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SafeLand

Living with landslide risk in Europe: Assessment, effects of global change, and risk management strategies

7th Framework Programme
Cooperation Theme 6 Environment (including climate change)
Sub-Activity 6.1.3 Natural Hazards

Deliverable 3.6

Database of human activity factors affecting the local landslide risk at selected sites (including maps of controlling factors and changes in these factors; land cover, demographic and economic scenarios; trajectory of key indicator of changes)

Work Package 3.2 – Human activity and demography scenarios

Deliverable/Work Package Leader: BRGM

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2			

SUMMARY

Human activities, in association with natural factors, can directly trigger or amplify landslides. This work focuses on the evolution of human activity factors impacting landslide risk from 2030 till 2100 and at the level of test sites. Among the controlling factors affecting landslide risk we have concentrated on land use / land cover and demography.
The idea of this work is to check data availability at the level of selected hotspots. Providing information on the evolution of such factors requires the collection, compilation and interpretation of more global studies. When they exist, prospective data are used. Unfortunately, they are seldom, rarely spatialized and not always adapted to the local context. However, this lack of information can be partially compensated by the analysis of past and present trends.
Satisfactory data have been collected for the Barcelonnette site and have allowed the elaboration of demography scenarios at local level by 2030. The land use change scenario by 2100 has been studied. Acknowledging significant uncertainties, the demographic forecasts can be extended from 2030 to 2100. The economic changes scenario has not been treated as such a scenario is really difficult to implement at a local scale and also to integrate in risk analysis process.
Demographic scenarios have been partially developed for the Nedre Romerike site (Norway). Concerning the other proposed test sites: Pizzo d'Alvano (Italy) and Slanic (Romania), data concerning human activities are not sufficient for the moment to elaborate any kind of prospective scenario.
These prospective data will be used, taking account of their inherent uncertainties, to pursue the work as planned in work package 3.3. Land use will be linked with other indicators of landslide susceptibility in order to assess its impact on hazard, whereas demographic changes will be used for exposure changes and as far as possible used to assess hazard changes due to demographic pressure.

Note about contributors

The following organisations contributed to the work described in this deliverable:

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Other contributors:
CNRS (J.P. Mallet) who has provided all Barcelonnette site's data

List of acronyms

CLC: Corine Land Cover
CRIGE: Centre Régional de l'Information Géographique
IFN: Inventaire Forestier National (French National Forestry inventory)
IPGS: Institut de Physique du Globe de Strasbourg
NGI: Norwegian Geological Institute
NGU: Geological Survey of Norway
PPR: Plan de Prévention des Risques (risk assessment plans)
RTM: Restauration des terrains en montagne (mountain restoration terrain office)

CONTENTS

1 INTRODUCTION AND OBJECTIVES

Although landslides are natural hazards, human activities play an important role in landslide risk. Human activities are not only affected by landslides, but they might also influence the hazard (e.g. occurrence see deliverables D1.1 and D1.6; and impacts, see D2.6).

Thus, in order to estimate the probable evolution of landslide hazard and landslide risk at selected sites, scenarios of future conditions should not be limited to climatic parameters, but should also include information on future human activity factors that would affect landslide risk.

The present study aims to gather, compile and interpret all available data at selected sites to provide information regarding the prospective evolution of human activities, demography and land-use, which will be used in the different tasks of work-package 3.3 “Landslides hazard evolution in Europe and risk evolution in selected “hotspot” areas”.

However, such evolution of human behaviour depends upon a large number of factors and is inherently variable and unpredictable. Indeed, even at large scales, no accurate predictions can be performed further than few years ahead. In order to deal with these uncertainties, scenarios are drawn based on general assumptions. Furthermore, this problem is exacerbated at local scale, where even singular events can have profound impacts on human activities and their evolution. Thus, the resolutions of existing prospective scenarios are often too coarse compared to the precision required by the risk analysis models that will be used at local sites. Indeed, precise scenarios are too sparse, and methods have to be developed to downscale large scale (regional up to national) tendencies to a local scale.

This deliverable presents the selected sites, where local assessments of landslides risks will be performed in the different tasks of work-package 3.3. Then the way the different materializations of human activities affect the different dimensions of risks are detailed. After that, the methodologies used to adapt the existing data to the requirement of local scale models are described. And finally, some data for selected sites, where prospectives are possible, are presented.

2 TEST SITES

The test sites selected are located in five different countries of Europe *(Figure 1)*: Norway, Spain, France, Italy and Romania. This gives a selection of sites with very different contexts.

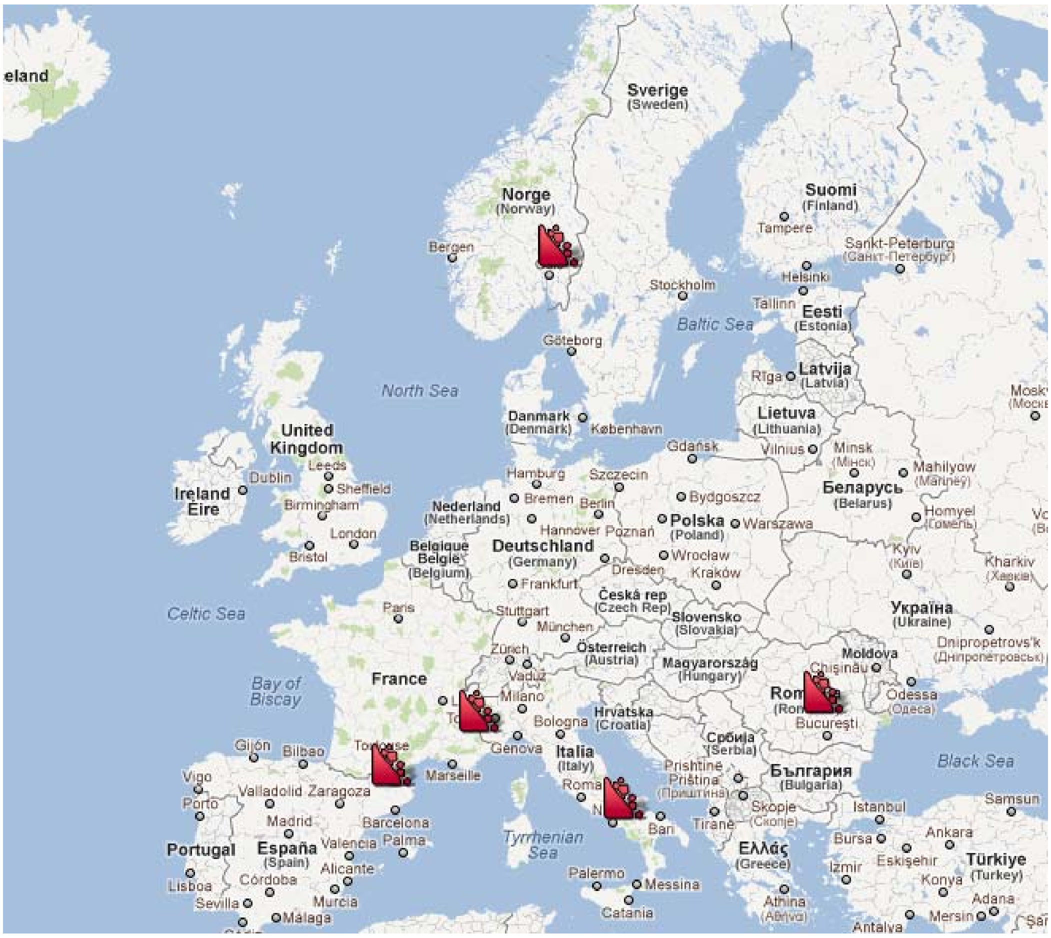


Figure 1 Location of test sites among Europe (Google Maps)

2.1 NORWAY, NEDRE ROMERIKE

The Nedre Romerike area included in this study comprises the following municipalities which are part of the county of Akershus: Fet, Gjerdrum, Nannestad, Rælingen, Skedsmo, Sørum and Ullensaker. This region lies to the East of Oslo, the capital of Norway (see *Figure 2*). The total population in 2010 was about 160 000+ habitants, which constitutes more than 30% of the total population of the Oslo suburbs. In addition to the urban areas, Nedre Romerike includes important industrial and agricultural areas. Land use plans from authorities consider urban expansion for the next 100 years. The study area is widely covered with marine deposits (clayey soils) and many slopes are of marginal stability. The main triggering factors for landslides are human activity (anthropogenic) and precipitation.

Figure 2 (left) Location of the Nedre Romerike site. (right) Typical landslide on marine deposits, similar to the ones included in the inventory used in the present study (Jaedicke and Kleven, 2008).

2.2 ITALY, CAMPANIA REGION AND PIZZO D'ALVANO SITE

The Campania region is situated in the South of Italy and covers 13 595 square kilometers to the West of the Apennine Mountains (*Figure 3, left*). The mountainous area of this region has been directly or indirectly modeled by volcanic activity in the region: the Somma-Vesuvius and the Phlegraean Fields have been active during the last 22,000 years, the last eruption of Vesuvius dating from 1944. Over a period of time, the slopes of the mountains near these volcanoes have been covered by wind-blown pyroclastic materials, creating a mantle covering irregularities in the calcareous bedrock. This cyclic deposition of air-borne volcanic material, separated by periods of weathering, has created a complex layered structure of often loose, low density materials prone to landslides.

In fact, Campania has been the site of very destructive landslides over time. A quite recent example took place in Sarno (*Figure 3, right*), in May 1998, and killed 161 persons. The landslides in this area generally begin with small debris slides on steep slopes that develop into large debris flows. Then, the phenomena evolve into hyper-concentrated stream flows due to the dilution by water, which can travel over many kilometers and are highly destructive.

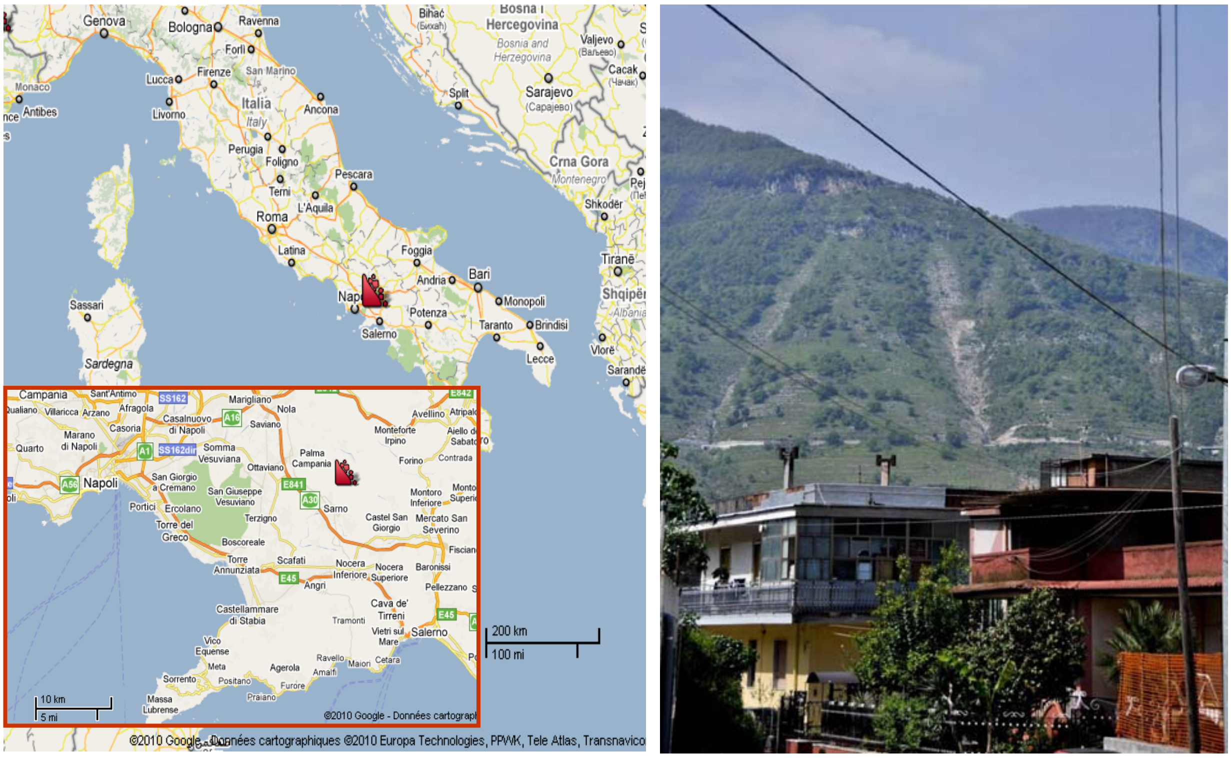


Figure 3 (left) Pizzo d'Alvano site location: general view and zoom in (Google Maps) (right) Sarno site (Photo: A. Baills)

Within the Campania region, Pizzo d'Alvano site has been chosen as a test site. Pizzo d'Alvano comprises a group of_rainfall-induced shallow, flow type landslides in pyroclastic soils for which six different triggering mechanisms have been detected on the basis of the predisposing and triggering factors, as well as of the corresponding landslide source areas. The estimated volume of the landslide is 2 million m^3 for a surface of 800 000 m^2.

2.3 FRANCE, BARCELONNETTE SITE

The Barcelonnette site (*Figure 4*) is a 200 km² zone, situated in the South of France in the département Alpes de Haute Provence. It is located in a mountainous area, reaching altitudes of approximately 3100 m, with an average altitude of 1100 m, and is crossed by the Ubaye River.

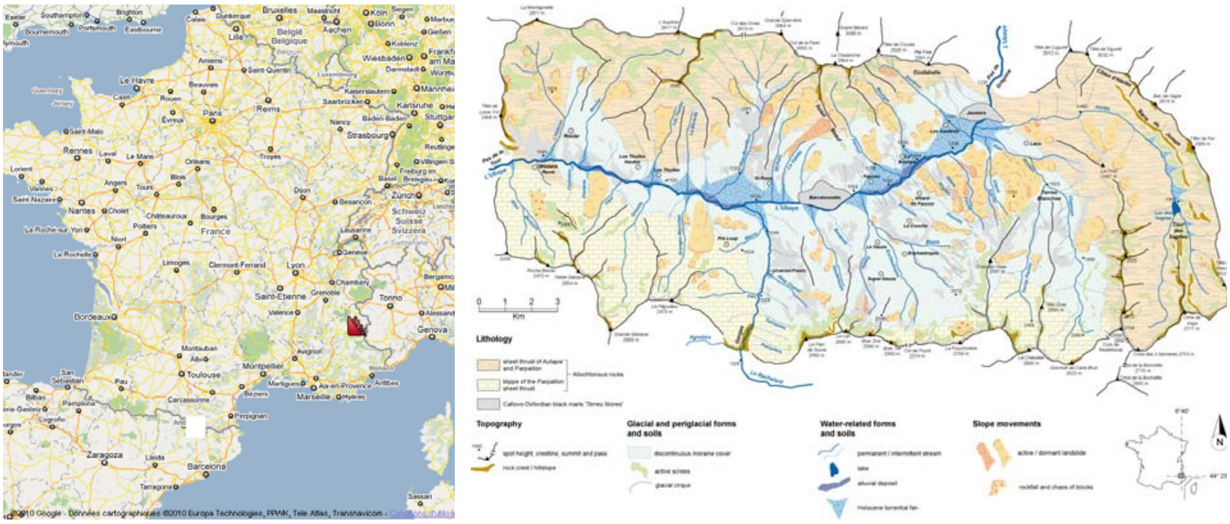


Figure 4 (left) Barcelonnette site location: (Google Maps) and (right) Geological map of the Barcelonnette site, with in particular the location of active and dormant landslides (http://eost.u-strasbg.fr/omiv/barcelo_area_intro.html)

The landslide hazard is important in this area, the slopes being notably affected by severe gullying, shallow landslides, and deep-seated large landslides (for example La Valette and Super-Sauze, see *Figure 5*).

