GIS CASE STUDY

Application of GIS for hazard and risk assessment: Tegucigalpa, Honduras

Part 3: Elements at risk mapping

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This exercise deals with the preparation of the spatial data necessary for developing a building and infrastructure risk assessment. The work will be split amongst the participants and the various pieces will be glued together to produce one map. Due to the time available, this exercise will be done for a portion of the city. The flow-chart on Figure 1 illustrates the procedures which are necessary for generating the spatial database necessary for mapping the elements at risk.

Disclaimer

The material in this exercise is for training purposes only. The results should not be used in actual planning of the city of Tegucigalpa as ITC does not guarantee the accuracy and precision of the input data.

The GIS software that will be used in this exercise is the Integrated Land and Water Information System (ILWIS), version 3.11, developed by the International Institute for Geo-Information Science and Earth Observation (ITC). Information: www.itc.nl

Acknowledgements

We would like to thank Gonzalo Ernesto Funes Siercke from COPECO for providing us the data.

3.1 On-screen digitizing building information on a Stereo image

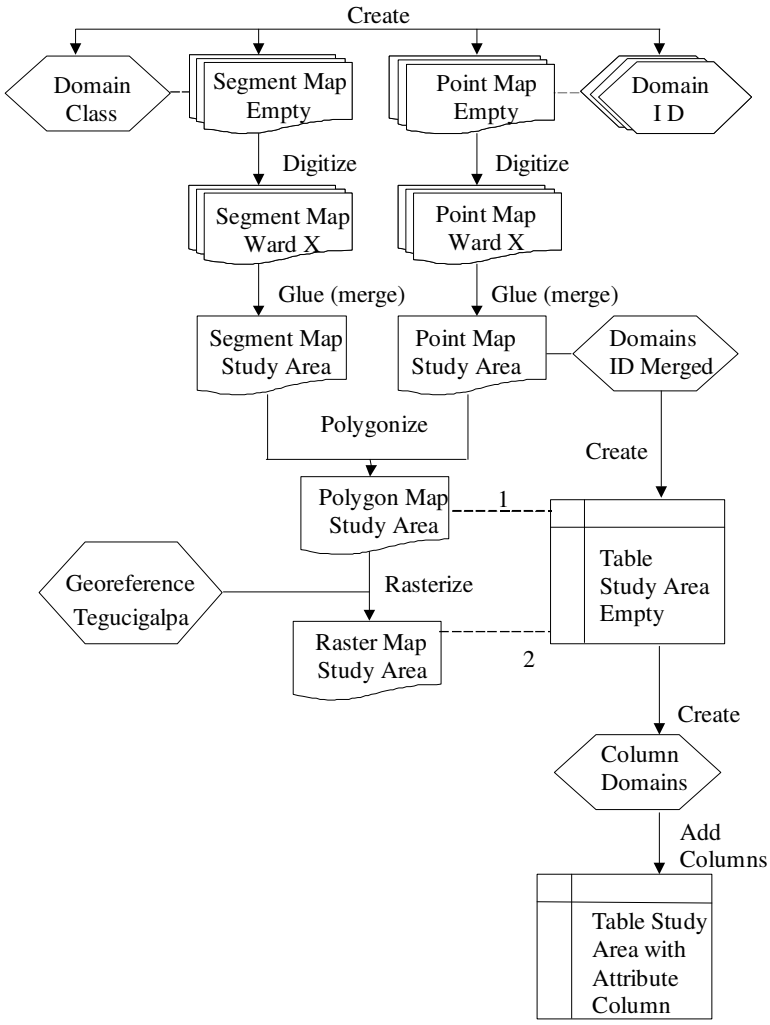

Figure 2.1: Flow Chart of Operations for Developing a Spatial Database for Mapping Elements at Risk

Time requirement: 2 hours

Objectives:

- On-screen digitize the homogeneous units (homogeneous in terms of building size and pattern) that can be identified on the satellite image.
- Generate a segment map and a point map, which will be combined into a polygon map.
- Generate a table with the information that will later on be collected in the field.

