PROJECT ACT

ADAPTING TO CLIMATE CHANGE IN TIME

Climate Change and Cultural Heritage

Raffaela Gaddi

Rome 20th July 2010

ISPRA Institute for Environmental Protection and Research

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Summary

- ✓ Risk indicators method
- ✓ Climatic parameters and impacts
- ✓ Vulnerability
- ✓ Case study
- ✓ Adaptation strategies
- ✓ Conclusions

The risk indicators method

The risk indicators method has been applied by ISPRA and ISCR (Institute for Conservation and Restoration) to evaluate the potential weathering hazard caused by climate and environmental factors on cultural heritage

The Risk Map of Cultural Heritage (ISCR,1995)

The objective of the project is to identify the space/time distribution of *the risk* in order to plan the maintenance activities and to reduce the restoration works certainly more expensive and invasive.

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

The risk

The risk for cultural heritage in Ancona, Bullas and Patrasso can be defined through three indicators:

Territorial Risk **(R_t), concerning the state of susceptibility to a weathering process of the aggregate of monuments located in a specific area.**

$$R_t = n \bullet TD$$

- n: number of monuments
- TD: Territorial Danger

Individual Risk **(R_i), that indicates the state of susceptibility to a weathering process of a single asset.**

$$R_i = V_j \bullet TD$$

- V_j: Vulnerability
- TD: Territorial Danger

Local Risk **(R_l), that indicates the state of susceptibility to a weathering process of a single asset, estimating the territorial danger in the area near the monument**

$$R_l = V_j \bullet TD_j$$

- V_j: Vulnerability
- TD_j: Territorial Danger near the monument

TERRITORIAL DANGER

(impacts)

climatic and environmental parameters

(that contribute to deterioration phenomena)

VULNERABILITY of the single item

(its conservation condition)

distribution of cultural properties

sensitivity of monuments to climate change

Climatic and environmental parameters

temperature	→	freeze- thaw damage, deterioration phenomena of surfaces due to thermal stress, biochemical colonization
moisture	→	cycles of crystallisation and dissolution of soluble salts due to "wetting and drying" mechanisms
wind	→	erosion phenomena
precipitation	→	erosion and corrosion phenomena
air pollutants	→	the stone decay by dissolution of carbonates, blackening of materials, corrosion of metals, the biological deterioration

Territorial Danger

The damage on a monument is due to the climatic and environmental conditions of the area where the asset is placed (*territorial danger*); the effects usually depend on the composition and nature of materials constituting the cultural heritage.

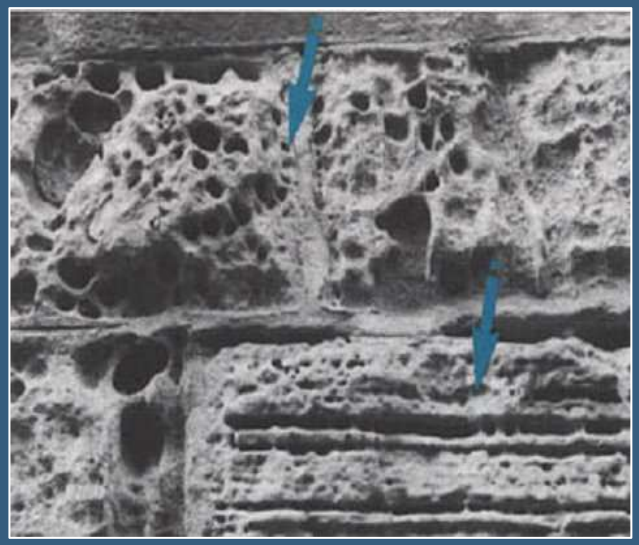
The calcareous assets could be undergone to following mechanisms:

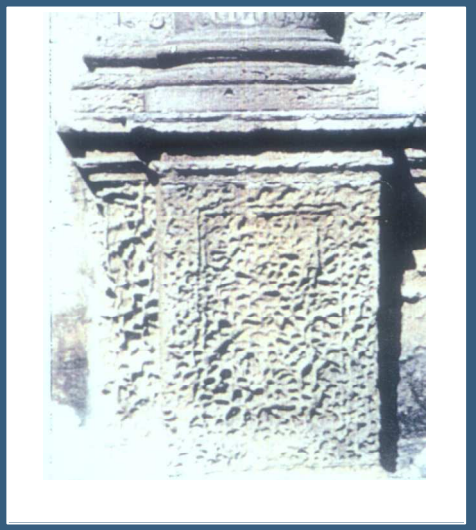
- ✓ **erosion / corrosion**
- ✓ **salt crystallization**
- ✓ **thermoclastism**
- ✓ **biological deterioration**
- ✓ **blackening**

