

Exercise 4c: Participatory GIS for risk assessment.

Expected time: 3 hours
Data: data from subdirectory: RiskCity_exercises/exercise04c/data
Objectives: This exercise shows you the possibilities that are available when you carry out a survey using participatory GIS . You will learn how the collection of local knowledge will help you to better characterize the buildings, describe the population with its vulnerability and capacity, evaluate the problems related to landslides, and reconstruct historic flood scenarios.

The collection of local knowledge is very important in risk assessment. Local communities are the most important stakeholder in risk assessment, and are often the ones that are most at risk. They have local knowledge that is indispensable for hazard assessment, elements at risk characterization, vulnerability & capacity assessment, and development of risk scenarios. Disaster Risk Reduction efforts should be tailored to the local communities and be implemented in consultation with them, and mostly by them. In a course like this it is not possible to go and collect information using Participatory GIS techniques by yourself. You cannot visit RiskCity. Therefore we will concentrate not so much on how data can be collected locally, but focus more on what you can do with local data.

Name	Type	Meaning
Image data		
High_res_image	Raster	High resolution image of the situation in 2006
Airphoto_1998_ortho	Raster	Orthorectified airphoto taken just after the disaster event in 1998.
Participatory GIS data		
PGIS_Location	Point map	A point map with the locations of the interviews that were carried out for 200 buildings, of which 100 are located in the floodplain and 100 on steep slopes.
PGIS_survey	Table	Table with the main results of the Participatory mapping exercise. This table contains columns related to building attributes, population characteristics, landslide damage , and reconstruction of flood scenarios.
Flood data		
Flood_100y, Flood50y, Flood_10y	Raster map	Flood depth maps resulting from flood modeling study for scenarios with 100, 50 and 10 year return period.
Other data		
Building_map_1998	Raster map	Updated map of buildings for the situation after the disaster of 1998. For all buildings information is available on the urban landuse, number of floors, building area, and total floorspace.
Building_map_1997	Segment map	Boundary lines of the buildings in the area, for the situation before the disaster in 1998.

Participatory GIS approach

The survey was carried out in 2008, 10 years after the major disaster event of 1998, which produced a large number of landslides, and caused widespread flooding in the area. The survey was carried out by interviewing persons in 200 buildings, located either in the flood affected area, or in one of the landslide prone areas. Mapping was carried out together with representatives of the communities (See photo).

The representatives of the community serves as guides and translators and introduced the mapping team to the inhabitants of the buildings where the interviews would take place. These ladies were also an important source of local information, as they were very well aware of the hazards in the area and how these affect the daily life of the inhabitants of the squatter areas in RiskCity. The interviews were recorded and information was collected using Mobile GIS linked with a GPS. The high-resolution image and the building map were used as backfrop information in the handheld device. The results were stored in a table (**PGIS_survey**) that is linked to a point map (**PGIS_Location**).



Figure: Representatives of the community that were involved in the Participatory mapping in RiskCity.



- Open the image **Airphoto_1998_ortho**. Display the segments of the buildings made in 1997: **Building_map_1997**. Also display the buildings that are now in the area: use the segment map **Building_map_1998**.
- Compare the building maps, in particular in relation to the flooded areas and landslide areas.

As you can see many of the buildings that were present in 1997 were destroyed in 1998, or have been subsequently demolished. The map **Building_map_1998** contains the building information after the year 1998. Now we will add the point that have been mapped using the Participatory approach.

If you open Pixel Information you can select Options, Always on Top, so that the window is always visible



- Add the point map **PGIS_Location**.
- Open **PixelInformation** and add the map **PGIS_Location**.
- Check a number of the points of the map **PGIS_Location** and their attribute information, stored in table **PGIS_Survey**.
- Display some of the attributes using the Display Option Window.
- Open the table **PGIS_Survey**.

The buildings that were destroyed during the large flood event of 1998 could still be identified, and neighbours could give information on the building type and the waterlevel that was experienced. However, there is no information available for these buildings regarding the population characteristics. These buildings are indicated in the **PGIS_Survey** with the landuse "Vac_damaged".