Data needed:

- Ortho image: **Ortho_tegu** (year 200?), (raster image)
- Stereo image in colour, for use with screenscope: **Ortho_stereo**
- Stereo image in black and white, to be used as anaglyph: **Ortho_stereo_bw**

- Road map: **Roads_tegu** (segment)
- Map of the colonias: **Colonia_tegu** (polygon map with table)
- Flood extend map of the Mitch event: **Flood_Mitch** (polygon map)

3.1.1 Extracting boundary lines of building blocks from the road map.

The following section explains first how to make a segment map for buildings using existing information from the road network. (Note: this part can be skipped in case of time problems. In that case use the file **buildings_blocks** (in the directory /results) and proceed with the next exercise .

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- Open the domain **Roads_tegu** and add an extra class called **Include**.
- Copy the segment map **Roads_tegu** (with Edit / Copy Object to) to another file with different name: **Roads_temp**
- Open the map **Ortho_tegu** and add the layers: the polygon map **Flood_mitch** and segment map **Roads_temp**
- You will see the roads that are in the area covered by the Mitch flooding. Those are the ones that will be renamed to the name **Include**, so that we can copy them to another file and use them for the building mapping.
- Select *Edit / Edit layer* and select the segment map **Roads_temp**.
- Select all the roads in the area covered by the polygon map **flood_mitch** and rename them to **Include**. You can select multiple segments using the CTRL button.
- Close the segment editor and the map window.
- Copy the segments with the name Include from the file **Roads_temp** into another file **Buildings_tegu**. You can do this by selecting *Operations / vector operations /Segments /Mask segments.* Use mask Include. The new file only contains the roads in the flood-affected areas and can be used as the basis for digitizing the elements at risk.
- Before you can edit the file **Building_tegu**, make sure to break the dependency
- Create a table **Roads_tegu** using the domain **Roads_tegu**, and add a column **Building_blocks**, which should have a class domain **Building_blocks**, and only one class (building_blocks)
- In the properties of the map **Building_tegu**, add the table **Roads_tegu**
- Create an attribute map of the segment map **Building_tegu**, using the column **Building_blocks** from the table **Roads_tegu**. Name the output segement map: **Building_blocks**. This map now has its own domain, and is no longer linked to the domain Roads_tegu. Break the dependency of the segment map **Building_blocks**.

3.1.2 Digitizing homogeneous units

Now we start with the actual screen digitizing the segment of the homogeneous units in the map **Building_blocks**. It is possible to do that in three ways:

- On top of the orthoimage Ortho_tegu. In this case you will not be able to see stereo, which is a disadvatage in the interpretation.
- On top of the colour stereo image Ortho_stereo. This is the best way, but you will need a screen stereoscope for that.
- On top of the anaglyph stereo image Ortho_tegu_bw. You will need anaglyph glasses for the interpretation. The problem is that the lines will not exactly match with the features in the image. In ILWIS 3.12 this can be adjusted using the Pixel shift option.

In this exercise we will show two options:

1 . Segment map Building_blocks displayed on top of the orthoimage, while you compare the result with the anaglyph image.

