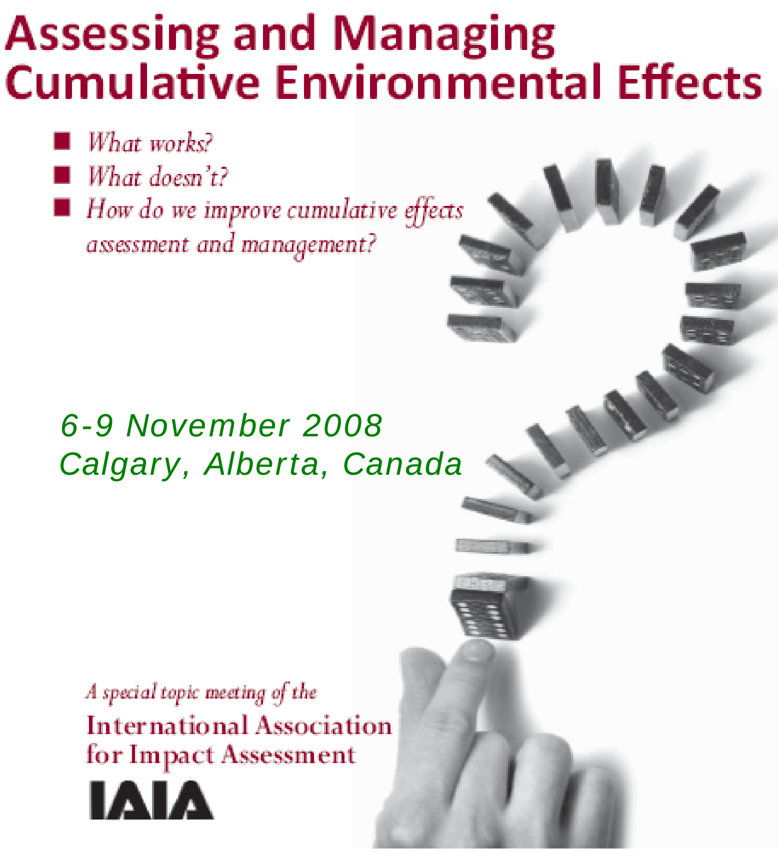
An Operative GIS-Based Methodology for Quantifying Impacts of Past, Present and Future Cumulative Actions of Projects



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Giuseppe Magro
Nuclear engineer
Dept. of Energy, Nuclear Engineering and Environmental Control D.I.E.N.C.A., University of Bologna
President IAIA Italia Affiliate

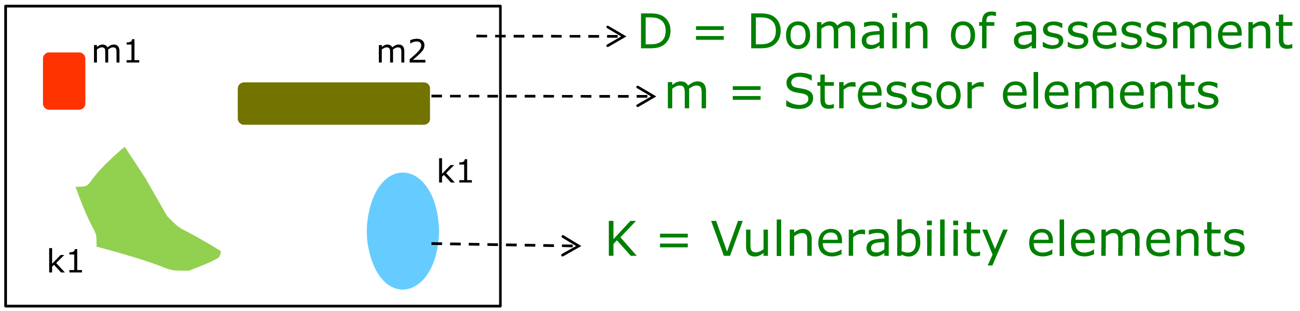
Stefania Pellegrini
Civil engineer
IAIA Italia

Federico Pelizzari
Environmental consultant
IAIA Italia

Operative GIS-Based Methodology

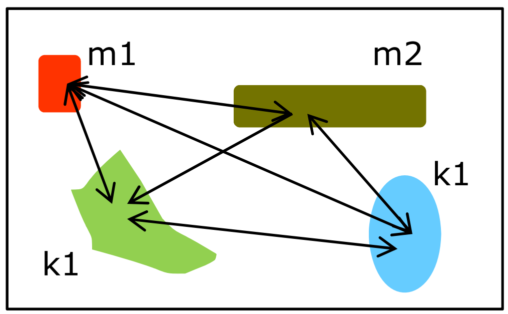
Let's see the space-time framework of the methodology

CONCEPTUAL MODEL



The model characterizes their **interaction** in a space-time frame

STRESSOR VULNERABILITY INTERACTION FRAME - SVIF



Each stressor element $\mathbf{m_i}$ is characterizated by stressor attributes or pressure attributes in space-time frame so that we write them in a space-time function $a_{ij}(r,t)$.

$$\mathbf{m_i} = \sum a_{ij}(r,t)\,\mathbf{u_j}$$

Ex.