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Erosion

for calcareous monuments

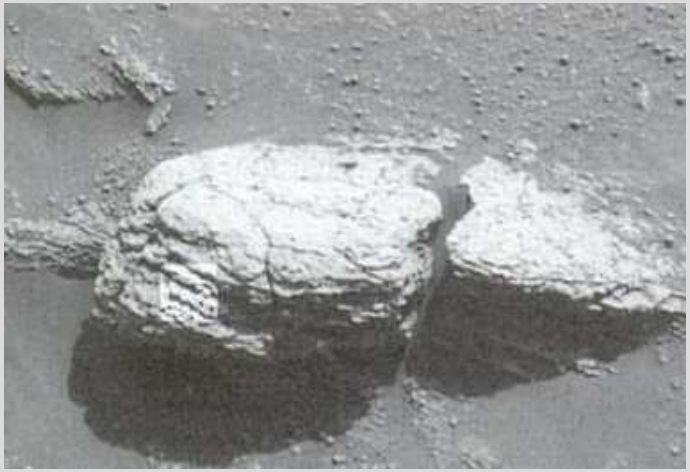




$$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

Salt Crystallization

Termoclastism



Biological deterioration

Several algorithms are available to calculate the surface recession (erosion) expressed in μm year $^{-1}$ for calcareous assets.

clean rain effect

(karst effect)

SO_2 deposition

$$R = 18.8 \cdot Rain + 0.016 \cdot [H^+] \cdot Rain + 0.18 \cdot (V_{ds} \cdot [SO_2] + V_{dN} \cdot [HNO_3])$$

solubility of $CaCO_3$ in equilibrium with 330 ppm CO_2

acid rain effect

HNO_3 deposition

Lipfert formula (1989)

Corrosion
for metals

Multiassess dose-response functions

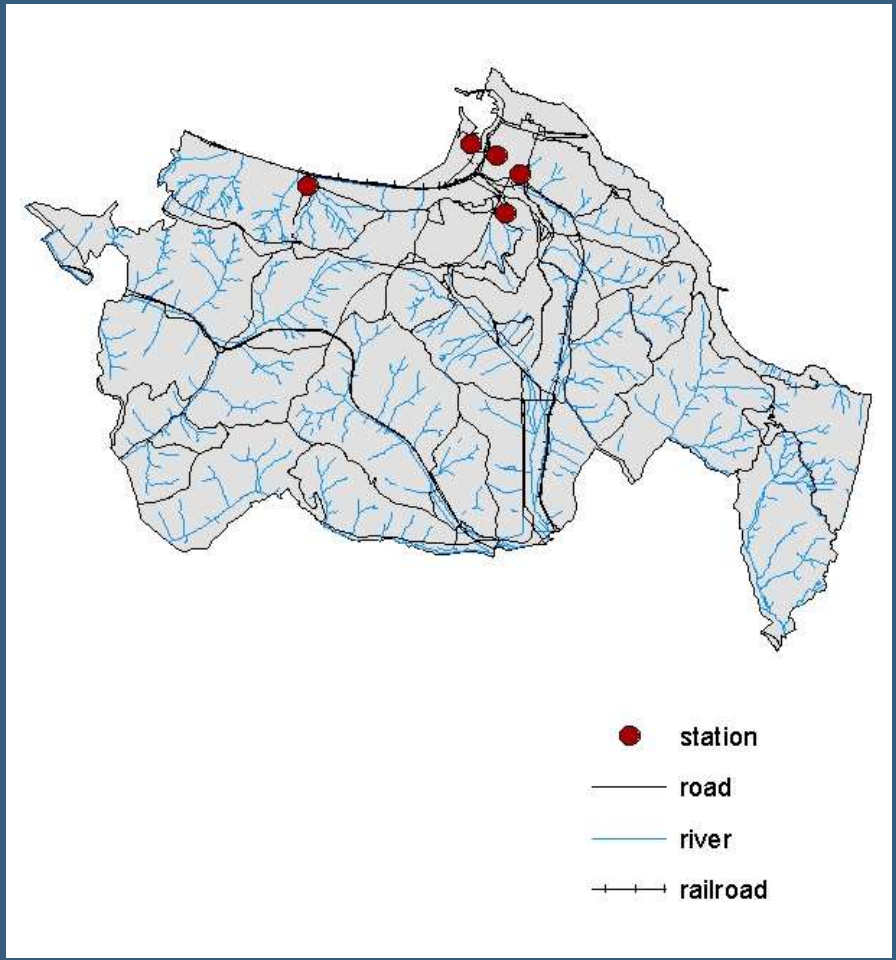
Copper

$$ML = 3.12 + (1.09 + 0.00201 \cdot [SO_2] \cdot 0.4 \cdot [O_3] \cdot Rh_{60} \cdot e^{f(T)} + 0.0878 \cdot Rain \cdot [H^+]) \cdot t$$

Bronze

$$ML = 1.33 + (0.00876 \cdot [SO_2] \cdot Rh_{60} \cdot e^{f(T)} + 0.0409 \cdot Rain \cdot [H^+] + 0.0380 \cdot [PM_{10}]) \cdot t$$

The calculation of erosion/corrosion at urban level is usually done using climatic and pollutants data collected by air quality stations located not far from the considered monuments.