2. Segment map Building_blocks displayed on top of the stereo colour image, using the screenscope.

3.1.2.1 Screen digitizing on ortho image

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- Open the raster image **Ortho_tegu**. Check its properties (by selecting its Properties in the File menu) to make sure that the map is linked to the georeference **Tegucigalpa**.
- On the **Layer** Menu, go to **Add Layer** and select the **Building_blocks** segment map (if you didn't make it in the previous exercise, copy the file form the directory results). Repeat the same procedure to add the **Flood_Mitch** polygon map, tick *Boundaries Only*, select the *Boundary Color* red and a *Boundary Width* of 2).
- Now you can view the segments of the different Building blocks within the flood affected area. Select a few building blocks to digitize. Discuss with your teaching staff that one should be digitized.
- Open the map **Ortho_tegu_bw** as anaglyph map in another window. Zoom in on the same area as you want to digitize in the ortho_tegu map. Use anaglyph glasses to get stereo.
- In the map window of **Ortho_tegu** select *Edit / Edit layer* and select the segment map **Building_blocks**
- Next you must on-screen-digitize the boundary of the homogeneous units inside it. Given the resolution of the imagery available, one can distinguish between different building types within the same building block. You may also decide to map individual buildings. Also digitize vacant land. Use the pen in the editor menu to digitize. Compare with the three dimensional image in the anaglyph.

- Make sure to connect all lines together.
- When you finish digitizing one segment, select the segment with the *Select Mode* icon (the hand) and choose the correct class. Next select the *Insert Mode* icon (the pencil) and digitize the following segment.
- When you are finished with the digitizing procedure, go to the *File*

Menu, first select *Exit Editor* and next select *Create Point Map*. Name the output map **Building_block_tegu** and create a *domain type Identifier* with name **Building_block_tegu**. After the domain window opens, close it and also close the *Create Point Map* window.

- Digitize one point inside each of the homogeneous units with the *Insert Mode* tool (the pencil). If you did not enter any classes in the domain yet, choose *new* and enter a name for this area. Give each of these points a unique identifier, starting with the Tegucigalpa colonia number and a sequential number to identify each homogeneous unit (e.g **001-001 or 085-012**). When you finish digitizing the necessary points, go to *File* and select *Exit Editor.*
- Next you will open the editor of the segment map and you will check the segments. Go to the *File* menu and select *Check Segments*. Select *Self Overlap*. Repair all the mistakes. Ask a teacher to assit you the first time.
- Then check segments using *Dead Ends*, and *Intersections.* Repair all mistakes.
- Next you will use the editor of the segment map and you will attempt to polygonize it. Next go to the *File* menu and select the *Polygonize* operation. Select the point map **Building_blocks_tegu**, the domain **Building_blocks_tegu** and name the resulting polygon map **Building_blocks_tegu**. If the software detects any error, it will highlight the type of error and its location. If there are errors in your layer, you can use the Select Mode, Move Points, Insert Mode and Split/Merge Mode tools (see icons below) to correct the error(s). When you finish, go to the File Menu and select *Exit Editor.*

3.1.2.2 Screen digitizing using the screen stereoscope

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- Open the three dimensional image **Ortho_stereo**
- Make sure the right image button is selected. On the **Layer** Menu, go to **Add Layer** and select the **Building_blocks** segment map (if you didn't make it in the previous exercise, copy the file form the directory results). Repeat the same procedure to add the **Flood_Mitch** polygon map, tick *Boundaries Only*, select the *Boundary Color* red and a *Boundary Width* of 2).
- Place the screen stereoscope before the screen. Maximize the window, zoom in on the area surrounding the stadium and click the unlock button (red traffic sign). Adjust one of the two windows until you see good stereo. Click on the lock button.
- Now you can view the segments of the different Building blocks within the flood affected area. Select a few building blocks to digitize. Discuss with your teaching staff that one should be digitized.
- Select *Edit / Edit layer* and select the segment map **Building_blocks**
- Next proceed in the same way as described in 3.1.2.1 starting from the bullet with the picture.
- When you finish, go to the File Menu and select *Exit Editor.*

3.2 Table(s) and Attribute Column Generation (pre-fieldwork)

You have concluded the phase of mapping the elements at risk. The next phase consists of building the table (s) necessary for storing the attributes of the elements at risk.

