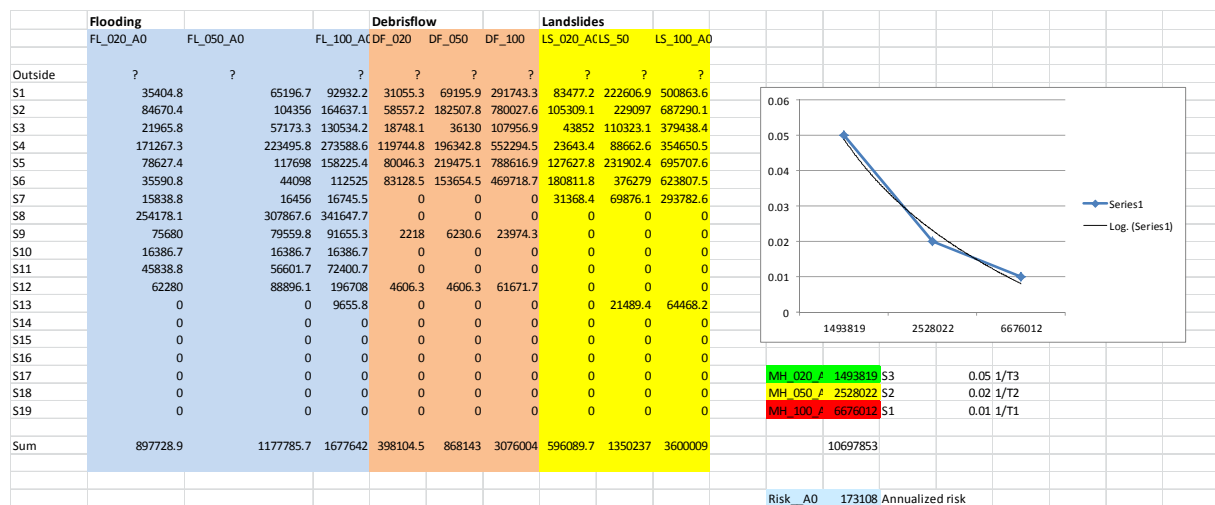
Scenario: Possible Future trends	Alternative: risk reduction options			
		NPV	IRR	Which one is best?
S1 Business as usual				
	A1 Engineering			
	A2 Ecological			
	A3 Relocation			
S2 Risk informed planning				
	A1 Engineering			
	A2 Ecological			
	A3 Relocation			
S3 Worst case (Rapid growth + climate change)				
	A1 Engineering			
	A2 Ecological			
	A3 Relocation			
S4 Climate resilience (informed planning under climate change)				
	A1 Engineering			
	A2 Ecological			
	A3 Relocation			

## 10. References

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- Scolobig, A., J. Bayer, L. Cascini, Settimio Ferlisi (2011) Design and testing: a risk communication strategy and a deliberative process for choosing a set of mitigation and prevention measures. Deliverable D5.7. SafeLand. Living with landslide risk in Europe: Assessment, effects of global change, and risk management strategies <http://www.safeland-fp7.eu/results/Documents/D5.7.pdf>
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# Results.