Figure 5 La Valette (left) and Super Sauze (right) landslides (Photos: A. Baills)

In fact many factors that tend to make slopes unstable are present in this area: the predisposing geological structure of the basin (*Figure 4 (right)*), the presence of steep slopes and of a complex geomorphism that have been carved out by the slow erosion of glaciers and torrents, the dry and mountainous Mediterranean climate, with strong inter-annual rainfall variability and finally the scarcity of vegetation, the slopes having been cleared for cultivation which has begun during the Roman period and reached a maximum of activity in the middle of the 20th century. (http://eost.u-strasbg.fr)

2.4 SPAIN, VALLCEBRE LANDSLIDE

Vallcebre is a Spanish town situated in the Eastern Pyrenees, 140 km North of Barcelona (*Figure 6*, left). A large and active translational landslide is located near this town, on the eastern slopes of the torrents of Vallcebre and Llarg (*Figure 6*, right). This huge landslide, whose active part is estimated of 1200 meter in length by 600 m wide (that is, an area of 0.8 km²) comprises a set of shale, gypsum and claystone layers gliding over a thick limestone bed.

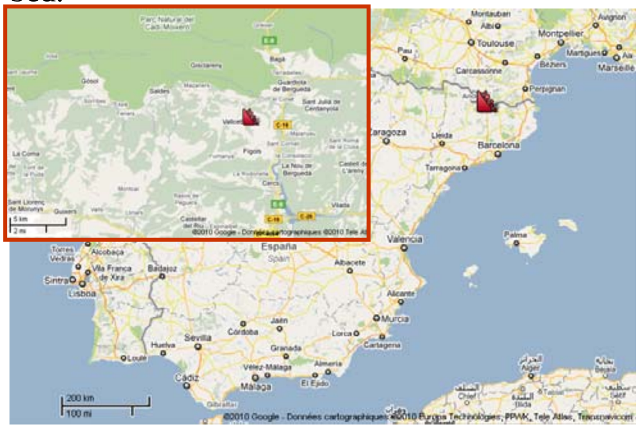


Figure 6 (left) Vallcebre site location:general vue of Spain and local map (Google Maps). (right) General view of the Vallcebre landslide

The slope, whose average inclination is around 10°, shows superficial cracking and a stair-shape profile, three main slide units of a few tens of meters high each having clearly been identified. The Vallcebre torrent plays an important role in the activity of this landslide, the foot of the landslide being continuously eroded by this torrent. This landslide has been studied in depth in the past, including by means of instrumentation with inclinometers, extensometers and piezometers that were being installed in 1997 (Corominas and Santacana, 2001)

2.5 ROMANIA

Telega is situated 5 km from Campina, in the western part of Prahova County (*Figure 7*). This village is located in a medium-altitude area (550m), in a region characterized by rugged landscapes, where water often accumulates as lakes and swamps. Slopes are often very steep, cut by many fissures, and constituted by very complex layered structures. All of these factors contribute to the existence of multiple areas prone to landslides. For instance, on the left bank of the Telega valley several slides have occurred, affecting areas of importance for the presence and production of salt, Romania holding the largest salt reserve in Europe. This salt has also an important influence on the instability of slopes.

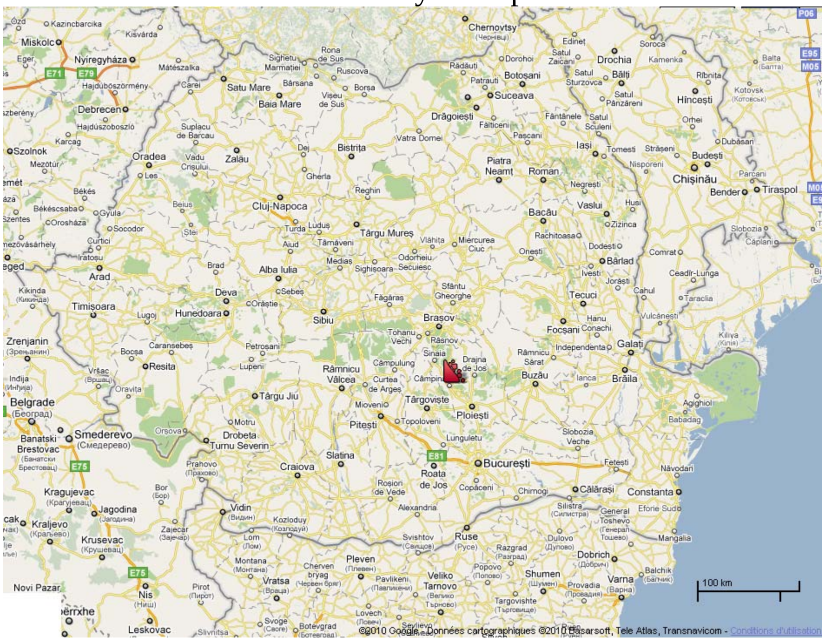


Figure 7 Site location (Google Maps)

3 CONTROLLING FACTORS AFFECTING LANDSLIDE RISK

Human activities may affect landslide hazard both positively and negatively by making triggering conditions more or less likely, usually by modifications to the topography, hydrology or hydrogeology (see deliverable D1.6, Analysis of landslides triggered by anthropogenic factors in Europe). In addition, human beings and their artefacts (buildings, infrastructure, etc) form the elements at risk and the associated patterns of use of these artefacts have a significant influence upon the vulnerabilities to a specific hazard.

It is thus clear that a variety of change scenarios that are not of a climatic origin must be considered.

3.1 DEMOGRAPHY

3.1.1 Elements at Risk

Demographic changes will directly affect the elements at risk by means of increases or decreases in the population and/or the population density. Such changes may be effected by the construction of new buildings (a more likely scenario) or by more (or fewer) people inhabiting existing buildings. Each is likely to have an effect on both the local population and the local population density and, dependent upon the spatial interaction with the landslide hazards, may increase the elements at risk in terms of both buildings and people. Indeed, the construction of new buildings is likely to place people in previously unoccupied areas and may thus introduce new risks.

Demographic changes also affect the elements at risk on linear transport infrastructure. An increase in the population of a town or village inevitably increase the traffic levels on roads connecting it to the outside world and thus the number, and value, of vehicles and road users using it at any given point in time also increases (see also Section 3.3.2).

3.1.2 Vulnerability

As studied in deliverable 2.6 ("*Methodology for evaluation of the socio-economic impact of landslides (societal vulnerability)*"), the age demographic, and other features (such as wealth, employment) of the population may have an effect upon the vulnerabilities to the landslide hazard. The young, old and disabled may all be less mobile than others and such mobility issues must be dealt with during the evacuation. In addition, such demographic groups may also be more vulnerable to the physical effects exerted by the hazard although this is considered to be an issue somewhat too detailed for the present study

3.1.3 Hazard

As mentioned in deliverable D 1.1 (Landslide triggering mechanisms in Europe – Overview and state-of-the-art) and deliverable D1.6 (Analysis of landslides triggered by anthropogenic factors in Europe), changes in stability conditions due to man-made works, such as slope modifications (e.g. undercutting of the toe), is one of the "most common and most obvious causes of landslides" (Terzaghi, 1950). Construction of new roads, railways or other lifelines (gas pipelines, water pipelines…) requires excavation works, modifications to slope profiles and drainage, and have the potential to result in an increased hazard, if poor construction practices are applied.

Moreover, infrastructure interferes with *inter alia* hydrological processes, modifying the evapotranspiration processes and infiltration paths, resulting in changes in soil humidity and water table. Thus changes to infrastructure assets can either mitigate or exacerbate the consequences of changes in rainfall patterns. Furthermore, the construction (or destruction/demolition) of infrastructure (e.g. buildings, dams, linear infrastructure) modifies the loads applied to slopes. Such modifications may make the slopes more unstable and may combine with induced vibrations from traffic or mining activities.

However these changes of slopes stability might not immediately result in instability. There can be preconditioning situations, which could be degraded in the future, for example during a future heavy rainfall event.

Equally, it is important to note that competent and well-considered construction of, for example, linear infrastructure can be ‘hazard-neutral’.

3.1.4 Elements at Risk

New infrastructure construction will introduce additional elements at risk, which are likely to be of higher value than the elements that they replace. Such infrastructure also can provide a degree of protection to elements previously at risk: linear infrastructure cuttings can function, albeit inadvertently, as a debris trap for example providing protection to elements at risk further down slope

It is also worth noting that as infrastructure ages its condition may also deteriorate, regardless of the maintenance regime applied during its in-service life. While this implies that its value may decrease, in monetary terms as the costs of restoration to an as new’ condition increases, its value as an asset is likely to be dependent upon, and proportionate to, the population that it serves and, by extrapolation, depends upon it for transport, electricity, etc (see also Section 3.2.1).

3.1.5 Vulnerability

The impacts of damage to linear infrastructure can have an impact much more widespread than the limited footprint of the hazard as the vulnerability shadow often extends across a much wider area. The severance of electricity lines for example can deprive many thousands of households of power often during periods of heightened vulnerability due to other hazards such as adverse weather conditions and/or earthquakes.

Damage to, or destruction of, linear transport infrastructure can sever the access of populations to social and economic activities: these activities might include access to education, healthcare, leisure and employment opportunities; tourism; and the import and export of goods. The geographic extent of such populations can be significant casting an extensive vulnerability shadow from a relatively small landslide hazard footprint.

A real-world example of a small event footprint casting a large vulnerability shadow can be found in Jamaica. A relatively small landslide event destroyed a short length of the B1 road which severed the most direct route for the transport of high value Blue Mountain C of fee from its source to its point of export. This clearly demonstrates how a single, isolated event can cast a large vulnerability shadow and have a far greater than anticipated impact. (Winter and Bromhead, 2008).

3.2 LAND COVER

Change in land cover (either due to human actions or as a result of natural processes) will also modify landslide risk patterns.

3.2.1 Hazard

In addition to changes due to urbanization (see Section 3.1), modification of the land cover will affect landslides hazards, mostly due to the evolution of the vegetation cover. Indeed, on the one hand, the resulting change of hydrological process (infiltration, evapotranspiration but also suction) and loads (e.g. the effects of changes in agricultural activities) might modify the triggering mechanisms and so modify the occurrences of landslides. On the other hand, modification of the land cover will also influence the volume of materials moved, due to a modification of the soil cohesion (with roots and other aeration processes).

It is important to note that the changes to land use can have positive and negative impacts on instability.

3.2.2 Elements at Risk and Vulnerability

Changes in land cover will also modify both the elements at risk and the associated vulnerabilities. This may be directly as a result of changing socio-economical activities in area, with associated changes to the potential losses. It may also occur indirectly as a result of modifications of the susceptibility of the area; for example, a forested area might help to bind the soil mass together with the tree roots, decrease infiltration and increase water uptake thus inhibiting mass movement, although this is not always the case, whilst bare soil will facilitate infiltration of water and potentially encourage mass movement.

4 METHODOLOGY

This deliverable aims to gather the current and prospective data for the mapping of landslide evolution at selected hotspots.

The lack of available data is the main challenge for each of the test sites studied. Ideally local maps of demography, land cover and infrastructures data for both present time and future dates would be available, but they seldom exist.

The first step at each of site is a precise assessment of the existing data. In the absence of specific prospective scenarios, present and past data is necessary to build scenarios of evolution.

If scenarios have to be built, and as the construction of detailed prospective scenarios for all factors and all sites is beyond the scope of the work reported here, simplified methods are used. The amount of detail that is contained with the scenarios depends upon regional patterns derived from European Scenarios (Deliverable 3.5, "*Overview on and interpretation of available data and information of human activity and demographic evolution*") and/or on past and present data to determine likely evolution of demography, land cover and infrastructure.

4.1 THE PROSPECTIVE RATE OF EVOLUTION

In order to quantitatively assess the evolution of key indicators at local sites, two methods have been selected and then compared.

The first based on the downscaling of the larger scale predictive patterns (if they exist) to local sites. This method assumes that the evolutionary processes will be reasonably similar, regardless of the scales. Thus the prospective rates of evolution at local sites will be equal to the ones previewed for larger areas (regional or national scale)

The second relies on the extrapolation of tendencies from past and present data. The main assumption of this method is that the evolutions will continue to follow current trends. Thus this method supposes that the causes of, or reasons for, evolutions will remain reasonably stable (disputable hypothesis)

For instance, considering the demography factor, the rate of progression could be an increase of 50% of the population by 2050 in the area considered or a decrease of 10% in rural areas.

4.2 THE PROSPECTIVE SPATIALIZATION RULES

These rules describe the way some factors are likely to develop in a spatial sense (i.e. as represented on a map). For example, for a town or a village, it could be an urbanisation concentrated along the main roads, or a circular growth. It would mainly be determined from the extrapolation of past and current tendencies as these patterns are more likely to be city-specific than homogeneous over a large region, thus these rules would be mainly determined from the extrapolation of past and current trends.

4.3 THE PROSPECTIVE ECONOMIC STUDIES

With the exception of very specific cases, economic scenarios could be driven from the area patterns. Thanks to this simplified methodology, prospective scenarios for the different factors at the five selected hotspots may be constructed.

4.4 REVIEW OF NECESSARY DATA

Some data appear essential to conduct a consistent analysis of the human activities and to build scenarios. This data set is summarized in *Table 1* according to the level of impact: hazard, exposure or vulnerability.

Table 1: Necessary data impacting human activity studies at different levels

Categories	Description		Units	Spatial resolution	Hazard	Exposure	Vulnerability
Population	building occupancy	quantitative	number of inhabitants	buildings		*	
	population density	quantitative	inhabitants / m²		(NGI model)	*	
Social vulnerability	aggregation of indicators regarding social vulnerability	Quantitative / semi-quantitative	% or classes				*
Land use	land use	qualitative	categories		*	*	*
Economy	building values	quantitative	values of buildings	buildings		*	
	turn-over	quantitative	income/year			*	
Infrastructure	road traffic	semi quantitative	cars/road	road	*	*	*

5 APPLICATION TO TEST SITES

5.1 FRANCE, BARCELONNETTE SITE

5.1.1 Demography

5.1.1.1 Permanent Population

The INSEE, has gathered information in several censuses at the national scale. The population surveys of five municipalities surrounding Barcelonnette are available for six different dates (*Table 2*).

Table 2 Population of the towns of the studied site from 1968 to 2006 (INSEE, December 2008)

	1968	1975	1982	1990	1999	2006
Barcelonnette	2476	2626	2735	2976	2815	2818
Enchastrayes	322	365	437	474	507	439
Faucon-de-Barcelonnette	153	128	113	199	209	296
Jausiers	628	681	747	860	891	1013
Saint-Pons	178	350	401	507	641	675
Total (5 municipalities)	3757	4150	4433	5016	5063	5241

However, as these municipalities are quite small and the figures are affected by singular events. For example the construction of a private housing estate or the closure of an important factory may significantly change the demographic pattern of the area. Consequently it is impossible to estimate accurately how population will evolve in the relatively near future (2030) at this scale. This is confirmed by INSEE surveys, which only provides prospects at French “département” scale and not at larger scale. The INSEE forecasts for the Alpes de Haute Provence département (which is the département of the five municipalities considered) are summarized in the *Table 3*.

