FP7 PROGRAMME

DORIS - Ground Deformations Risk Scenarios:
an Advanced Assessment Service

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REFERENCE DOCUMENTS

DR-1	Annex I - Description of Work of DORIS – "Ground Deformations Risk Scenarios: an Advanced Assessment Service"
DR-2	Deliverable 5.1- Large scale thematic maps for selected test-sites (1:50.000)
DR-3	Deliverable 5.3- Landslide event maps (1:10.000)

LIST OF ACRONYMS AND ABBREVIATIONS

ALTAMIRA	Altamira Information
CA	Consortium Agreement
CNR	Consiglio Nazionale delle Ricerche
CP	Civil Protection
DAP	Data Access Portfolio
DInSAR	Differential Synthetic Aperture Radar Interferometry
DOW	Description of Work
DPC	Dipartimento della Protezione Civile
EC	European Commission
ELGI	Magyar Allami Eotvos Lorand Geofizikai Intezet
EO	Earth Observation
ERCS	Emergency Response Core Service
ERS	Emergency Response Service
ESA	European Space Agency
EU	European Union
EUAC	External User Advisory Committee
FOEN	Bundesamt fuer Umwelt
FP	Focal Point
FP7	7th Framework Programme
FTS	Fast Track Service
GAMMA	Gamma Remote Sensing Research and Consulting
GMES	Global Monitoring for Environment and Security
IGME	Instituto Geológico y Minero De España
INSPIRE	Infrastructure for Spatial Information in Europe
IT	Information Technology
NFP	National Focal Point
PGI	Panstwowy Instytut Geologiczny - Panstwowy Instytut Badawczy
R&D	Research and Development
SAFER	Services and Application For Emergency Response
TRE	Tele-Rilevamento Europa
UNIFI	Università degli Studi di Firenze
WP	Work Package

EXECUTIVE SUMMARY

The main income of the island of Majorca comes from tourism (83% of its GDP), as it welcomes over 9 million visitors each year. During the years 2008-2010, Majorca experienced one of the coldest and wettest winters in living memory. The result was that several mass movements were triggered distributed along the Tramuntana Range. Fortunately, there were no deaths but there were numerous cases of damage to dwellings, holiday apartment blocks, barns and power stations, and especially the road network in the range, most significantly the numerous blockages on the Ma-10 road, which caused significant economic losses in the different tourist resorts. On the southern coast of the range, 17 holiday homes have been evacuated recently due to the impending risk of a large rockfall. This document aims to contribute to the evaluation of the damage and costs caused by the mass-movements in the Tramuntana range (Majorca), during the years 2008 to 2010. Total economic losses are valued at approximately 11 Million Euro, which represents 0.042% of the Balearic Autonomous Region GDP

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1. INTRODUCTION

Since the early 1950's, the economy of Majorca has gone through many changes with the tourist trade leading the way. Nowadays, the tourism business has become the main source of revenue for the island (83% of its GDP). The population of Majorca is approximately 800,000, most of which work in the tourism sector, attending to over 9 million visitors every year. The Tramuntana range is the main mountainous alignment of the island of Majorca. This region encompasses 16 municipal districts with a total population of 115,000 inhabitants, with the northern face much more heavily populated and urbanised. The economy of this region revolves exclusively around tourism, which accounts for 95% of its GDP. The steep topography of this chain, which is linked to its geological complexity and Mediterranean climate, determines intense slope dynamics with the consequences movements of all categories (Mateos, 2002, Mateos and Azañón, 2005). The vast urban development that the Tramuntana range has undergone in the past 30 years has considerably increased the risk originating from mass movements. During the hydrological years 2008 to 2010, Majorca experienced one of the coldest and wettest winters in living memory. Not only did the accumulated rainfall show twice the average recorded values, this period also witnessed the highest rates of intense rainfall (up to 296 mm/24h) since instrumental records have been available (1944). These rainy episodes have also coincided with temperatures around 0ºC and minima at -6.8ºC, anomalous values in the mild Mediterranean climate. The result was that several movements were triggered distributed along the Tramuntana Range. The structural layout of the materials that outcrop on the Tramuntana Range conditioned the distribution of the movements. The northern face is more hazardous due to the existence of steeper slopes and a higher presence of outcroppings of soft materials (Gelabert, 1992). Fortunately, there were no deaths but there were numerous cases of damage which caused significant economic losses in the different tourist resorts.