## 42: Calculating risk for the current situation

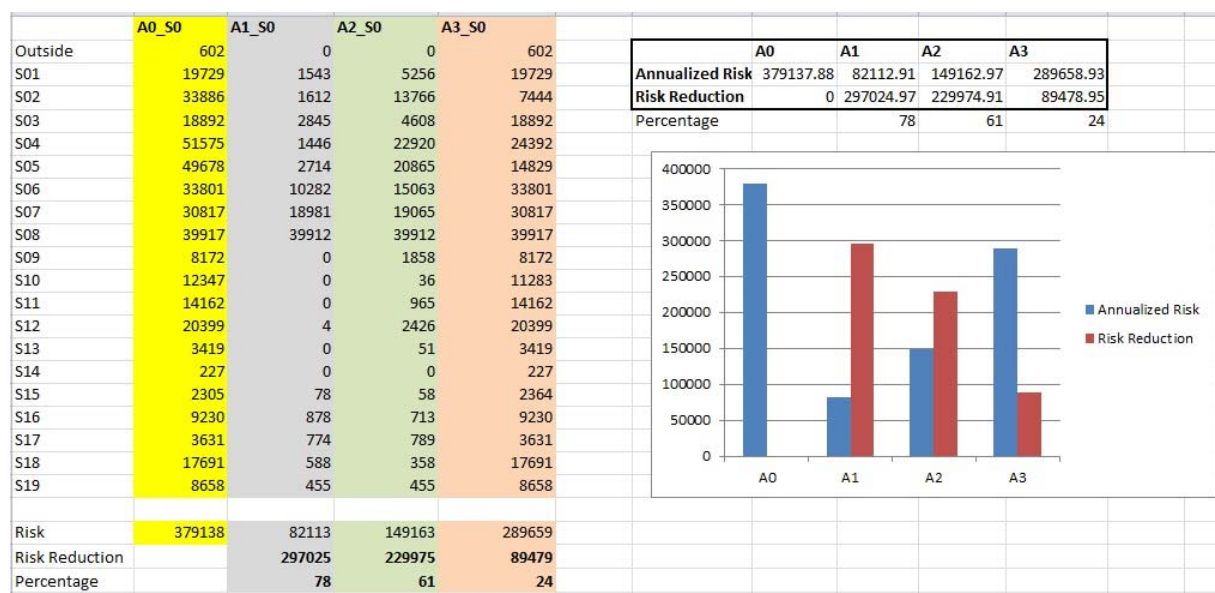


The results show the resulting loss values for the three hazard types (flooding, debrisflows and landslides) for different return periods (1 in 20 years, 1 in 50 years and 1 in 100 years). The table shows the results for the 19 administrative units. As you can see the results show that in some of the administrative units the risk is higher than in others. For instance administrative units 4,5 and 6 have high potential losses for all three hazards. Unit 8 has only flood losses. Unit 13 has predominately landslide losses. You can also see that the average annual losses for the entire area, based on the three hazards are high: 173 thousand Dollars per year. Therefore it is important to take action and plan for risk reduction measures to reduce the risk.

A similar calculation can be done for population losses.

## 4.3

### Calculation of average annual risk after the implementation of the alternatives:



**Cost estimation:**

	Items related to construction cost	Time of construction	Benefit starts	Annual Maintenance
Alternative 1: engineering solutions	<ul style="list-style-type: none"><li>• Storage basins</li><li>• Slope stabilization</li><li>• Expropriation of land and existing buildings where construction will take place</li></ul>	3 years	4 <sup>th</sup> year	From year 4
Alternative 2: Ecological solutions	<ul style="list-style-type: none"><li>• Expropriation of land and existing buildings where construction will take place</li><li>• Slope stabilization</li><li>• Water tank construction</li></ul>	3 years	From 4 <sup>th</sup> year with 100% benefit in 10 <sup>th</sup> year	From year 2
Alternative 3: Relocation	<ul style="list-style-type: none"><li>• Compensation of owners of buildings</li><li>• Expropriation of existing buildings</li><li>• Lawsuits</li></ul>	10 years	100% benefit starts from 11 <sup>th</sup> year	From year 11

## Costs for alternative 1:

Alternative 1	Engineering solutions		
<b>Storage basins</b>			
	nr	6	
	Per basin	250000	1800000
	Years construction	3	
	Maintenance	25000	
<b>Slope stabilization</b>			
	Area (m2)	92052	92052
	Soil removal (per m2)	1	
	Years construction	3	
	Maintenance	5000	
<b>Expropriation</b>	60000 m2 * 5	300000	
When does benefit start:		year 4	