Table 3 Population prediction for the period 2010-2030 for the département Alpes de Haute Provence

	2010	2015	2020	2025	2030
Alpes de Haute Provence	160 837	168 264	175 964	183 818	191 410

These prospective figures of the département population can be used to roughly estimate the population of the five municipalities in 2030. Assuming that the municipalities’ population will represent the same fraction of the département population in 2006 and in 2030, the following prospective figures have been obtained (*Table 4*):

Table 4 Forecasts for 2030 for the population and the density of the towns of the studied site computed from INSEE forecasts for the département Alpes de Haute Provence

	Population		Density	
	2006	2030	2006	2030
Alpes de Haute Provence	154501	191 410	22.3	28
Barcelonnette	2818	3491	171.63	213
Enchastrayes	439	544	9.93	12
Faucon-de-B.	296	367	17	21
Jausiers	1013	1255	9.41	12
Saint-Pons	675	836	21.05	26

The past evolution of the population in the municipalities and in the département demonstrates that this method is by no means perfect. In fact, if we apply the method to the 1990 figures assuming that the municipalities' population represents the same fraction of the département population in 1990 and in 2006, we obtain forecasts for 2006 population which are quite different to the survey figures (*Table 5*):

Table 5 Validation of the above-exposed method applied on 1990-2006 and the population registered in the 2006 census

	1990	2006 (survey figures)	2006 (population prospects using the above-exposed method)	absolute error	relative error
Barcelonnette	2976	2818	3513	695	23%
Enchastrayes	474	439	560	121	25%
Faucon-de-B.	199	296	235	-61	31%
Jausiers	860	1013	1015	2	0%
Saint-Pons	507	675	598	-77	15%
Alpes de Haute P.	130883	154501	154501	-	-

Absolute and relative errors are quite important, despite the fact that it is only a 16 years prospect.

Consequently, another prospective method has been employed to produce more reliable forecasts: the evolution rates (inhabitants/year) of the population between each census have been calculated and for each town, the maximum and minimum values have been noted (see *Table 6*). These ratios have been applied to the population figures of the last census (2006): low and high predictions for 2030 have been obtained. The 2030 population will most probably be in this range of values. The details of the results derived from this methodology are given in *Table 7*, and *Figure 8*.

Table 6 Evolution rate of the population (inhabitants/years) computed from the population figures.

	1968-1975	1975-1982	1982-1990	1990-1999	1999-2006
Period (years)	7	7	8	9	7
Barcelonnette	0.87%	0.59%	1.10%	-0.60%	0.02%
Enchastrayes	1.91%	2.82%	1.06%	0.77%	-1.92%
Faucon-de-Barcelonnette	-2.33%	-1.67%	9.51%	0.56%	5.95%
Jausiers	1.21%	1.38%	1.89%	0.40%	1.96%
Saint-Pons	(13.80%)	2.08%	3.30%	2.94%	0.76%

Table 7 Minimum and maximum values predicted for 2030 with the second method described

	Ratio min	Ratio max	2030 min	2030 max	Density min	Density max
Barcelonnette	-0.60%	1.10%	2411	3563	146.9	217.0
Enchastrayes	-1.92%	2.82%	237	736	5.4	16.6
Faucon-de-B.	-2.33%	9.51%	130	972	7.5	55.8
Jausiers	0.40%	1.96%	1110	1489	10.3	13.8
Saint-Pons	0.76%	3.3% (13.80%)	798	1210 (2911)	24.9	90.8

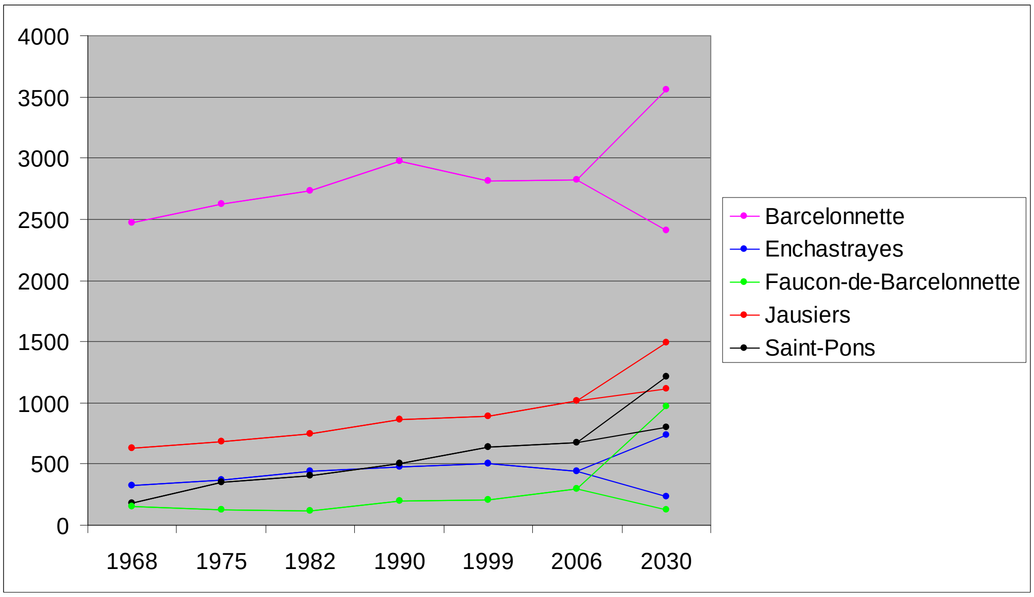


Figure 8: Evolution of the population forecasted with the second method

It should be noted that the forecasts made with the two methods are not contradictory: the forecasts from the first method are within the range of values calculated with the second method.

5.1.1.2 Non-permanent residents

The economy of the Barcelonnette area depends heavily upon tourism. In fact, The Ubaye Valley, which is included within this site, is well known for its ski resorts. The Sauze Super Sauze ski resort, which is located near Enchastrayes, and the Pra Loup resort, situated near Barcelonnette, have an important influence on the seasonal demography of the area. In fact, these facilities generate an important population of non-permanent residents during the tourist seasons. These people should be considered in this study, because they could also be impacted by landslides.

a) Accommodation capacity

To estimate this non-permanent population, the number of second homes detailed in INSEE reports has been considered (*Table 8*). As the evolution of these values was quite steady in the past, it seems acceptable to extend the trends until 2030 with linear regressions (nevertheless, values before 1990 have not been used for the regression, in order to ensure that current evolution trends only are considered for this indicator):

Table 8 Evolution of the number of secondary homes observed by INSEE between 1990 and 2006. Forecast for2030.

	1 968	1975	1982	1990	1999	2006	2030
Barcelonnette	240	385	670	1 141	1 451	1513	2121
Enchastrayes	93	432	1 172	1 659	1 686	1830	2052
Faucon-de-B.	24	44	50	81	92	102	133
Jausiers	196	149	420	554	605	648	788
Saint-Pons	38	98	139	133	165	200	298

The two previously mentioned ski resorts clearly have a great influence on the nearby towns of Enchastrayes and Barcelonnette, with the presence of more than a thousand secondary homes in these towns in 1990. There is also an increasing number of secondary homes in Jausiers, probably because of the presence of the small ski resort of Saint Anne, which is located some 10 km from the town.

The number of hotel rooms and the number of campsites must also be considered to evaluate accurately the non-resident population. Here the data available are over a shorter period and so the projection is not so straightforward as for the previous data. Nevertheless, the forecast made for the number of secondary homes can be used, assuming the fact that all these infrastructures are based on the same accommodation needs of tourists. That is to say the construction of hotels and camp sites and the construction of second homes are both dependent upon the same factors: town policy, attractiveness of ski resort, existence of building lands, etc. As the data gathered on hotels and camp sites cannot be extrapolated easily, the prediction for the future capacities of campsites and hotels are be based on the previously calculated evolution of the number of secondary houses. For instance, in 2030, for Barcelonnette municipality a capacity as follows was forecast: 199 (capacity of 2009)* 2121 (number of secondary houses predicted for 2030)/1513 (number of secondary houses in 2009) = 266 (capacity in 2030).

Consequently, the following prospective figures were obtained

Table 9 Capacities of the campsites in the test site from 2003 to 2009 and prediction for 2030

	2003	2006	2009	2030
Barcelonnette	201	188	190	266
Enchastrayes	66	66	66	74
Faucon-de-B.	0	0	0	0
Jausiers	36	36	36	44
Saint-Pons	0	0	0	0

Table 9 forecast no further ahead than 2030 figures as the past evolution is not steady enough to extrapolate over a greater period.

Table 10 Hotel capacities for the test site from 2003 to 2009 and prediction for 2030 (rooms)

	2003	2006	2009	2030
Barcelonnette	78	88	91	128
Enchastrayes	136	131	65	73
Faucon-de-B.	0	0	0	0
Jausiers	26	28	28	34
Saint-Pons	0	0	0	0

Finally, the occupancy rate of these facilities must be estimated.

<u>b) Occupancy rate of camping and hotels</u>

It is considered that two constant values are sufficient to approximately model the evolution of the occupancy rate during the year, one for the tourist season and the other for the rest of the year. In fact, this ratio is highly variable: for example the occupancy rate is expected to be much higher during some weekends compared to during the week (see *Figure 9*).

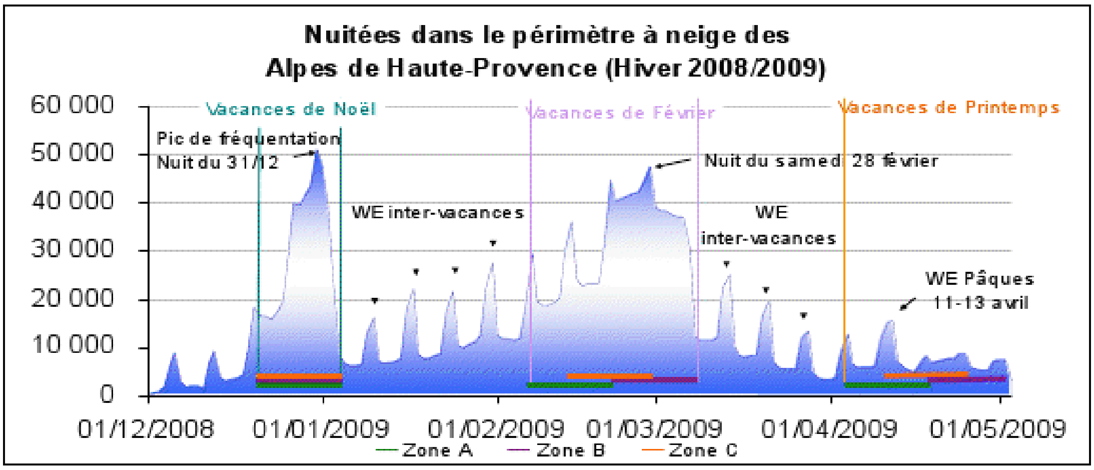


Figure 9: Evolution of the number of overnight stays during the winter 2008/2009 in the département Alpes de Haute Provence, for the hotels near the ski resorts (Observatoire du Tourisme des Alpes de Haute Provence, 2007).

Data on the occupancy rate of hotels in the towns has not been found. However, a good estimation of this ratio can be made by exploiting a small number of published facts. For instance Observatoire du Tourisme des Alpes de haute Provence (2007) states that six out of ten of the overnight stays during the winter are made in the Christmas holidays and the winter holidays in the département. INSEE also provides monthly information about the occupancy rate for the Alpes de Haute Provence département (*Table 11*, INSEE, 2010).

Table 11 Distribution of the overnight stays during the year in the département Alpes de Haute Provence (percentages).

	2007	2008	2009
January	30.3	33.6	34.6
February	41.0	48.5	43.8
March	35.5	37.4	37.0
April	45.9	42.6	41.3
May	51.1	50.8	53.4
June	58.5	56.1	59.9
July	67.5	68.5	67.6
August	76.0	80.9	77.2
September	63.0	58.9	58.8
October	42.9	41.2	45.4
November	35.8	30.3	34.1
December	34.8	35.5	32.9
mean value	48.5	48.7	48.8

There are several main holiday periods in France: two weeks for Christmas holidays, four weeks for winter holidays and four weeks for spring holidays (three successive holiday periods) and finally around 6 weeks of summer holidays.

The data illustrated in *Table 10* demonstrates that the occupancy rate is stable over the three year period 2007 to 2009 at around 50%. It is further assumed that the occupancy rate is about 75% during summer, winter and Christmas holidays. (This figure is observed for August and it is assumed that it is a good approximation for the other high season periods.) That means that during 16 weeks of the year the occupancy rate is 75%. If we also assume that the 36 other weeks of the year correspond to low season with an occupancy rate of x, the following formula gives the x value:

$16*0.75+36*x=0.5*52$ which means, $x=39\%$

That means we can use as an approximation an occupancy rate in low season of 40%.

<u>c) Occupancy rate of secondary homes</u>

It is difficult to find statistics regarding the occupancy rates of second homes; this will impact greatly upon the precision of the estimates. Consequently, a few hypotheses have been made to quantify this occupancy rate.

The French national institute of statistics indicates that 200 millions nights per year are spent in the 3 millions second homes in France (http://www.insee.fr/fr/themes/tableau.asp?ref_id=NATTEF05455&reg_id=0). This means that second homes are inhabited for 66 nights each year by the owner or their family / friends.

Considering that the high season represents 18 weeks, second homes are occupied for 52% of the high season period much as was found for the hotel occupancy rate in the département Alpes de Haute Provence (*Table 10*). In order to account for the commercial rental of second homes a slightly higher percentage should be considered. Although this is purely an assumption, it seems reasonable to consider that 25% of the second homes are rented for six weeks (four weeks in summer and two weeks in winter), which leads to the following assumption: second homes will be considered empty during low season and 60% occupied in high season.

d) Estimation of seasonal workers

During the tourist season, the proportion of seasonal workers in the mountainous areas of the region Provence-Alpes-Cote-D'Azur can approach 25% of the total number of salaried workers (SUD INSEE, 2007). Considering that seasonal workers only work during the high tourist season and that the number of seasonal jobs follows the same evolution as the capacities of the hotels, an approximate (high) estimate of the seasonal workers can be provided for that period.

Table 12 Evaluation of the number of seasonal workers in 2006 and prediction for 2030

	2006		2030	
	High season	Low season	High season	Low season
Barcelonnette	285	0	370	0
Enchastrayes	44	0	57	0
Faucon-de-Barcelonnette	4	0	5	0
Jausiers	66	0	86	0
Saint-Pons	29	0	38	0
Total	428	0	556	0

e) Estimation of the non-permanent population

Finally, knowing that the second homes when occupied are inhabited by 3.5 persons on average (3S Marketing, 2009), the numbers of non-permanent residents in the towns of the site in 2006 are estimated, and then calculated for 2030. The results are given in *Table 13*.

Table 13 Evaluation of the number of non-permanent residents in 2006 and prediction for 2030

	2006		2030	
	High season	Low season	High season	Low season
Barcelonnette	4235	386	5927	552
Enchastrayes	4439	276	4778	206
Faucon-de-Barcelonnette	218	0	285	0
Jausiers	1604	90	1959	109
Saint-Pons	449	0	663	0
Total	10945	752	13612	867

These evaluations and estimations must be treated with caution, as they are based on several assumptions, approximations and estimates.

Local population forecasts beyond 2030 are too uncertain to be relevant. Indeed, the INSEE provided forecasts for 2050 only at the national scale. It is not realistic to suppose that the Ubaye Valley population will follow the same trends as the whole country while a substantial part of the population is concentrated in big cities.

5.1.2 Infrastructure

The evolution of infrastructure vulnerability will be treated within WP 3.3 and integrated in Del. 3.9.

