Contract:

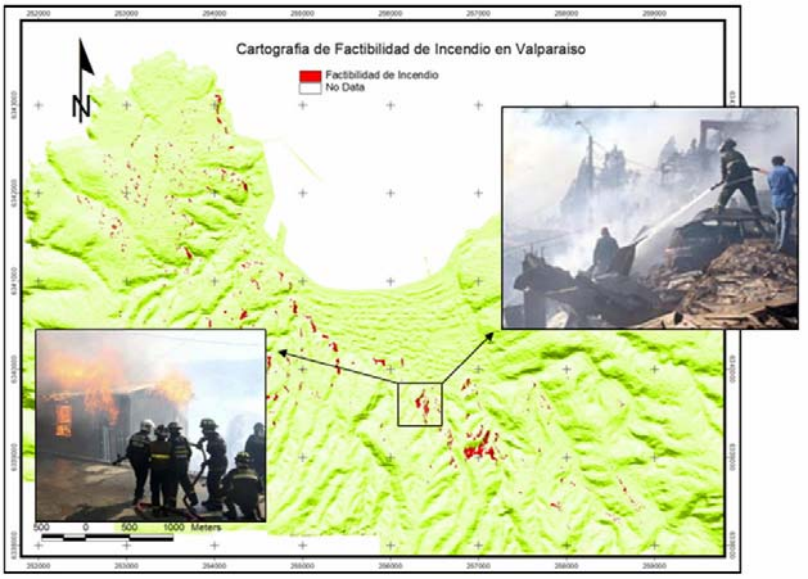
ENEA – Banco Interamericano de Desarrollo (BID)/InterAmerican Development Bank (IDB)

Manejo de Riesgos en Valparaiso, Servicios Técnicos

Acronym: *"MAR VASTO"*

ATN/II-9816-CH

Contract n. **PRM.7.035.00-C**



FIRE HAZARD
IN THE CITY OF VALPARAISO

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0	**Date**	**15.06.2008**	**Name**	**F. GEREMEI**	**M. INDIRLI**			
			Signature					
				AUTHORS				

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PREFACE

The work has been carried out during the *in situ* investigation of the Italian experts, done in the framework of two missions at Valparaíso (May and October-December 2007), with the help of many local Organizations **[01-03]**. In particular, we appreciated very much the cooperation of the personnel of the "Oficina de Gestion Patrimonial – OGP" of the Valparaiso Municipality (the director Paulina Kaplan Depolo, the geographer Mauricio Gonzalez Loyola, together with the student Juan Carlos Leiva G. of the Pontificia Universidad Católica de Valparaíso). Moreover, a fundamental support came from the Regional Civil Defense ("OREMI") and the Firemen of Valparaiso (Cuerpo Voluntario de Bomberos and the "Bomba Italia").

1. INTRODUCTION

Fires certainly are the most common and dangerous disaster in Valparaiso. The "state-of-the-art" information has been provided by the Firemen Corp and OGP, with particular regard to the Calle Serrano tragedy. In fact, on February 3rd, 2007 a violent explosion due to a gas leak killed four people, destroyed some heritage buildings and damaged others in Calle Serrano, in the core of the UNESCO zone of Valparaíso (Fig. 1).

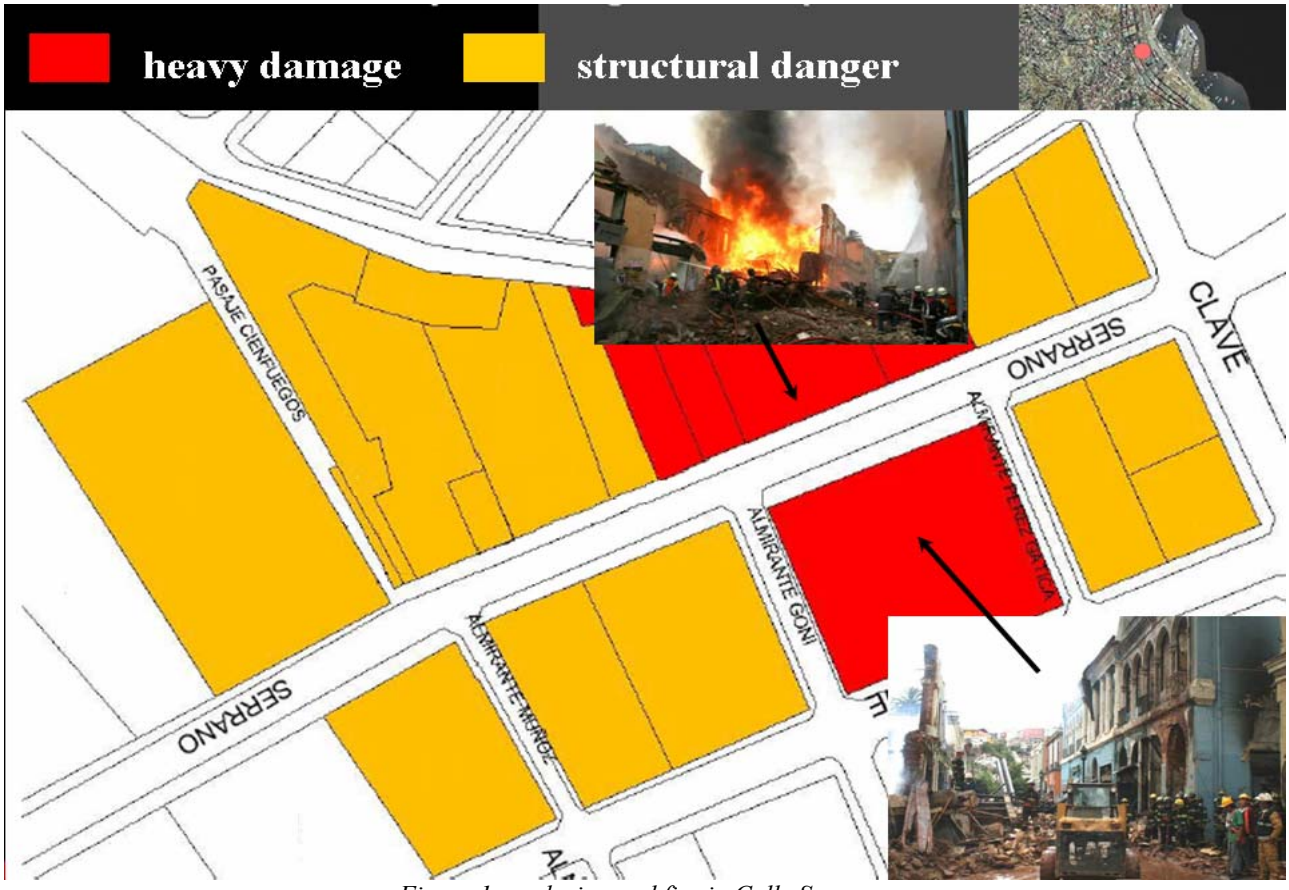


Figure 1: explosion and fire in Calle Serrano.

Despite the good expertise of the local Firemen, fires occur in the urban area (due to bad maintenance of electric systems - Fig. 2 - and gas pipelines, building materials, lack of education and vandalism), but also in the surroundings forests and bushes (mainly human-made events). Furthermore, the risk is worsened by usual windy weather, narrow and tortuous hill roads, presence of wooden houses and sometimes insufficient water pressure in the hydrants. Also the presence of the close harbor facilities represents a further risk factor.

Figure 2: lighting cables in Valparaíso.

Moreover, important monuments were severely damaged by past fires, as happened to the Church of "San Francisco del Baron" in 1983 (Fig. 3). Thus, in the framework of a cooperation with OREMI and the Valparaíso Firemen, the "MAR VASTO" project foresees a first evaluation of fire hazard, implementing the general GIS database (**[04]**). Related information ca be found also in **[05]**. Of course, the GIS database should be implemented, in the framework of future cooperation and projects, gathering and incorporating additional information.

Figure 3: the San Francisco Church after the fire (1983).

2. FIRE HAZARD ANALYSIS IN THE VALPARAISO AREA

The main goal of the work has been the implementation of the GIS database, in order to provide a first analysis in the City of Valparaiso, detecting the most fire hazard prone areas. The basic work steps have been the following:

i) to gather and organize all the available information into a digital GIS database, according to the existing cartography owned by OGP;
ii) to identify the basic parameters for the analysis and detect the Valparaiso areas characterized by high fire hazard;
iii) to implement a GIS database identifying the areas with the greatest fire hazard.

2.1 Organization of the existing information into a digital GIS database

The basis has been the cartography provided by MINVU (Ministerio de Vivienda y Urbanismo de Chile) to OGP in October 2005, referring to the survey made by the Servicio Aerofotogramétrico de la Fuerza Aérea de Chile (SAF) in the year 2005 (Fig. 4).

MINVU CARTOGRAPHY	
DATUM	WGS84
TIME ZONE	19 SOUTH
FILE	ESRI Shapesfiles (shp)
YEAR	2005
SOURCE	Servicio Aerofotogramétrico de la Fuerza Aérea de Chile (SAF) www.saf.cl

Figure 4: basic cartography.

Thus, it was possible to extract and organize the geographic layers shown by Fig. 5.

LIST OF GEOGRAPHIC LAYERS			
thematic item		**description**	**layer (dxf-layer)**
arboles	*trees*	tree location points	arbol
palmeras	*palms*	palm location points	palmera
matorrales	*bushes*	bush area perimeters	matorral
curvas	*elevation*	elevation lines	curvas indice curvas secundarias
vialidad	*streets*	streets	barrera call_no_pav call_pav huella berma puente

Figure 5: list of geographic layers (source OGP – IMV).

Another cartographical source has been the DEM (Digital Elevation Model) produced for the "MAR VASTO" project **[04-05]**, including all the Valparaiso Municipality urban area (Fig. 6).