This table **PGIS_Survey** contains the following columns:

Factor	Meaning	Usefulness
Building data		
Landuse	Urban Land use. Note that there are many buildings coded as "Vac_damaged".	Link to other information for the entire city.
Area_building	Area of the building in m2	Used for calculation floorspace and value of building & contents
Nr_floors	Number of floors	Used for flood and seismic vulnerability assessment
Building_type	Building type	Used for physical vulnerability assessment
Population data		
Nr_adults	Number of people between 18 and 60	Population characterisation and social vulnerability assessment.
Nr_old_people	Number of old people (>60) per building	
Nr_children	Number of children (<18) per building	
Nr_households	Number of households per building	
Nr_people_daytime	Number of people present in the building during the daytime	Population vulnerability assessment for different temporal scenarios
Nr_people_nighttime	Number of people present in the building during the nighttime	
Workers	Number of people per residential building that are working	Economic loss estimation.
Livelihood	Main type of work	
Landslide data		
Landslide_damage	Observed landslide damage in buildings	Landslide mapping
Flood data		
Remember_Flood_100y	Classes of the water height that people can still remember, for the 1998 event with a return period of 100 years.	Flood hazard assessment, validation of flood modeling maps, and flood vulnerability assessment
Remember_Flood_50y	Classes of water height, that people can still remember for the 1993 event with return period of 50 y.	
Remember_Flood_10y	Classes of water height, that people can still remember for the 2007 event with return period of 10 y.	
Flood_damage	Estimated degree of damage to the buildings and contents for the flood event of 1998, estimated by the people that were interviewed.	We will use this information in the exercise 5a dealing with vulnerability functions

The **Landuse** column in the table is very important: this forms the link between these sample points and the rest of the buildings in RiskCity. The information that is derived from the 200 interviews can then be used to characterize the buildings. Calculate how many samples have been made for each landuse class.

 In the table **PGIS_Survey**, select *Column, Aggregate*. Select the column: **Landuse**, Function: **Count**, Group by: **Landuse**, Output Table: **Landuse**, Output Column: **Nr_samples**.

- Open the table **Landuse** and check the number of samples per land use type. Which one has the largest number of samples?

Most of the Interviews for the PGIS survey have been carried out in squatter areas. Also a substantial number of interviews were held to reconstruct information from buildings that have been destroyed during the 1998 event (**vac_damaged**).

	Number
Number of sampled squatter buildings	
Number of sampled buildings that have been destroyed	

Part A: Using PGIS for evaluating the building characteristics.

We will first use the PGIS survey to better characterize the building in RiskCity.

Several building types have been defined in the area. The most important ones are:

- **Wood and other scrap materials:** these buildings are made up of boards, plastic, corrugated iron sheets etc. They normally have only 1 floor.
- **Adobe:** these buildings are made of dried mud.
- **Fieldstone:** made of fieldstones with limited cementation, and wooden ceilings.
- **Brick in mud:** masonry building with homemade bricks not well cemented
- **Brick in cement:** masonry buildings that have been constructed with a bit more care, and often have columns with some reinforcement.
- **Reinforced concrete:** engineered reinforced concrete buildings.

The box shows a typical interview which was held with some of the people

Person: My dream is to built a real house for my family.

Interviewer: I thought your family had already a house, I was there.

Person : Of course not, you cannot call that a 'real house'.

Interviewer Then...What do you mean by a 'real house'?

Person A 'real house' for me is one made of concrete, where I know my family is safe and I would not be worried on what to do or what is going to happen whenever a typhoon is announced.

Person : Do you know the difference between a *house* and *home*?

Interviewer Well... I guess a house is the one made from bricks or wood and a home is formed by the people, the family...

Person : That's ok; so you will see how in this area everyone has a *home* but very few people have a *house*.



Figure Buildings in the confluence of the two rivers in RiskCity

A concatenated key is a key column that is made of two other key columns in a table. In ILWIS we can combine two class columns by first adding the two as strings and then converting to a new domain. We use the CODE term to only use the code and not the full class name

Let's find out the most important building types per landuse class.



- In the table **PGIS_Survey**, select *Column, Sort*. Select the column: **Landuse**.
- Find out the most important building type for each landuse type (you would have to do this manually), and indicate this in the table below
- You can also do this more automated, by making a "concatenated Key". Type the following command:
Landuse_building_type:= Code(Landuse)+Code(Building_type)
- Select Domain: **String**.
- After calculating double click on the column header **Landuse_building_types**, and click the button: *Create New Domain from Strings in Column*. Create the domain **Landuse_building_type**
- Now you can aggregate the information. Select column **Landuse_building_type**, use *Count* function, Group by **Landuse_building_type**, and output table **Landuse_building_type** with column **Number**.
- Also indicate what the predominant building height is for each type in Number of floors. Fill in the table below.