5.1.3 Land cover

5.1.3.1 First approach

Several land cover maps of the Barcelonnette site are available from 1974 to 2006. These maps are provided by different sources and it is therefore difficult to compare them. Indeed they do not cover exactly the same area and they use different land cover classification. The IPGS[1] and CLC[2] data include 15 land cover categories whereas CRIGE data include 19.
Moreover there are some significant differences between the 2006 data from CLC and CRIGE. If we take the example of Bare Rocks, the total surface area covered according to the two sources are not so different: 9734 ha for CLC and 9904 ha for CRIGE[3], but the congruent areas described as Bare Rocks by both data sets only represents 5821 ha. This leads to the decision to compare data from one source.

Thus land cover data from the same source at the different dates available have been compared: IPGS (1974, 1982, 2004), CLC (2000, 2006) and CRIGE (1999, 2006). For each of the data sources, the evolution of urban and forest areas of land cover, which are important from the point of view of landslide risk, are described.

5.1.3.1.1Descriptions of the different land cover maps

a) <u>Land cover maps from IPGS between 1974 and 2004</u>

As can be seen on the 2004 land cover map (*Figure 10*), these data do not cover the entirety of the study site.

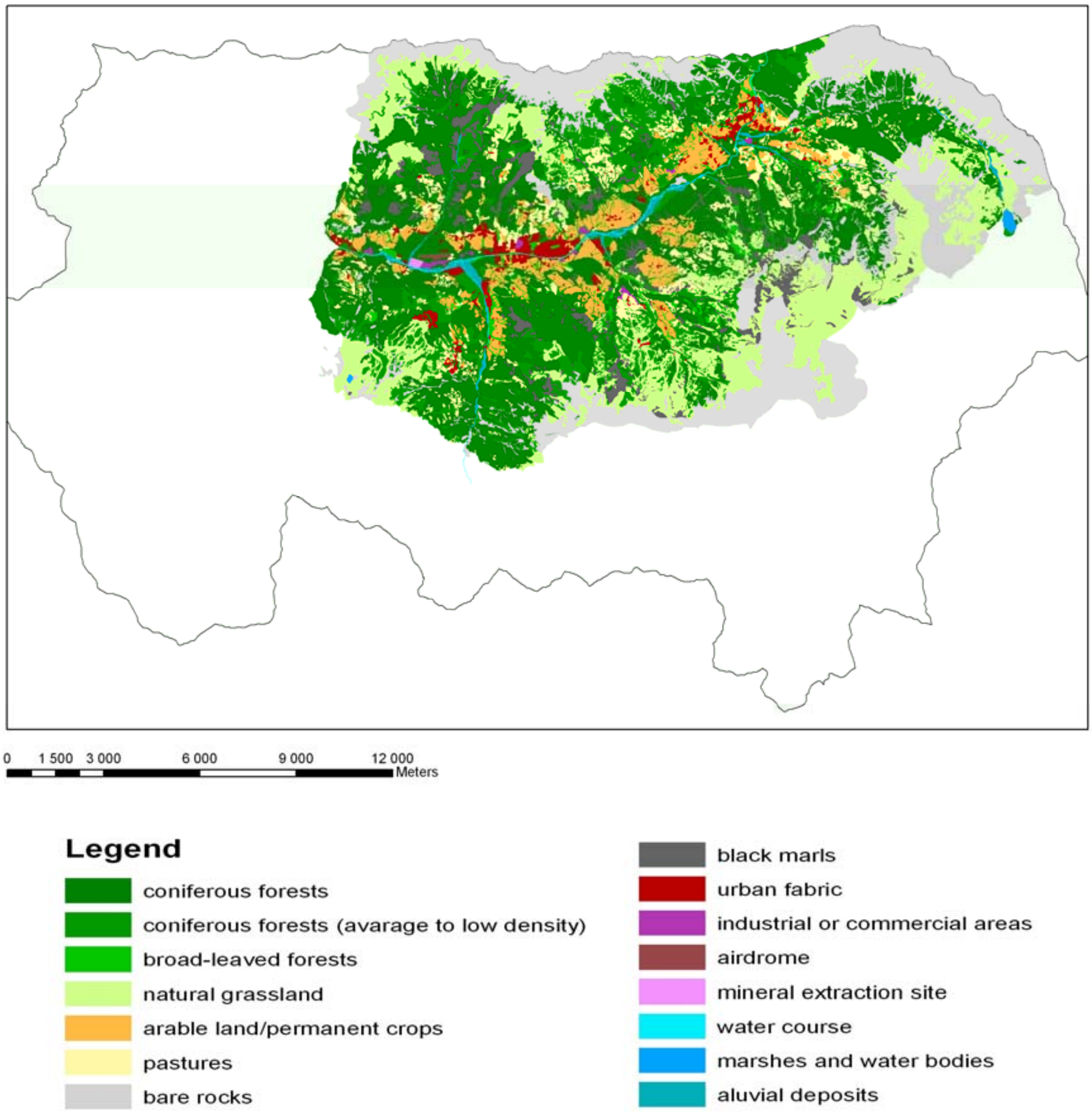


Figure 10 Example of 2004 land cover map (IPGS)

b) Land cover maps from CLC between 1990 and 2006

Data from CLC, which covers the whole site, is available for three different dates: 1990, 2000 and 2006 (*Figure 11*). The data set provided for 2000 is very similar to the one provided for 2006. Indeed, the only changes are a change of 113 ha from "Coniferous forest" to "Transitional woodland – shrub" and 5 ha from "Land principally occupied by agriculture" to "Sport and leisure facilities". Comparing data sets between 1990 and 2006, we can determine the evolution of forests and urbanized areas (see below).

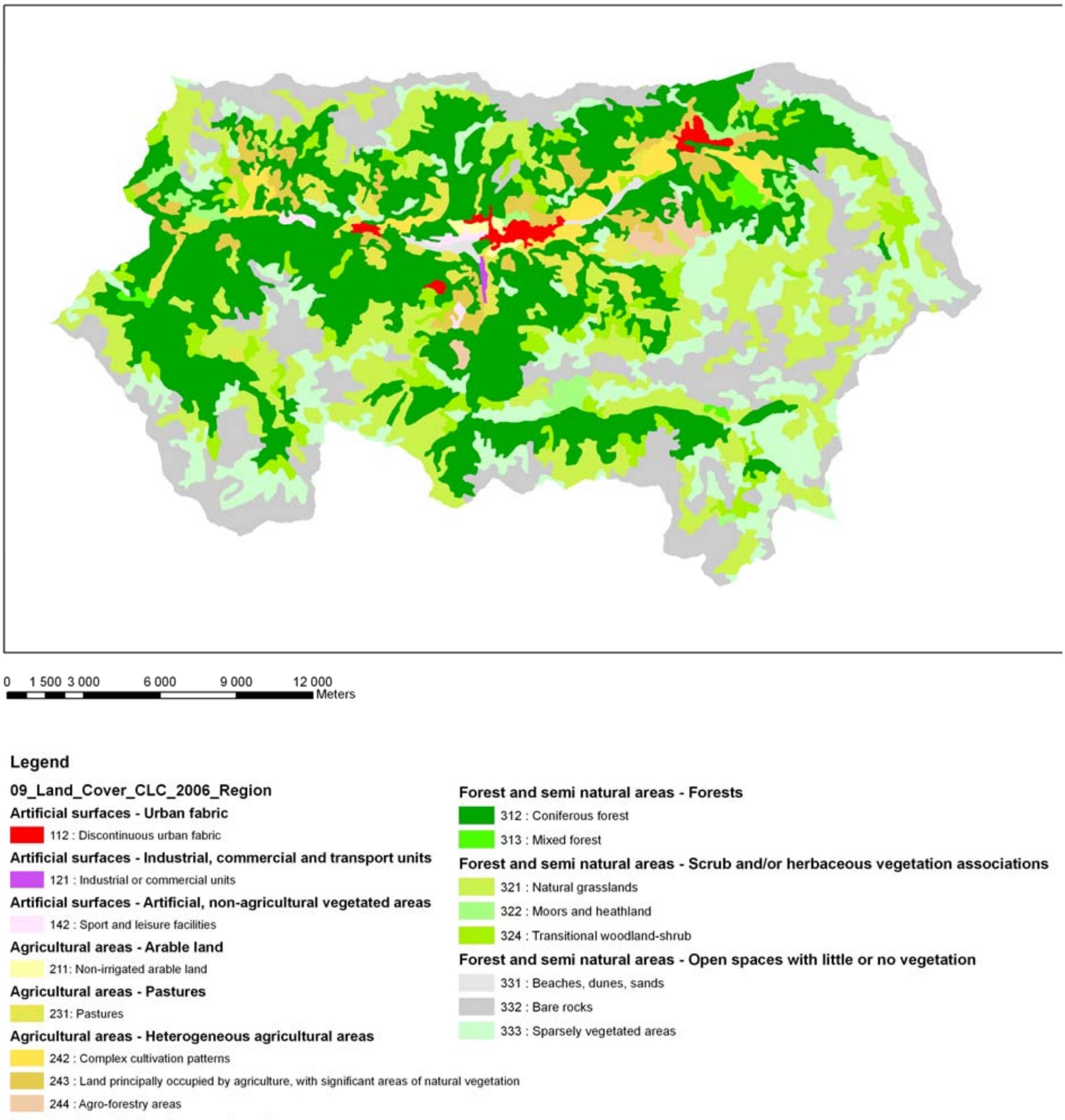


Figure 11 Example of 2006 land cover map (CLC)

c) Land cover maps from CRIGE between 1999 and 2006

Figure 17 illustrates the land cover map of the area in 2006. The main land cover shown is forest.

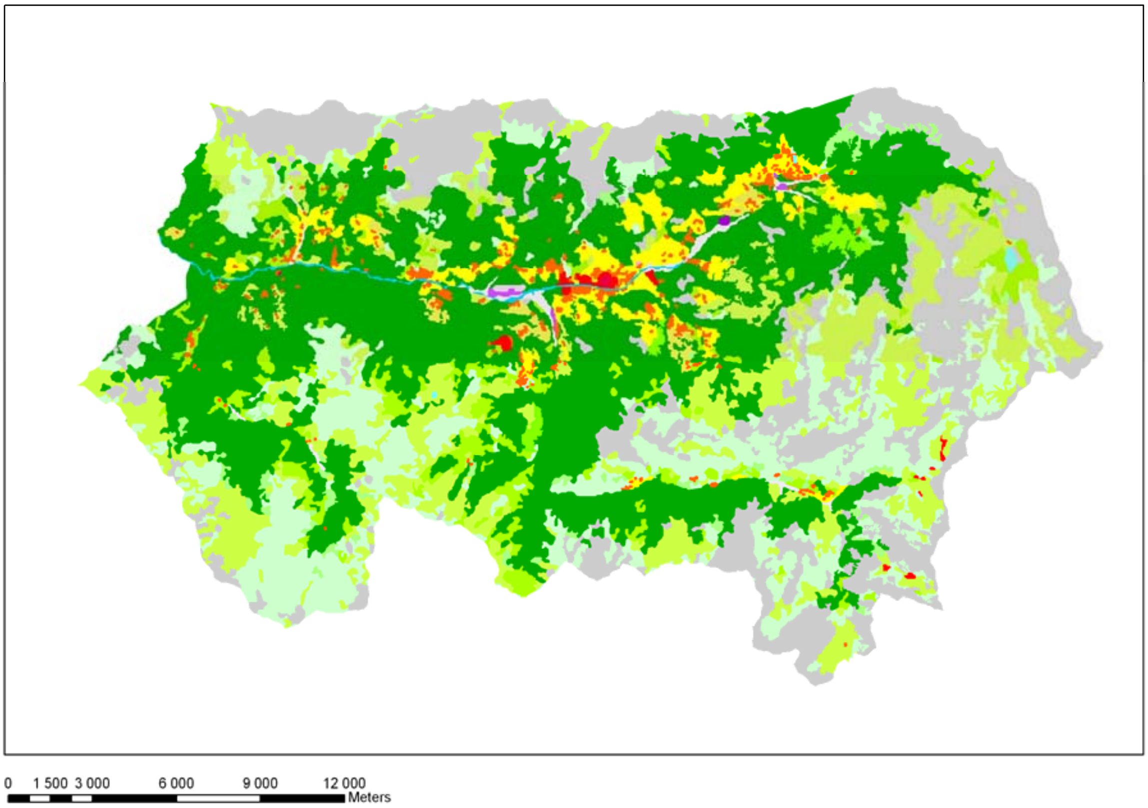


Figure 12 Example of 2006 land cover map (CRIGE)

5.1.3.1.2Evolution of forest areas

For IPGS data, it is possible to examine the evolution of forest areas (including coniferous and broad-leaved forests) in this area (*Figure 13* (IPGS)).

The congruent forest area between 1974 and 2004 data sets represent 6424 ha, while 558 ha have been deforested (mapped as forest in 1974 and not in 2004) and 1800 ha reforested (not mapped as forest in 1974 but mapped in 2004). This corresponds to an increase in forested areas of 19% in 30 years.

Analysis of the CLC data sets (*Figure 14*), illustrates rather different trends as the forest area remains almost constant between 1990 and 2006 regardless of the forest type considered (broad-leaved forest, coniferous forest or both). Considering only coniferous and mixed forests, for example, 15,843 ha has remained wooded between 1990 and 2006, 518 ha have been deforested and 800 ha reforested in 16 years, which corresponds to less than 2% of deforestation.

CRIGE data (*Figure 15*) do not show any deforestation between 1999 and 2006, while the area covered by broad-leaved, coniferous and traditional woodland has barely changed from 21,557 ha to 21,746 ha.

According to IFN, the forests of the whole Alpes de Haute Provence have increased by 6 to 17% between 1985 and 2005/06 and the département is now covered by more than 45% of forest.