Time requirement: 1 hour

Data needed:

- Building block map that you generated in the previous section: polygon map **Building_blocks_tegu** (if you don't have it copy it from the directory results)
- Road map: **Roads_tegu** (segment)
- Map of the colonias: **Colonia_tegu** (polygon map with table)

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- On the main window, select the polygon map **Building_blocks_tegu**, click on the mouse's right button and select *Properties*. Tick on *Attribute Table* and select the create table icon. Select the domain of the **Building_blocks_tegu** and name the resulting table **Building_blocks_tegu**.
- After the table opens, you can add a column with the code of the Colonia. Create a column **Colonia**, and use the domain **Colonia_tegu**.
- Enter for each record the number of the Colonia (the first number without the zero)
- Join the table with the table **Colonia_tegu**. Use *Columns / Join*. Select the column Barrio. Accept the defaults of the join wizard and name the output column **Colonia_tegu**.
- You can now proceed by adding the columns related to the attribute information (see the table below for the names of columns and domains). Therefore, on the table's *Columns* menu, select *Add column*.
- Note that in case several persons are doing the field collection and the tables from the individual surveyors will have to be glued together, one must make sure that all surveyors use the same names for the columns and for the domain classes.
- This information can then be used in the field for collecting information on the different types of buildings.

The polygon map and its table can be used on a handheld computer in the field for collecting the attribute information about the characteristics of the homogeneous units. Esri's ArcPad is an example of a software package that allows to do GIS on handheld computers.

Keep in mind that if the field collection of attributes will also be split into teams, if during fieldwork you decide to further subdivide an area or edit a boundary, you would have to make the edits on the individual segment map and the individual label point map rather than on the glued ones. This would imply that after fieldwork you would have to glue the individual segments and point maps as well as the tables plus polygonize and rasterize again.

Note that if you were going to use this dataset to make inferences about the density of population, you would need to record detailed landuse classes (e.g. primary school) as well as the general classes (e.g. other educational). The detailed classes

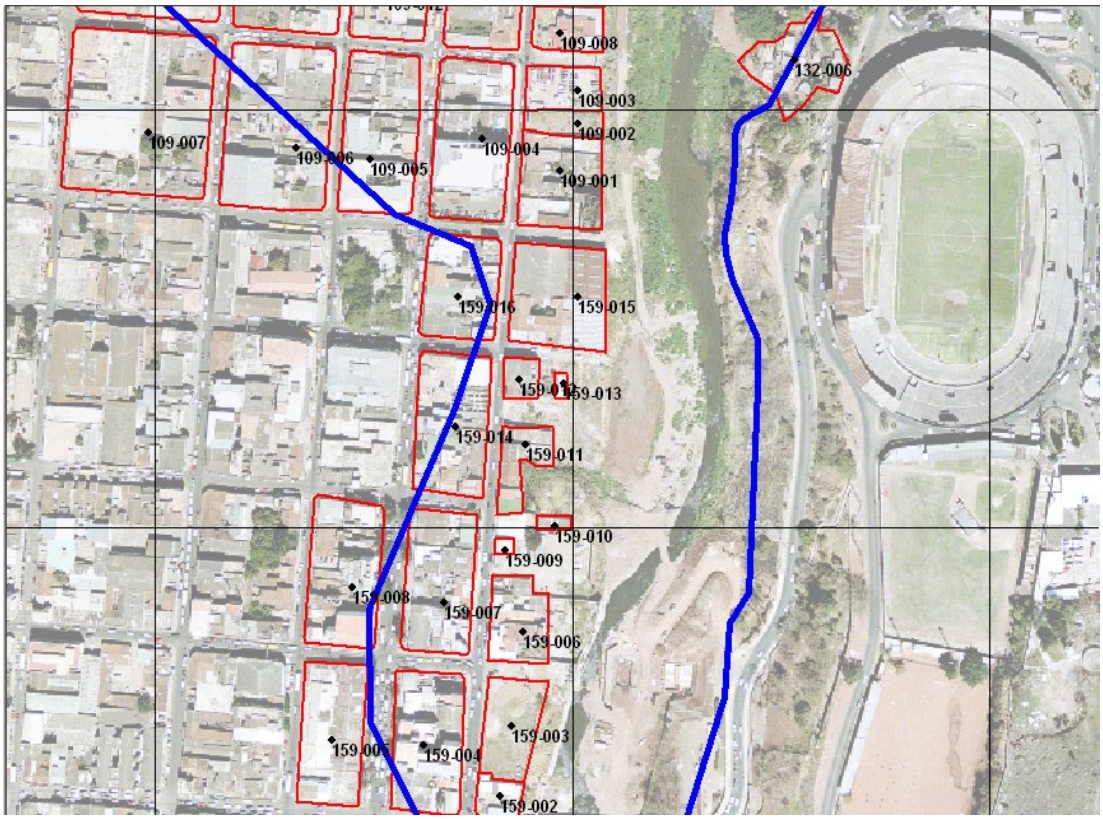
are also important for emergency planning purposes. The general classification could be stored in a separate table and joined into this main table only if required.