Emission of traffic produces several pollutants each one with is concentrations, with its “story”.

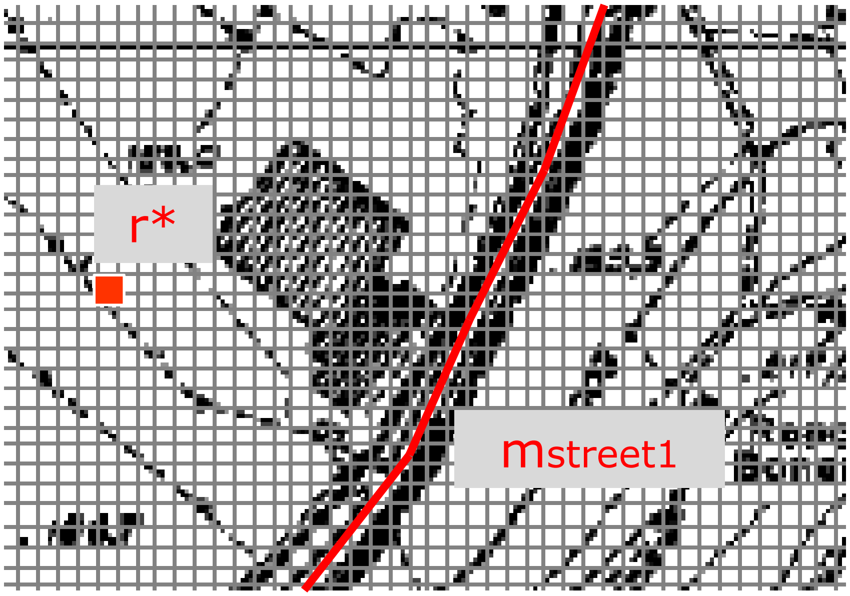
$$\mathbf{m_1} = a_{11}(r,t)\,\mathbf{u_1} + a_{12}(r,t)\,\mathbf{u_2} + \ldots$$

Stressor element

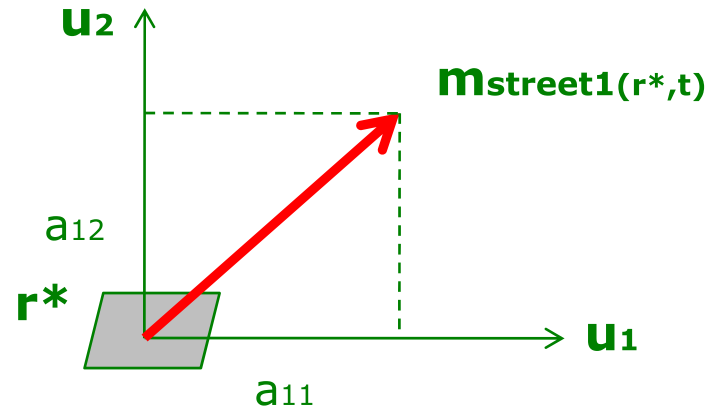
Concentration function (sampled function or modelling simulation)

Space of a_{11} function corresponding with one of our GIS space

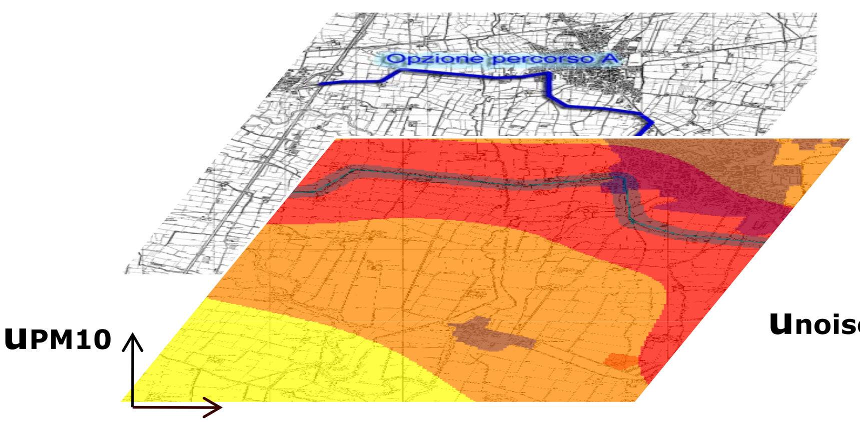
$$\mathbf{m_{street1}} = a_{1PM10}(r,t)\,\mathbf{u_{PM10}} + a_{1noise}(r,t)\,\mathbf{u_{noise}} + \ldots$$