Georeferencing of monitoring stations in Ancona
(**source: BRACE data-base**)

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Distribution of monuments

The risk assessment is based on a deep knowledge of distribution of cultural properties in a specific area and their chemical – physical characteristics

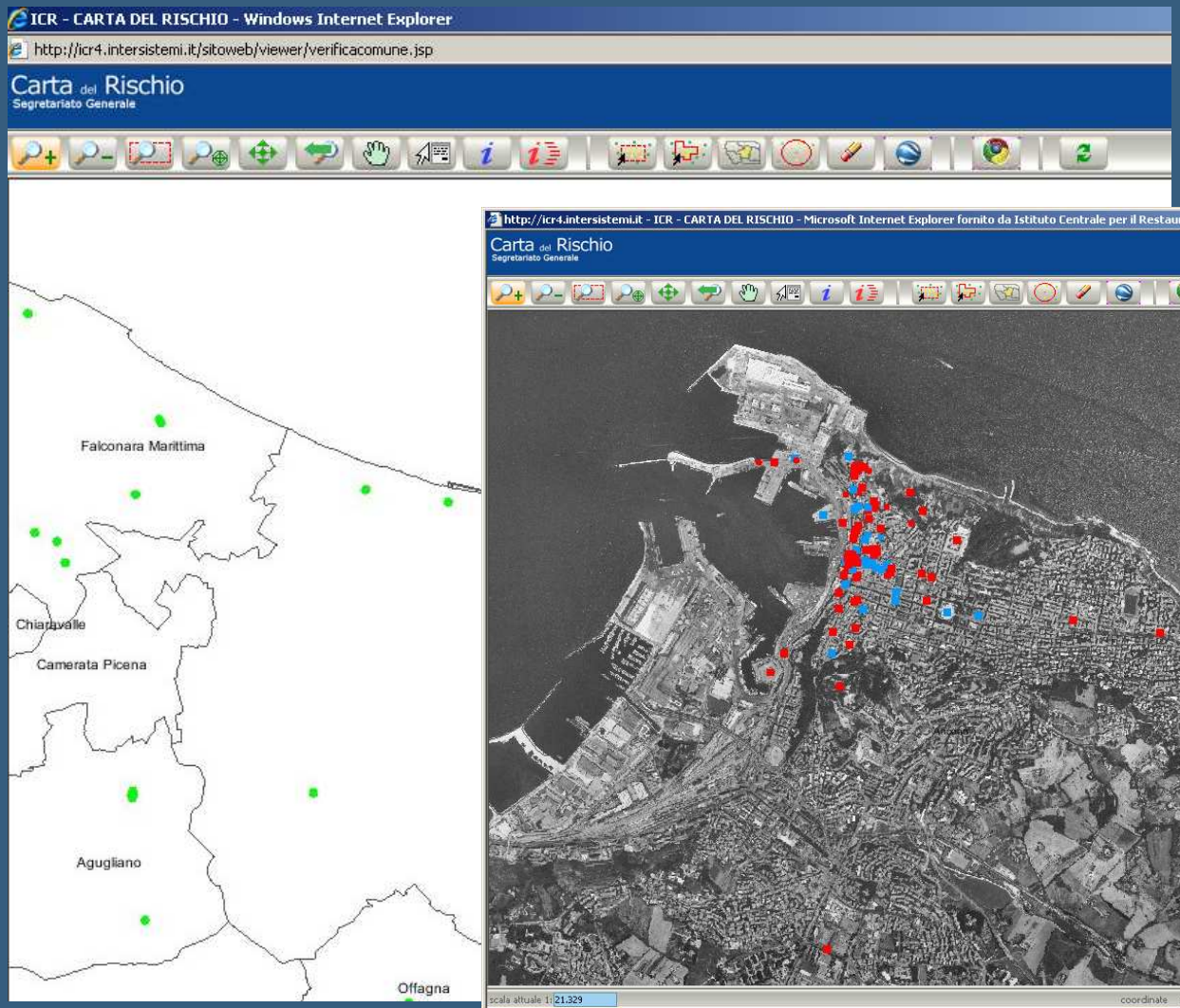
The Risk Map of Cultural Heritage provides an evaluation about the number, position, nature and function of archaeological sites and architectural properties