	Wood	Adobe	Fieldstone	Brick in Mud	Brick in Cement	RCC
Com_shop						
Ins_school						
Res_mod_single						
Res_multi						
Res_small_single						
Res_squatter						
Vac_Damaged						

	Wood	Adobe	Fieldstone	Brick in Mud	Brick in Cement	RCC
1 floor						
2 floors						
3 floors						
4 floors						
5 floors						
> 5 floors						

This information is very important because the vulnerability methods require to know the building type and the height of the buildings in stead of the land use type. Of course in this exercise we still have a limited sample of buildings to characterize the different building types per landuse. In a real application we need to know the building types in more detail.

We can also calculate the average floorspace per land use type.

 In the table **PGIS_Survey**, calculate the floorspace per building using the equation:

Floorspace:=Area_Building*Nr_floors

- Calculate the average floorspace per landuse type (Use Column, Aggregation), and store the result in the table **Landuse**
- What is the most common building type and number of floors of the destroyed buildings?

The floorspace per building is very important because we need to know this for:

- Making a good population estimation. In the population estimation we use the sampled buildings to estimate the average area (in square meters) per person per land use class
- Making an estimation of the cost of buildings and contents.

The box shows examples of interviews in the flood affected areas.

Family Q.

Before November 2004 Family Q. used to get their livelihood from Mr. Q's Job (butcher) and a small shop attended by Ms. Q in a shed annexed to their house. During a cyclone the shop was smashed by an uprooted Mango tree and part of their house's roof and walls were blown away. The flood also ruined some vegetables Ms. Q grew to sell in the shop. Savings and relief from the government were used to rebuild the house; yet their economic reserves were not enough to restore the shop. They could not afford a loan or use their father' income as this was just enough to meet their daily needs. From their point of view their current situation is disastrous as after one year they have not managed to fully recover, they lost capital and a, much needed, second livelihood and now the entire family of five depends on the single income brought in by the father.

Mr M.

Mr M. used to work as an ice cream vendor in the area for which he uses a small wooden trolley. The daily income from this activity (around 200 pesos) was low but he managed to cover the basic needs of his family of three. During 1998 his house was destroyed and the trolley got shattered. To get some income he shifted his work to collect scrap material; from this activity he got half of the money (around 100 pesos/day), but most now he has to travel on foot across several other wards. One year later the family was still living with their in-laws and he had not managed to raise the capital for rebuilding their house and recovering his more convenient previous livelihood.

Part B: Using PGIS for evaluating population characteristics.

PGIS is essential for collection reliable population information. The census data for riskcity is not very reliable, and it is only available for large areas (Wards) which makes it difficult to break it up to the individual mapping units that form the basis of the risk assessment. In the survey we have collected different types of building information. This refers to the following aspects:

- The population distribution in age classes (adults, old people and children). This information is important for the population vulnerability assessment
- The population distribution in time (daytime and nighttime). This is important information for population loss estimations for instantaneous disasters like earthquakes, because they will cause very different losses depending on the time when they occur.
- The economic information of the population (Livelihood, number of workers). This information is needed in order to estimate the indirect economic losses, due to loss of income.

The livelihood information is summarized in the table below:

Group	Description
1: Labourers	People engaged in work that requires bodily strength and manual labour rather than skill or training. This consists of marginal or subordinate activities performed mostly outdoors, sometimes on mobile units (including carts and bicycles) and usually takes places close to the place of residence as transportation is too expensive. These jobs report daily earnings in unstable and irregular amounts and are highly susceptible to weather conditions and flooding. Activities found in the study area and classified in this group correspond to: Baggage and burden carrier, dispatcher; Food (candies) manufacturers and packers
2: informal workers and small business:	Correspond to a group of non- formal workers with special skills or knowledge; they supply day to day services and labour, often as freelancers, without formal contracts and benefits. Services are performed door to door or in the worker’s house and usually provide daily, unstable and irregular income. Activities performed by this group of workers are highly susceptible to weather conditions and flooding (see Figure). However it was found that some of them render higher profits after typhoons and floods during the rehabilitation processes.
3: Formal workers	Includes educated/skilled workers usually working under formal conditions for medium and big scale business, shops and industries. Permanent or temporarily contracts provide stable income, even during flood or typhoon episodes; though not always high wages.
4: Highly skilled and independent workers	comprises University and highly skilled and specialized workers who most of the times run their own businesses or are absorbed by the governmental institutions and industry. Their income is stable, regular and not affected by weather conditions, flooding or typhoons.
5: Transferred income	This group is characterized by family units receiving their economic support from external sources or pensions. Relatives working abroad or in bigger cities (e.g. Manila) usually provide support by monthly sending money enough to sustain their families in Naga. Remittances from external workers tend to be regular and are usually increased in order to assist their families during flooding or typhoon episodes