Note that this section is only a demonstration. We will not use the dataset that you made in the next exercises on vulnerability assessment.

Variable	**Type**	**Min**	**Max**	**Precision**
Colonia	Existing class-domain **Colonia_tegu** of polygon map **Colonia_tegu**	-	-	-
Landuse	Class-domain "Landuse" with the following classes: • Residential • Commercial • Industrial • Educational • Other institutional • Recreational • Agricultural • Vacant	-	-	-
BuildingType	Class-domain "Type" with the following classes: • Wood • Stone • Unreinforced masonry • Reinforced concrete frame • Concrete shear walls	-	-	-
Age	Class-domain "Age" with the following classes: • 0-5 years • 6-10 years • 10-25 years • > 25 years	-	-	-
NrOfFloors	Value	0	50	1
IncomeGroup	Class-domain "IncomeGroup" with classes: • High • Moderate • Low	-	-	-

3.3 Field data collection

In this exercise you will go in the field to collect the data for the elements at risk (buildings) that you have outlined in the previous exercises. The study will be made by evaluating buildings in the area affected by the flood during Mitch. You will be using a location map in which the homogeneous units are indicated. An example of such a map is shown below.



You will also work with a checklist in the field, that contains similar information as the columns you have entered in the database earlier. The checklist is shown on the next page. The survey is done by sampling typical buildings within each building block. If within one building block there are several types of building, sample more.

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- Work in groups of 2 persons. Each group will have its own number and will visit another area.
- Describe individual buildings.
- Plot for each building a point on the overlay over the location map.
- Enter in the table (column Building_block_tegu) the number of the homogeneous unit that is indicated on the map (e.g. 159-003)
- Give each building a separate nr (Building_nr) per block.
- Indicate the percentage of the buildig block with similar buildings
- Use the codes for entering the classes of Landuse, BuildingType, Age and IncomeGroup. The number of floors can be entered as a single value.

Names:
Group number:
Date:

Building_block_tegu	Building Nr.	Perc, similar	Colonia	Landuse	BuildingType	Age	NrOfFloors	IncomeGroup

Legend

Landuse		BuildingType		Age		IncomeGroup	
R	Residential	W	Wood	0	0-5 years	H	High
C	Commercial	S	Stone	6	6-10 years	M	Moderate
I	Industrial	UM	Unreinforced masonry	10	11-25 years	L	Low
E	Educational	RC	Reinforced concrete	25	>25 years		
OI	Other Institutional	CS	Concrete shear walls				
Re	Recreational						
A	Agricultural						
V	Vacant						

3.4 Entering result in the database

After returning from the fielddata collection, the next step is to enter the data in the GIS database. As you have made samples of buildings within the homogeneous units (building blocks), you will make a point file with the samples, and enter the data in a table linked to this point map. Later you can join all information from all groups together into a single table (Building_blocks_tegu).