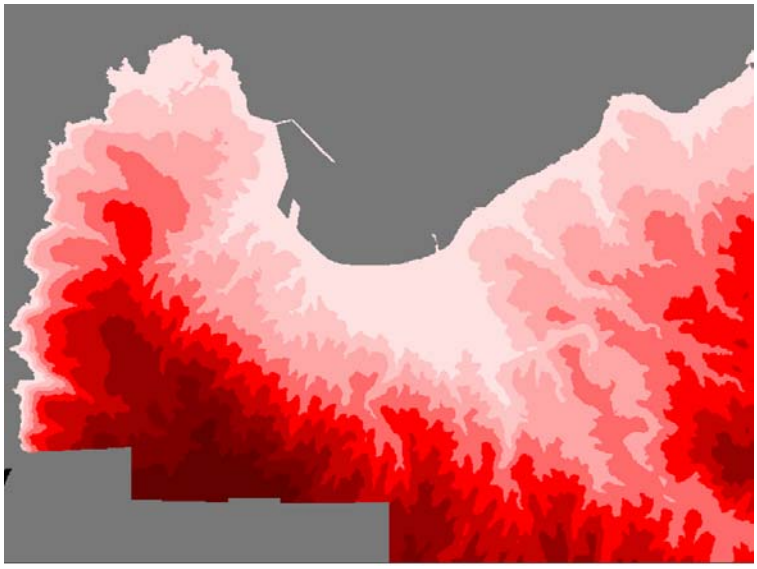


Figure 6: DEM of the Valparaiso area.

The above said layers have been summarized on similar characters to obtain macro values (Fig. 7).

MACRO VALUES			
VEGETAL			
thematic item		**description**	**layer grid**
area verde	*green area*	location polygons	averd_1
matorral	*bush*	bush areas polygons	mato_1
arboleda	*grove*	grove location polygons	arb_1
FISICAL			
thematic item		**description**	**layer grid**
DEM	*DEM*	Digital Elevation Model	valpo_1
URBAN			
thematic item		**description**	**layer grid**
vialidad	*streets*	street classification	vial _1
casco urbano	ownership and blocks location	elements detailing ownership and blocks location in Valparaiso	pred_1 manz_1

Figure 7: list of macro values (source OGP – IMV).

2.2 Identification of fire hazard basic parameters in the Valparaiso area

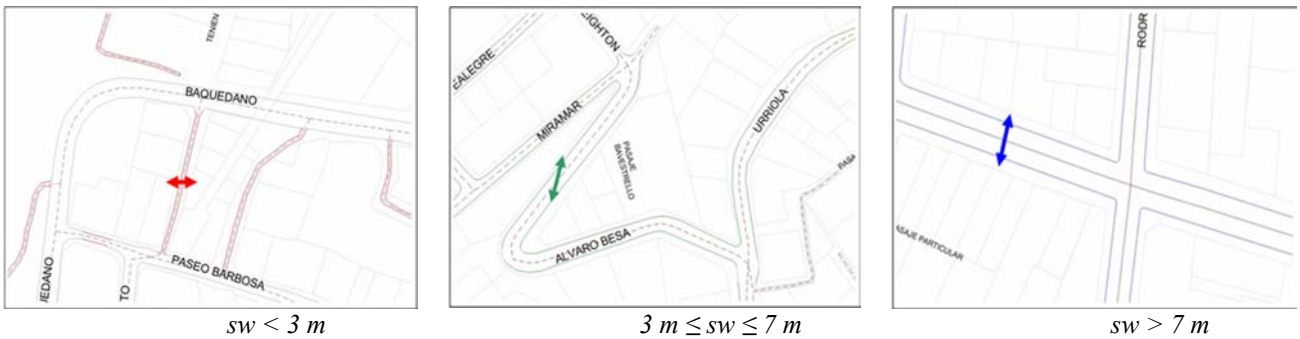
The following basic parameters have been analyzed:
- street accessibility;
- hill slope exposure (aspect);
- vegetation covering;
- urban covering.

Street width

The street accessibility has been defined as the capability to get in a quickly way by a fire brigade vehicle. Thus, a range of values has been assigned to the streets, establishing three hazard classes (Figs. 8-9), according to the Chilean General Law of urbanization and building (Art. 2.3.1.). It identifies a minimum width for local streets[1] (7 m) and pedestrian paths[1] (3 m).

street width sw	**class**
sw < 3 m	1
3 m ≤ sw ≤ 7 m	2
sw > 7 m	3

Figure 8: street width.



(a) *sw < 3 m* **CLASS 1 high hazard** (b) *3 m ≤ sw ≤ 7 m* **CLASS 2 medium hazard** (c) *sw > 7 m* **CLASS 3 no hazard**

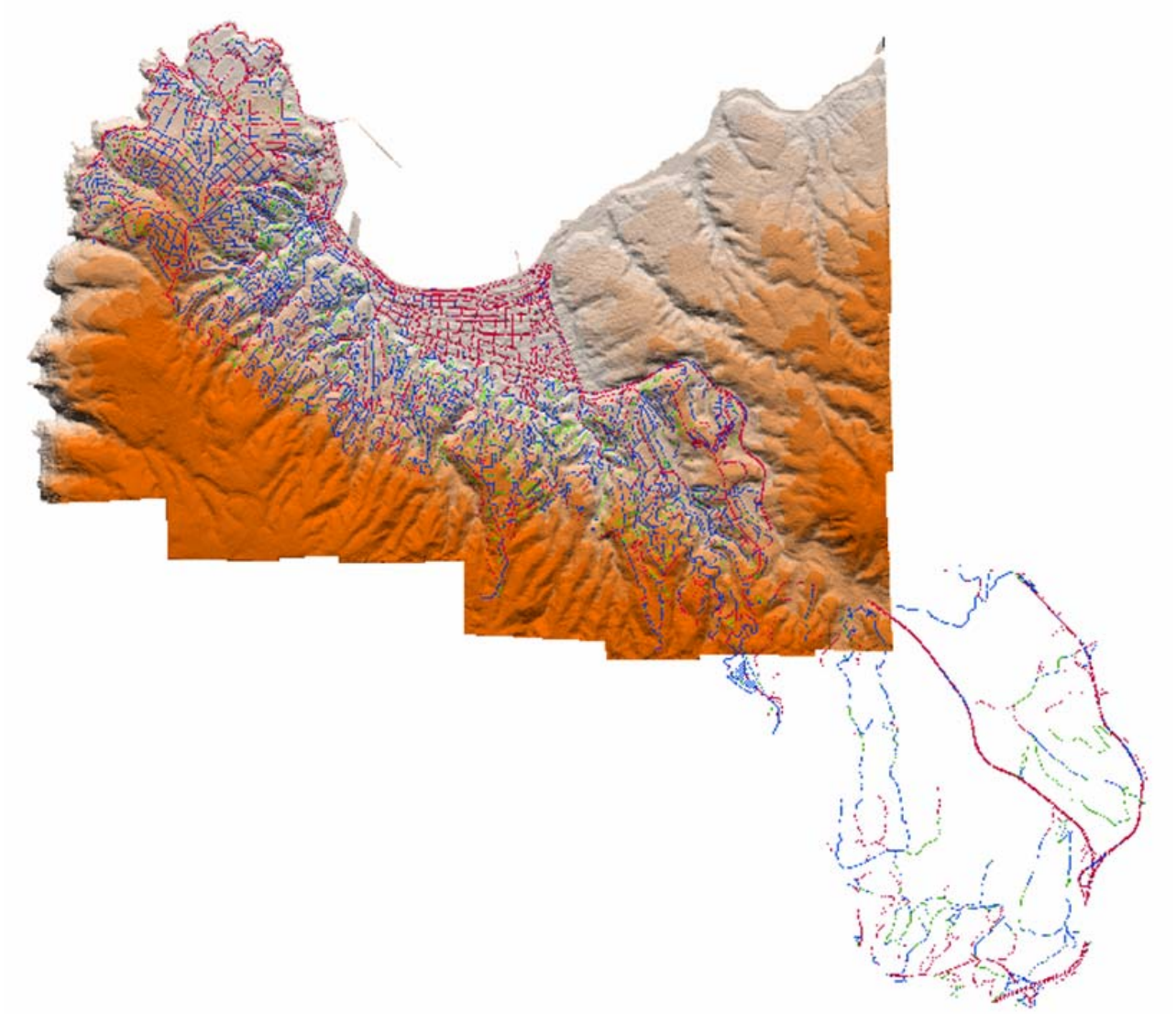
Figure 9: fire hazard in function of the street width.

[1]Local street (Vía Local) is the last vehicular class, considering the street width and use. Ordenanza General de Urbanismo y Construcciones, Art. 2.3.1. Chapt. N° 3, page 101 (351), year 2002, Chile.

The above said street classes have been identified in the GIS database (Fig. 10), obtaining the following results:

- 25,88% (3135) of the whole analyzed elements (12113) corresponds to high fire hazard streets;
- among them, 19,55% show a slope greater than 30%;
- most of them (98,08%) corresponds to streets with length greater than 10 meters.

The CLASS 1 viability (vial_1) is shown by Fig. 11.



Metadata
file: GRID
shp typology: line
objects in layer: 3135
Datum: WS84
time zone: 19S
year: 2005
source: SAF

Figure 10: fire hazard street classes in Valparaiso.