Figure : Examples of workers from groups 1 and 2. Left: a laundress, Right: a street vendor, both deal with rains and flooding characteristic of the wet season.

In this exercise we will only concentrate on the estimation of the average area per person per landuse type. This is very important information for the vulnerability and risk assessment procedures that we will do later. We will start by calculating from the table the floorspace per person per building. We have to use the daytime and nighttime scenarios as buildings have different number of people present in these periods. Some buildings, like school, even don't have any persons present during the nighttime but many during the daytime.



- In the table **PGIS_Survey**, check the total number of people present in the daytime and compare it to those in the nighttime. What causes the difference?

	Total number of persons	Total floorspace in m2	Average floorspace per person
Daytime			
Nighttime			

Now we will calculate the floorspace per person per building during daytime and nighttime



- In the table **PGIS_Survey**, calculate the floorspace per person during the daytime using the equation:

$$\text{Floorspace_person_day} = \text{Floorspace} / \text{nr_people_daytime}$$
 (Make sure to have a precision of 0.1, and)

$$\text{Floorspace_person_night} = \text{Floorspace} / \text{nr_people_nighttime}$$
- Check your results. Which landuse types have the lowest floorspace per person? Note down the five smallest ones.

Landuse	Floorspace in square meters per person	
	Daytime	Nighttime

The information on the floorspace per person for the daytime and nighttime scenarios are now average per landuse type. The results are stored in the table Landuse. Later on we can then extend this information over the rest of area, for buildings with the same landuse.



- In the table **PGIS_Survey**, use the aggregation function to calculate the average floorspace per person in a daytime period. Group the information by **Landuse**, and store the results as **Avg_Floorspace_person_day**.
- Do the same for the floorspace per person during the night. Store the result in the table **Landuse** with column name **Avg_Floorspace_person_night**.
- Open the **Landuse** table and check your results. Which landuse types have the lowest floorspace per person? Which landuse type do not have any information obtained from the sample?

In order to be able to link this to the building map of the entire city we would need to fill in this table also for the other missing land use types

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- In the table below try to make an estimation of the floorspace per person per landuse type for the missing classes. Some of them you can directly fill in as 0, because they don't have any people. For other it will be more difficult. The larger the PGIS survey the better these values would have been.

Landuse	Description	Average floorspace per person in M ²	
		Daytime	Nighttime
Com_business	Business offices		
Com_hotel	Hotels		
Com_market	Commercial area: market area		
Com_shop	Commercial: shops and shopping malls		
Ind_hazardous	Hazardous material storage or manufacture		
Ind_industries	Industries		
Ind_warehouse	Warehouses and workshops		
Ins_fire	Fire brigade		
Ins_hospital	Hospitals		
Ins_office	Office buildings		
Ins_police	Police station		
Ins_school	Institutional : schools		
Pub_cemetery	Cemetery		
Pub_cultural	Institutional: cultural buildings such as musea, theaters		
Pub_electricity	Electricity installations		
Pub_religious	Religious buildings such as churches, mosques or temples		
Rec_flat_area	Recreational: flat area or football field		
Rec_park	Recreational: park area		
Rec_stadium	Recreational : stadium		
Res_large	Residential: large free stading houses		
Res_mod_single	Residential, moderately sized single family houses		
Res_multi	Residential: multi storey buildings		
Res_small_single	Residential, small single family houses, mostly in rows		
Res_squatter	Residential, low class houses: squatter areas		
River		0	0
Vac_car	Vacant : car parking and busstation		
Vac_construction	Area recently damaged by hazard events		
Vac_damaged	Vacant area which is prepared for building construction	0	0
Vac_shrubs	Vacant land with shrubs, trees and grass	0	0

Once you have filled these in the table , you can transfer them to the ILWIS table **Landuse**, in the column **AVG_Floorspace_person_day** and **AVG_floorspace_person_night**

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- Open the table **Building_map_1998** and join with the table **Landuse**. Read in the two columns.
- Now you can make an attribute map of the daytime and nighttime population for the entire city.
- How many persons are in RiskCity during the day and during the night?