2. DAMAGE DESCRIPTION

During the years 2008 to 2010, Majorca experienced one of the coldest and wettest winters in living memory. The result was that 67 mass movements were triggered distributed along the Tramuntana Range. Fortunately, there were no deaths but there were numerous cases of damage to dwellings, holiday apartment blocks, barns and power station, and especially the road network in the range, most significantly the numerous blockages on the Ma-10 road, which caused significant economic losses in the different tourist resorts.

The road network

Ma-10 road

The Ma-10 road, located on the northern face of the mountain range, has heavy traffic estimated at 7,200 vehicles per day on average, and constitutes the main road of this region. During 2008-2010 18 mass movements affected this road (Fig1). Rockfalls have been the most hazardous, being noted the Gorg Blau rockfall on 31st December 2008 (Fig1-2) and Estellencs landslide on 8th March 2010 (Fig1-4), which blocked the Ma-10 road for three and a half months, cutting off the access to several locations and villages.

Others roads in the range

Secondary roads through the range have also been affected by landslides, especially by karstic collapses. In Majorca, the predominance of a carbonated rocky substrate, mainly limestone and dolomite from the Lower Jurassic, determines the occurrence of common processes in karstic areas, like sinkholes and shallow subsidence depressions. During the past two years, pre-existing holes have increased considerably. This is mainly due to the increase of the recharge prompted by the intense and continuous rainfall on the island. This additional recharge has not only led to an elevation in the piezometric level of the aquifers, but also (1) a rise in the load due to soil saturation, (2) a loss in internal resistance of the surface materials, (3) the increase in the dissolution processes which affect the rocky substrate, (4) the migration towards the surface of the cavities and cracks formed in the rock (Hyatt & Jacobs, 1996, Benito et al., 1995). The results are some karstic collapses with a clear visualization on roads.
Fig. 2 (4,5,6) shows some karstic collapses affecting the road network as well as the Cala Tuent landslide (fig 2-1,2) which blocked the road and cut off the tourist resort of Cala Tuent for a couple of months.

Buildings, dwellings and others

Rockfalls and landslides during 2008-2010 have also caused serious damage to buildings, holiday houses, dwellings and a power station in several places through the range. The area of Costa d´en Blanes, in the southern sector of the Tramuntana Range, should be noted, where 17 holyday houses haven been evacuated due to the impeding

risk of a large rockfall. This urban area was built in the 90`s surrounding a former gypsum quarry (Fig. 3-6). The geology determines the movement. Highly karstified carbonatic rocks (limestone) outcrop on the surface with a thickness of up to 10 m. At the base of the quarry, and below the limestone, we can see the marls which gypsum which were exploited during the mining activity. Large blocks of limestone are sliding over the soft materials, and large cracks have recently appeared at the top of the quarry, affecting some of the houses. Small rockfalls have also affected houses (Fig. 3-2,3,5) and apartment blocks (Fig. 3-4) causing a great alarm in the population. Fortunately, there were no deaths. Damages to barns and a power station (Fig. 3- 1) have also been registered.

Figure 1 Photographs of the most important movements affecting the Ma-10 road. 1) Sa Calobra (3/12/2008), 2) Gorg Blau (31/12/2008), 3) Estellencs (15/01/2010), 4) Estellencs (8/03/2010), 5) Banyalbufar (09/05/2010) and 6) Pilar (12/10/2010).

Figure 2 Photographs of secondary roads on the range affected by landslides and karstic collapses (sinkholes). 1 and 2) Cala Tuent landslide (15/12/2008), 3) Es Verger landslide (15/12/2008), 4) Búger sinkhole (Jan 2010), 5) Es Verger sinkhole (15/12/2008) and 6) Crestatx sinkhole (3/5/2010).