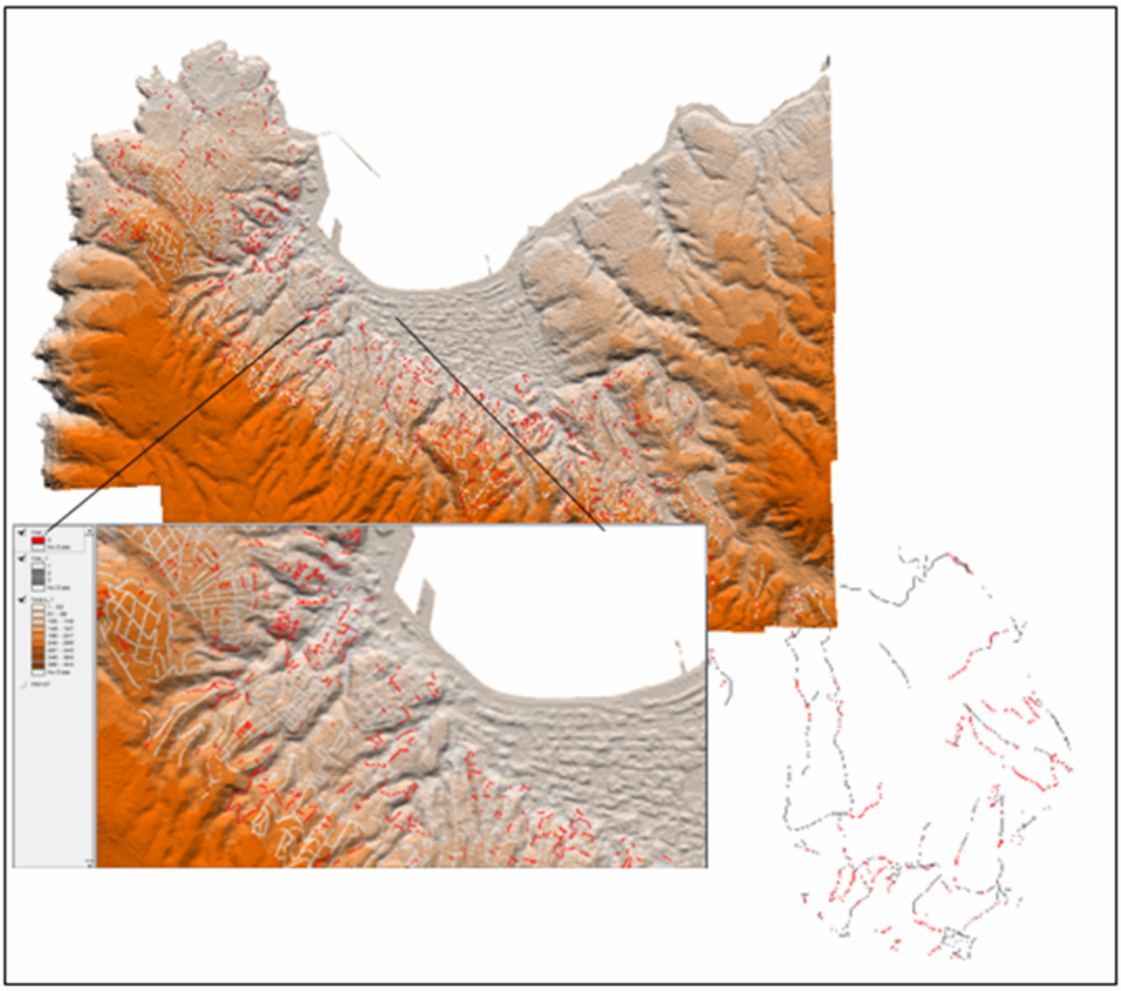


Figure 11: CLASS 1 streets in the GIS database (vial_1).

Hill slope exposure (aspect)

The analysis identified several classes of hill slope exposure (aspect) in the City of Valparaiso (Fig. 12), extracting orientations (aspect_1, see Fig. 13) subjected to the highest sun exposure (North, North-East and East).

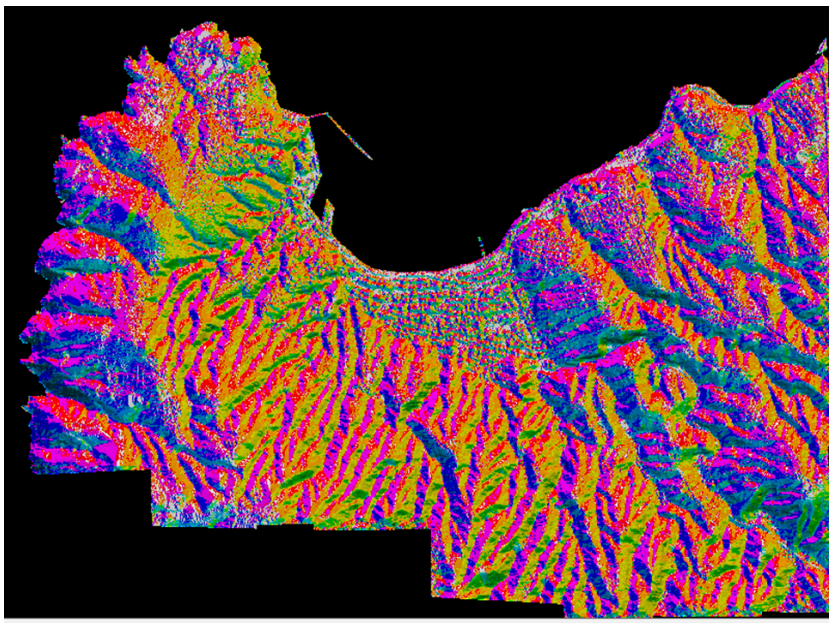


Figure 12: hill slope exposure general data.

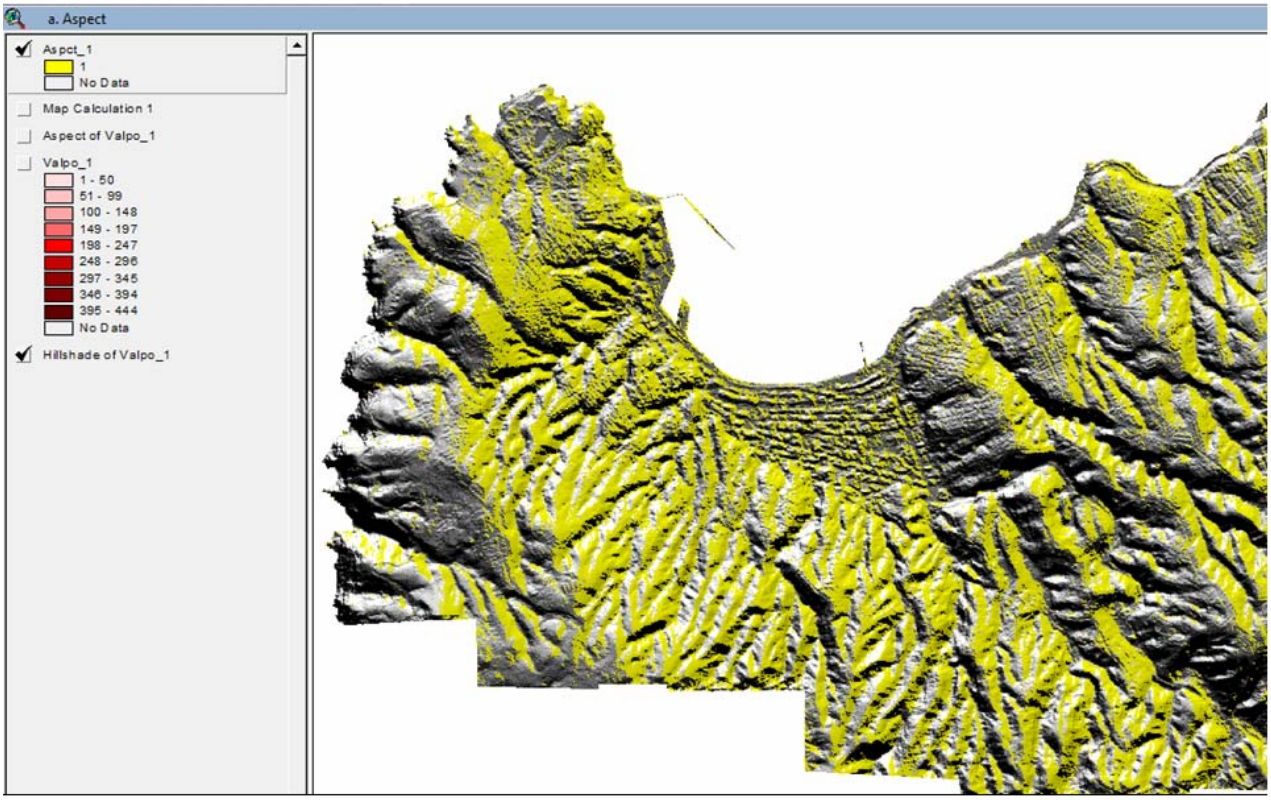


Figure 13: maximum hill slope sun exposure in the GIS database (aspect_1).

Vegetation covering

Among the overall information (Fig. 14), only bush (mato_1) and grove (arb_1) grids (at least 5 m) have been taken into account (vege_1, see Fig.15), neglecting green areas (averd_1) as fire source.

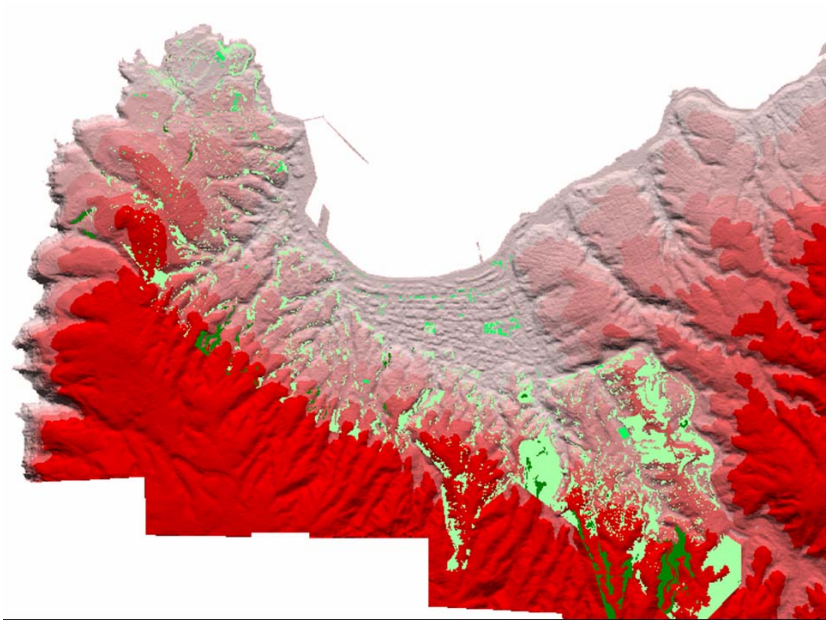


Figure 14: vegetation covering general data.