Part C: Using PGIS for evaluating landslide problems

The area also has a number of neighborhoods with severe landslide problems. Within the city many steep slopes are occupied by residential areas. Most of these are squatter areas, with illegally constructed buildings, that have been slowly upgraded over the years. The municipality of RiskCity has provided electricity and water supply to most of these squatter areas. The squatter areas in these very steep slopes suffer frequently from landslides during the rainy period. Since the slopes are so steep, buildings are often constructed with an excavation in the mountain slope, and the buildings are constructed in steps, one almost on top of another. Landslides therefore often initiate in one part, but as they move down slope will affect many buildings. This is illustrated in the figure below.



Figure: Typical examples of landslides that affect squatter areas constructed on steep slopes.

Find out the number of buildings in squatter areas that are located on steep slopes (over 30 degrees).



- Find out the number of buildings in squatter areas that are located on steep slopes (>30 degrees).
- You need the following maps to find this out: **Building_map_1998** (they have the landuse as attribute. Make sure to rasterize this map first) and **Slope_cl** (Slope class).
- Find out a method to do this yourself.

Land use type	Number of buildings
Squatter areas	

Although landslides are a real problem to many inhabitants in the area, the municipality has not put a major effort in evaluating the landslide problems or work on risk reduction measures. The municipal authorities mainly react in response to landslide disasters once they happen, but are not active in disaster preparedness and prevention. There have been a number of Non Governmental Organizations that have been working with the local communities in assessing the risk due to landslides.

In several neighborhoods they have carried out community mapping projects, resulting in maps as shown below.

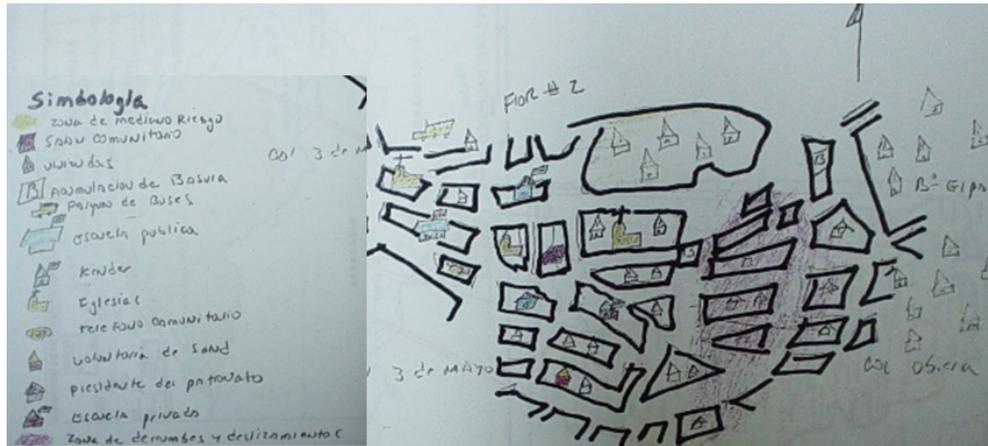


Figure: Typical example of a community map drawn during a workshop that shows the landslide problems in one of the neighborhoods.

Unfortunately such maps cannot be stored in GIS, and need to be translated first to a base map that has a proper georeference. In the framework of our project we have carried out a community mapping exercise in one of the neighborhoods of RiskCity with the most severe landslide problems.

- Find out the names of the neighborhoods where the mapping was done.
- The neighborhoods are in the map **Wards**, and the location of the interviews are in the map **PGIS_Locations**.