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- Open the raster map Ortho_tegu and overlay the polgonmap Building_blocks_tegu (only show boundaries).
- Create a point map **Building_sample_XX** (in stead of XX use a number of your group) use a domain Building_sample_XX (Identifier domain).
- Digitize the sampling points that you surveyed. Give each point the name of the homogeneous unit plus the building number. For example in homogeneous unit 159-003 if you have made 5 samples, they will get the names 159-003-01 , 159-003-02 etc.
- Create the following columns with the following domains:
  - Building_block_tegu domain: building_block_tegu
  - PercentageSimilar domain percentage
  - Colonia domain Colonia_tegu
  - Landuse domain Landuse
  - BuildingType domain BuildingType
  - Age domain Age
  - NrOfFloors domain NrOfFloors
  - IncomeGroup domain IncomeGroup
- Enter the values of your checklist in the table

When you have finished digitizing the points and entering the data in the table, give the point map and the table to the teacher. He will combine the files in a single table and point map.

3.5 Estimating building heights using DEM's

Time required: 2 hours

The objective of this exercise is to use two DEM for the estimation of the building heights. The following DEMs are available:

- A DEM made from LIDAR survey, which contains very detailed information on all objects on the surface, including buildings, trees, and even cars during the time of data acquisition. The file is available as **Lidar_dem**.
- A DEM derived from detailed contourlines, digitized from topographic maps. For Tegucigalpa contour lines are available with a contour interval of 2.5 meters. They are stored in a segment map called **Contour_map**.

For the calculation you will also need the building map that was generated in the previous sections (**Building_block_tegu**)

- Open the raster map **Lidar_dem** and overlay the segment map Contour_map (use single colour and keep info on)
- Use PixeInfo to compare the values of both maps.
- Select *Operations / Interpolation / Contour Interpolation*. Select segment map **Contour_map**, and georeference **Tegucigalpa**. Select output map: **Topo_dem**. Use value range from 500 to 2000 and precision of 0.01. The interpolation will take some time.
- When the calculation is finished and the map is displayed, ad the segment map Raods_tegu and check again the values of the two DEM using PixelInfo especially in the streets. What can you conclude?
- It is clear that the two DEMs are not exactly the same. They have a certain degree of difference. Later on we will evaluate how much

Now that the two DEM are made, we can use them to find out the difference between them. We do this by simple subtraction.

- Type the following formula on the command line of the main window:

Difference:=Lidar_dem – Topo_dem

- Accept the default values and click Show. In the display options window use a stretch from 0 to 20 meters.
- The difference map is now displayed. Overlay the road map Roads_tegu and check the result with PixelInfo. What can you conclude?
- You can clearly read the altitude of the buildings. However, also in the streets there is a difference, which should not be there, but is due to inaccurries in both DEMs.
- Measure with PixelInfo the difference between the two DEMs for at least 25 points in the streets. Write down the difference in the table on the next page, or put them in an Excell sheet. Calculate the average difference.

Table for storing difference in altitudes in roads;

Point	Difference	Point	Difference	Point	Difference	Point	Difference
1		11		21		31	
2		12		22		32	
3		13		23		33	
4		14		24		34	
5		15		25		35	
6		16		26		36	
7		17		27		37	
8		18		28		38	
9		19		29		39	
10		20		30		40	
Average difference =							
Standard deviation =							

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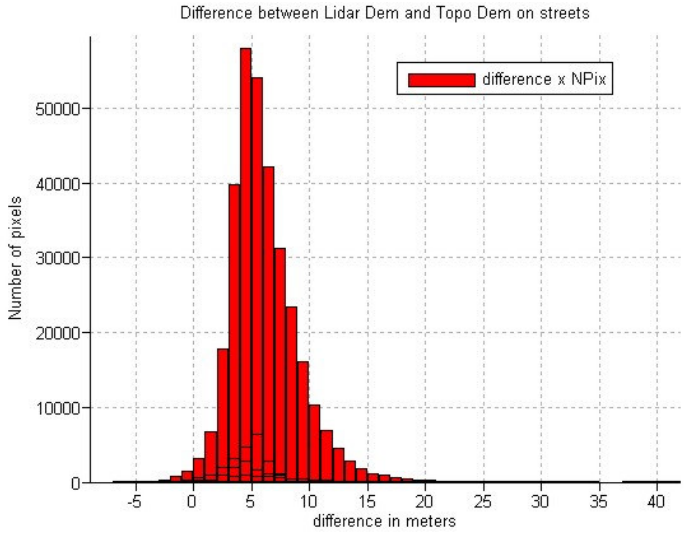
- Another way to find out the error range is to rasterize the road map **Roads_tegu** and cross this map with the map **Difference**. Cross operation can be found under *Operations / Raster Operations /Cross*
- From the cross table display the columns Difference (X-axis) and Npix (Y-axis). The graph you will get looks like the one below.



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- Now that you know more about the average error, we will subtract a value from the difference, so that we might get a good differentiation between built-up and vacant areas. Type the following formula on the command line of the main window:

Object_altitude:=difference – 6

- Use value range from 0 to 50 and a precision of 1. Accept the default values in the display options window.
- The difference map is now displayed. You can now see that most of the areas that are not built-up have an undefined value Overlay the orthoimage map **Ortho_tegu** (use 50 % transparency) and evaluate the result. The colour map nicely coincides with the buildings.

The value of 6 meters was used basically to filter out the objects such as buildings, bridges and trees and distinguish them from the rest of the area. The value of 6 is too much to accurately measure the height of the buildings. A value of 4 meters would have been better.

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- Now that you know more about the average error, it may be best to subtract this value from the difference map, so that the values for the building altitude are more realistic. We will now calculate a map with the number of floors. We assume a floor height of 3 meters. Type the following formula on the command line of the main window:

Number_of _floors:=(difference – 4) / 3

- Use a value range from 0 to 25 and a precision of 1. Check the result. It shows that most of the city is two stories or lower. The buildings in the center are higher.

Now that the number of floors are known, we will calculate the percentage of buildings with 1-floor, 2-floors, 3-floors, and more than 3 floors for each building block.

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- Rasterize the polygon map **Building_blocks_tegu** using the georeference **Tegucigalpa**.
- Cross the raster map **Building_blocks_tegu** with the raster map **Number_of *floors***. Create a cross table **Building_blocks_nof.** Don't ignore the undefineds in the **Number_of_floors** map
- In the cross table **Building_blocks_nof**, first calculate the total area of each building block. Select *Columns / Aggregate*. Select the column **Area**, group by Building_blocks_tegu, output column: **area_block**
- Now you can make a separate column indicating the percentage of each building block with buildings with a specific number of floors.

Type on the command line in the table window:

Perc1floor:=iff(number_of_floors=1,100*(area/area_block),0)
Perc2floors:=iff(number_of_floors=2,100*(area/area_block),0)
Perc3floors:=iff(number_of_floors=3,100*(area/area_block),0)
Percover3floors:=iff(number_of_floors>3,100*(area/area_block),0)

For the columns use value range of 0 to 100 and precision of 1

- The last step is to get this information in the attribute table **Building_block_tegu**, though table joining. Open the table **Building_block_tegu**. Select *Columns / Join.* Select table **Building_blocks_nof** and the column **Perc1floor**. In the Join Wizard accept most of the default values. Only the aggregate function should be Maximum.
- Repeat this for the other columns **Perc2floor**, and **Perc3floor**. For the column **percover3floors**, you have to use the SUM aggregation function, instead of the maximum.

Now you have made an estimation of the percentage of each building block covered by buildings with different number of stories. You can compare the results with the field descriptions you have made earlier. How well is the fit?