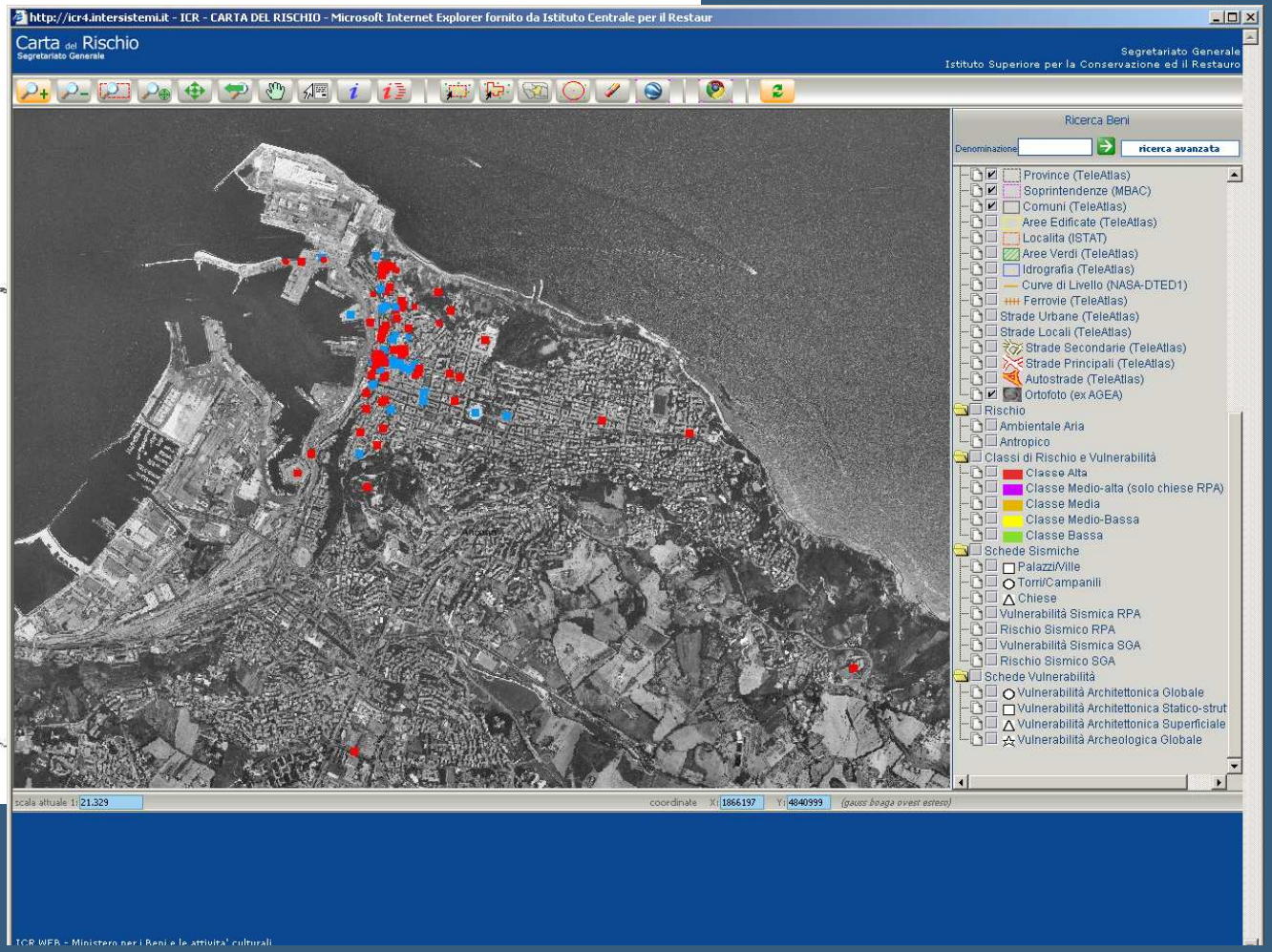
The recorded items in Ancona are 14 archaeological sites and the 111 architectural monuments

The available data sheets are:

Data sheets binding decrees	87
Data sheets TCI- Laterza	53
Data sheets earthquake Marche- Umbria (1997)	1
Vulnerability data sheets s archaeological asset	2
Vulnerability data sheets archaeological find	1

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale


ICR - CARTA DEL RISCHIO - Windows Internet Explorer
http://icr4.intersistemi.it/sitoweb/viewer/verificacomune.jsp
Carta del Rischio
Segretariato Generale
Falconara Marittima
Chiaravalle
Camerata Picena
Agugliano
Offagna


http://icr4.intersistemi.it - ICR - CARTA DEL RISCHIO - Microsoft Internet Explorer fornito da Istituto Centrale per il Restaur
Carta del Rischio
Segretariato Generale
Segretariato Generale
Istituto Superiore per la Conservazione ed il Restauro
Ricerca Beni
Denominazione
ricerca avanzata
Province (TeleAtlas)
Soprintendenze (MBAC)
Comuni (TeleAtlas)
Aree Edificate (TeleAtlas)
Localita (ISTAT)
Aree Verdi (TeleAtlas)
Idrografia (TeleAtlas)
Curve di Livello (NASA-DTED1)
Ferrovie (TeleAtlas)
Strade Urbane (TeleAtlas)
Strade Locali (TeleAtlas)
Strade Secondarie (TeleAtlas)
Strade Principali (TeleAtlas)
Autostrade (TeleAtlas)
Ortofoto (ex AGEA)
Rischio
Ambientale Aria
Antropico
Classi di Rischio e Vulnerabilità
Classe Alta
Classe Medio-alta (solo chiese RPA)
Classe Media
Classe Medio-Bassa
Classe Bassa
Schede Sismiche
Palazzi/Ville
Torri/Campanili
Chiese
Vulnerabilità Sismica RPA
Rischio Sismico RPA
Vulnerabilità Sismica SGA
Rischio Sismico SGA
Schede Vulnerabilità
Vulnerabilità Architettonica Globale
Vulnerabilità Architettonica Statico-strut
Vulnerabilità Architettonica Superficiale
Vulnerabilità Archeologica Globale
scala attuale 1:
21.329
coordinate
X:
1866197
Y:
4040999
(gauss boaga ovest esteso)
ICR WEB - Ministero per i Beni e le attivita' culturali