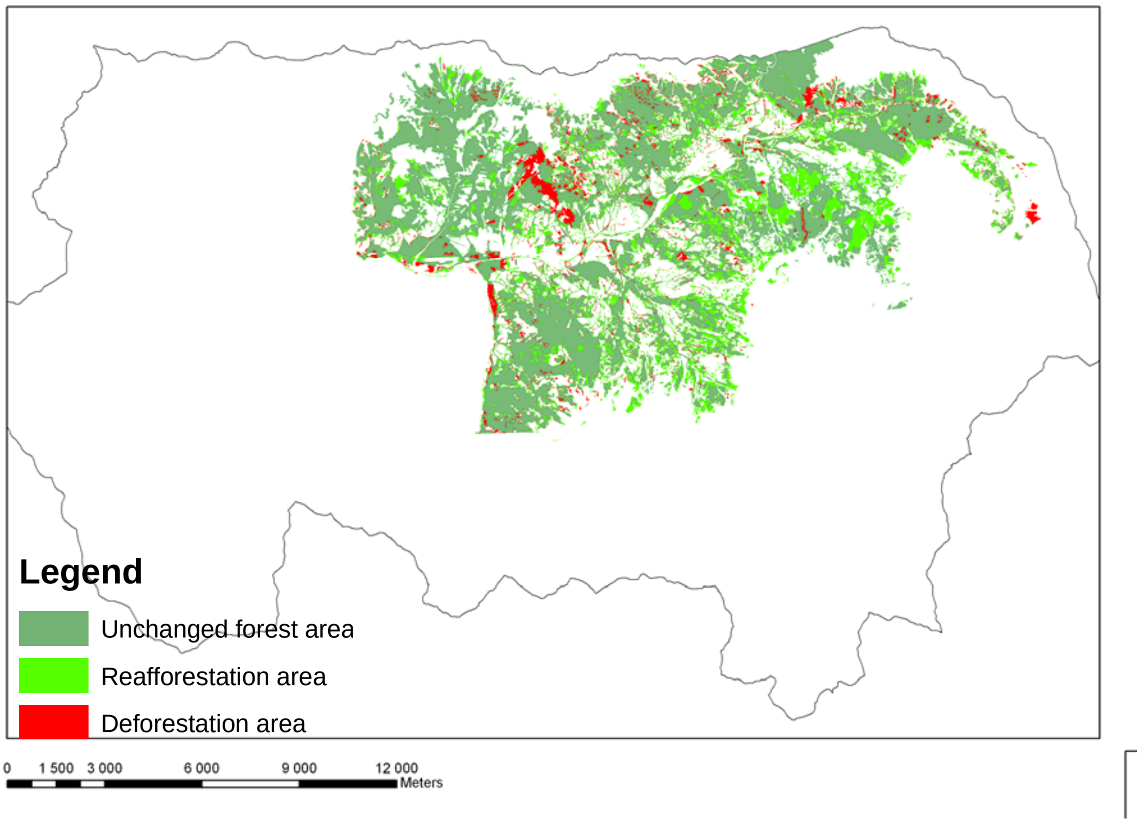


Figure 13 Evolution of forest areas from 1974 to 2004 (IPGS)

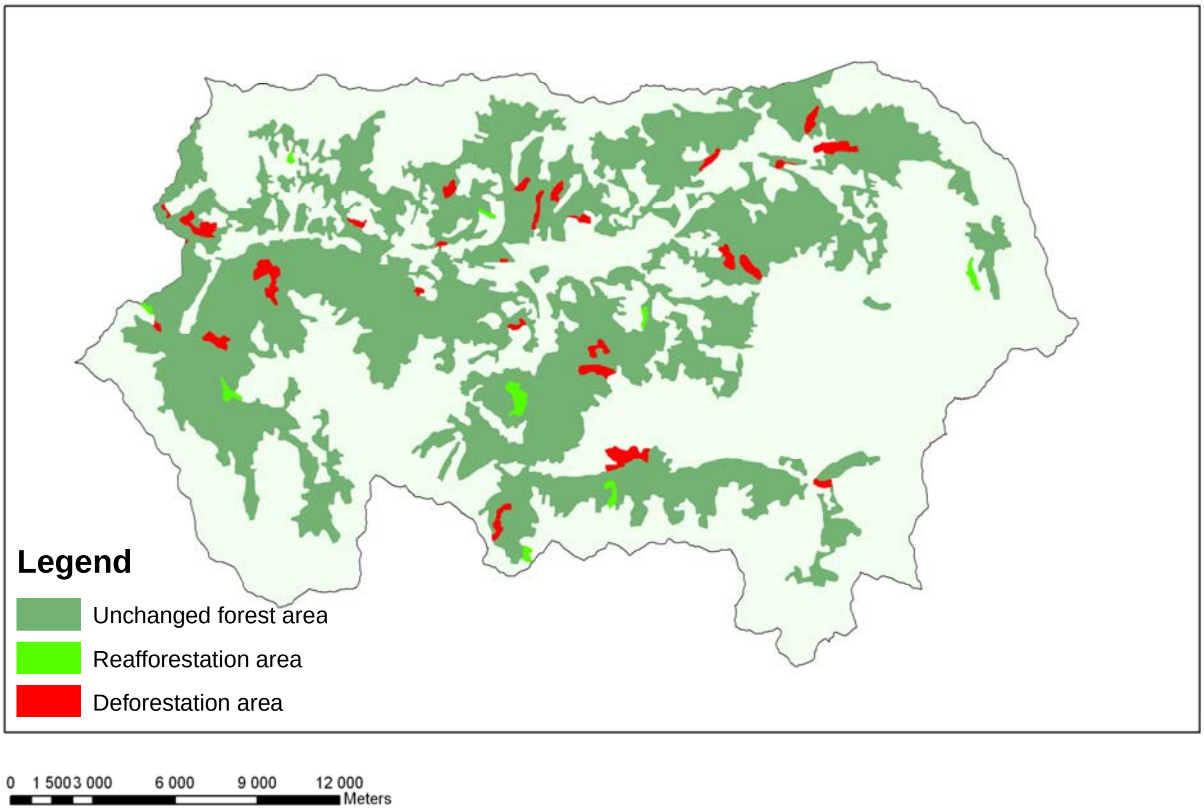


Figure 14 Evolution of forest areas from 1990 to 2006 (CLC)

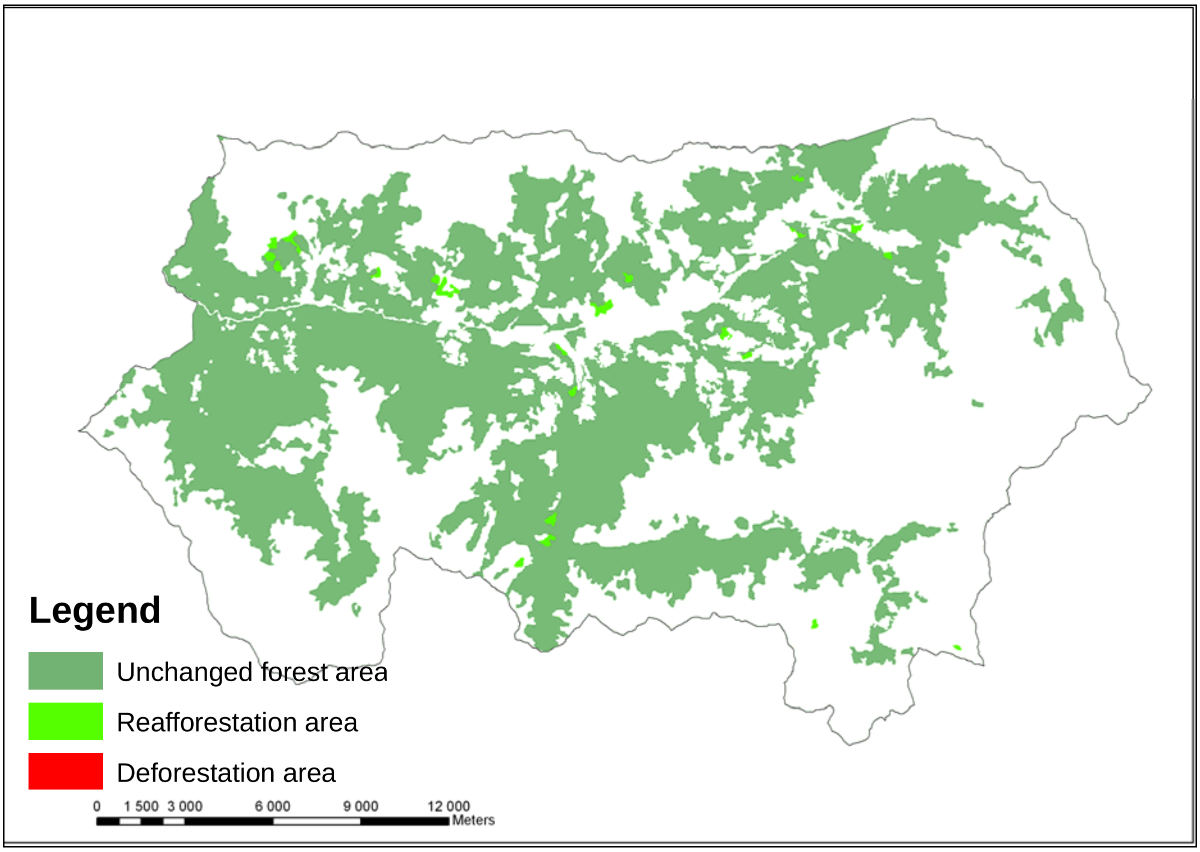


Figure 15 Evolution of forest areas from 1999 to 2006 (CRIGE)

5.1.3.2 Urban areas

Changes in land use patterns in urban areas potentially include the creation of extensive impermeable areas, which have potential implications for the concentration of run-off. Thus the following data sets have been examined:

- IPGS data: airport / aerodrome, industrial or commercial areas, urban fabric
- CLC data: discontinuous urban fabric, sport and leisure facilities
- CRIGE data: continuous, discontinuous and diffuse urban fabric, industrial and commercial units, airports

All of the data sets show an increase in urban areas.

The IPGS data demonstrates an increase in the urban areas of two thirds during the period 1974 to 2004. This seems not to correlate well with the limited increase in the population (see Section 5.1.1), but might be due in large part to the increase in tourism activities (*Figure 16*).

The CLC data indicates that urban areas have more than doubled between 1990 and 2006, from 272 ha to 596ha (*Figure 17*), while the CRIGE data suggests a stable situation at 1039 ha for the period 1999 to 2006 (*Figure 18*).

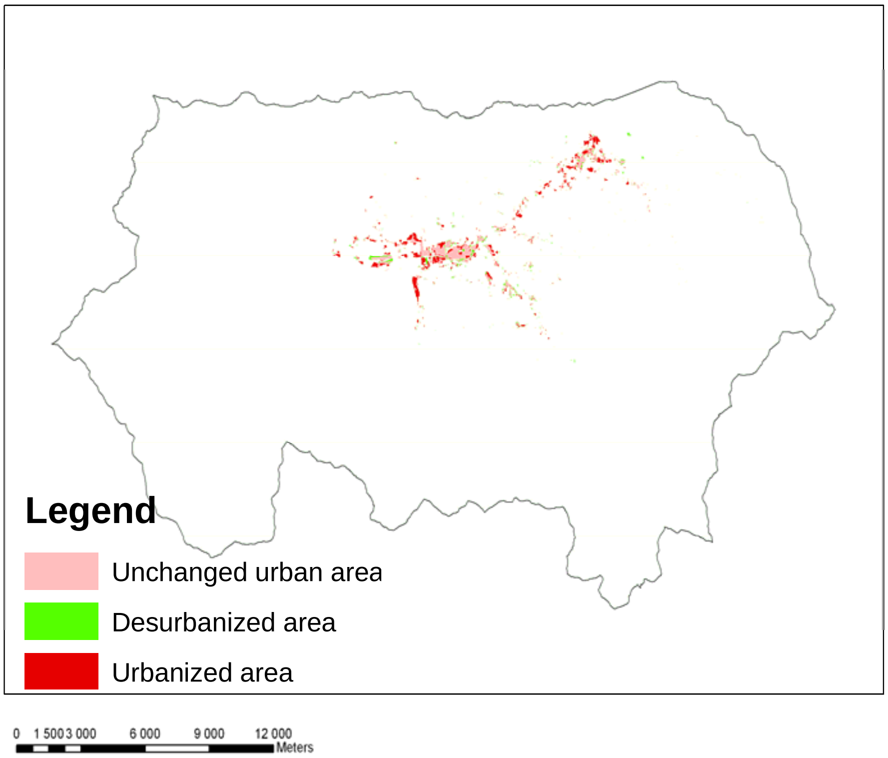


Figure 16 Evolution of urban areas extension between 1974 and 2004 (IPGS)

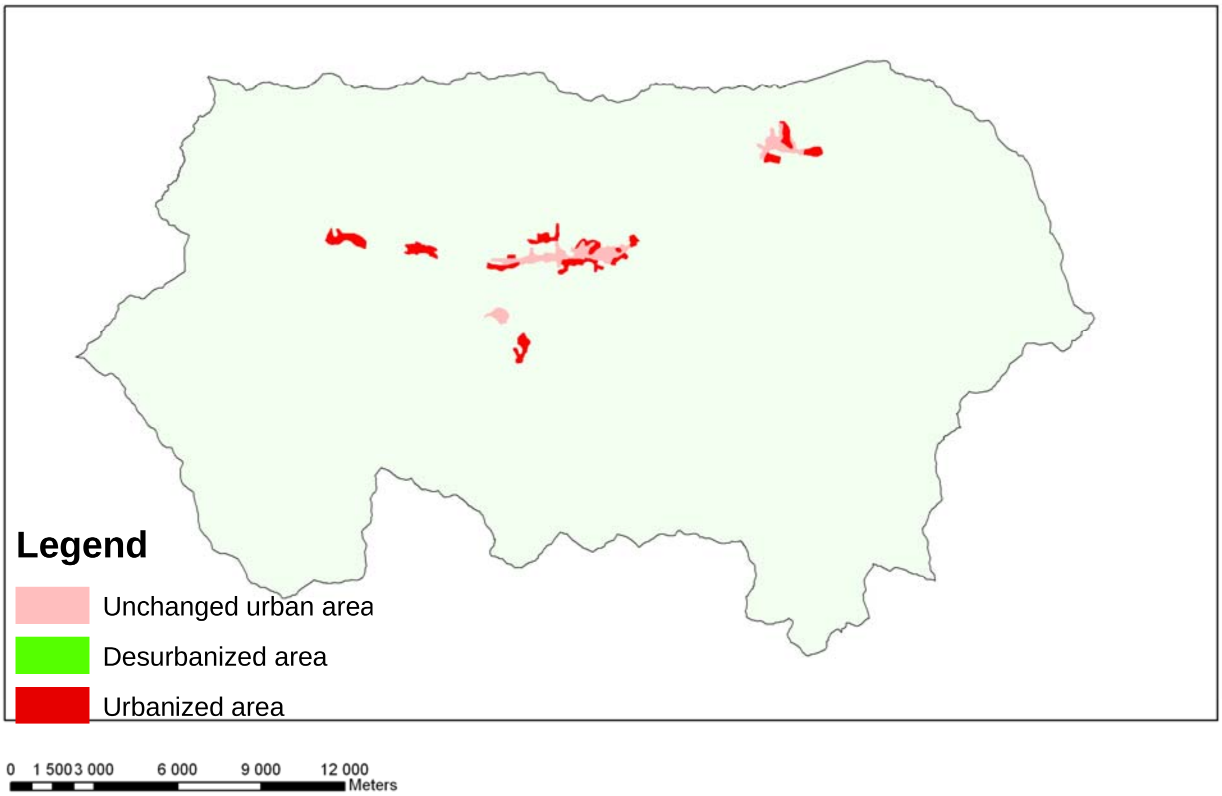


Figure 17 Evolution of urban areas extension between 1990 and 2006 (CLC)

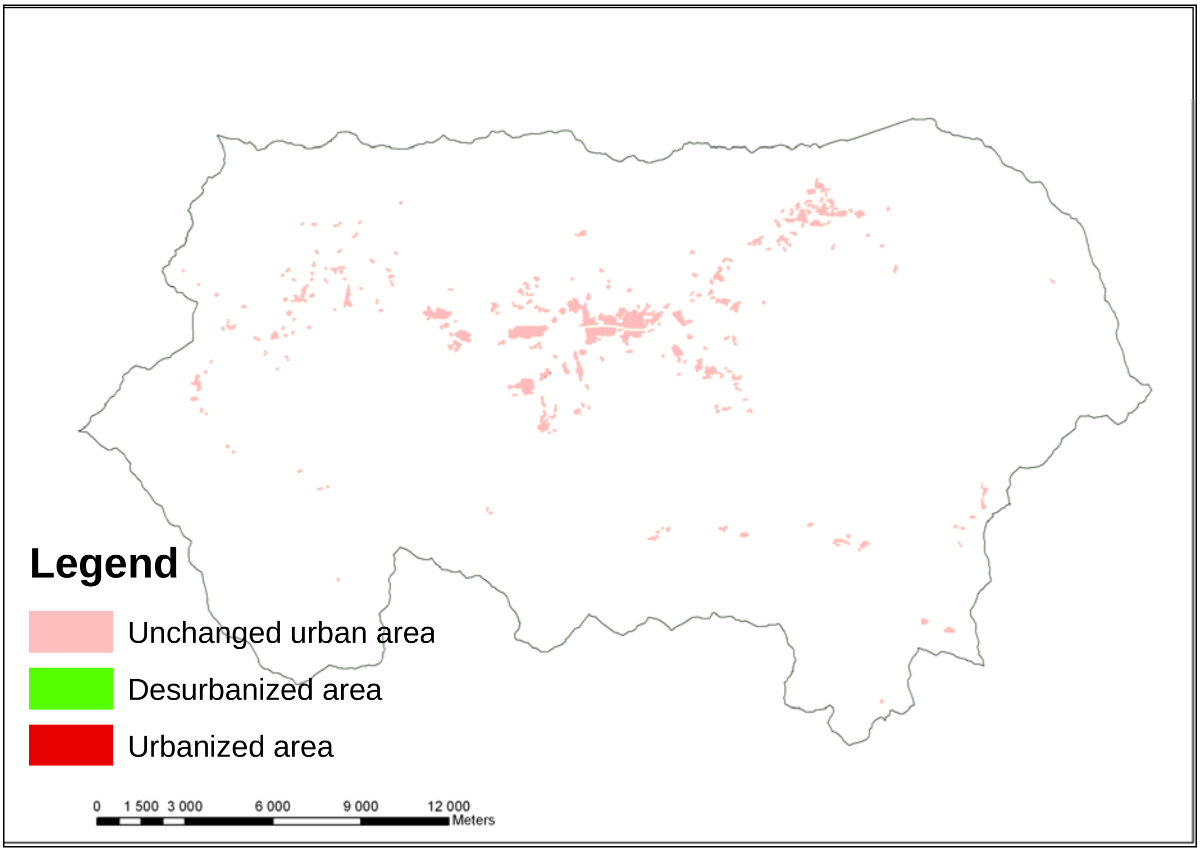


Figure 18 Evolution of urban areas extension between 1999 and 2006 (CRIGE)

In conclusion, it is difficult to reveal detailed trends in urbanised areas. Nevertheless urban areas seem to have increased along the valleys especially in the 1990s and the area has been reafforested in the past and forest areas tend to consolidate. This last conclusion is in line with the meeting organised with stakeholders (see Annexe for more detail). Indeed the RTM engineers have said that reafforestation has been ongoing during the previous 150 years and is completed.