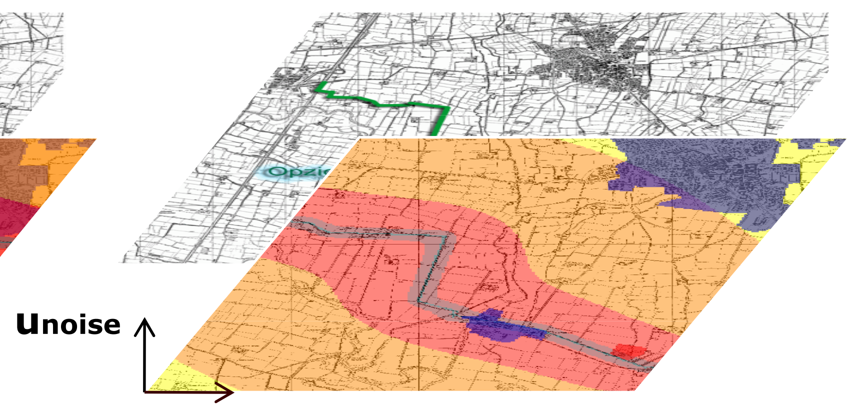


$$\mathbf{m}_{street1}(\mathbf{r}^*,t)=a_{11}\,(r^*,t)\;\mathbf{u}_1+a_{12}\,(r^*,t)\;\mathbf{u}_2$$



We can also represent in GIS mode:





It is possible to introduce a general stressor frame **σ(r,t)** which takes into consideration all stressor elements of assessment domain.

σ(r,t)	u_{PM10}	u_{noise}	**…**
$m_{street1}$	a_{1PM10}	a_{1noise}	
m_2	a_{2PM10}	a_{2noise}	
m_3	a_{3PM10}	a_{3noise}	
…			

This row takes into consideration different contribution given only by $m_{street1}$ ON all pressure attributes (indicators)

This column takes into consideration contributions given by all stressor elements ON PM10 space

σ(r,t) is defined on Domain of assessment and represents the STATE OF ANTHROPIC PRESSURE ON THE SYSTEM

→ it is now necessary to introduce environment in the model

Environment is represented by K elements of our conceptual model so that is possible to define a, similar to σ(r,t), matrix for it.

VECs frame

ε(r,t)	$\mathbf{v}_1$	$\mathbf{v}_2$	…
$\mathbf{k}_1$	b_{11}	b_{12}	
$\mathbf{k}_2$	b_{21}	b_{22}	
$\mathbf{k}_3$	b_{31}	b_{32}	
…			

$$\mathbf{k}_h = \sum b_{hk}(r,t)\, \mathbf{v}_k$$

For example:

$$K_{\text{urban area}} = b_{\text{urban density}}(r,t)\mathbf{v}_{\text{density}} + b_{\text{urban children density}}(r,t)\mathbf{v}_{\text{children density}}$$

CALCULATING CUMULATIVE IMPACTS

STRESSOR ELEMENTS

TENSOR OF STRESSOR $\sigma(r,t)$

u-frame	u_1	u_2	u_{OTHER}
TYPE 1	✓	✓	…
TYPE 2	0	✓	…
OTHER type	…	…	…

Pressure attribute associated with ranking analysis of models (University of Brescia)

VULNERABILITY ELEMENTS

TENSOR OF VULNERABILITY $\varepsilon(r,t)$

v-frame	v_1	v_2	v_{other}
K_1	✓	0	…
K_1	0	✓	…
K_{other}	…	…	…

Vulnerability attribute

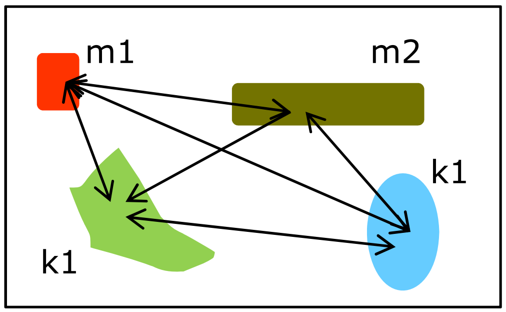
MATRIX OF CORRELATION θ

$\sigma(r,t)$ → ← $\varepsilon(r,t)$

	u_1	u_2	u_{OTHER}
v_1	✓	✓	…
v_2	0	✓	…
v_{other}	…	…	…

$i = \sigma\ \varepsilon$

It is possible to study the **interaction frame** previously introduced by conceptual model



$$\mathbf{i = \sigma \cdot \varepsilon} = \begin{bmatrix} u_1v_1 & u_1v_2 \\ u_2v_1 & u_2v_2 \end{bmatrix}$$