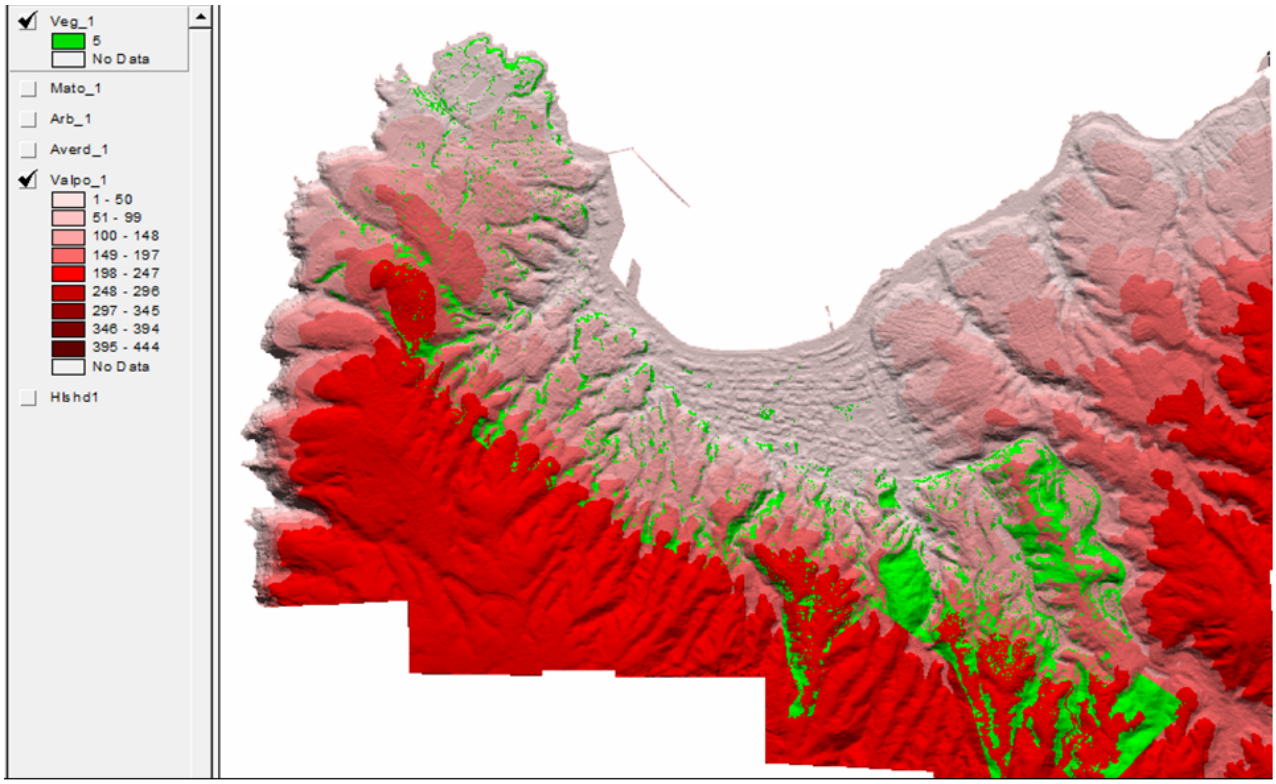


Figure 15: vegetation covering (bush and grove with at least 5 m grid) in the GIS database (vege_1).

Urban covering

The Valparaiso building map has been analyzed, extracting the following layers:

a) pred_1

it is the grid layer showing city blocks with the highest quantity of owners, taking into account that the average in Valparaiso is 10 ownerships per block; in fact, the block fragmentation decreases the possibility of management in case of fire (Fig. 16).

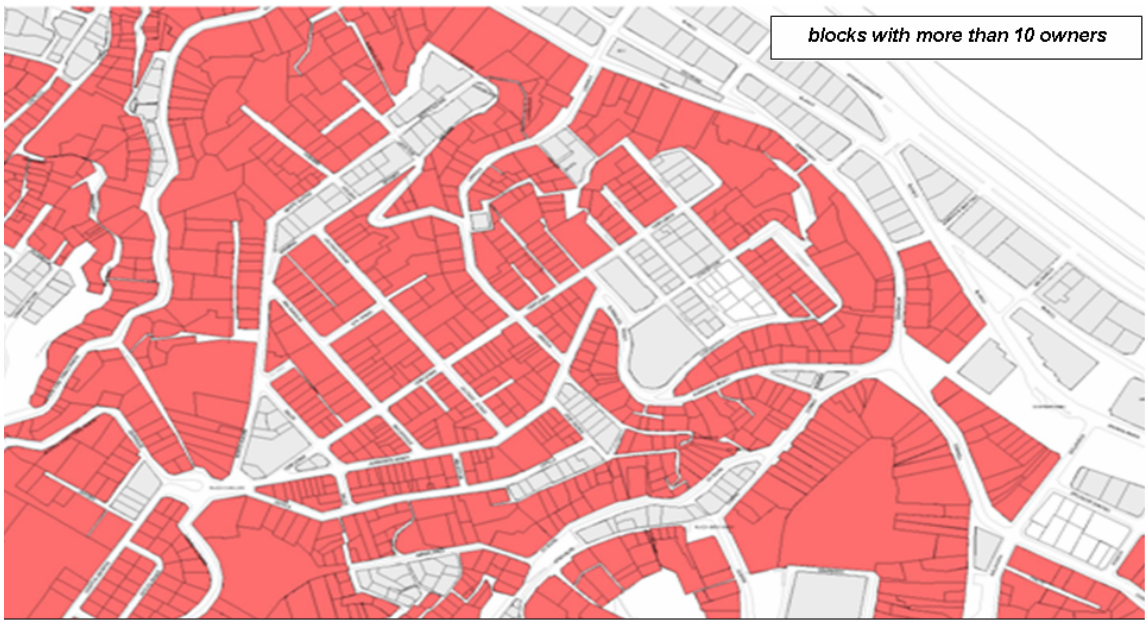


Figure 16: grid showing city blocks with the highest quantity of owners (pred_1).

The final grid (pred_1) is shown by Fig. 17.

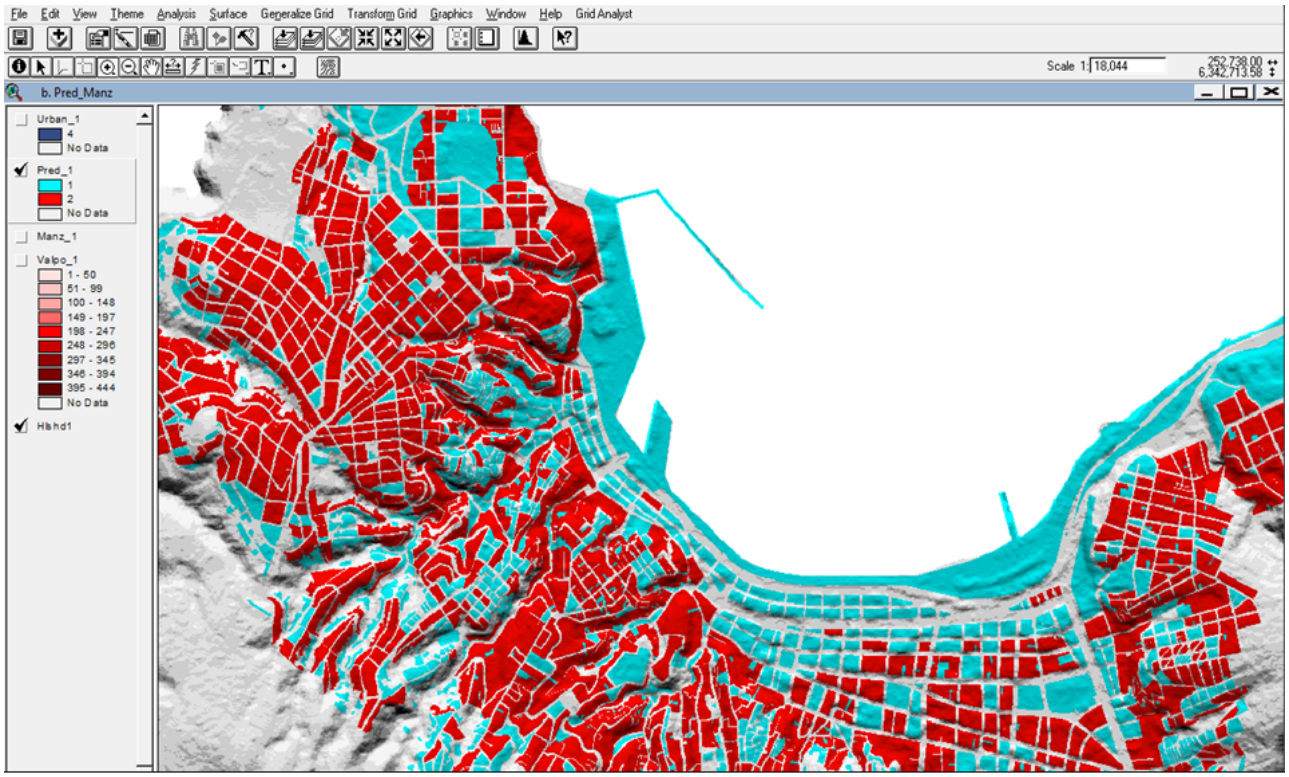


Figure 17: block fragmentation due to ownership in the GIS database (pred_1).

b) manz_1

it is the grid layer showing city blocks with the highest surface, taking into account that the average in Valparaiso is 3834 square meters per block; in fact, fire propagates quickly in continuous blocks than blocks interrupted by lanes and streets (Fig. 18).