5.1.3.3 Other approach

A study has been conducted by MORAVEK Andrej in CNRS on the "Modelling of land cover changes in the Barcelonnette basin", 2011.

The approach is based on the CLUE dynamic model (http://cluemodel.nl/) and consists in the identification of land use change sequences and transition rules before the application of a logistic regression model.

Four scenarios of evolution were considered

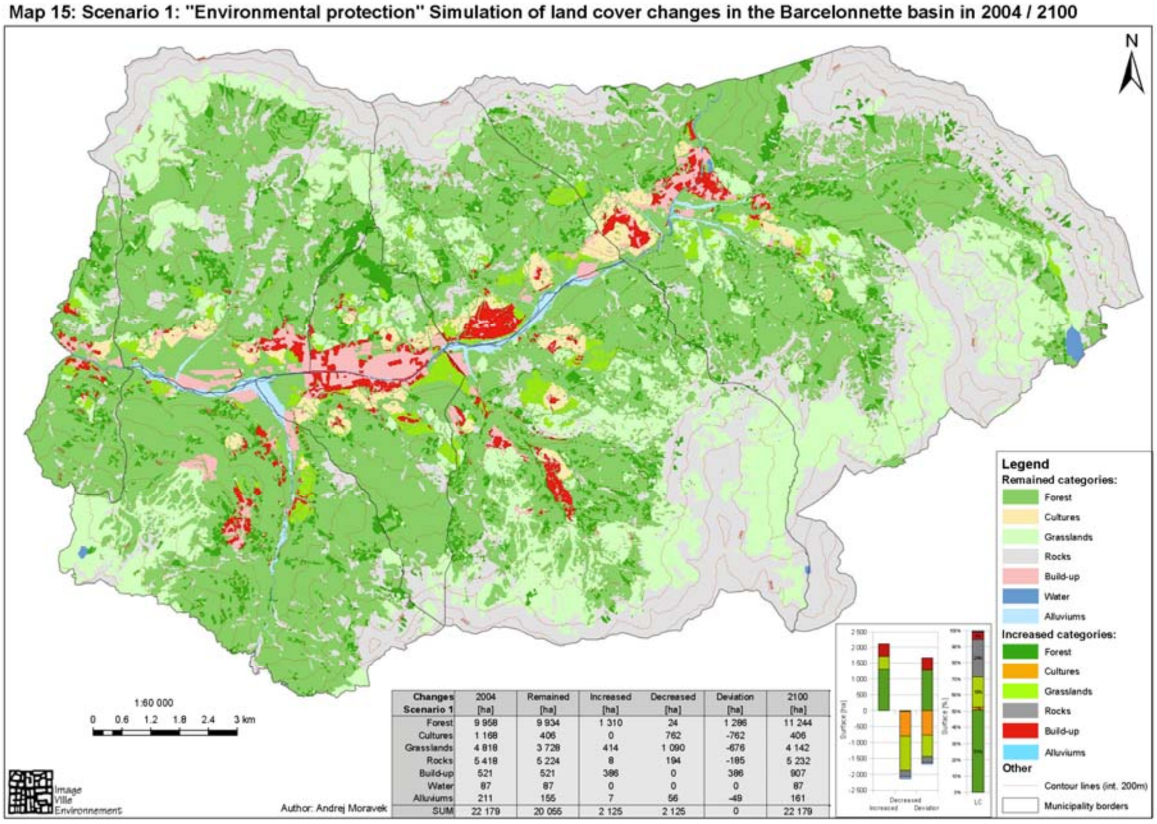
- The first scenario named "Environmental protection" can be otherwise described as the continuation of the previous changes with the same trends and tendencies, although the amounts of changes are numerically less significant (average annual changes).
- The second scenario which was called "Tourism progression" and this differs from the first one mostly in placing emphasis on an increase in built-up areas (by 250 %) to provide accommodation and service to the visitors of the basin.
- The third scenario "Agricultural recultivation" is somehow the "return to the past". Even though tourism rises slightly (built-up areas increase by 75%), agriculture is the

most important change as there is a demand for local agricultural products and the reclamation of land for agricultural purposes increases by one half … OF WHAT?.

- The fourth and the last scenario “Landslide hazard” is the “catastrophic” one. The main distinguishing feature from the oher scenarios is low environmental awareness with extreme and worsening weather conditions linked with global warming: e.g. repeated drought and storm occurrences. Moreover, large amounts of arable and grazing lands are abandoned (two–thirds of the levels in 20##) and there is a doubling of tourism activities which also influence landslide hazard and therefore it is also included in this model.

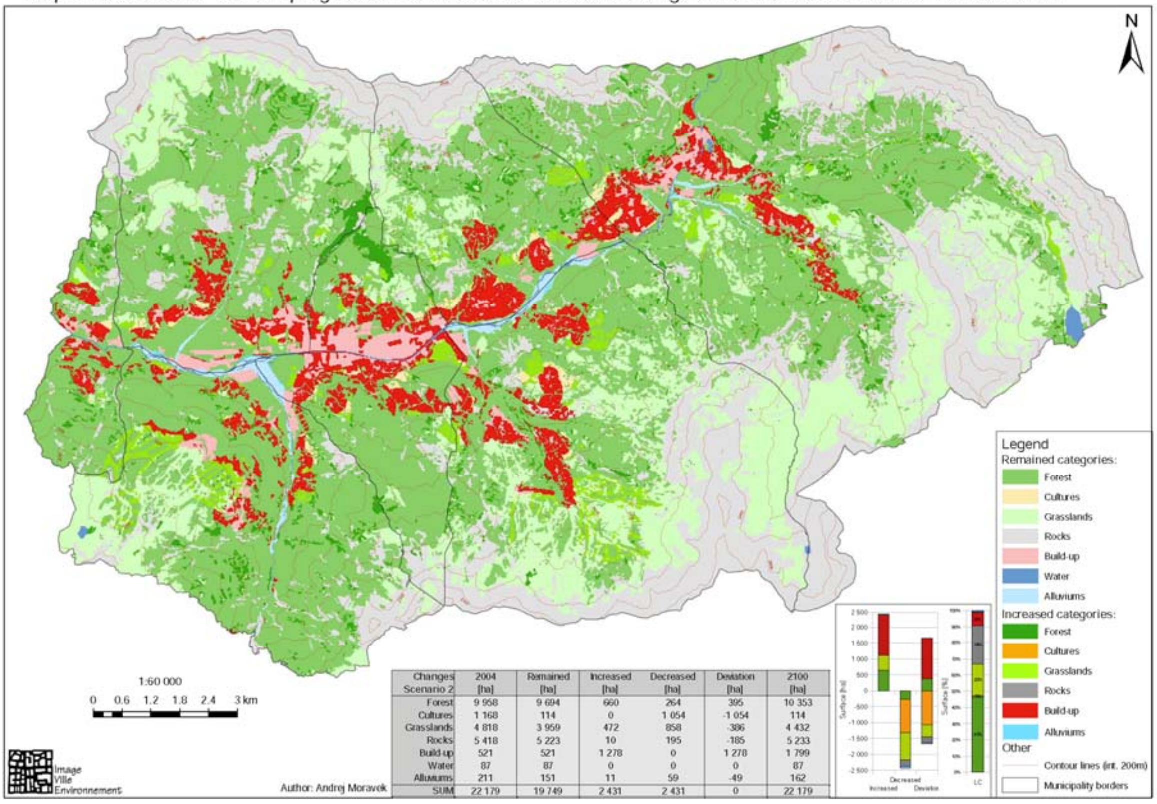
The final results of land use evolution scenarios are represented on the maps below:

Map 15: Scenario 1: "Environmental protection" Simulation of land cover changes in the Barcelonnette basin in 2004 / 2100



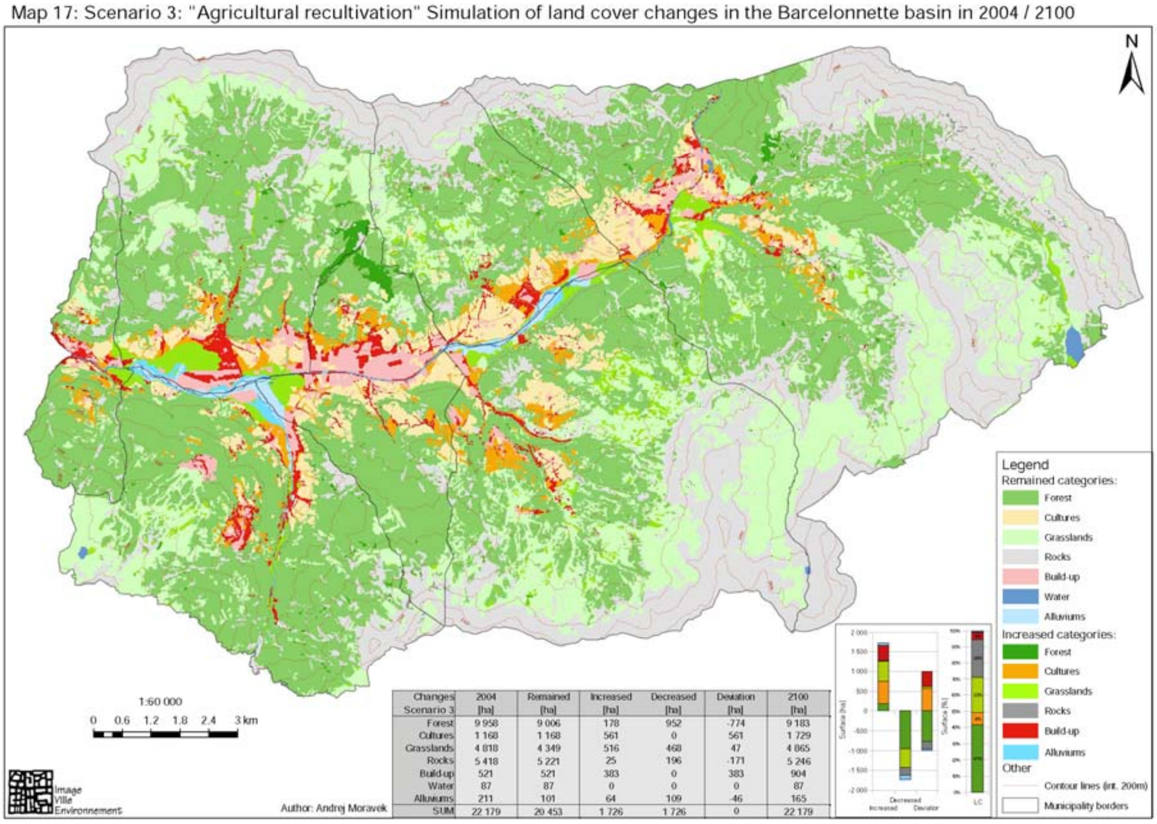
Changes Scenario 1	2004 [ha]	Remained [ha]	Increased [ha]	Decreased [ha]	Deviation [ha]	2100 [ha]
Forest	9 958	9 934	1 310	24	1 286	11 244
Cultures	1 168	406	0	762	-762	406
Grasslands	4 818	3 728	414	1 090	-676	4 142
Rocks	5 418	5 224	8	194	-185	5 232
Build-up	521	521	386	0	386	907
Water	87	87	0	0	0	87
Alluviums	211	155	7	56	-49	161
SUM	22 179	20 056	2 125	2 125	0	22 179

Map 16: Scenario 2: "Tourism progression" Simulation of land cover changes in the Barcelonnette basin in 2004 / 2100



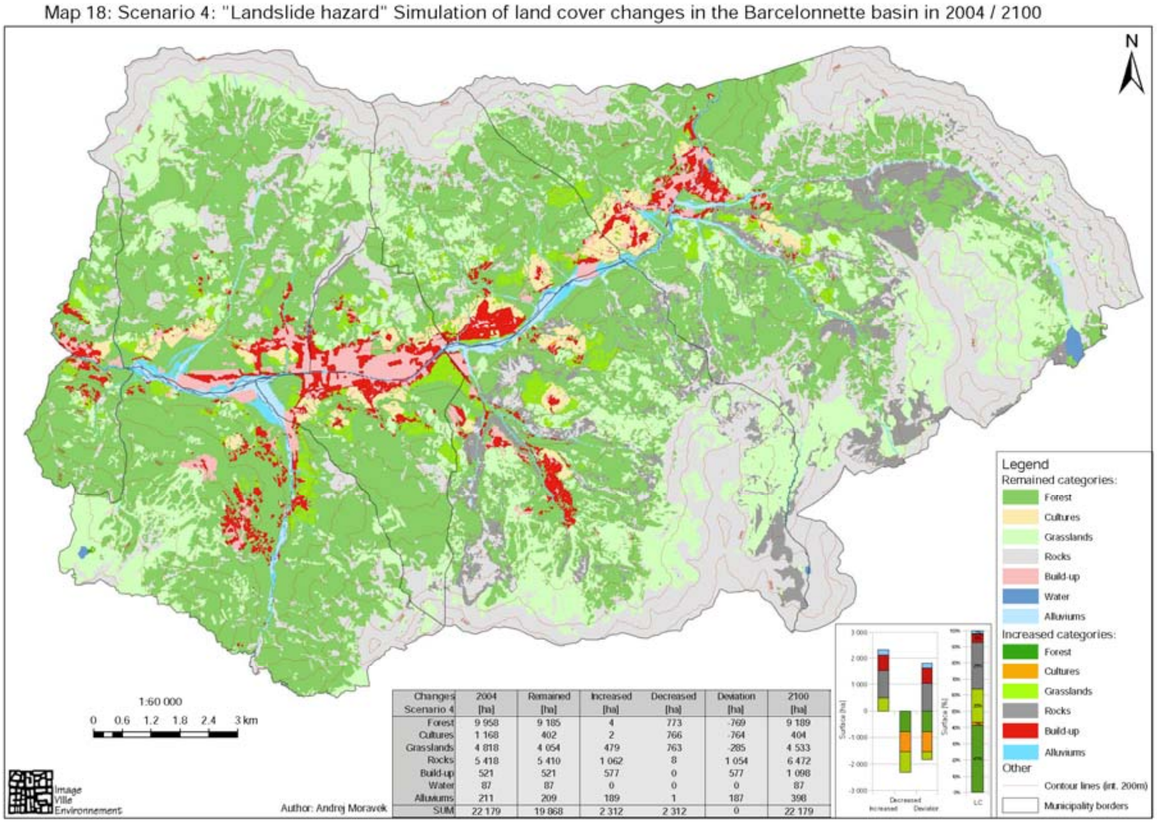
Changes Scenario 2	2004 [ha]	Remained [ha]	Increased [ha]	Decreased [ha]	Deviation [ha]	2100 [ha]
Forest	9 958	9 694	660	264	395	10 353
Cultures	1 168	114	0	1 054	-1 054	114
Grasslands	4 818	3 959	472	858	-386	4 432
Rocks	5 418	5 223	10	195	-185	5 233
Build-up	521	521	1 278	0	1 278	1 799
Water	87	87	0	0	0	87
Alluviums	211	151	11	59	-49	162
SUM	22 179	19 749	2 431	2 431	0	22 179

Map 17: Scenario 3: "Agricultural recultivation" Simulation of land cover changes in the Barcelonnette basin in 2004 / 2100



Changes Scenario 3	2004 [ha]	Remained [ha]	Increased [ha]	Decreased [ha]	Deviation [ha]	2100 [ha]
Forest	9 958	9 006	178	952	-774	9 183
Cultures	1 168	1 168	561	0	561	1 729
Grasslands	4 818	4 349	516	468	47	4 865
Rocks	5 418	5 221	25	196	-171	5 246
Build-up	521	521	383	0	383	904
Water	87	87	0	0	0	87
Alluviums	211	101	64	109	-46	165
SUM	22 179	20 453	1 726	1 726	0	22 179

Map 18: Scenario 4: "Landslide hazard" Simulation of land cover changes in the Barcelonnette basin in 2004 / 2100



5.1.4 Economy / activity

5.1.4.1 Standard of living

It seems reasonable to assume that the elements at risk in a town are related to the standard of living of its inhabitants. For instance, wealthier people may be expected to live in more expensive houses but poorer people are likely to live in areas of higher housing density.