MATRIX OF IMPACTS

$$\mathbf{i_{u1v1}} = a_{11} \cdot b_{11} \cos\theta_{11}$$

Entity of pressure

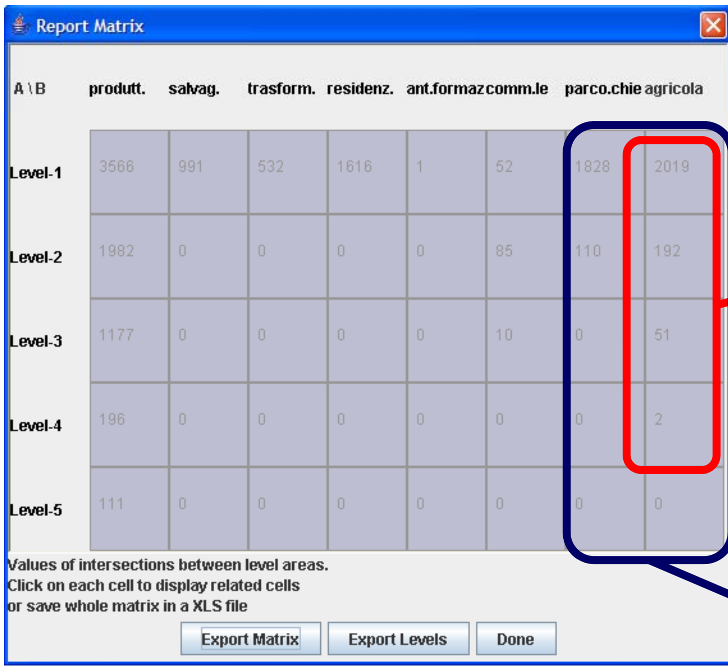
Entity of vulnerability

Entity of tipological interaction

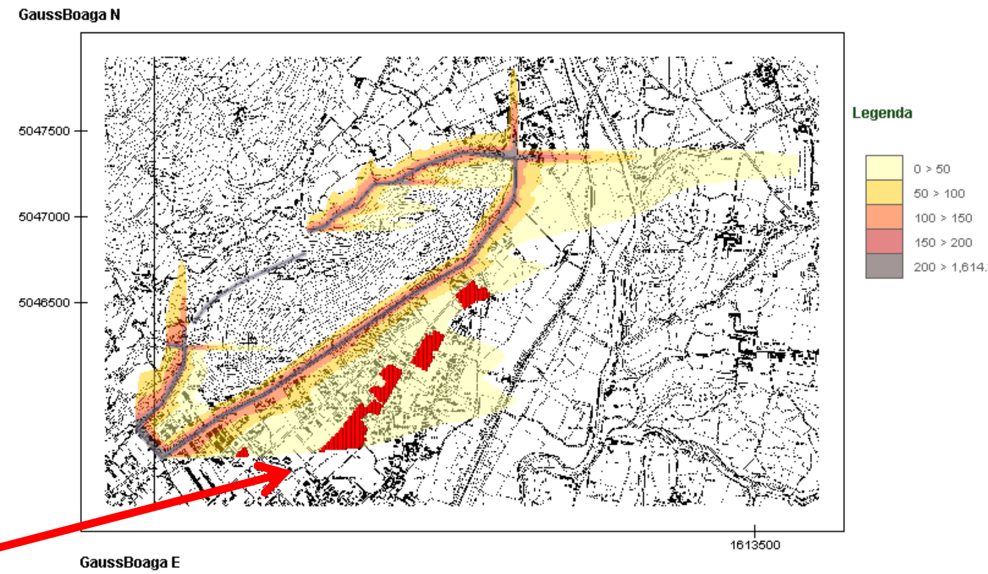
For example, if a_{11} is concentration of PM10 [µg/mc] and b_{11} is urban density [people/mq], we can study interaction through report analysis.

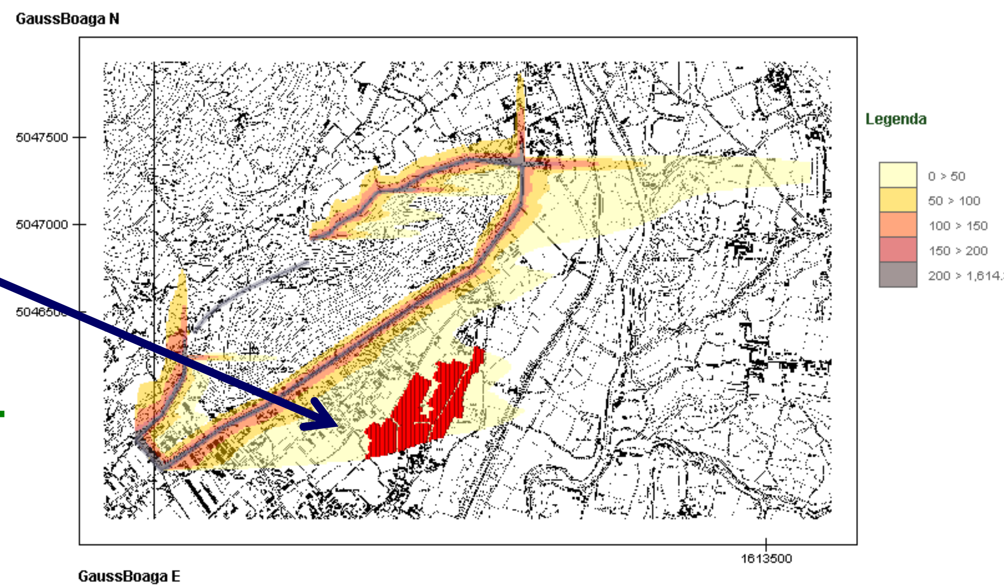
$b_{11}=[l_1 \dots l_m]$

$a_{11}=[L_1 \dots L_n]$



A \ B	produtt.	salvag.	trasform.	residenz.	ant.formaz	comm.le	parco.chie	agricola
Level-1	3566	991	532	1616	1	52	1828	2019
Level-2	1982	0	0	0	0	85	110	192
Level-3	1177	0	0	0	0	10	0	51
Level-4	196	0	0	0	0	0	0	2
Level-5	111	0	0	0	0	0	0	0