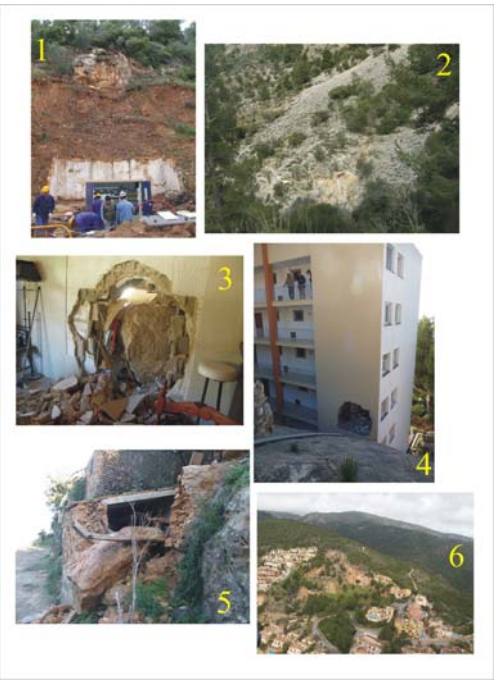


Figure 3 Damage caused to buildings, dwellings and others by rockfalls and landslides during 2008-2010 in several places on the range. 1) Deià power station (29/10/2008), 2) Biniaraix (6/01/2009), 3) Puigpunyent (14/09/2009), 4) Siesta (8/01/2009), 5) Son Albertí (Jan 2010) and 6) Costa d´en Blanes (Jan 2010).

3. ECONOMIC REPERCUSSIONS

Aiming to evaluate the economic losses caused by the mass movements, we have contacted with various local and regional departments of the Government of Majorca. Road damage was evaluated in accordance with information from the Road Maintenance Services, and included: debris removal from road, adequacy of banking, research and stability projects, as well as those relating to the repair of the road. Indirect costs have also been calculated referring to the economic losses of the different municipal districts affected by the cutting off of the road, such as Banyalbufar, Estellencs and Cala Tuent.

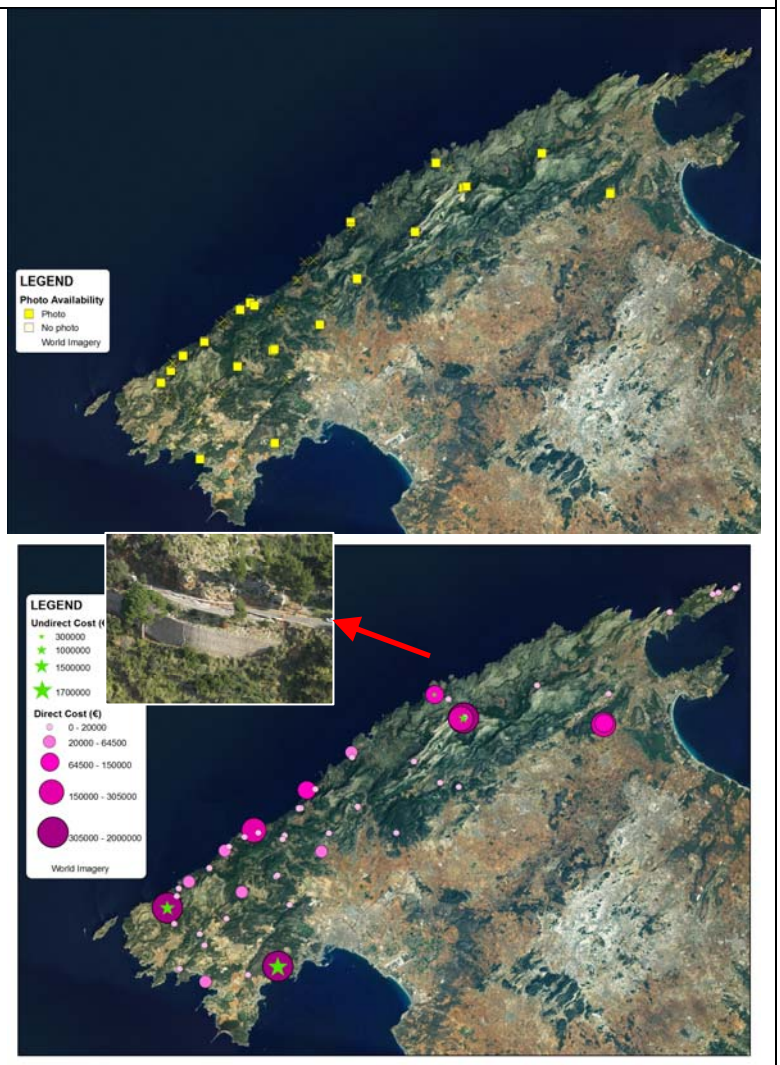
The interruption in tourist arrivals at these localities for several months led to the closure of restaurants, hotels and snack bars, with the consequent loss of jobs and profits. These councils have provided information concerning these indirect economic losses, valued by them to seek compensation from the State and insurance companies.

Referring to repair costs of houses, buildings and others, information was reported by private individuals. In the case of the Costa d´en Blanes development, all economic data relating to ground studies and repair projects, the indirect cost of houses evacuation, repair cost, etc., have been provided by the Calvià council. Tab. 1 show all the costs related to each event. Total economic losses are valued at approximately €11M, which represents 0.042% of the Balearic Autonomous Region GDP.

Movement Inventory No. and date	Damage	Cost (€)	
		Direct	Indirect
S'Estaca (30001) 15 Feb 2008	Dwellings	150,000	
Costa Deià (30002) 29 Oct 2008	Power station	60,000	
Sa Calobra (30004) 03 Dec 2008	Ma-10	225,000	
Es Verger (30005) 15 Dec 2008	Es Verger road	10,000	
Es Verger (30006) 15 Dec 2008	Es Verger road	10,000	
Cala Tuent (30007) 15 Dec 2008	Cala Tuent road	130,000	300,000
Gorg Blau (30009) 31 Dec 2008	Ma-10	1,500,0000	1,000,000
Banyalbufar (30012) 02 Jan. 2009	Ma-10	5,000	
Biniaraix (30014) 06 Jan 2009	Small building	12,000	
Port de Valldemossa (30015) 07 Jan. 2009	Ma-1133	2,100	
Crestatx (30016) Jan 2009	Housing development street	120,000	
Edificio Siesta (30017) 08 Jan 2009	Building	30,000	
Son Albertí (30018) 23 Jan 09, Jan 10	Small building	20,000	
Casa Puigpunyent (30020) 14 Sep 2009	Dwelling	30,0000	
Estellencs (30221) 15 Jan 2010	Ma-10	35,000	
Costa d'en Blanes (30022) Jan 2010	Dwelling	1,500,000	1,700,000
Son Antic (30030) 17 Feb 2010	Barn and terraces	30,000	
Estellencs (30032) 08 Mar 2010	Ma-10	2,000,000	1,500,000
Petrol station (30034) 09 Apr 2010	Ma-10	15,000	
Crestatx (30035) 03 May 2010	Housing development street	200,000	
Banyalbufar (30036) 09 May 2010	Ma-10	305,000	
Andratx (30037) 12 Oct- 2010	Ma-10	6,900	
Several rockfall (400xx)	Ma-10	125,800	
Several rockfall (400xx)	Others road	72,200	

Table 1. Direct and indirect costs (€) caused by mass movements in the road network , buildings, dwellings, houses and others located in the Tramuntana range, during the rainy and cold period 2008-2010.

4. DAMAGE MAP

Damage assessment map		
File name	Damage map	
Date	March 2013	
Spatial Resolution	1:5.000	
File Format	Feature class	
Reference System (Geodetic System - Projection)	ERTS89 - UTM 31 N	
Source:	Working data generated from LANDSLIDE INVENTORY.	
Description:	Maps shows damages caused by the mass-movements during the years 2008 to 2010. Where values are estimated, Direct and Undirect Costs are symbolized. Photo availability is also represented and photo can be displayed.	