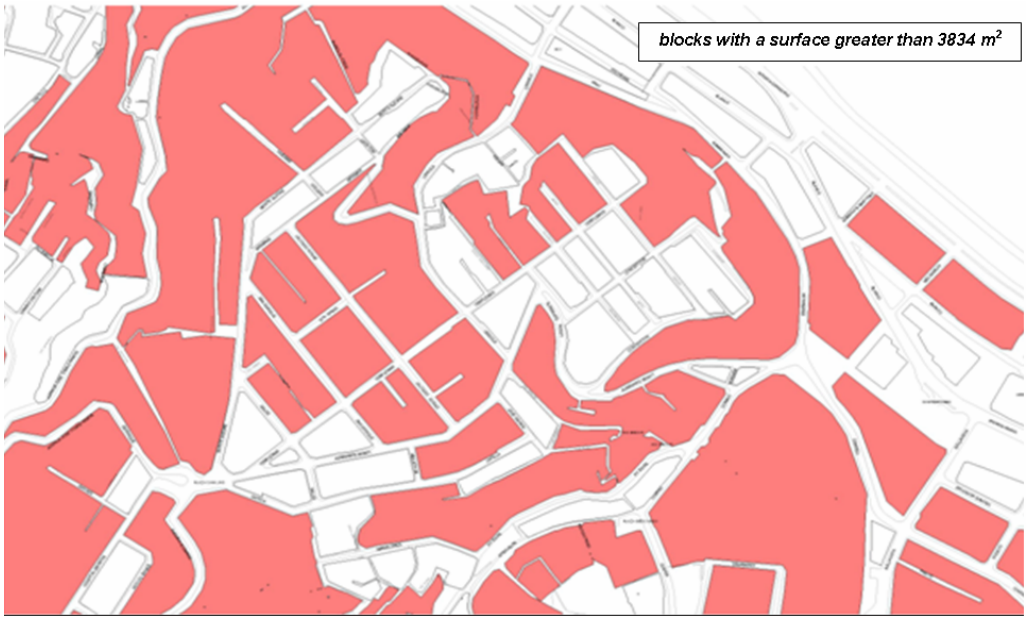


Figure 18: grid showing city blocks with highest surface (manz_1).

The final grid is shown by Fig. 19.

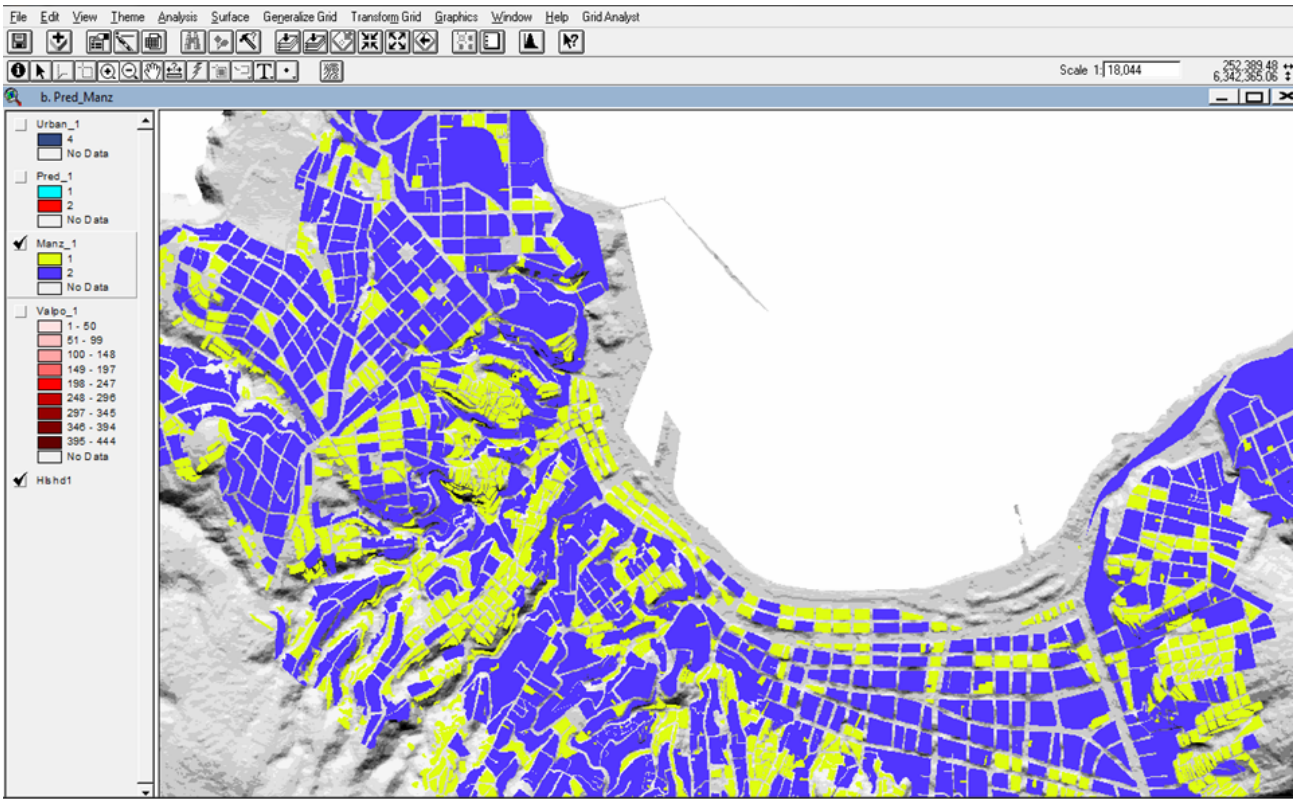


Figure 19: block surface in the GIS database (manz_1).

c) urban_1

it is given by the combination of the two previous layers (Fig. 20).

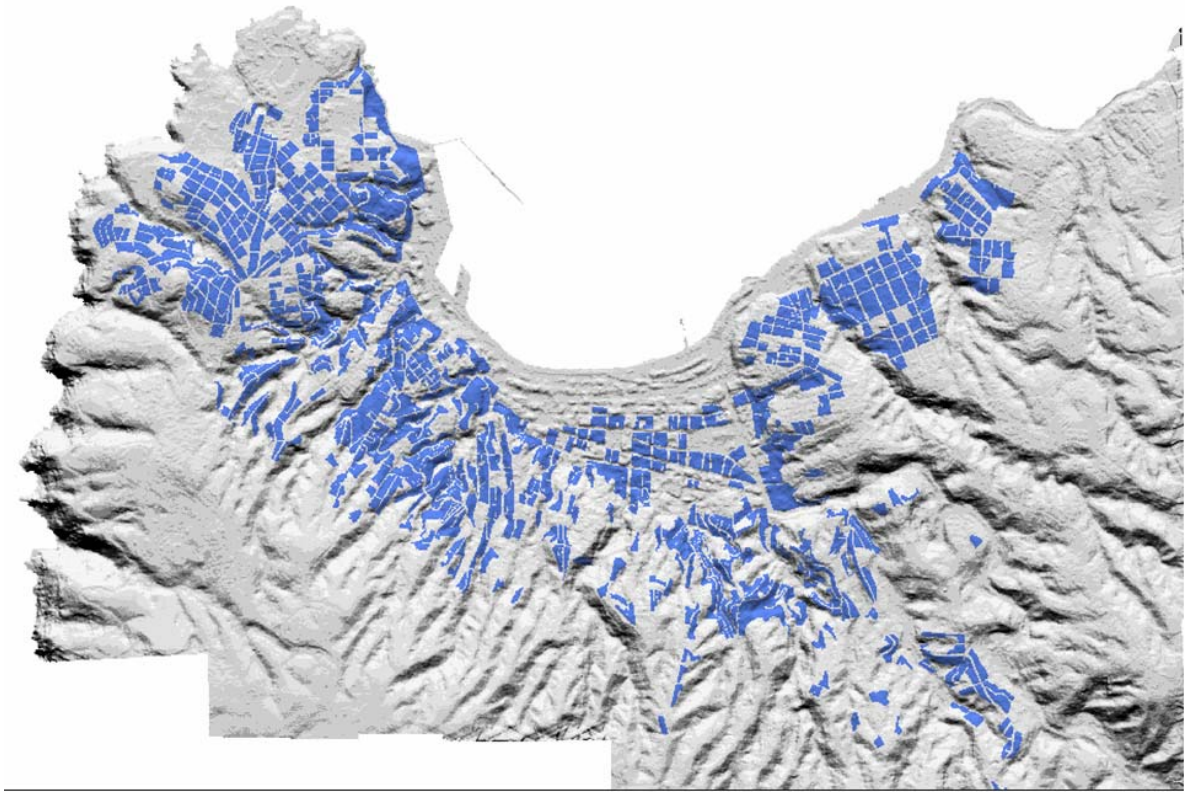


Figure 20: combination of layers pred_1 and manz_1, giving urban_1.

2.3 GIS database development identifying the greatest fire hazard areas

The final step regarded the combination of the results achieved (vial_1, aspect_1, vege_1 and urban_1, the latter as a combination of pred_1 and manz_1), by using a specific procedure (Figs. 21-23). Through the ARCVIEW 3.2 software and its module MODEL BUILDER, a weighted overlay procedure permitted a spatial analysis of the above said variables, assigning them a weighted factor and representing them in percentage.