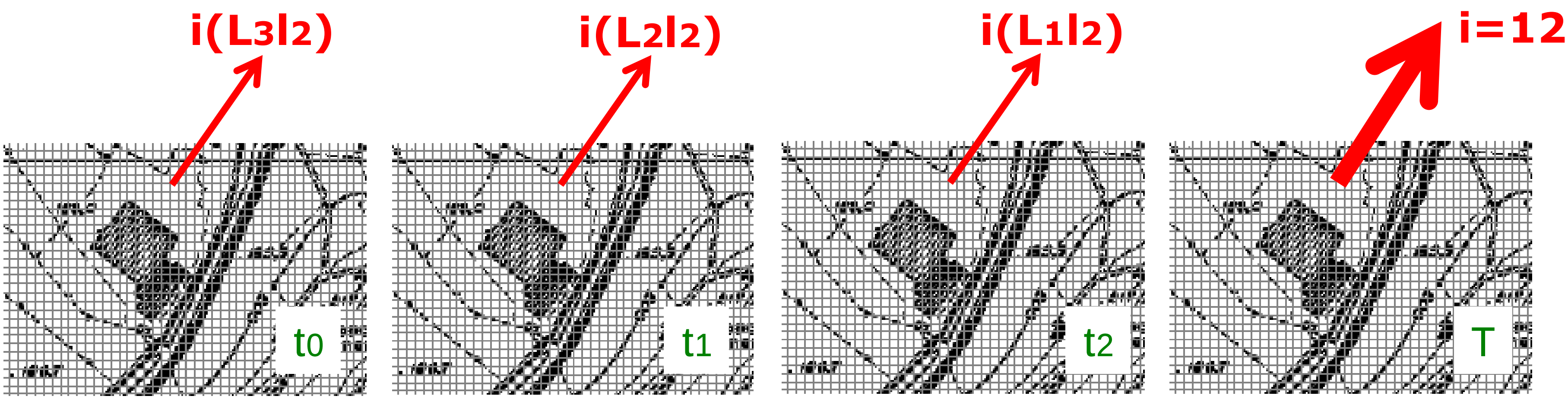
DCGIS GEO-REPORT

Calculation of past, present and future **cumulative impacts:**

a) Cumulative σ-frame $\int \sigma dt$

b) Cumulative σ·ε-frame $\int \sigma \cdot \varepsilon \, dt = \int i dt$

σ(r,t) and **i(r,t)** have $L_i l_j$ state “outcomes” and we can compute then in **past, present and future** or having a istantaneous value of the matrix function.



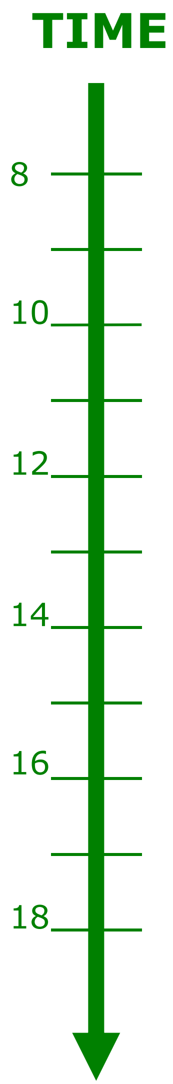
$\int \sigma dt=3$	$\int \sigma dt=5$	$\int \sigma dt=6$	$\sigma(r,T)=6$
$\int i dt=5$	$\int i dt=9$	$\int i dt=12$	$i\ (r,T)=12$

Cumulative impacts: an example

TENSOR OF STRESSOR
σ(r,t)

	u_{PM10}	u_{dB}
m_1	0	$a_{1,dB}$

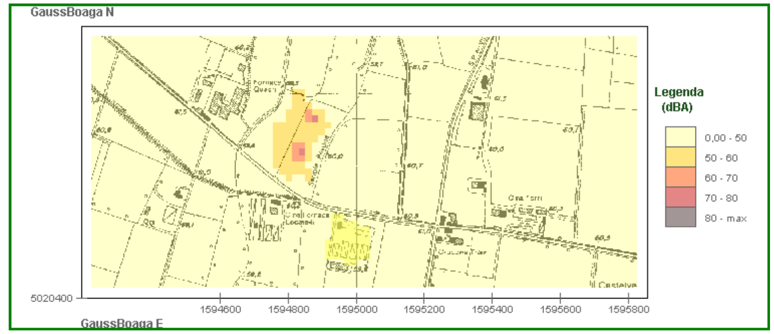
DCGIS tool produces cumulative impact matrixes for specific stressor-vulnerability interaction.