Sensitivity

The sensitivity depends on:

- ✓ **location of the monument**
- ✓ **composition of the constitutive materials**
- ✓ **framework, surface, preparatory layers**
- ✓ **hygroscopic nature of materials**

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Vulnerability

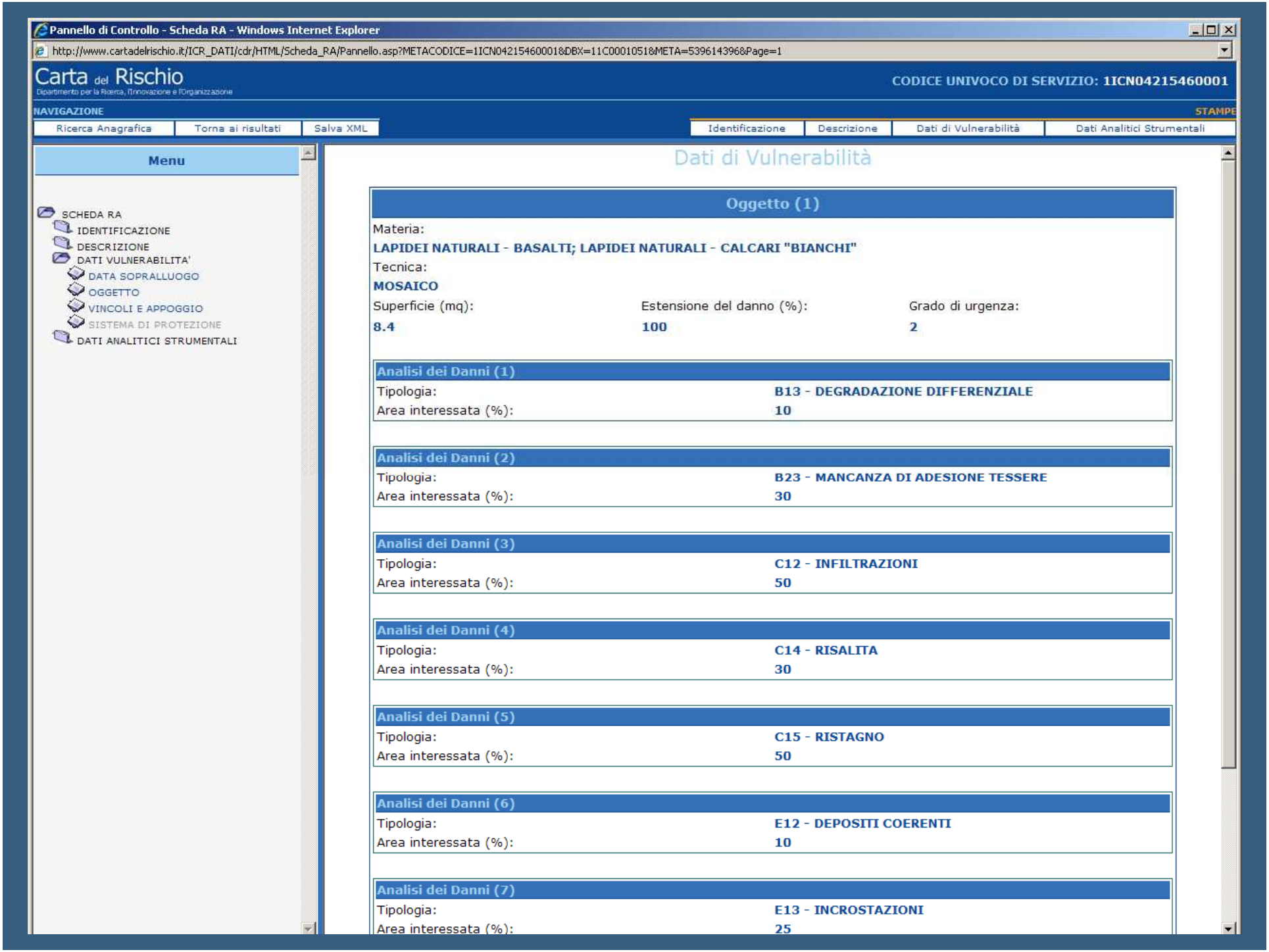
(conservation condition of a monument)