Moreover, the standard of living of people also has an impact on their vulnerability in the face of a natural disaster (Mutter et al., 2007). Thus, houses of wealthier people will be probably better-designed, with greater build quality, and could consequently be impacted less in some landslide situations. In France, for example, a part of the population living with the lowest incomes lives in concrete buildings, called HLM (housing at moderate rent), that were built in the 1970s and are very robust. Consequently, this argument may not be so clear. Furthermore, households with sufficient money in reserve will be less affected by disasters, because they will be able to start up again faster. Finally, the poorest people may not consider the insurance of their goods as a priority, whereas the wealthier people may choose insurance with the best warranties: consequently, the latter will be less affected by natural disasters.

From a socio-economic point of view, education could also be a factor affecting vulnerability: less educated people that may be less well informed about landslide risks and may build their houses in more vulnerable areas. The poorest people may also have less choice as to whether they live in these areas or not, and insufficient resources to make other choices. Hopefully, thanks to the PPR these situations are almost nonexistent in France.

The indicators gathered at each census permit a better understanding of the quality of life of the local population. Although this approach is somewhat simplistic, it has been decided to quantify the standard of living of the population by indicators based on household incomes.

The first indicator considered is the median income by consumption unit. (It is an indicator a little more accurate that the median income by person, because it takes into account, thanks to a simple weighting system, that the needs of the household do not increase proportionally to its size.) The values of this indicator, in Euros for the towns within the studied site are presented in *Table 14*:

Table 14 Median income by consumption unit from 2003 to 2007(unit: €/ (year c.u.) (INSEE, 2008)*

	2003	2004	2005	2006	2007
Barcelonnette	13,378	13,649	14,161	15,000	15,289
Enchastrayes	15,694	16,608	16,334	17,011	18,050
Faucon-de-Barcelonnette	15,553	15,979	15,906	16,884	17,040
Jausiers	13,921	14,119	14,655	16,123	16,627
Saint-Pons	15,099	16,214	16,254	16,295	17,188
District of Barcelonette	13,877	14,337	14,623	15,449	15,704
Alpes de Haute Provence	14,292	14,643	15,114	15,688	16,259
"Région" PACA	15,000	15,443	16,023	16,626	17,243

From this data, we can compute the ratio between the indicator for each town and the indicator for the region PACA (Provence Alpes Côtes d'Azur) which includes the department Alpes de Haute Provence:

Table 15 Ratio between the median income by consumption unit of each town and of region PACA

	2003	2004	2005	2006	2007
Barcelonnette	89.2%	88.4%	88.4%	90.2%	88.7%
Enchastrayes	104.6%	107.5%	101.9%	102.3%	104.7%
Faucon-de-Barcelonnette	103.7%	103.5%	99.3%	101.6%	98.8%
Jausiers	92.8%	91.4%	91.5%	97.0%	96.4%
Saint-Pons	100.7%	105.0%	101.4%	98.0%	99.7%
District of Barcelonette	92.5%	92.8%	91.3%	92.9%	91.1%
Alpes de Haute Provence	95.3%	94.8%	94.3%	94.4%	94.3%
"Région" PACA	100.0%	100.0%	100.0%	100.0%	100.0%

The evolution of the ratios (*Table 15*) in the five different towns in the five-year interval (2003 to 2007) is sufficiently small that this ratio may be considered constant over the next few decades.

Another indicator that may help to better understand the social structure of the study site is the inter-decile ratio per consumption unit. This ratio between the income of the richest people (90th percentil[4]) and the income of the poorest people (10th percentile[5]) highlights the social disparities within the population. Thus, the greater the value is, the greater the disparity between the richest and poorest members of society. The values of this ratio for the District of

[4] 10% of the population earns more than the 90th percentile
[5] 10% of the population earns less than the 10th percentile

Barcelonnette (the detailed values for each town are not given by the statistic institute) and for France are given in *Table 16*:

Table 16 Inter-decile ratio per consumption unit between 2003 and 2007

	2003	2004	2005	2006	2007
District of Barcelonette	4.28	4.43	4.57	4.42	4.62
France	5.46	5.46	5.47	5.54	5.48

It can be noted that the population of this district is slightly more homogenous (i.e. the gap between rich and poor is less) than the French population as a whole.

Finally, the unemployment rate (for people between 15 and 64 years) can be also a good indicator to characterize the population (see *Table 17*):

Table 17 Unemployment rate in the Barcelonnette site at two different date (1999 and 2006)

	1999	2006
Barcelonnette	11.55	6.47
Enchastrayes	6.86	5.88
Faucon-de-Barcelonnette	1.03	0.76
Jausiers	10.91	8.11
Saint-Pons	7.55	3.8
District of Barcelonnette	9.7	5.7
Alpes de Haute Provence	13.7	11.9
"Région" PACA	17.4	13.3
France	10.3	9.1

Here, the low populations of the towns prevent strong conclusions being drawn from the data. Nevertheless, we can see that the unemployment rate is a little bit lower in the Barcelonnette district than in France as a whole, generally corroborating the concept that the social homogeneity in the population is slightly greater.

To conclude, there are not many disparities within the population of the test site, and no evidence for change in the near future. Consequently, it does not seem necessary to take this variable into consideration in the study for this site.

5.1.4.2 Elements at risk

The statistics institute INSEE provides extensive information about the residential buildings of the towns in the area studied: for example the number of residences (but also their status as either main residences, second homes or vacant dwellings) for each census between 1968 and 2006. However, only values for 1990, 1999 and 2006 were used to extrapolate future values, in order to reflect the current trends.

In order to forecast future values for 2030, and thanks to a quite steady evolution trend, a linear regression has been performed (*Table 18*).

Based on the forecasts of main residences and of population, the average number of dwellers has been computed. This indicator is a useful one to assess the population potentially exposed to the effects of landslide hazards.

Table 18 Evolution of the number of residences and related indicators from 1990 to 2006 and predictions for 2030

	Barcelonnette			
	1990	1999	2006	2030
Residences	2 809	2 965	3152	3648
Main residences	1 277	1 261	1368	1471
Second homes	1 141	1 451	1513	2121
Vacant dwellings	391	253	271	56
Average number of dweller (main r.)	2.3	2.2	2.1	2.4

	Enchastrayes			
	1990	1999	2006	2030
Residences	1 852	1 911	2046	2312
Main residences	190	216	200	225
Second homes	1 659	1 686	1830	2052
Vacant dwellings	3	9	16	35
Average number of dweller (main r.)	2.5	2.3	2.2	2.4

	Faucon-de-Barcelonnette			
	1990	1999	2006	2030
Residences	174	184	221	283
Main residences	76	85	116	169
Second homes	81	92	102	133
Vacant dwellings	17	7	2	0
Average number of dweller (main r.)	2.6	2.4	2.6	2.2

	Jausiers			
	1990	1999	2006	2030
Residences	941	984	1084	1280
Main residences	316	335	398	508
Second homes	554	605	648	788
Vacant dwellings	71	44	38	0
Average number of dweller (main r.)	2.5	2.5	2.5	2.5

	Saint-Pons			
	1990	1999	2006	2030
Residences	365	444	495	693
Main residences	193	249	280	414
Second homes	133	165	200	298
Vacant dwellings	39	30	14	0
Average number of dweller (main r.)	2.6	2.6	2.4	2.0

A pertinent fact is the number of second homes in the studied site. *Table 19* shows that the ratio of second house exceeds 40% in all the towns, and is near 90% for Enchastrayes. It also indicates that these ratios are not expected to change a lot in the next 20 years.

Table 19 Predicted evolution of the proportion of secondary homes in the towns of the studied site

	2006	2030
Barcelonnette	48%	58%
Enchastrayes	89%	89%
Faucon-de-B.	46%	47%
Jausiers	60%	62%
Saint-Pons	40%	43%

The average number of dwellers for the main residences of the towns is also expected to remain relatively constant: this indicator will stay between 2.0 and 2.5 in the towns of the studied site.

Finally, the number of vacant dwellings, which is already quite small, is expected to decrease in most of the towns.

5.1.4.3 Vulnerability of dwellings

The age of a building can be a good indicator to quantify its vulnerability towards natural events: for instance, the oldest buildings are usually made in traditional masonry and their structures can be in a poor state of repair. They could consequently be less resistant. In addition, newer buildings are made with reinforced concrete elements, and are stronger. Moreover, the quality of construction of these reinforced-concrete buildings has evolved in the recent years: steel of better quality has been used, and higher standards of construction have been introduced (for instance earthquake-resistant building standards).

The INSEE report classifies by date, the construction of the main residences in every town of the test site (http://www.statistiques-locales.insee.fr, see *Table 20*):

Table 20 Main residences in the towns of the studied site classified by dates of construction

	Barcelonnette		Enchastrayes		Faucon-de-B.		Jausiers		Saint-Pons	
	M.R.	%	M.R.	%	M.R.	%	M.R.	%	M.R.	%
Before 1949	461	37%	44	20%	22	26%	157	47%	28	11%
1949-1974	334	26%	74	34%	4	5%	49	15%	68	27%
1975-1989	429	34%	85	39%	38	45%	95	29%	97	39%
1990-2006	38	3%	13	6%	21	25%	31	9%	55	22%
Total	1262	100%	216	100%	85	100%	332	100%	248	100%

The most important towns, Jausiers and Barcelonnette, include quite a significant proportion of aged buildings. In addition, the proportion of buildings for each construction period is quite similar in each town; new houses have been built quite homogeneously over time, with a small increase for the period 1975-1989.

Also of use for the vulnerability studies is the information contained in the INSEE reports on multi-storey buildings (*Table 21*).

Table 21 Number of multi-storey buildings (main residences) classified by dates of construction. Percentage of multi-storey buildings (main residences) in the towns of the test site.

	Barcelonnette	Enchastrayes	Faucon-de-B.	Jausiers	Saint-Pons
Before 1949	340	3	0	70	3
1949-1974	170	22	2	6	20
1975-1989	310	26	0	35	22
1990-2006	10	1	0	0	0
Collective dwellings	66%	24%	2%	33%	18%

Barcelonnette and Jausiers are characterized by a significant proportion of multi-storey buildings and a significant proportion of these were built before 1949. Theses two towns include a traditional Mediterranean town centre characterized by a dense area of old buildings. Moreover, Barcelonnette is also composed of more recent collective housing, constructed between 1949 and 1989. These buildings have generally been constructed from reinforced concrete elements and are likely to be more landslide-resistant compared to most of individual houses.

There are two key conclusions to be drawn regarding the housing-stock of the study site:

1. The houses in the centre of Barcelonnette and Jausiers are expected to be on average slightly less resistant than the other residences of this test site, primarily because of their age.
2. Barcelonnette also has a significant proportion of relatively modern apartment blocks, which are expected to be slightly less vulnerable to landslides.

The INSEE report also classifies secondary homes by their age of construction (*Table 22*).

Table 22 Secondary residences in the towns of the studied site classified by dates of construction

	Barcelonnette		Enchastrayes		Faucon-de-B.		Jausiers		Saint-Pons	
	S.R.	%	S.R.	%	S.R.	%	S.R.	%	S.R.	%
Before 1915	196	14%	40	2%	21	24%	176	30%	30	17%
1915-1948	47	3%	2	0%	0	0%	23	4%	3	2%
1949-1974	141	10%	345	21%	11	13%	122	21%	71	41%
1975-1989	1019	72%	1198	71%	45	51%	247	42%	50	29%
1990-2006	7	0%	94	6%	11	13%	27	5%	20	11%
Total	1410	100%	1679	100%	88	100%	595	100%	174	100%

The data in *Table 22* show that a significant proportion of the secondary residences in the area were constructed in the period 1975-1989, and that this fact is all the more true for the towns near the ski resorts of Barcelonnette and Enchastrayes. In fact, these two resorts have experienced significant development during this period. A break-down of the number of residences within each apartment block is given in *Table 23*:

Table 23 Classification of the residential building (secondary housing only) by the number of dwellings they are composed of.

	Barcelonnette	Enchastrayes	Faucon-de-B.	Jausiers	Saint-Pons
1 housing	26%	14%	98%	48%	68%
2-9 dwellings	16%	20%	20%	22%	26%
10+ dwellings	58%	84%	0%	30%	6%

The towns can be clearly divided into two groups with different characteristics:

- Enchastrayes and Barcelonnette are characterized by large buildings, most of them comprising more than ten dwellings, constructed in the period 1957-1989.
- Faucon-de-Barcelonnette, Jausiers and Saint-Pons are characterized by small individual chalets that are either old (built before 1915) or built in the period 1957-1989. These chalets are expected to be less resistant than the larger constructions of Barcelonnette and Enchastrayes.