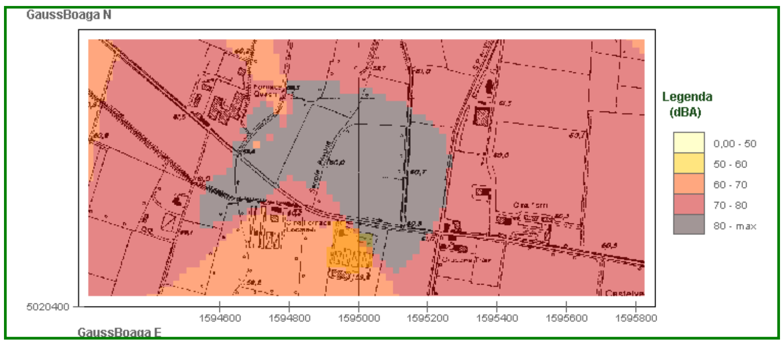
	ACTION 1	ACTION 2	ACTION 3	ACTION 4
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				

h. 8

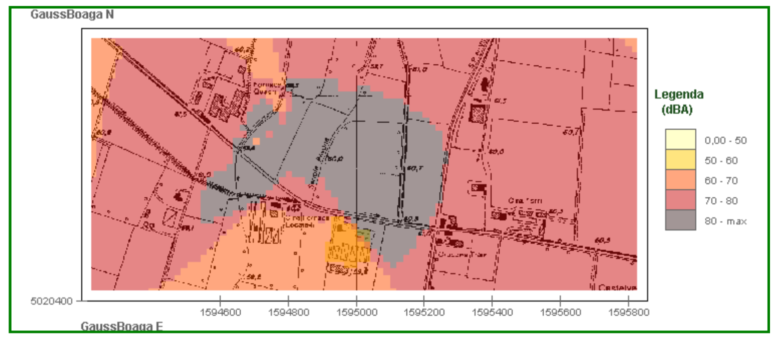
h. 9



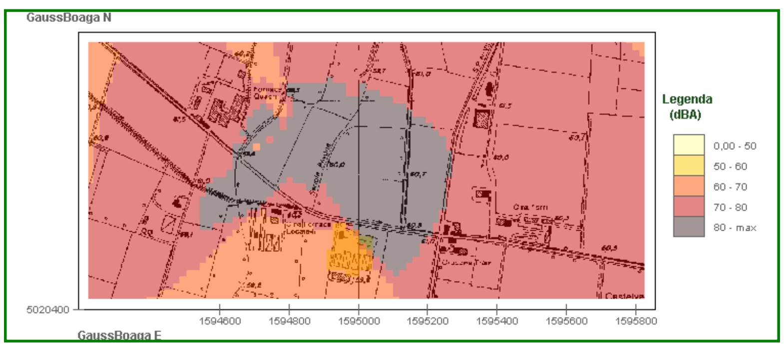
h. 10



h. 11



h. 12



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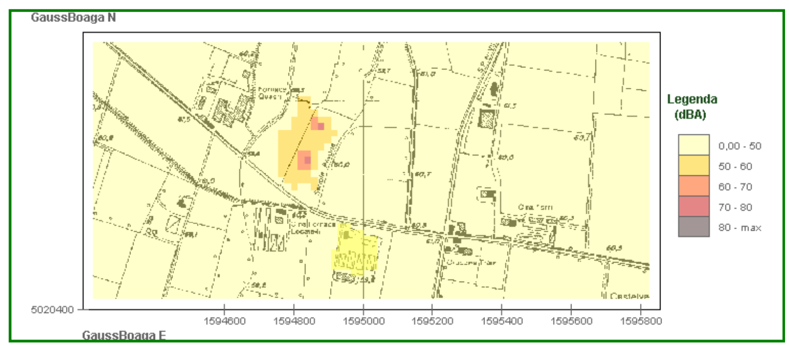
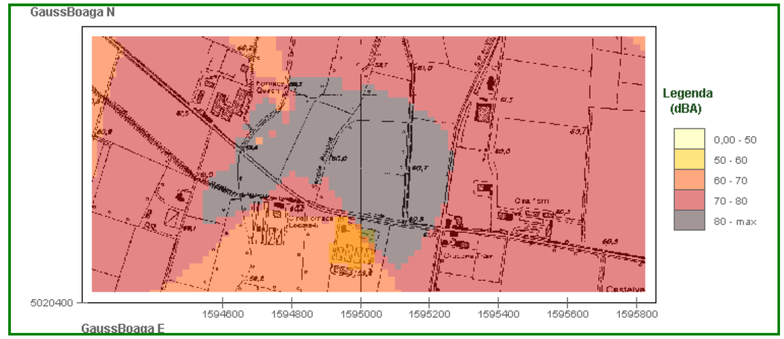
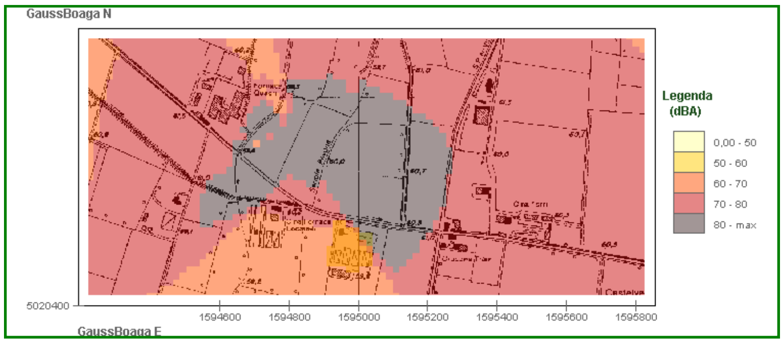