The vulnerability of each items represents the variable that indicates *its level of exposure to environmental/territorial danger in relation with its conservation condition*. The information, acquired through a data sheets model, are elaborated in order to obtain data on the conservation condition for 12 architectonic and decorative elements:

foundations
vertical structures
horizontal structures
roofing structures
vertical links
indoor paving
outdoor paving
claddings
indoor decorations
outdoor decorations
outdoor openings
indoor openings

generic damage
material decay
moisture
biological deterioration
surface deterioration
lacunae, missing fragments/pieces

seriousness
extent
urgency


Pannello di Controllo - Scheda RA - Windows Internet Explorer
http://www.cartadelrischio.it/ICR_DATI/cdr/HTML/Scheda_RA/Pannello.asp?METACODICE=1ICN042154600018DBX=11C0001051&META=5396143968Page=1
Carta del Rischio
Dipartimento per la Ricerca, l'Innovazione e l'Organizzazione
CODICE UNIVOCO DI SERVIZIO: 1ICN04215460001
NAVIGAZIONE
STAMPE
Ricerca Anagrafica
Torna ai risultati
Salva XML
Identificazione
Descrizione
Dati di Vulnerabilità
Dati Analitici Strumentali
Menu
SCHEDA RA
IDENTIFICAZIONE
DESCRIZIONE
DATI VULNERABILITA'
DATA SOPRALLUOGO
OGGETTO
VINCOLI E APPOGGIO
SISTEMA DI PROTEZIONE
DATI ANALITICI STRUMENTALI
Dati di Vulnerabilità
Oggetto (1)
Materia:
LAPIDEI NATURALI - BASALTI; LAPIDEI NATURALI - CALCARI "BIANCHI"
Tecnica:
MOSAICO
Superficie (mq):
8.4
Estensione del danno (%):
100
Grado di urgenza:
2
Analisi dei Danni (1)
Tipologia:
B13 - DEGRADAZIONE DIFFERENZIALE
Area interessata (%):
10
Analisi dei Danni (2)
Tipologia:
B23 - MANCANZA DI ADESIONE TESSERE
Area interessata (%):
30
Analisi dei Danni (3)
Tipologia:
C12 - INFILTRAZIONI
Area interessata (%):
50
Analisi dei Danni (4)
Tipologia:
C14 - RISALITA
Area interessata (%):
30
Analisi dei Danni (5)
Tipologia:
C15 - RISTAGNO
Area interessata (%):
50
Analisi dei Danni (6)
Tipologia:
E12 - DEPOSITI COERENTI
Area interessata (%):
10
Analisi dei Danni (7)
Tipologia:
E13 - INCROSTAZIONI
Area interessata (%):
25

The algorithm using for calculation of vulnerability is:

$$INDvul(k) = \Sigma\ (Pj \bullet Q_{ji}/(m-n) \bullet (cost/m))$$

INDvul (k) = vulnerability index of k- monument

m = number of variables used for quantifying the superficial conservation condition in relation with the urgency, seriousness and extent.

n = number of variables for which information is not available

P_j = weight of j -variable

Q_{ji} = i- value of j -variable

cost/m = updated constant in relation with updated weight of variables

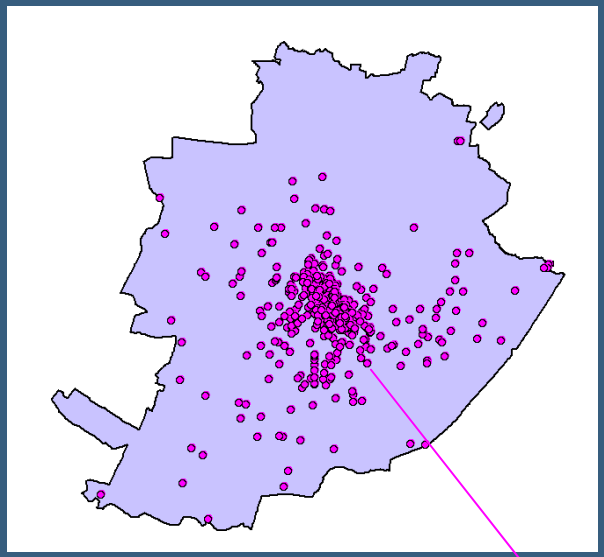
ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Torino: a case study