In the Participatory GIS mapping, apart from the general aspects that have been mentioned before, we also have asked in the interviews to the inhabitants whether they have experienced problems with landslides in their buildings. The answers were interpreted into the following classes:

Class	Meaning
None	No cracks in the building, and no cracks in the soil have been observed. Occupants are not worried about the landslide problem
Slight	The building shows some cracks, and is also located in a position where landslide might be a problem.
Moderate	The building has cracks and part of the soil as well. It shows clear sign that the soil is moving. Urgent measures to stabilize the slope are needed.
Severe	The building has severe structural damage due to soil movements. It has many cracks, and also the soil has cracks. In future the building could collapse, and the building should be abandoned.
Collapse	The building has collapsed due to landslide movements. The occupants have not reconstructed the building.

From the answers given by the inhabitants it might be possible to see a certain pattern that might help in identifying the main landslide problems in the area.

- Find out the pattern of landslide damage in the neighborhoods that have been interviewed.
- Display the point map **PGIS_Locations** as attribute and show the attribute **Landslide_damage** on top of the high resolution image.

- What can you conclude regarding the location of possible landslide zones, and how do these relate to the neighboring areas?
- Can you differentiate landslide areas based on the participatory GIS mapping?

One of the NGO's has been very active in this neighborhood together with the local population to help them to control the landslide problem. They did this using the following approaches:

- Several workshops were organized with the community to understand and discuss the landslide problems and how these affect their daily life.
- An emergency committee was organized with the most active members of the community. Over 70% of these were women. They have a very good local knowledge of the people living in the area, and the problems occurring. They have been trained to provide basic assistance to local people, for instance in the case of medical problems and with childbirth. Since the area is so steep, during the rainy period it is not possible to walk up the very steep paths. People living in the lower parts of the slopes therefore cannot leave their buildings in case of emergency, and they certainly cannot be transported on stretchers during an emergency to the medical center which is on the top of the slope. Therefore the assistance of local people is essential.
- The NGO has provided basic building materials to the neighborhood and training on the construction of simple retaining walls that are constructed between the buildings. The figure below illustrates this.



Figure: Support for community-based landslide risk reduction in RiskCity. Left: simple retaining walls are constructed by the local inhabitants with building materials supplied by the NGO. Right: equipment donated by the NGO for local landslide risk management: rain gauges, communication equipment etc.

- The emergency committee is also in charge of making a landslide warning to the people in the neighborhood. They have been given simple rainfall gauges, and are trained to record the daily rainfall and the accumulated rainfall over the past 3 days. When the rain surpasses a predefined threshold value of 60 mm in 3 days, then the system moves into "Yellow alert", which is moved to the stage of "Red alert" when small landslides are occurring. At this stage the local community starts with evacuation procedures. The evacuation is continued until the accumulated rainfall becomes less than 60 mm over three days. The figure below provides a simple flowchart of the evacuation procedures (adopted from Oxfam, ESFRA, ISMUGUA, Guatemala).