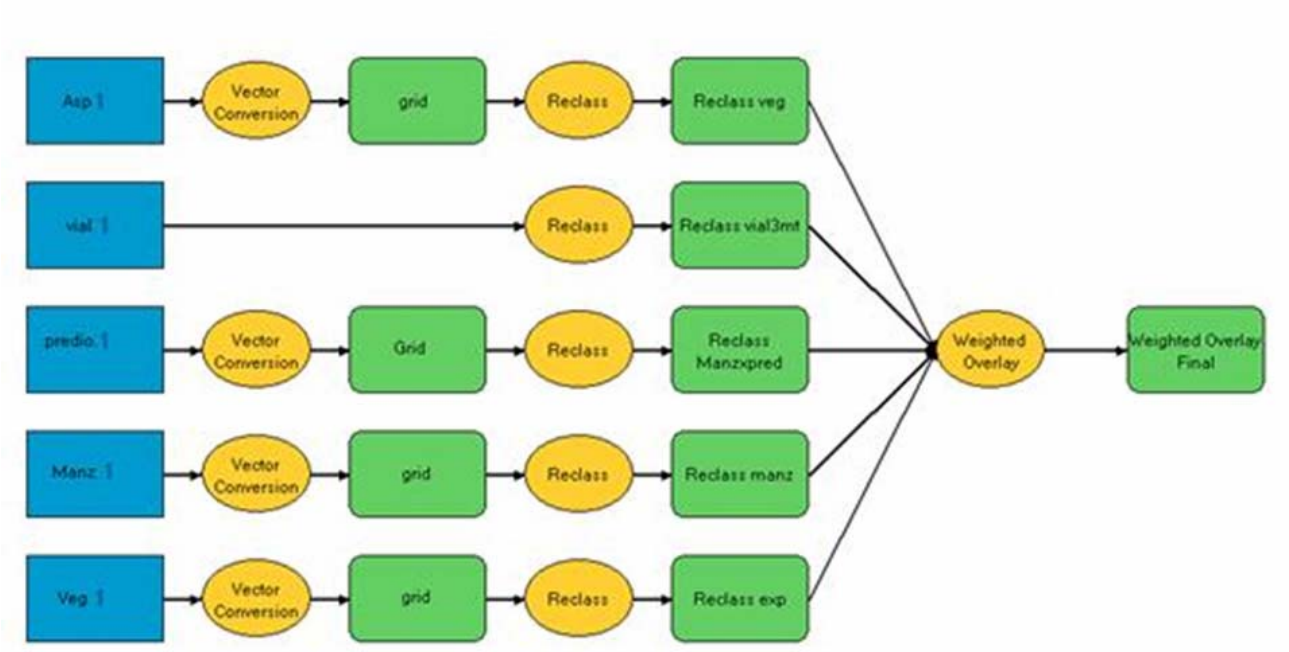


Figure 21: general procedure.

In detail, the following steps have been carried out:

ARCVIEW:
- extraction of the needed information from each layer;
- conversion of the vectorial variables into a raster (grid) format;
- definition of the weight factors.

MODEL BUILDER:
- raster reclassification;
- definition of the weight factors;
- extraction of a Weighted Overlay Map.

	Variable weight		**NULL 0**	**LOW 1**	**MEDIUM 2**	**HIGH 3**	
	viability (vial_1)	*vegetation (vege_1)*	*slope exposure (aspect_1)*	*block ownership (pred_1)*	*block area (manz_1)*	**TOTAL**	**PERCENTAGE**
viability (vial_1)		**0**	**0**	**3**	**2**		**20**
vegetation (vege_1)	**0**		**3**	**1**	**1**		**26**
slope exposure (aspect_1)	**0**	**3**		**0**	**0**		**16**
block ownership (pred_1)	**3**	**3**	**1**		**3**		**19**
block area (manz_1)	**3**	**2**	**1**	**2**			**19**
TOTAL	**6**	**8**	**5**	**5**	**6**	**31**	**100**

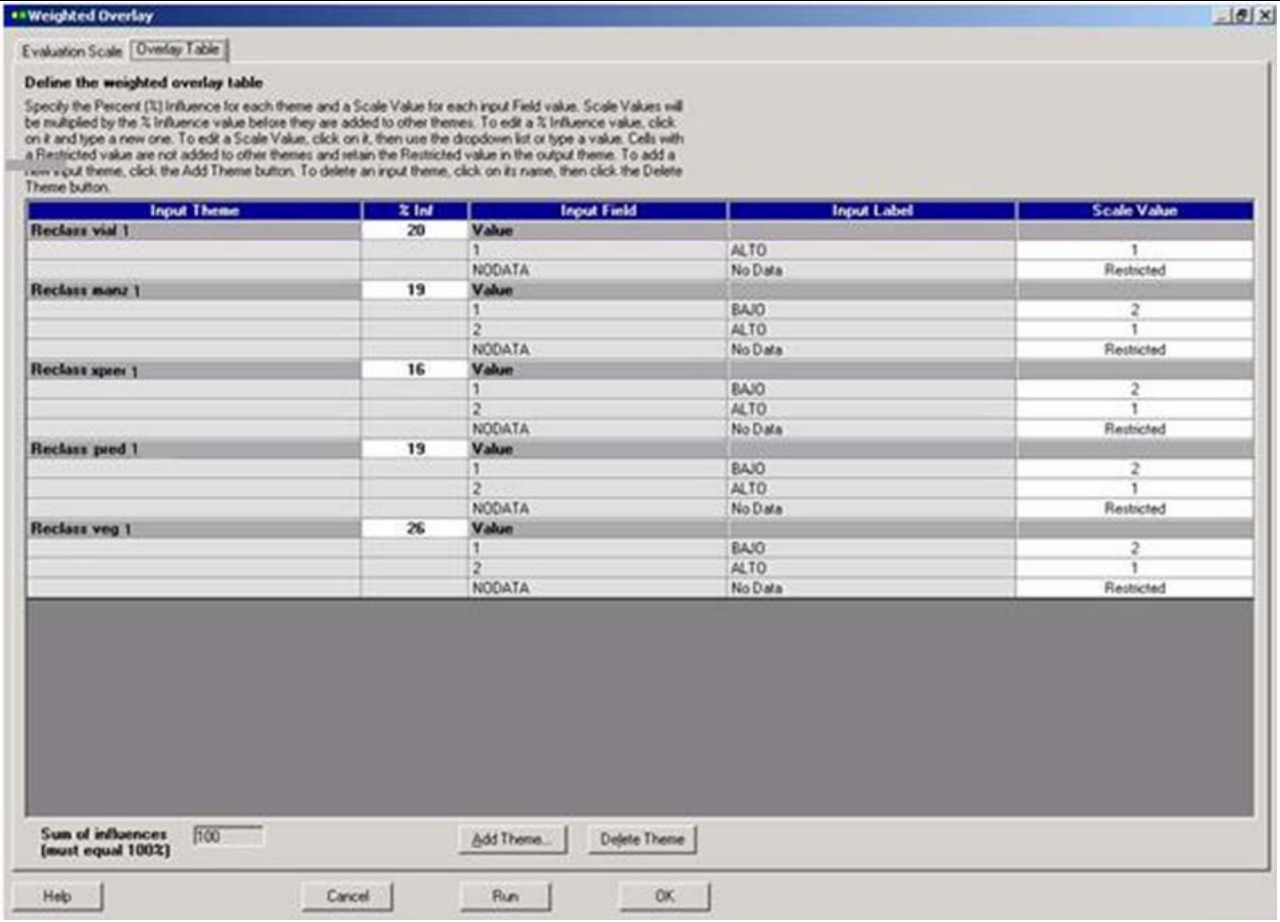
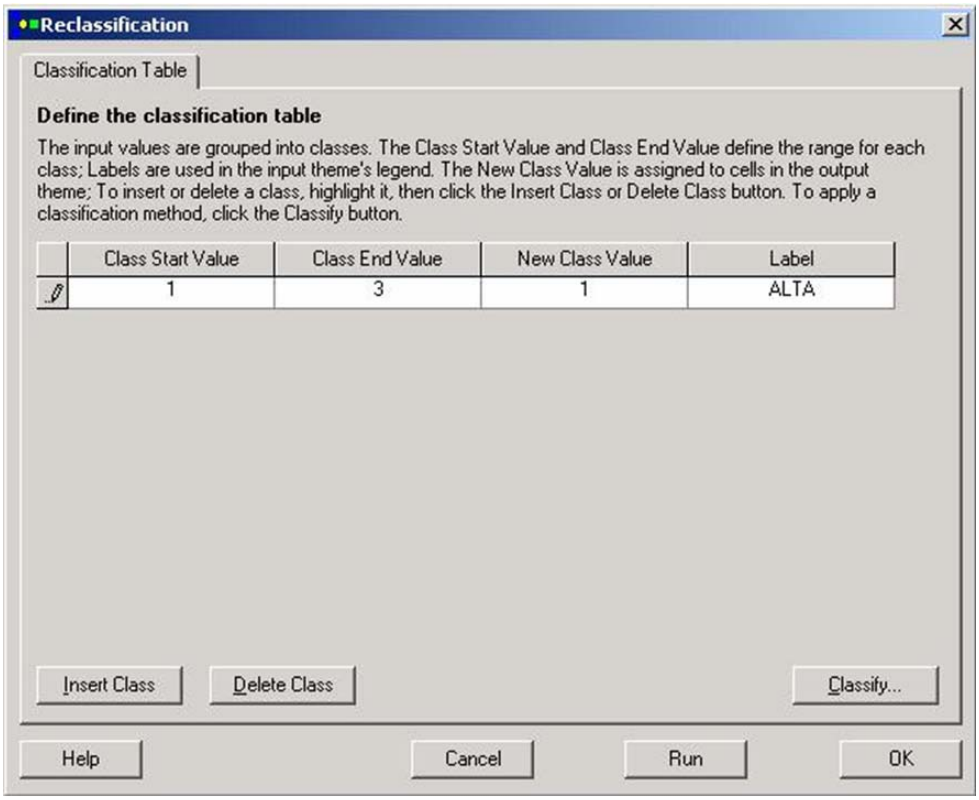