## Results CBA Alternative 1:

Year	Alternative 1: Engineering solutions							
	Storage basin construction	Slope stabilization	Maintenance	Total	Benefit_Risk Reduction	Incremental Benefits		
1	600000	30684	0	630684	0	-630684		
2	600000	30684	0	630684	0	-630684		
3	600000	30684	0	630684	0	-630684		
4			30000	30000	297025	267025		
5			30000	30000	297025	267025		
6			30000	30000	297025	267025		
7			30000	30000	297025	267025		
8			30000	30000	297025	267025		
9			30000	30000	297025	267025	NPV	5%
10			30000	30000	297025	267025	€ 2,430,104.23	12%
11			30000	30000	297025	267025		
12			30000	30000	297025	267025		10%
13			30000	30000	297025	267025	NPV	
14			30000	30000	297025	267025	€ 415,033.92	12%
15			30000	30000	297025	267025		
16			30000	30000	297025	267025		20%
17			30000	30000	297025	267025	NPV	
18			30000	30000	297025	267025	€ (556,029.09)	12%
19			30000	30000	297025	267025		
20			30000	30000	297025	267025		
21			30000	30000	297025	267025		
22			30000	30000	297025	267025		
23			30000	30000	297025	267025		
24			30000	30000	297025	267025		
25			30000	30000	297025	267025		
26			30000	30000	297025	267025		
27			30000	30000	297025	267025		
28			30000	30000	297025	267025		
29			30000	30000	297025	267025		
30			30000	30000	297025	267025		
31			30000	30000	297025	267025		
32			30000	30000	297025	267025		
33			30000	30000	297025	267025		
34			30000	30000	297025	267025		
35			30000	30000	297025	267025		
36			30000	30000	297025	267025		

## Costs for alternative 2:

Alternative 2	Ecological solutions		
<b>Tree planting</b>			
	Area (m2)	153526	1683011
	Cost per m2	1	
	Years	1	
	Maintenance/year	0.1	7676
<b>Exporiation</b>	Protective forest area	302229	1511145
	Watertanks	3668	18340
<b>Water tanks</b>			
	Number	10	50000
	Construction	5000	
	Years	2	
	Maintenance	500	
<b>Slope stabilization</b>			
	Area (m2)	92052	2301301
	Soil removal (per m2)	25	
	Years construction	3	
	Maintenance	5000	
When does benefit start:		year 10	

## Results CBA Alternative 2:

	Tree planting	Slope stabilization	Water Tank	Maintenance	Total	Risk Reduction	Incremental Benefit		
1	1683011	30684	25000		1738695	0	-1738695		
2		30684	25000	7676	63360	0	-63360		
3		30684		8176	38860	0	-38860		
4				13176	13176	45995	32819		
5				13176	13176	91990	78814		
6				13176	13176	137985	124809		
7				13176	13176	160983	147807		
8				13176	13176	183980	170804		5%
9				13176	13176	206978	193802	NPV	IRR
10				13176	13176	229975	216799	€ 1,197,423.50	8%
11				13176	13176	229975	216799		
12				13176	13176	229975	216799		10%
13				13176	13176	229975	216799	NPV	IRR
14				13176	13176	229975	216799	€ (381,695.56)	8%
15				13176	13176	229975	216799		
16				13176	13176	229975	216799		20%
17				13176	13176	229975	216799	NPV	IRR
18				13176	13176	229975	216799	€ (1,097,601.96)	8%
19				13176	13176	229975	216799		
20				13176	13176	229975	216799		
21				13176	13176	229975	216799		
22				13176	13176	229975	216799		
23				13176	13176	229975	216799		
24				13176	13176	229975	216799		
25				13176	13176	229975	216799		
26				13176	13176	229975	216799		
27				13176	13176	229975	216799		
28				13176	13176	229975	216799		
29				13176	13176	229975	216799		
30				13176	13176	229975	216799		
31				13176	13176	229975	216799		
32				13176	13176	229975	216799		
33				13176	13176	229975	216799		
34				13176	13176	229975	216799		
35				13176	13176	229975	216799		