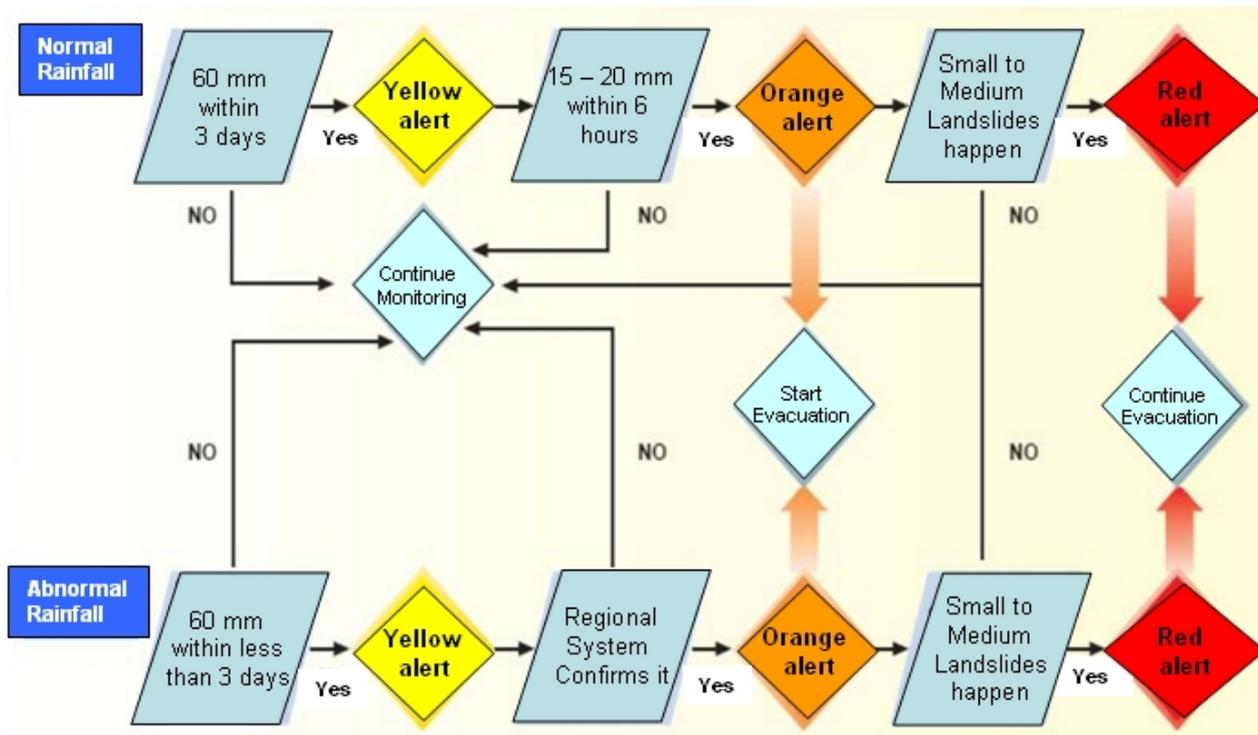


Figure: Simple alert system for landslide risk preparedness adopted by the local community with the help of an NGO (Source: Oxfam, ESFRA, ISMUGUA project in Guatemala).

We have information from the local rainfall station, called **Rainfall_station**, in the middle of the landslide prone area. We will use this information to decide the alert levels as indicated in the figure above.

If you use the notation [%R] it will give the record number in the table. Therefore %R-1 is the previous record and %R-2 two records before. This allows you to make a calculation of the cumulative rainfall over the last 3 days.

- Display the **Rainfall_station** on the map **Building_map_1998** and add the point map **PGIS_Locations** to it, which you display with the attribute **Landslide_damage**.
- Open the table **Rainfall_record**, and use the flowchart indicated above to calculate the alert levels for the days in the rainfall record.
- Calculate the cumulative rainfall over the last three days using the equation:

$$\text{Rain2} = \text{Rain} + \text{Rain}[\%R-1]$$

$$\text{Rain3} = \text{Rain} + \text{Rain}[\%R-1] + \text{Rain}[\%R-2]$$

$$\text{Yellow_Alert} := \text{iff}((\text{Rain} > 60) \text{ or } (\text{rain2} > 60) \text{ or } (\text{Rain3} > 60), \text{"Yellow_alert"}, \text{"No_alert"}).$$
 (use the domain: Alert_level for the output column)
- To calculate the "Orange alert":

$$\text{Orange_Alert} := \text{iff}((\text{Yellow_Alert} = \text{"Yellow_alert"}) \text{ and } (\text{rain} > 20), \text{"Orange_alert"}, \text{"Yellow_alert"})$$
- How many days have a "Red alert"?

Write the results in the table below.

Alert level	Nr days	How many days without work?
Yellow Alert		
Orange Alert		
Red Alert		

Part D: Using PGIS for evaluating flood problems

During the PGIS Survey the flood height of historical events was not recorded in centimeters, but in the way the local people indicate it. The table below shows the 'reference' levels found during several fieldwork activities as used by the people to indicate and refer to floodwater depths.

Table. Community-based reference system for flood depths and their approximate equivalence centimeters

Community-based flood depth reference level in correlation to a person's body parts	Equivalence water height in centimeters
Ankle depth	< 20 cm
Knee depth	40 – 50 cm
Hip depth	50 – 100 cm
Breast depth	100 – 150 cm
Head depth	150-250 cm
First floor flooded	250 - 350 cm
Second floor flooded	> 350 cm

As discussed during the workshops the average of 10 cm difference in height between men and women may determine differences in the perception of hazard. In order to minimize the inconvenience this could cause the participants agreed and expressed the water depths in ranges, rather than in absolute or sharp values.