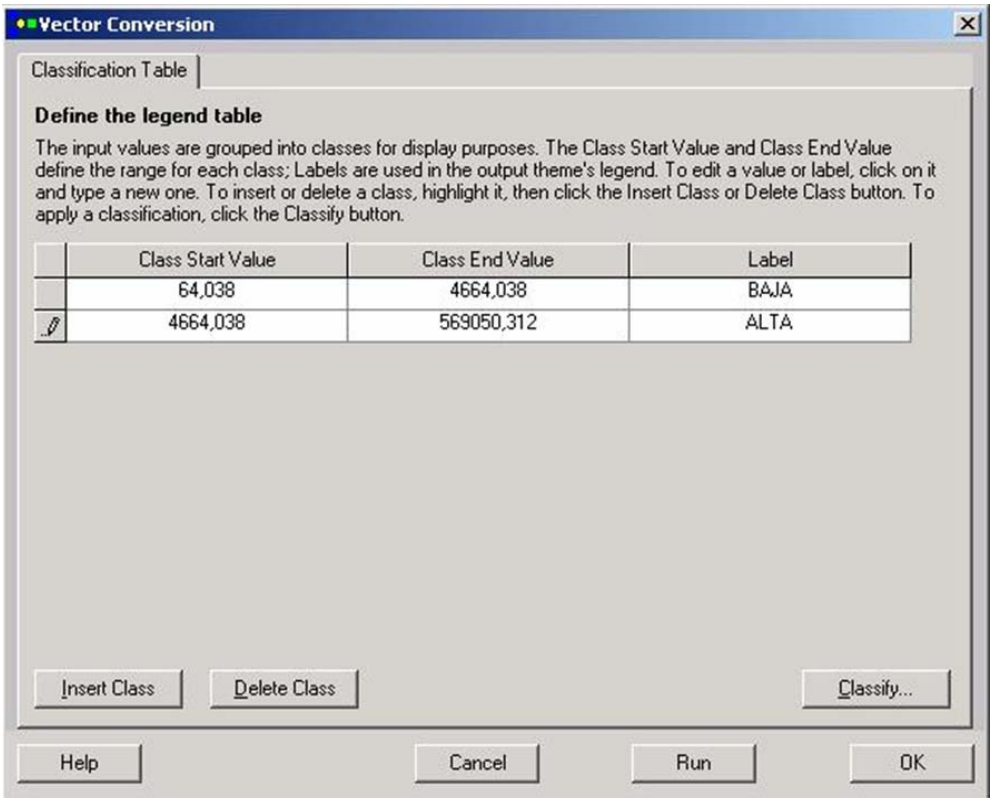
Figure 22: weight attribution to variables and weight overlay procedure.



vial_1

- street width sw < 3 m: HIGH HAZARD

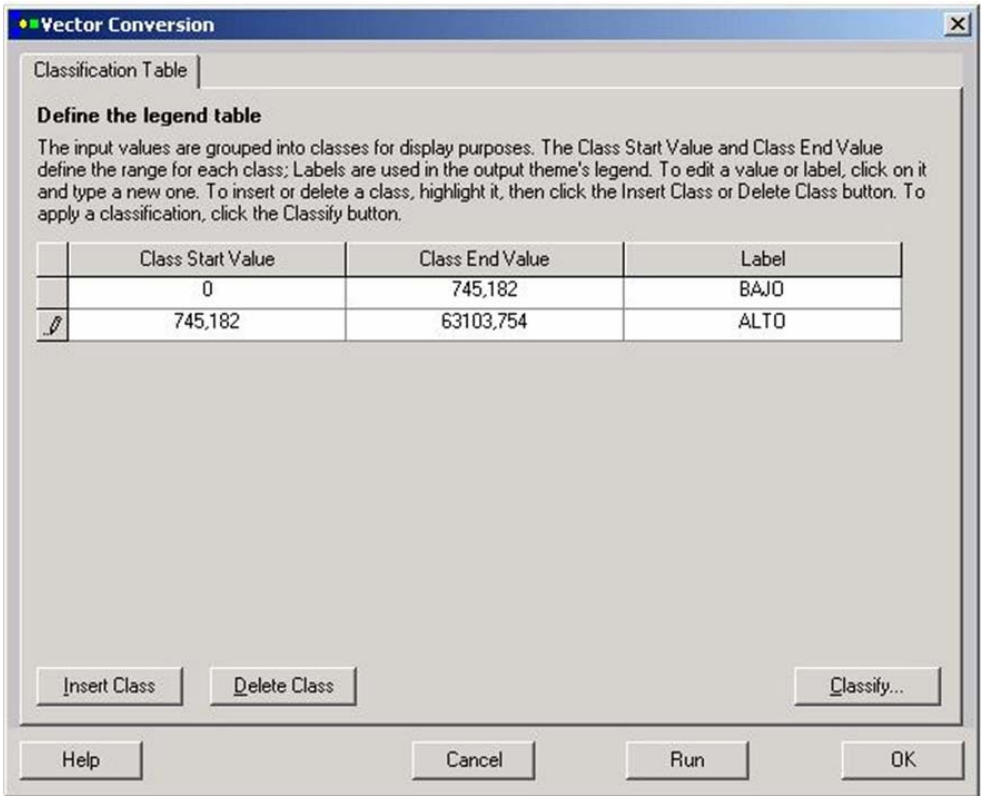
Fig. 23a: raster reclassification in MODEL BUILDER for street width.



aspect_1

- 64.038 – 4664.038: LOW HAZARD
- 4664.038 – 569050.312: HIGH HAZARD

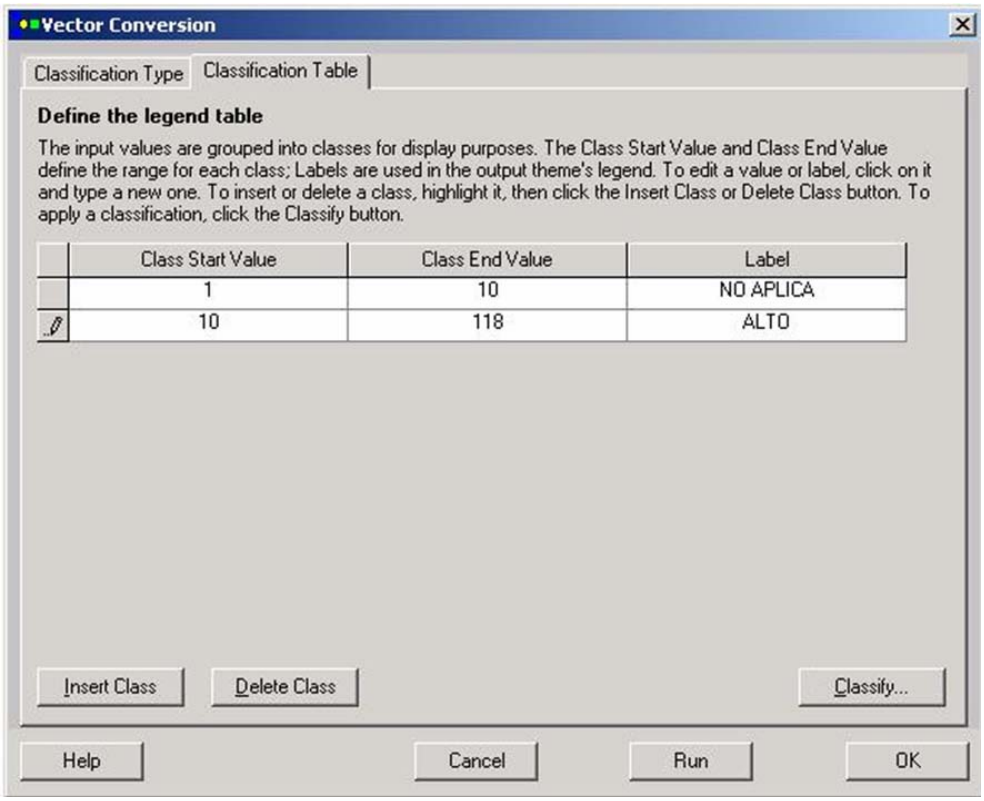
Fig. 23b: raster reclassification in MODEL BUILDER for hill slope exposure.



vege_1

- 0 – 745.182: LOW HAZARD
- 745.182 – 63103.754: HIGH HAZARD

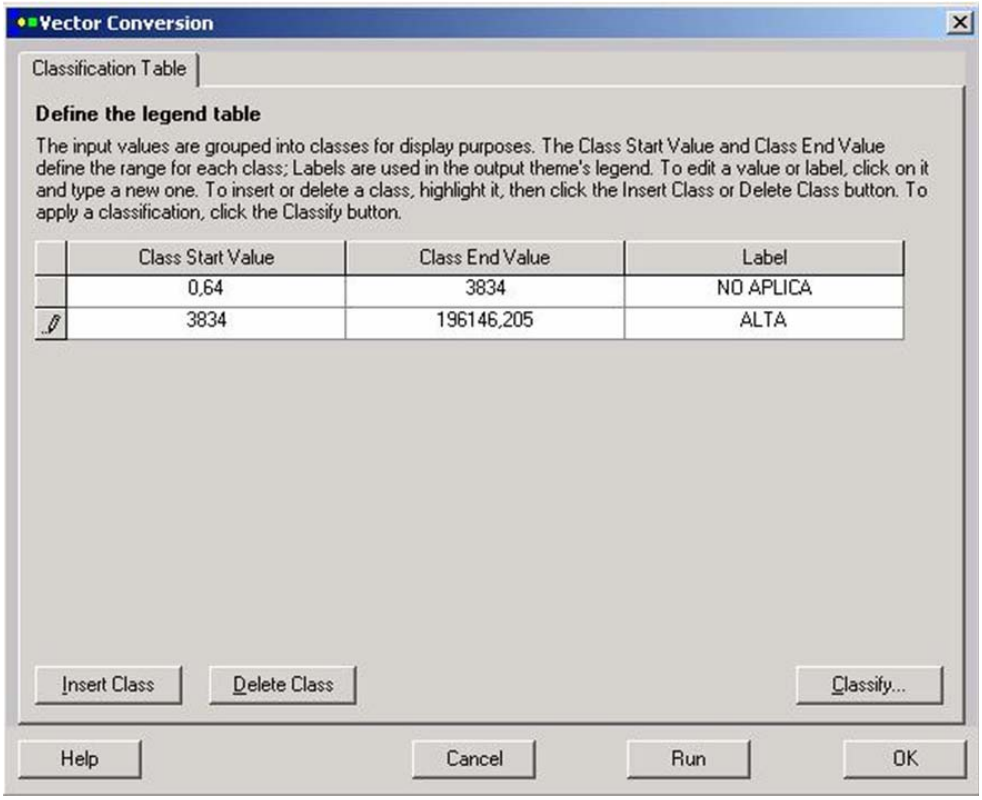
Fig. 23c: raster reclassification in MODEL BUILDER for vegetation covering.



pred_1

- 1 – 10: NO HAZARD
- 10 – 118: HIGH HAZARD

Fig. 23d: raster reclassification in MODEL BUILDER for quantity of owners in the city blocks.



manz_1

- 0.64 – 3834: NO HAZARD
- 3834 – 196146.205: HIGH HAZARD

Fig. 23e: raster reclassification in MODEL BUILDER for surface of the city blocks.