### Costs for alternative 3:

Alternative 3	Relocation	
How many houses	95	14250000
Value of buildings	14041177	
Lawsuits	50	500000
Value per lawsuit	10000	
Years this takes	10	
Compensation per building	150000	
Monitoring Cost	5000	

### Results CBA Alternative 3:

Year	Alternative 3: Relocation							
	New buildings	Financial compensation	Maintenance	Total	Risk Reduction	Incremental Benefit		
1	1475000			1475000	8947.895	-1466052.105		
2	1475000			1475000	8947.895	-1466052.105		
3	1475000			1475000	17895.79	-1457104.21		
4	1475000			1475000	26843.685	-1448156.315		
5	1475000			1475000	35791.58	-1439208.42		
6	1475000			1475000	44739.475	-1430260.525		
7	1475000			1475000	53687.37	-1421312.63		
8	1475000			1475000	62635.265	-1412364.735		5%
9	1475000			1475000	71583.16	-1403416.84	NPV	IRR
10	1475000			1475000	80531.055	-1394468.945	€ (10,207,900.66)	-5%
11			5000	5000	89478.95	84478.95		
12			5000	5000	89478.95	84478.95		10%
13			5000	5000	89478.95	84478.95	NPV	IRR
14			5000	5000	89478.95	84478.95	€ (8,531,766.17)	-5%
15			5000	5000	89478.95	84478.95		
16			5000	5000	89478.95	84478.95		20%
17			5000	5000	89478.95	84478.95	NPV	IRR
18			5000	5000	89478.95	84478.95	€ (5,992,954.80)	-5%
19			5000	5000	89478.95	84478.95		
20			5000	5000	89478.95	84478.95		
21			5000	5000	89478.95	84478.95		
22			5000	5000	89478.95	84478.95		
23			5000	5000	89478.95	84478.95		
24			5000	5000	89478.95	84478.95		
25			5000	5000	89478.95	84478.95		
26			5000	5000	89478.95	84478.95		
27			5000	5000	89478.95	84478.95		
28			5000	5000	89478.95	84478.95		
29			5000	5000	89478.95	84478.95		
30			5000	5000	89478.95	84478.95		
31			5000	5000	89478.95	84478.95		
32			5000	5000	89478.95	84478.95		
33			5000	5000	89478.95	84478.95		
34			5000	5000	89478.95	84478.95		
35			5000	5000	89478.95	84478.95		

### Summary results Cost-Benefit analysis:

	NPV at 5% Interest Rate	NPV at 10% Interest Rate	NPV at 20% Interest Rate	IRR
Alternative 1: Engineering solutions	€ 2,430,104.23	€ 415,033.92	- € 556,029.09	12%
Alternative 2: Ecological solutions	€ 1,197,423.50	- € 381,695.56	- € 1,097,601.96	8%
Alternative 3: Relocation	- € 10,207,900.66	- € 8,531,766.17	- € 5,992,954.80	-5%

This means that alternative 3 is always the worst one": the NPV values are always negative.

Alternative 1 (Engineering solutions) is the best one, although the differences with alternative 2 (Ecological solutions) are not so very high.

Which alternative would be selected is not only depending on the Cost-Benefit analysis . Also many other factors might play a role, and the stakeholders might have other reasons why they would prefer one particular alternative. Therefore a Multi-Criteria evaluation would be the best next step, in which stakeholders can bring in other indicators (social, environmental, legislation, support by population etc.) and wight them against the risk related indicators and cost-benefit related indicators.