h. 14

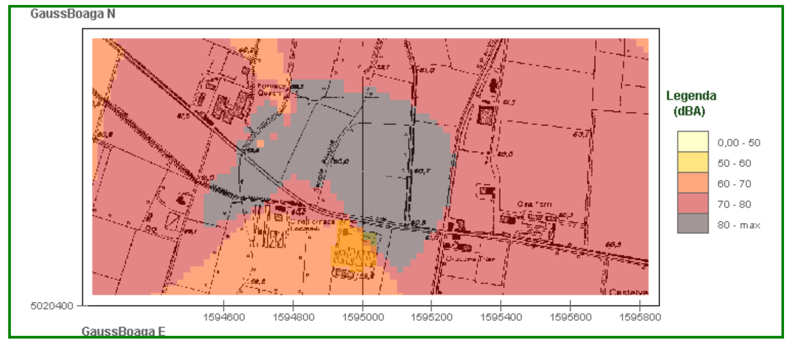
h. 15



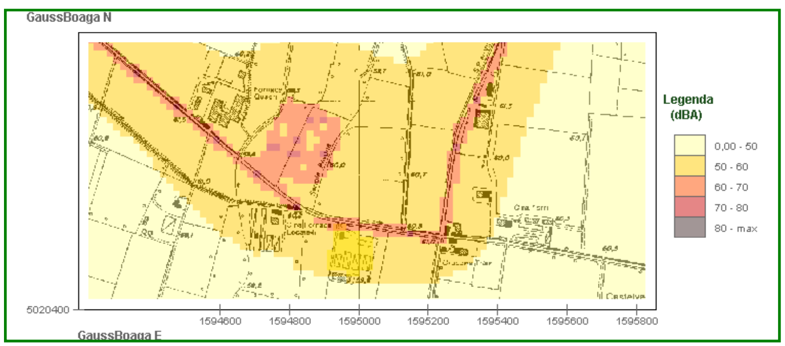
h. 16



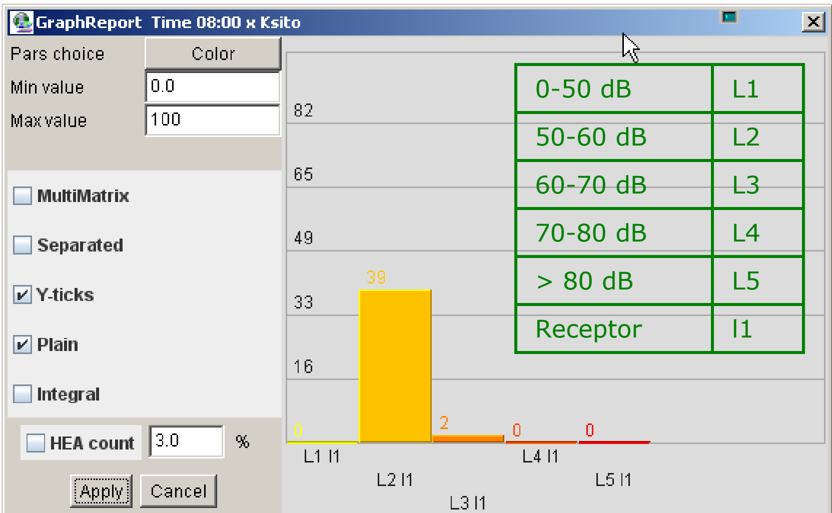
h. 17



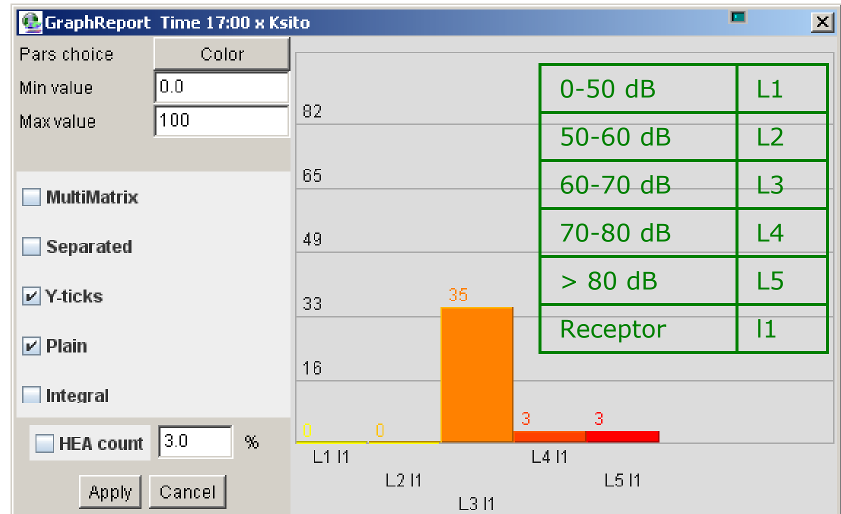
h. 18



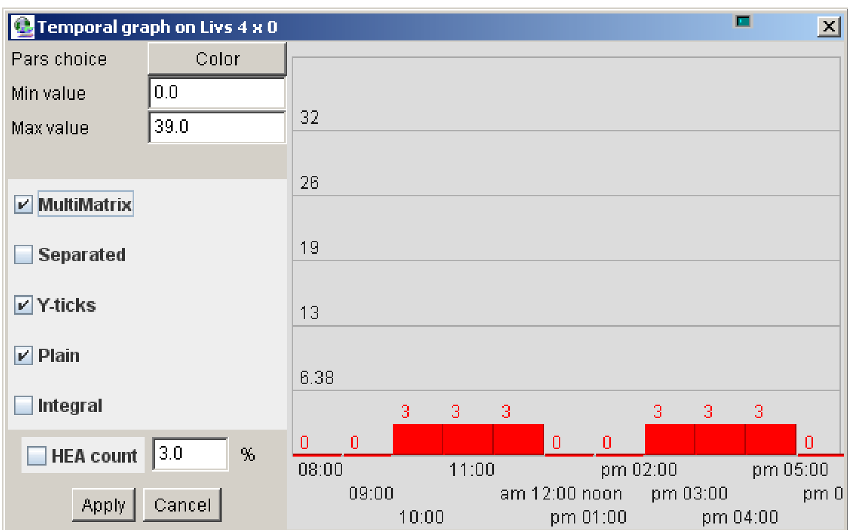
Graph report (h. 8)



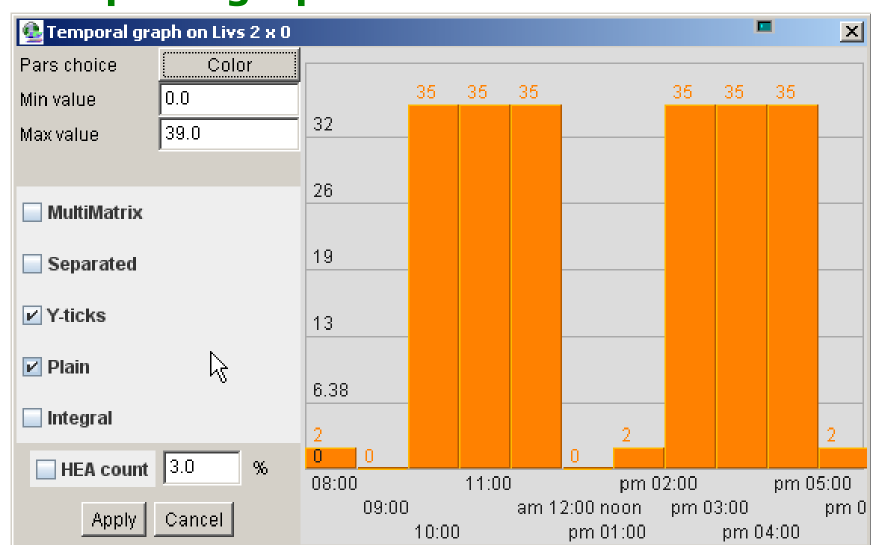
Graph report (h. 17)



Temporal graph of level L4



Temporal graph of level L2



CONCLUSIONS

- DCGIS methodology provide a **general framework** for cumulative impact analysis and evaluation, working with different kinds of analitical model defining pressure and vulnerability indicators;

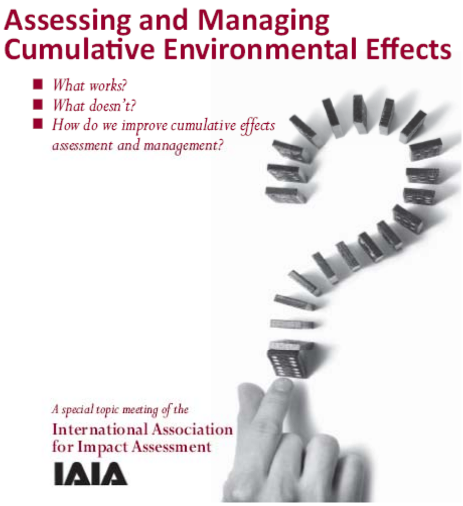
- Mathematical **vectorial characterization** of stressors and vulnerability elements introduce a new algebra for computing impacts in space-time frame;

-A GIS based tool for managing cumulative effects in terms of **prevention, protection and mitigation** in planning activities and control (scenarios comparative assessment)

-Operative language for managing **different levels of complexity** with an iterative process of assessment (EIA, SEA and Regional Risk assessment).

…questions?

info@iaiaitalia.it



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