Figure : Measurement of Community-based reference levels for flood depth in centimeters during workshops

We are going to evaluate the local knowledge on floods for three events that the local population was able to remember best:

- The main event from 1998, which was the most disastrous flood event in the area, and which destroyed also a number of buildings. The buildings destroyed during that event are indicated in the table with the landuse : "**Vac_damaged**". For these buildings it was still possible to obtain the waterheight during the event from the people living in the neighbourhood, and also the type of building could be reconstructed. However, the population information could not be retrieved.

- Another major, but smaller event, that happened in 1993. Many people couldn't remember this flood event as well as the one from 1998, also because quite some people didn't live in the area by that time.
- A recent and small event that happened in 2007. Since this was the last event, the local people can remember the flood height of this event still rather well.



- Open table **PGIS_Survey** and analyze the number of times each of the classes is mentioned.
- Use *Column, Aggregate* and select the column **Remember_flood_1993**. Use the function: *Count*, Group by: **Remember_flood_1993**. Store the results in Table **Water_heights**, as column: **Number_1993**. Do the same for the floods in 1998 and 2007.
- Open the table **Water_heights** and compare the results. Write down the numbers in the table below.
- What can you conclude from this?

Water height	Number of times mentioned in 1993 event	Number of times mentioned in 1998 event	Number of times mentioned in 2007 event
Cannot remember			
No_flood			
Ankle			
Knee			
Hip			
Breast			
Head			
First floor flooded			
Second floor flooded			
Total			

The three flood events cannot be remembered equally well. What would be the reason for that?

For the three events also a flood modeling study was carried out, and three flood height maps were produced: **Flood_100y** corresponding to the 1998 event, **Flood_50y** corresponding to the 1993 event and **Flood_10y** related to the 2007 event.



- Display the map **Flood_100y**, and overlay the segment map with the buildings from 1997 (**Building_map_1997**). Also display the point map **PGIS_Location**, and select the attribute **Remember_flood_1998**.
- Open *PixelInformation* and add the maps **Flood_100y**, **Flood_50y**, **Flood_10y**, and the point map **PGIS_Location**. Compare the local information with the modeled results.
- What can you conclude?

The manual comparison of the local information on the three floods events with the three modeled maps (**Flood_100y**, **Flood_50y** and **Flood_10y**) is not always easy, as they have two different measurement systems (water height in meters and water height in "human terms"). To compare them it is better to convert the community information into meters as well.



- Open the table **Water_heights** and add a column **Height_in_m** (Value, min: 0, max 15, precision 0.01).
- Fill in the values of the middle water height for each of the classes. E.g. Ankle: 0.1, Knee: 0.35 etc.
- Close the table **Water_heights** and open the table **PGIS_Survey**. Now Join with the Table **Water_height** and column **Height_in_m** and group by **Remember_flood_1993**. Call the output column: **Water_height_1993**.
- Do the same for 1998 and 2007.
- Open PixelInformation again and check data against the three flood maps.

Finally we can also calculate the agreement between the modeled results and the PGIS results. We can do that for instance by crossing the point map with the flood maps, but in ILWIS we can also do that by reading the information from the flood maps for all the points, using the point map **PGIS_Location**. We have then to use the Option: *Open as Table*.



- Right click on the point map **PGIS_Location** and select the option: *Open As Table*. Now the point map opens as a table, and you can see the coordinates of each point.
- You can read in the values of maps for the specific coordinates using the following equation (to view the command line, go to *view* and choose *Command Line*): :

$$\text{Water_Height_50y} := \text{Mapvalue}(\text{Flood_50y}, \text{Coordinate})$$
- Do the same for the 100 year and 10 year flood.
- Close the point map **PGIS_Location** and open the table **PGIS_Survey**. Join with the point map **PGIS_Location** and read in the three columns you have just created.
- Now that you have the two types of information in the same table you can calculate the difference:

$$\text{Difference_50y} := \text{Water_height_1993} - \text{Water_height_50y}$$

$$\text{Difference_100y} := \text{Water_height_1998} - \text{Water_height_100y}$$

$$\text{Difference_10y} := \text{Water_height_2007} - \text{Water_height_10y}$$
- Write the difference in the table below. What can you conclude?

Difference in water height between PGIS and model for	Minimum	Maximum	Average	Standard deviation
1993 (50 year flood)				
1998 (100 year flood)				
2007 (10 year flood)				