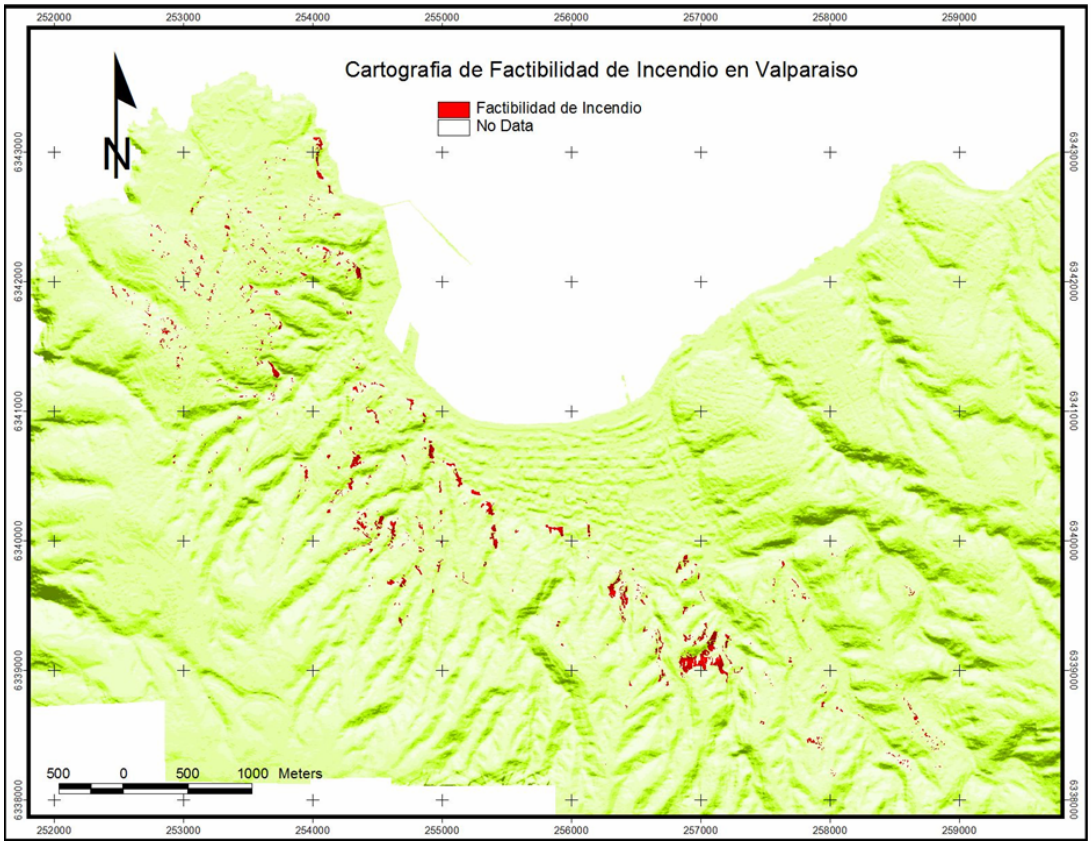


Fig. 24: final fire hazard map in Valparaiso.

Fig. 24 shows the final fire hazard map, marking the most Valparaiso fire-prone locations.
The work has been verified (Fig. 25) by a couple of recent fire events (see Appendix 1): they occurred exactly in one of the most prone areas identified in the GIS database.

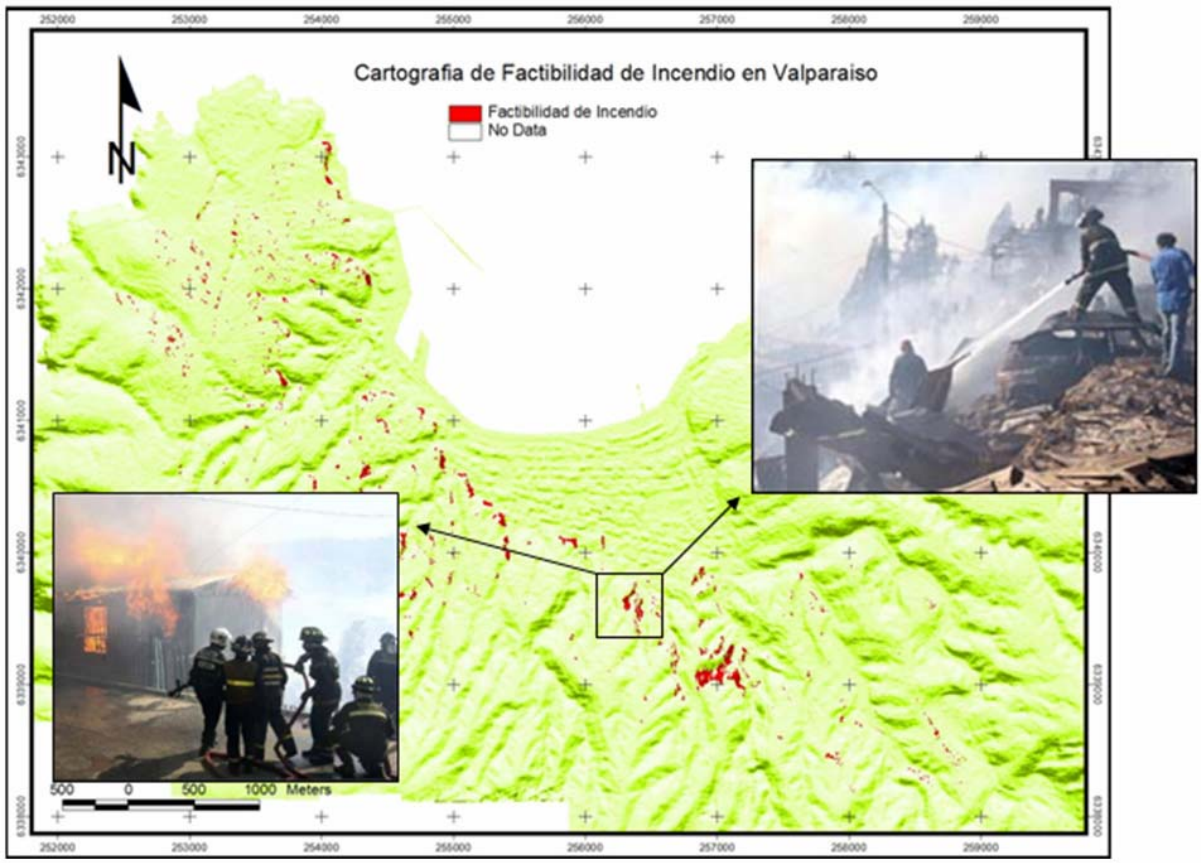


Fig. 25: location of a couple of recent fire events in Valparaiso.

3. CONCLUSIONS

This report contains the first work steps regarding the fire hazard evaluation in Valparaiso. Of course, the GIS database has to be implemented in the future, gathering and incorporating additional information:

building inventory
- year of construction;
- material of construction;
- building floor number;
- area of the construction;
- building maintenance;
- unoccupied, wild and abandoned areas;
- etc.

viability
- street length;
- street slope;
- street typology;
- etc.

green and playtime areas
- tree sites;
- location of squares and public areas;
- etc.

socio-demography variables
- socio-economic level;
- age classes of the population;
- number of persons per building;
- etc.

physical variables
- hill slope (in percentage);
- sun exposure in function of the day time (hours);
- elevation of the analyzed areas;
- etc.

utilities
- location of aqueducts and drains;
- location of hydrants;
- location of electric power;
- location of gas pipelines;
- location of phone lines;
- etc.

commercial variables
- industrial and commercial facilities;
- location and typology of shops;
- etc.

Furthermore, a special attention must be dedicated to fires following earthquakes and connections with other natural hazards.

REFERENCES

[01] MAR VASTO Project, General Progress Report n.1, 20.08.2007.
[02] MAR VASTO Project, General Progress Report n.2, 28.01.2008.
[03] MAR VASTO Project, General Progress Report n.3, 30.06.2008.
[04] MAR VASTO Project, A GIS database for the City of Valparaiso, 30.06.2008.
[05] MAR VASTO Project, Geomorphologic hazard in the City of Valparaiso, 30.06.2008.

APPENDIX 1

RECENT FIRE EVENTS

http://www.primeraplana.cl/noticias_detalle.php?recordID=2078
15/01/2008

INCENDIO EN CERRO DE VALPARAÍSO

Controlado pero con riesgo de poder rebrotar se mantenía hasta ayer el incendio que afecta al Cerro La Cruz y que ha dejado más de medio centenar de casas siniestradas y dos personas heridas. El siniestro se produjo a las 16:00 horas de ayer lunes en el sector Cerro la Cruz, comuna de Valparaíso y ha consumido 15 hectáreas de pastizal y matorrales. Según los reporte de la Oficina Nacional de Emergencia (ONEMI), hay 70 viviendas destruidas, 30 viviendas en evaluación, un Bombero identificado como Gabriel Lara, con quemaduras en un 60 por ciento de su cuerpo y una mujer con heridas cuya gravedad se desconoce. Ambos fueron trasladados al hospital Van Buren Valparaíso, informó el intendente regional, Iván De la Maza (La Nación / primeraplana.cl).

Un saldo de destrucción, dramas familiares y graves lesionados, ha dejado hasta el momento un incendio iniciado a las 16:30 horas en el cerro La Cruz. Bomberos, a esta hora, estima entre 60 y 70 las casas destruidas, informaba anoche diario La Estrella. Hay varias personas quemadas, entre ellas un bombero que tendría un alto porcentaje de su cuerpo quemado y está en riesgo vital. El calor, el fuerte y cambiante viento y, presuntamente una irresponsable quema para fabricar carbón en una quebrada, son las causas principales de este siniestro, el más grande de las últimas décadas (La Estrella de Valparaíso).