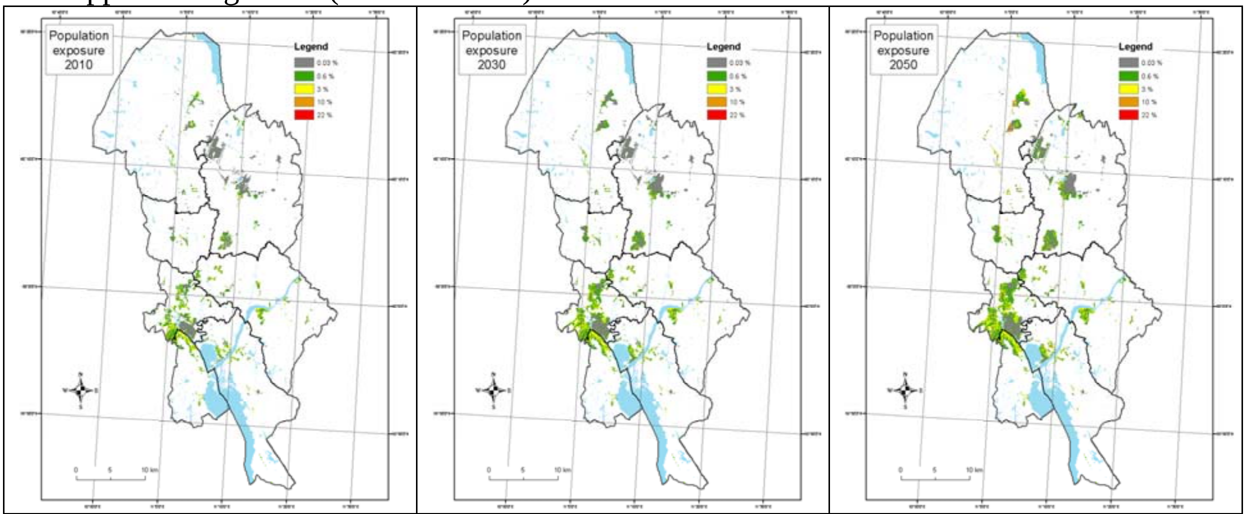
5.2 NORWAY, NEDRE ROMERIKE

5.2.1.1 Demography

The population data for Europe, produced by IIASA, reproduce the results from the GRUMP dataset for the year 2010 (used for the risk assessment in D2.10 and D3.7) reasonably well. The accuracy of future scenarios will decrease with time into the future. The population of Norway exposed to landslide hazards is expected to increase following the figures of the following table:

Year	Exposed Population of Norway
2010	99 790
2030	85 606
2050	109 929
2070	121 197
2090	119 335

Considering that the exposed population is limited to urban areas only and that the population density is constant over the period of analysis; the exposed population of the concerned area is mapped on Figure 21 (Safeland D3.9)



2010	2030	2050

Figure 19 Spatial distribution of percentage of exposed population over the three scenarios in 2010, 2030 and 2050.

5.2.1.2 Land cover and economy activity

The source for the land cover was the CORINE Land Cover (CLC) database. This is a seamless European land cover vector database which was completed by the Norwegian Forest and Landscape Institute in 2008.

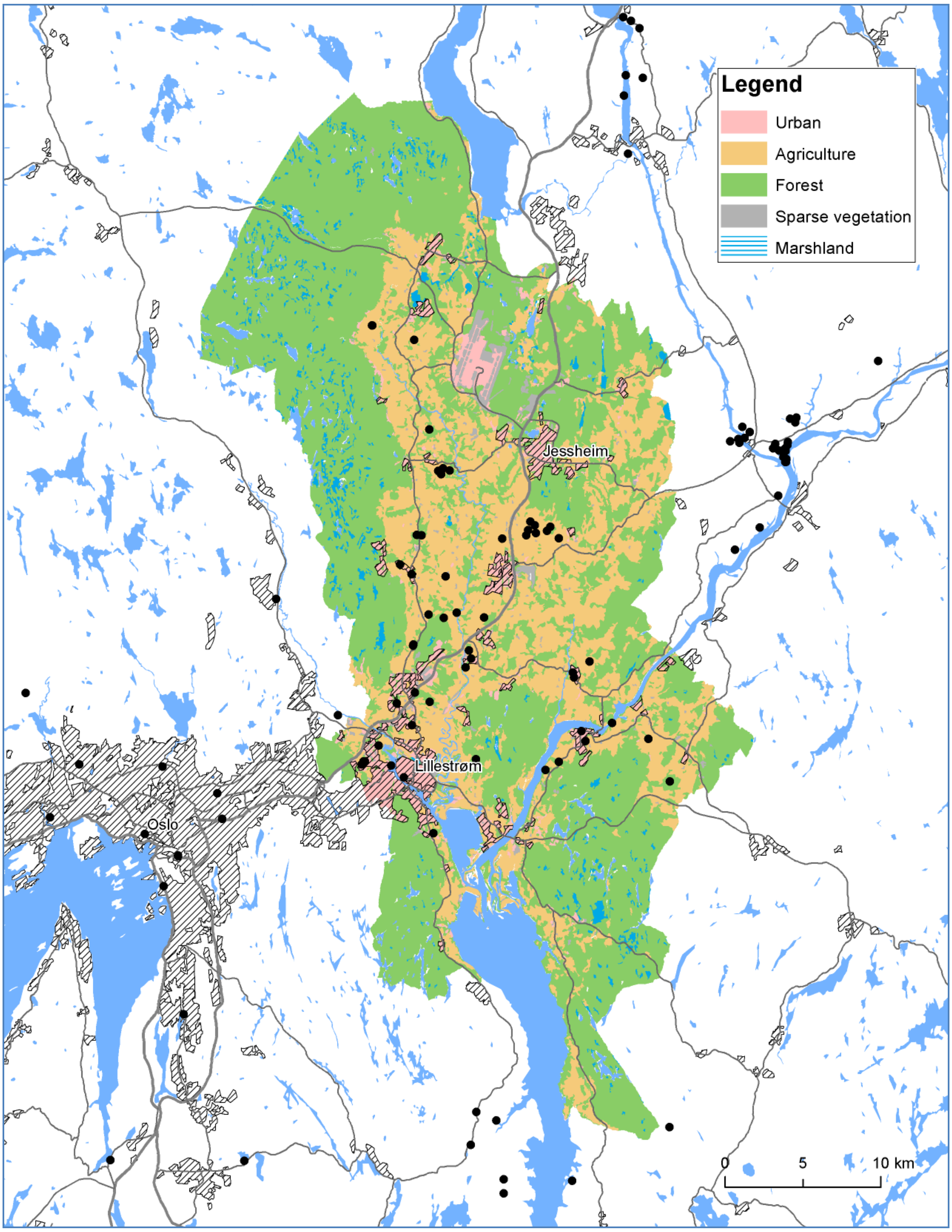


Figure 20 Land cover map of the study area as of 2010 based on the CORINE Land Cover database. Black circle markers are landslides from the Norwegian inventory of landslides.

The land cover was projected up to the year 2090 based on the current land cover dataset. The population of the region is expected to increase by 50% by 2040, resulting in a substantial growth of urban land covers. Plans from the Akershus county to which all municipalities belong indicate that a majority of this growth is expected in central towns, described as tie-point for communication. Though not a single list of tie-points exists yet, assumptions were made that the tie-points will be the largest of the existing towns. Smaller towns and villages will most likely see smaller changes. For this study, the urban growth was therefore modelled for the largest urban areas. For each 20-year period, these urban areas were expanded by a certain distance. Urban growth was limited by excluding water features. In addition, the urban area representing Oslo Airport was kept constant, even though an expansion is expected around 2030-2040. The model was calibrated versus expected area of the urban growth and versus plans for urban development of Skedsmo municipality for 2050. The spatial distribution of land cover evolution over the period 2010 to 2090 is presented in Figure 21 and the evolution of changes for each class is shown in Figure 22.

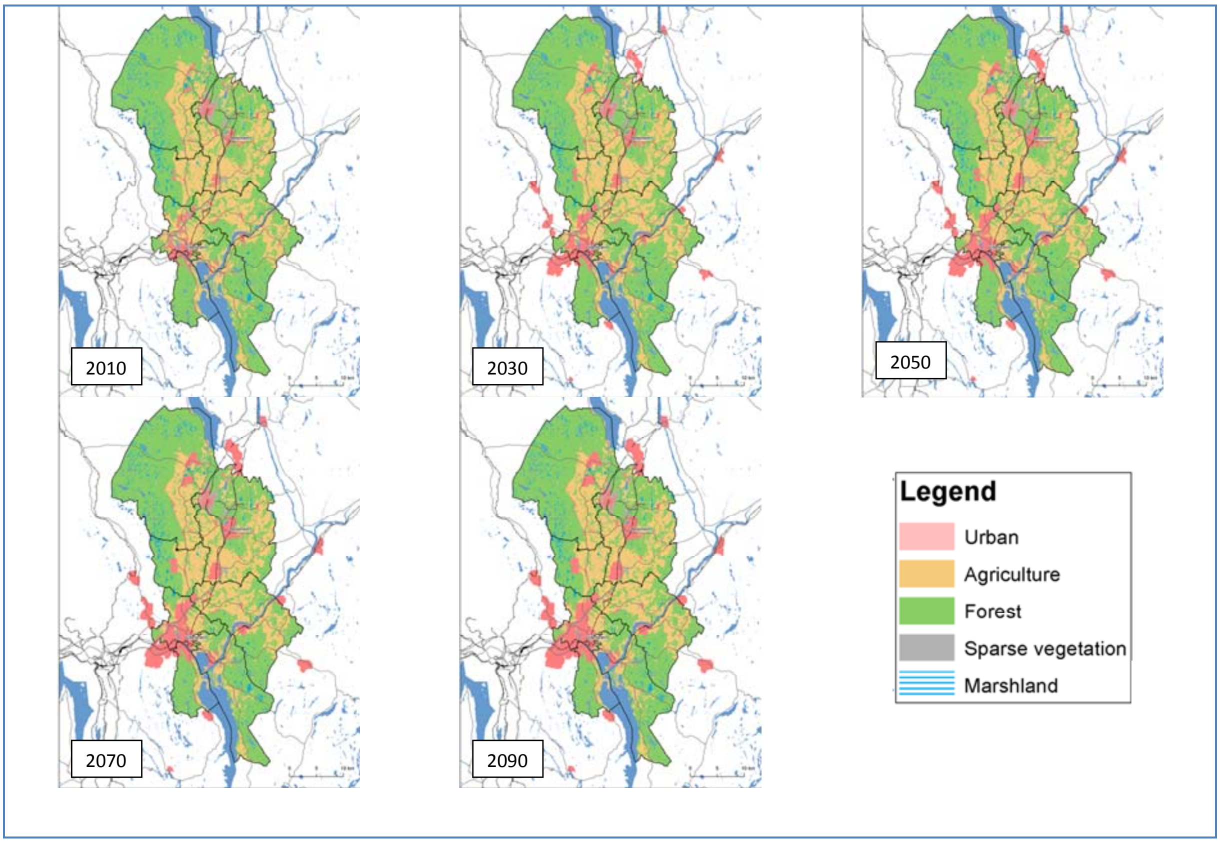


Figure 21 Land cover evolution within the period 2010-2090 in the study area.

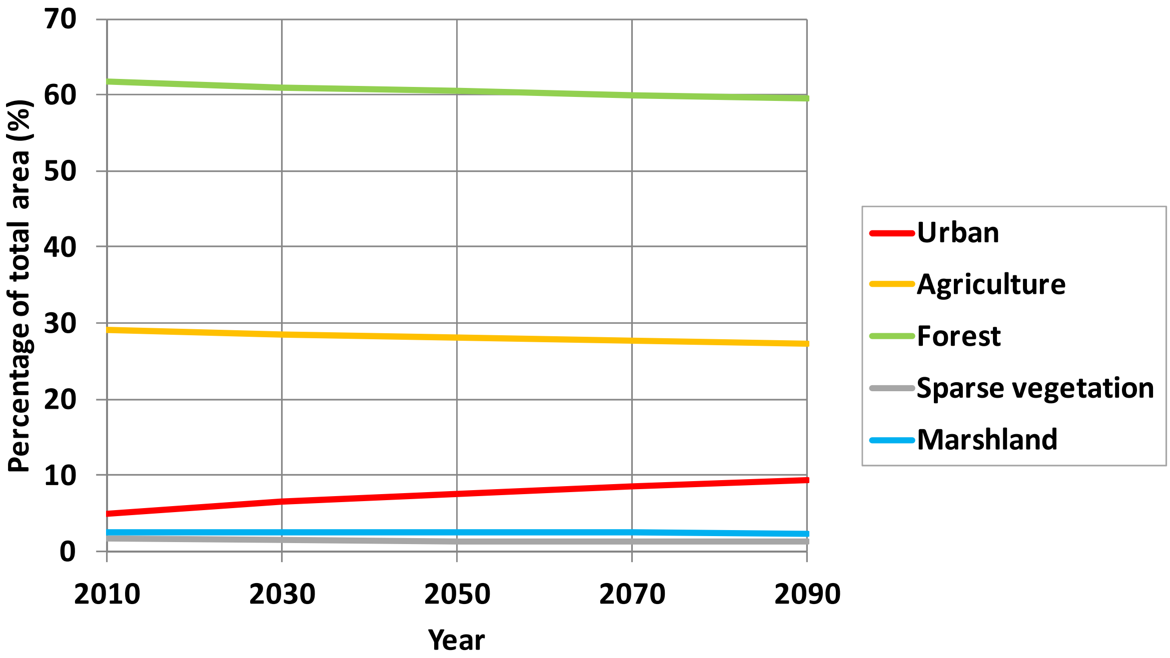


Figure 22 Evolution in changes on land cover classes over the period 2010-2090.

5.3 OTHER TEST SITES

Among the other test sites chosen for the WP 3 study, very few data were available in respect of human activities. The best we have obtained from partners dealing with the sites was data representing the present situation. But without historic data, it is impossible to propose any forecasts.

6 CONCLUSION AND PERSPECTIVE

To conclude, the scarcity of data is the main limit to the development of valid human activities scenarios affecting landslides.

Indeed, exhaustive historical data are often unavailable. Even when they are available and cover a sufficiently long time period, the possibility of evaluating future changes based on them is limited: the results are then simple extrapolations that do not take into account any future evolution hypothesis. In addition, local studies are often incoherent beyond a few decades.

Nevertheless we have analysed as precisely as possible the case of Barcelonnette located in the French Alps because it was the most complete. A cellular automaton (implemented by CNRS) has also been used to forecast more precisely land use changes on the next century. It appears that a valid estimation of the evolution of the main human activities over the next 20 years has been achieved.

Demographic scenarios have been partially developed for the Nedre Romerike site (Norway). Concerning the other proposed test sites: Pizzo d'Alvano (Italy) and Slanic (Romania), data concerning human activities are not sufficient for the moment to elaborate any kind of prospective scenario.

These prospective data will be used, taking account of their inherent uncertainties, to pursue the work as planned in work package 3.3. Land use will be linked with other indicators of landslide susceptibility in order to assess its impact on hazard, whereas demographic changes will be used for exposure changes and as far as possible used to assess hazard changes due to demographic pressure.

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8 ANNEXE: MEETING WITH THE BARCELONNETTE SITE STAKEHOLDERS

8.1 AIM OF THE MEETING

During the intensive course organised by the FP6 Mountain Risk project in Barcelonnette in June 2010, we have organized a round-table with some local stakeholders. The aim of the round-table was to present issues raised by the elaboration of human activity scenarios in the Ubaye Valley.

8.2 ROUND-TABLE

Before starting the round-table it-self, a brief presentation of SAFELAND work package 3.3 objectives has been given to the attendees. The local decision makers have manifested an interest in this kind of study but they have underlined the uncertainties linked to the hazard evolution as well as the urban development (it is difficult to foresee the evolution beyond some municipalities' term of office, 15 to 20 years).

8.3 SUBJECTS ADRESSED

The following points have been discussed:
- Concerning urban spreading, the constraint could come from strict European directives and local decision maker would thus have a very restricted room for manoeuvre.
- For vegetal cover, the reafforestation begun in the 19th century is now over, the main objective is to maintain this areas.
- There is no experience return concerning the quantification – even rough – of the "good practices" influence on the hazard evolution.
- Quick presentation of the project of a science campus for natural hazard studies in the former barracks.
- No information has been obtained concerning the potential development of tourism in the valley. The local urbanism plans should be consulted when they exist.