#### 44: Analyzing the changes related to different scenarios.

##### Results Land use change

		Land use according to scenario 1 and 3 (both have same landuse situation, but different climate change effect)			Landuse according to scenario 2 and 4 (both have same landuse situation, but different climate change effect)		
	2014	2020	2030	2040	2020	2030	2040
Agricultural_fields	85205	54342	0	0	24435	4301	4301
Animal_Farm	9639	9639	4301	0	9639	9639	9639
Bare	31354	2785	2042	0	1314	743	743
Commercial	18772	61989	90410	151300	25144	36918	42070
Cultural_heritage	4289	4289	4831	4831	4289	4289	4289
Farm	117829	99823	67847	42893	110705	98036	91086
Forest_natural	2687779	2674466	2667449	2685162	2678630	2671613	2690797
Forest_Planted_protective	309301	304793	332458	332458	362170	362170	362170
Grassland	35890	39970	16558	16558	39645	20461	16558
Highway	55811	55811	55811	55811	55811	55811	55811
Industry	44465	55188	63389	76736	44465	39750	39750
Orchard	665137	618232	517087	357962	632086	582562	560447
Parking_lot	1166	5063	13858	17281	1166	1622	1622
Parkland	18556	33679	70149	74450	39868	58919	54722
Quarry	115095	128408	140650	140650	128408	140650	140650
Residential	125954	194402	327795	465811	195936	279402	335971
Shrubs	90855	69325	63607	43445	35471	31374	9569
Toll_area	13960	13960	13960	13960	13960	13960	13960
Tourist_resort	22934	47884	64110	76705	30619	49581	49581
Vineyard	293786	273729	231465	191764	314016	285976	264041
Water_tank	2813	2813	2813	2813	2813	2813	2813

##### Percentage change with respect to the current situation

	Land use according to scenario 1 and 3 (both have same landuse situation, but different climate change effect)			Landuse according to scenario 2 and 4 (both have same landuse situation, but different climate change effect)		
	2020	2030	2040	2020	2030	2040
Agricultural_fields	63.8	0.0	0.0	28.7	5.0	5.0
Animal_Farm	100.0	44.6	0.0	100.0	100.0	100.0
Bare	8.9	6.5	0.0	4.2	2.4	2.4
Commercial	330.2	481.6	806.0	133.9	196.7	224.1
Cultural_heritage	100.0	112.6	112.6	100.0	100.0	100.0
Farm	84.7	57.6	36.4	94.0	83.2	77.3

Forest_natural	99.5	99.2	99.9	99.7	99.4	100.1
Forest_Planted_protective	98.5	107.5	107.5	117.1	117.1	117.1
Grassland	111.4	46.1	46.1	110.5	57.0	46.1
Highway	100.0	100.0	100.0	100.0	100.0	100.0
Industry	124.1	142.6	172.6	100.0	89.4	89.4
Orchard	92.9	77.7	53.8	95.0	87.6	84.3
Parking_lot	434.2	1188.5	1482.1	100.0	139.1	139.1
Parkland	181.5	378.0	401.2	214.9	317.5	294.9
Quarry	111.6	122.2	122.2	111.6	122.2	122.2
Residential	154.3	260.2	369.8	155.6	221.8	266.7
Shrubs	76.3	70.0	47.8	39.0	34.5	10.5
Toll_area	100.0	100.0	100.0	100.0	100.0	100.0
Tourist_resort	208.8	279.5	334.5	133.5	216.2	216.2
Vineyard	93.2	78.8	65.3	106.9	97.3	89.9
Water_tank	100.0	100.0	100.0	100.0	100.0	100.0

## Results Land use values

		Land use according to scenario 1 and 3 (both have same landuse situation, but different climate change effect)				Landuse according to scenario 2 and 4 (both have same landuse situation, but different climate change effect)		
		2014	2020	2030	2040	2020	2030	2040
Agricultural_fields	1.15E+04	5.66E+03	0.00E+00	0.00E+00	1.30E+04	2.52E+03	2.79E+03	
Animal_Farm	6.27E+06	6.27E+06	1.29E+06	0.00E+00	4.82E+04	4.82E+04	4.82E+04	
Bare	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Commercial	4.30E+06	1.54E+07	2.50E+07	4.63E+07	7.35E+06	1.95E+07	4.38E+07	
Cultural_heritage	1.52E+06	1.71E+06	2.38E+06	2.90E+06	6.87E+05	8.38E+05	1.02E+06	
Farm	1.82E+07	1.61E+07	1.21E+07	7.57E+06	1.66E+07	1.44E+07	1.39E+07	
Forest_natural	2.95E+07	2.93E+07	2.93E+07	2.95E+07	1.38E+06	1.43E+06	1.64E+06	
Forest_Planted_protective	4.02E+06	3.96E+06	4.32E+06	4.32E+06	9.90E+05	9.90E+05	9.90E+05	
Grassland	1.55E+05	1.55E+05	1.53E+05	1.53E+05	1.66E+05	1.64E+05	1.64E+05	
Highway	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Industry	9.76E+06	1.30E+07	1.54E+07	1.94E+07	6.84E+06	1.10E+07	2.16E+07	
Open_slope_soil_removed	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Orchard	2.22E+06	2.03E+06	1.47E+06	1.41E+06	1.34E+06	1.39E+06	1.81E+06	
Parking_lot	1.75E+05	7.59E+05	2.30E+06	3.85E+06	2.33E+03	7.81E+04	1.05E+05	
Parkland	1.59E+05	3.86E+05	9.33E+05	9.97E+05	3.27E+05	6.13E+05	5.50E+05	

Quarry	2.54E+05	2.56E+05	2.57E+05	2.57E+05	2.56E+05	2.57E+05	2.57E+05
Residential	2.32E+07	4.64E+07	1.08E+08	2.18E+08	5.89E+07	1.82E+08	5.88E+08
Shrubs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Storage_Basin	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toll_area	4.89E+06	4.89E+06	4.89E+06	4.89E+06	3.49E+04	3.49E+04	3.49E+04
Tourist_resort	4.70E+06	1.28E+07	2.56E+07	4.54E+07	8.60E+06	2.44E+07	4.37E+07
Vineyard	3.53E+06	3.92E+06	4.91E+06	7.28E+06	8.16E+05	1.18E+06	2.09E+06
Water_tank	8.44E+04	8.44E+04	8.44E+04	8.44E+04	9.85E+05	9.85E+05	9.85E+05
<b>Total value</b>	<b>1.13E+08</b>	<b>1.57E+08</b>	<b>2.39E+08</b>	<b>3.92E+08</b>	<b>1.05E+08</b>	<b>2.59E+08</b>	<b>7.20E+08</b>

## Results Population changes

		Land use according to scenario 1 and 3 (both have same landuse situation, but different climate change effect)			Landuse according to scenario 2 and 4 (both have same landuse situation, but different climate change effect)		
	2014	2020	2030	2040	2020	2030	2040
Agricultural_fields	0	0	0	0	2	0	0
Animal_Farm	0	0	0	0	2	2	2
Bare	0	0	0	0	0	0	0
Commercial	119	335	477	781	151	210	235
Cultural_heritage	15	15	16	16	13	13	13
Farm	305	273	168	89	238	206	199
Forest_natural	22	22	22	22	22	22	22
Forest_Planted_protective	6	6	7	7	7	7	7
Grassland	2	2	2	2	16	16	16
Highway	0	0	0	0	0	0	0
Industry	110	121	129	143	111	95	95
Open_slope_soil_removed	0	0	0	0	0	0	0
Orchard	27	24	1	1	16	6	6
Parking_lot	1	5	14	17	2	2	2
Parkland	2	5	12	13	6	10	9
Quarry	5	6	7	7	6	7	7
Residential	553	604	815	1180	779	2135	5757
Shrubs	0	0	0	0	0	0	0
Storage_Basin	0	0	0	0	0	0	0
Toll_area	70	70	70	70	42	42	42
Tourist_resort	142	180	206	224	158	186	186
Vineyard	60	57	48	39	64	58	54
Water_tank	0	0	0	0	0	0	0
Total population	1439	1725	1994	2611	1635	3017	6652

## Results Risk analysis