Experimental Data

Climatic Parameters

Relative Humidity
Temperature
Precipitation
recorded by monitoring stations

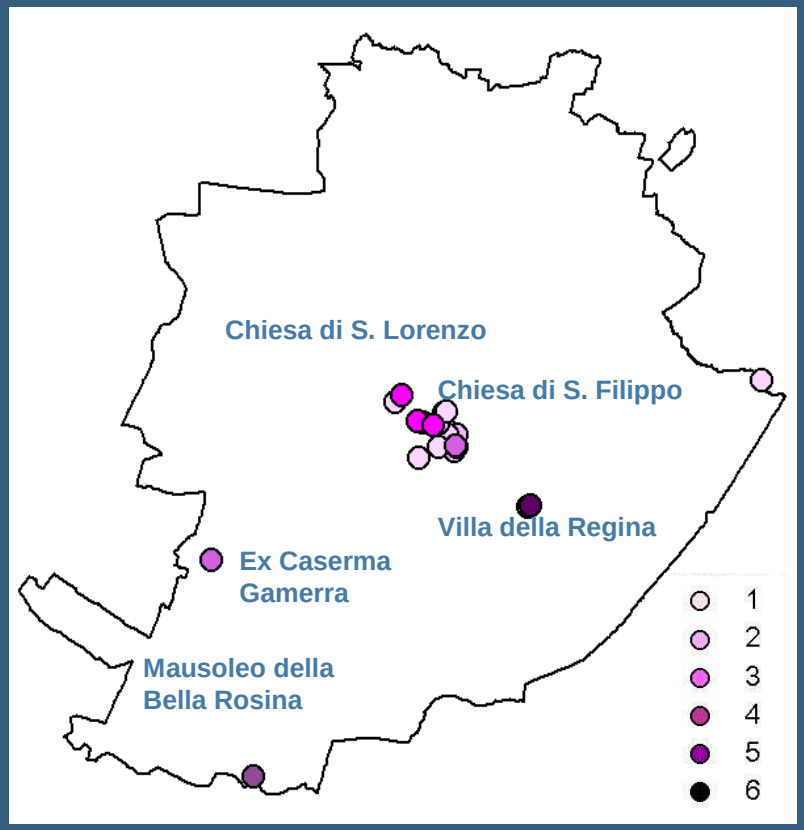


Air Pollutants

SO_2, HNO_3, PM_{10} concentrations elaborated by FARM model

	Rain (mm)	Rh(%)	T(℃)	pH
2004	594	72	13	4,85
2005	559	67	13	5,15
2006	674	67	14	5,04

Vulnerability

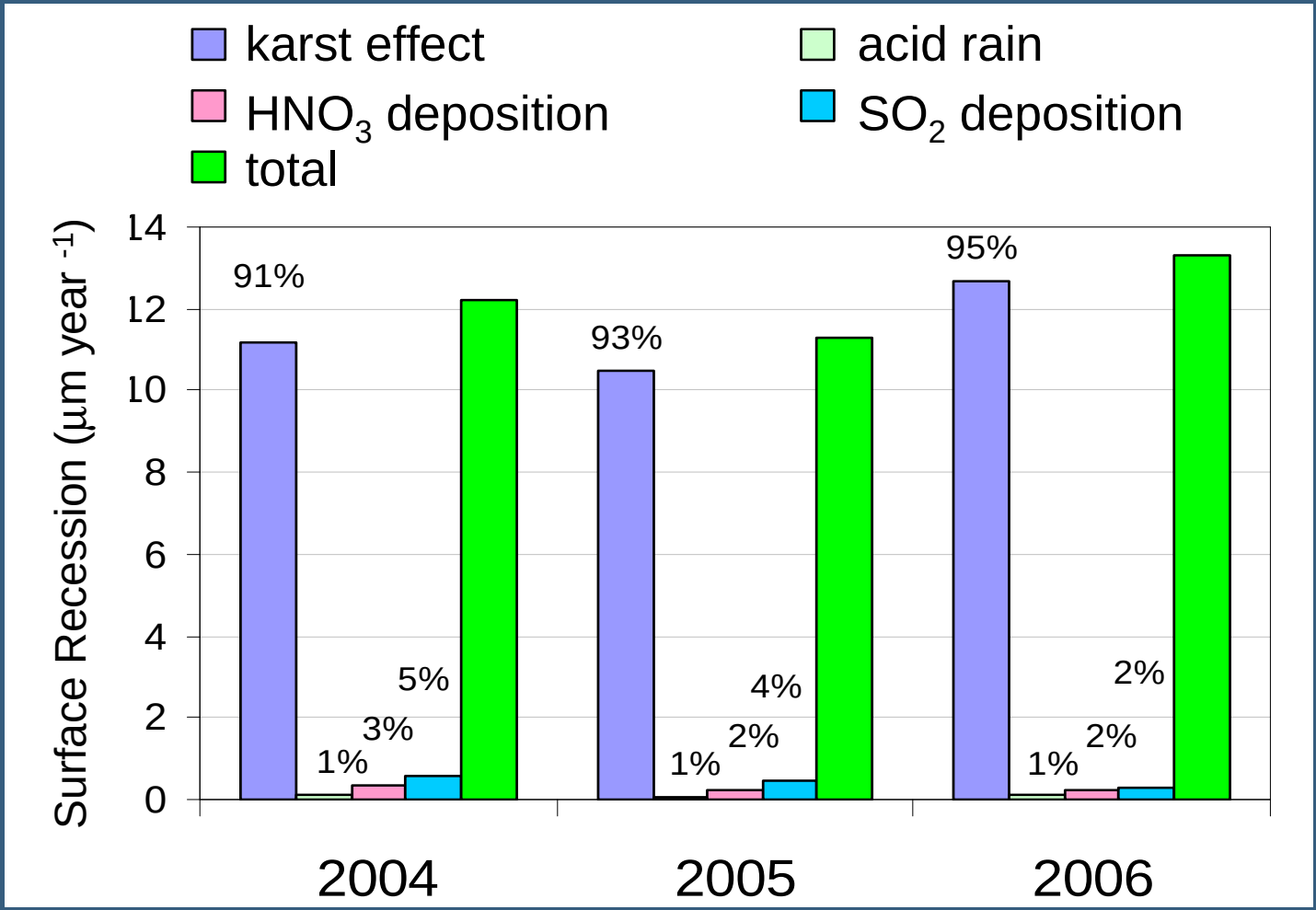


Villa della Regina

Palazzo Reale

Chiesa di San Lorenzo

Surface Recession (erosion)

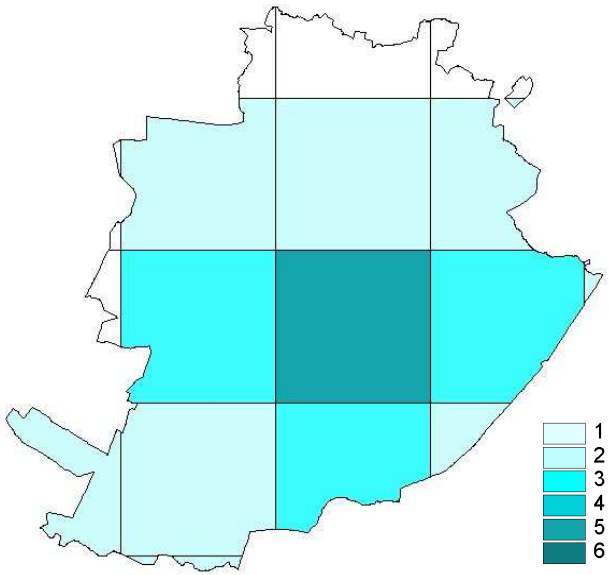


$$R = 18{,}8 \cdot Rain + 0{,}016 \cdot [H^+] \cdot Rain + 0{,}18 \cdot (V_{dS} \cdot [SO_2] + V_{dN} \cdot [HNO_3])$$

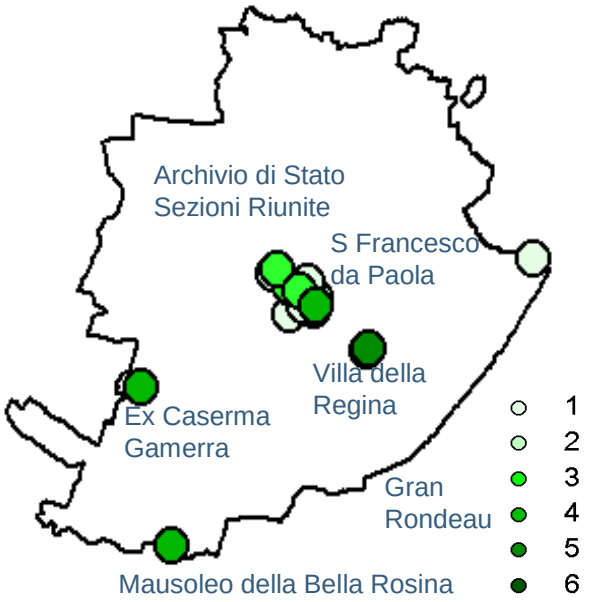
Risk indicators

2006

Territorial Risk



Individual Risk



Adaptation strategies

To maximise the adaptive capacity of built heritage and cultural landscapes, the following actions are suggested:

- ✓ **Reduction of the restoration interventions**
- ✓ **Individuation of the assets that can be shifted away from a threatened site**
- ✓ **Long-term reorganisation of sites with high level of risk**
- ✓ **Planning rigorous and frequent maintenance activities to monitor the conservation condition of the property**

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Conclusions 1/2

- ✓ **The effects of climate and environmental change on cultural heritage have been faced by international and scientific community only in recent years**
- ✓ **The actions realized by institutions and the funding destined to reduce the damage are insufficient yet**
- ✓ **The correlation between the monument vulnerability with territorial danger in each area permits the calculation of territorial and individual risk**

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Conclusions 2/2

- ✓ **The indicators assessment allows to individuate the most aggressive areas for monuments and their potential risk level**
- ✓ **This scientific approach can be a support to the decision makers to adopt specific strategies aiming to reduce the climate change effects by planning maintenance and monitoring actions.**

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale