

# Economic assessment of natural risks due to climate change. The case of a mountain Italian region.

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**ABSTRACT:** The paper introduces the approach used to analyse the consequences of climate change on the Adda river basin (Lombardy, northern Italy); the area offers three main reasons of interest: it is one of the biggest in Italy; it is located in the richest region in the country and, thanks to its geomorphologic heterogeneity, could be affected by a wide range of natural hazards. The northern part, Valtellina, is a mountain area characterized by several hazards.

The aim is to quantitatively assess the consequences of climate change on the socioeconomic system. The quantitative cause – effect approach is applied; climate change is the cause, and the effects are the outcomes on the social system. Such effects are described as “direct effects”, directly tied up with “physical damages”, and “indirect effects”, due to the interruption of economic activities. A particular attention to extreme events will be paid; first of all, landslides.

## 1 INTRODUCTION

The assessment of environmental risks can be considered an important challenge for scientific research. Many aspects related to this topic need to be studied more in detail: the attempts to anticipate the risks (prevention rather than remedy), and therefore to forecast them, to assess the relationships between causes and effects, to balance the benefits with the costs associated to the control of risks.

The socioeconomic assessment of damages due to natural hazards is getting even more important since the progressive climate change is threatening the safety of people and assets.

Extreme events such as floods, tornadoes, hurricanes are becoming stronger and stronger, and their increasing power could seriously compromise not only the structures involved, but also the socioeconomic asset.

In the 45 years following the second world war, natural disasters cost Italian government 33,000,000 million liras (about 25,000 million euros in 2006), and landslides account for nearly 37 % of lost lives (Catenacci 1992).

As a matter of fact, the interest towards direct and indirect damages due to natural hazard is increasing in the public opinion and decision-makers are asking for socioeconomic scenarios to face this occurrence.

The RICLIC project (Regional Impact of Climate Change in Lombardy Water Resources:

Modelling and applications) has been funded by the Regional Agency for Environmental protection, the University of Milano, Bicocca and the main no profit foundation for Environment to assess consequences of climate change. In the project, socioeconomic damages caused by climate change in the region are investigated. This paper aims to explain the approach that it is going to be used to seek solutions to this problem.

The paper will analyse the approach applied in the RICLIC project to assess economic damages. The landslide happened in Valtellina in 1987 will be taken as an example. The quantification of related socioeconomic damages will explain landslide consequences from a different point of view.

## 2 SITE SETTING

The RICLIC project has been created with the aim to assess regional impact of climate change on Lombardy water resources. In detail, the study will analyse the most likely impacts on one of the most important river basin in the northern part of Italy: Adda river. Identifying three macro areas, different from a geomorphologic point of view, as from a socioeconomic one, could be useful in order to develop the socioeconomic assessment. The upper part, Valtellina, is a mountain area, a large glacial valley whose

economy is mainly based on viticulture, zootechnics and tourism. The central part hosts the Lake Como; mainly because of its geophysical characteristics, the presence of a very deep lake with mountains overhanging on his shores, the main inhabited centres are settled along the coastline. There are towns with tourist note and some important industrial sites. The lower part begins from the town of Lecco, where Adda river flows out from the lake, and ends in Castelnovo Bocca d'Adda, where it enters the Po river. In this southern part, Adda river flows through the Pianura Padana, the main industrial area of Italy. Figure 1 shows the study area.

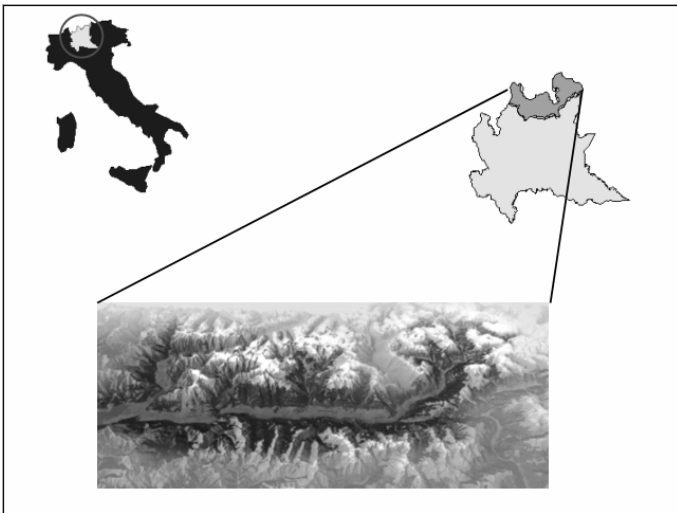


Figure 1. Valtellina location.

Defining different scenarios is therefore useful in order to assess economic damages. In this paper only the possible consequences on the upper part, the most susceptible to landslide phenomena, will be discussed.

### 3 SOCIO-ECONOMIC ASSESSMENT

Socioeconomic assessment of environmental risk is a difficult, but very important matter in the management of territory.

The approach often used in risk analysis evaluates risk from hazard, vulnerability and value of elements involved (Varnes 1984). Nevertheless, this approach could not be easily used in a socioeconomic assessment, because it is not easy to determine the value of elements involved. Moreover, it could be difficult to agree with the identification of money value for human life, for ethical as well as practical reasons. Besides, the socioeconomic research has a different approach towards natural hazards, that is centred on people, on different behaviour that people have towards them.

In the last years a great number of new approaches toward the estimation of economic dam-

ages due to natural hazard can be found in literature (Bell & Glade 2004, Bell et al. 2005, Australian Geomechanics Society 2000).

The economic approach discussed in this paper is based on the quantitative cause - effect correlation (Giacomelli 2005), which was developed and applied in the ALARM project (funded by EU, 2002-2004).

Such correlation is developed on three parallel levels: climatic, physical and socioeconomic level.

After the determination of climate change scenarios, several physical effects of climate change on the investigated area will be identified (floods, landslides, drought).

The aim of the socioeconomic analysis is to determine the main economic drivers in the study area, the most important elements for the development of local economy and the weaknesses of the regional economic system.

In the socioeconomic cause - effect method, the phenomenon analyzed is the cause, described by its physical characteristics, identified by its physical data, and effects are the structural damages to the elements directly involved by the phenomenon. After the assessment of physical effects, the socioeconomic analysis supports the geomorphologic analysis in the determination of economic effects. In Figure 2 it is possible to understand how socioeconomic assessment completes the holistic concept of risk assessment (Hollenstein, 1997).

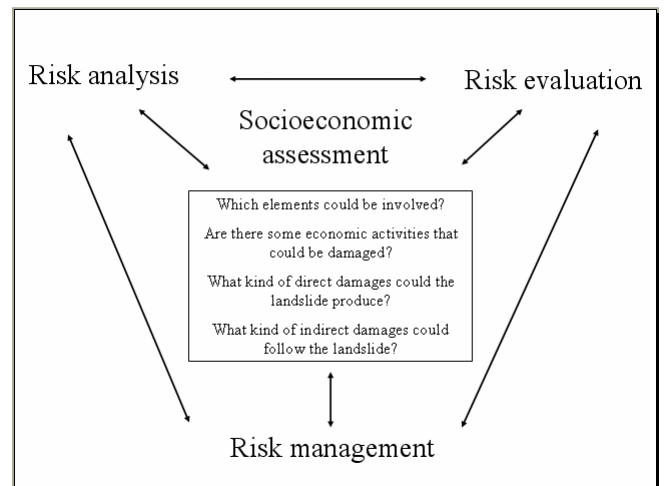


Figure 2. Integrated holistic concept of risk assessment, modifies from Bell & Glade (2004).

First of all, the analysis starts with the study of meteorological data, carried out with the collection of historical series of pluviometric data, maximum and minimum temperatures and their fluctuation in the last century. These meteo - climatic data will be useful for the analysis conducted by the other work packages involved. The impact of climate change on

surface and underground water resources, the consequences of glaciers melting on the release of persistent organic pollutants (POP), the effects on agriculture and the hypothesis of rationalization of water resources to optimize their management will be studied.

All the experts together will analyse, at least, physical consequences on the territory as a whole, combining their result to offer realistic scenarios on which estimate economic damages. One probable physical phenomenon will be considered for every scenario. The analysis starts with the description of the phenomenon itself; the study has to be made by technicians with an historical experience in geophysical analysis, and the first assessment must produce quantitative and spatial information that aim to understand the physical dimension of the phenomenon itself.

The second step is directed towards the assessment of physical effects; using GIS support, geophysical data are matched on socioeconomic data, which represent the key elements potentially involved. With geographic instruments it is possible to identify which elements (roads, houses, dams, productive plants) are threatened in each step of the emergency.

According to this approach, landscape elements are not only considered as elements at risk, but first of all they are constituent of the socioeconomic structure and their role allows society to keep itself alive; the attention must be twofold for the elements on which is based the economic system: as a matter of fact, the interruption of their usual activities could have effects on the social equilibrium of the area.

This remark explains the importance of indirect damages in risk assessment. During the emergency, the socioeconomic damages could be not understood, but they can affect the regional economic system for long time.

#### 4 THE IMPORTANCE OF WATER RESOURCE

What climate change could really cause on water resources is very difficult to predict, but studying the historical series it is possible to record that with the increasing in temperature, the managing of water resources could become even more difficult.

Interest in this study does not result only from damages that extreme phenomena could bring on the elements involved, but also from social implication connected to the management of this resource, especially during long periods of drought, when decision makers have the delicate problem to decide how to exploit water resources.

One of the most important social problems connected to water shortage is the use of water to produce hydroelectric power, instead of civil and productive uses. Every year, in summer, a water crisis

takes place; all the local authorities in charge of the water management system are called together to decide how to solve the situation.

After the identification of physical damages, this analysis will be focused on the evaluation of economic damages due to climate change. This analysis is directed towards the assessment in two main scenarios: water shortage and water floods. Whereas management of floods involves the assessment of direct and indirect damages, the scenarios interested by water shortage are more important for the assessment of indirect damages on a regional scale; as a matter of fact, the management of water resources involved a great number of interests, from a political and an economic point of view, and the choice between different solutions could compromise the social equilibrium.

#### 5 CLIMATE CHANGE

According to the results achieved by the team of meteorologist working in this project, in Lombardy region there are strong evidences of climate change. From the eighties, all the weather stations sited in Lombardy have registered abnormal conditions of temperature that proved a significant climate change at a regional scale. This alteration is revealed by an increase in heat waves frequency in summer and thermal zero elevation in winter, with snowfall at higher altitude. Moreover, the occurring climate change is the main responsible of the increasing extreme events, such as drought and floods. These phenomena must not be individually considered, because their occurrence involves other phenomena: first of all landslide.

#### 6 CASE HISTORY

To explain the importance of socioeconomic analysis in the occurrence of landslide, the one that occurred in Valtellina valley on July 1987, from the mountain of Pizzo Coppetto is given as an example. Such example is given to understand how socioeconomic analysis could help decision-makers in managing natural hazards and to comprehend how much the area is vulnerable to natural phenomena.

##### 6.1 *Valtellina flood*

In summer of 1987 in Valtellina a series of natural calamity took place. After some days of heavy rain (on 17th July, fell 305 millimetres of rain down in 24 hours: a quarter of the total water that usually rains in this valley within the whole year), on 18<sup>th</sup> July 1987 in the town of Tartano, a huge mass of debris destroyed two residence buildings, killing eleven people. Afterwards, Adda river overflowed

and flooded the town of Ardenno, in the central part of Valtellina, interrupting connections with the eastern part of Sondrio Province; also railway was swept away by the water. Many people were evacuated from their houses. Many other villages were flooded.

Bridges, farms, cultivated fields, graveyards and sheds were swept away: hundred of animal carcass floated on the huge lake that took up part of Valtellina. Also Sondrio, the chief town of Province, was in danger: Mallero torrent seemed to overflow. The same thing occurred in Morbegno, while Adda river overflowed, flooding the valley floor in the industrial area between Talamona and Morbegno.

Meanwhile, the inhabitants of the upper part of Valtellina were evacuated. Moreover, the connections with Swiss were interrupted: the Piattamala custom was completely unfit for use.

On 28<sup>th</sup> of July a landslide broke off from the Cime di Pedasco, Pizzo Coppetto (3066 meters high mountain), swept away and completely destroyed Sant'Antonio Morignone (Valdisotto).

The town was previously evacuated and this caution saved the majority of people; despite it, the landslide swept a team that was working on reinforcement in Sant'Antonio and some inhabitants of the village of Aquilone were killed, wrongly judged out of danger.

Nobody could expect the pressure wave due to forty millions of cubic meters of debris flow, and the landslide's power itself, that climbed the mountain on the other side of the valley for several hundred of meters. The strength of landslides was so big that the debris climb up on the opposite mountainside like a huge wave, destroying the town settled at the bottom of the valley. The debris blocked the usual stream of Adda river, forming an artificial lake that impend over the valley below. The threat of "Vajont effect" was felt: a new fall of material from the mountain could produce a new catastrophic wave of flood. Within the whole month of August, civil protection succeeded in bring the valley to normality, and in keep the lake under control, slowly emptying the valley from water and debris .

Valdisotto suffered the greatest amount of damages: 947 people were evacuated during the flood, 144 houses and a hundred of rural buildings were destroyed by the landslide, leaving 407 people homeless. Several productive activities were involved leaving 50 people out of work. Two months were needed to build temporary tracks; meanwhile, alternative routes were used.

Damaged areas are not restored yet; only some works of land management are already been carried out.

## 7 FUTURE SCENARIOS

As explained in the previous paragraphs, the climate change that is already being carried out is showing his effects with the intensification of extreme events. In this area, giving its physical and socioeconomic characteristic, the relevant intensification of extreme events due to climate change could bring damages even more important that those described for the landslide of Pizzo Coppetto.

Following the information of Sondrio Province, that rules Valtellina, is quite difficult to assess the economic damages that followed this event, even after twenty years. The government set aside 2,400,000 millions liras (about 2400 millions euros 2006) for the "rebuilding and development plan" but Lombardy region is still working on the land management programme.

Nobody is able to exactly quantify in economic terms the cost of Valtellina landslide. Certainly, this flow of money was not only seen as a compensation of damages, but was also a new source of earning, that brought a big amount of money to the areas involved.

## 8 METHODOLOGY

The method applied in the RICLIC project is based on the quantitative cause - effect correlation, where cause refers to the phenomenon itself, and effects concern all the economic damages, either direct or indirect. In Figure 3 is briefly described our methodological approach.

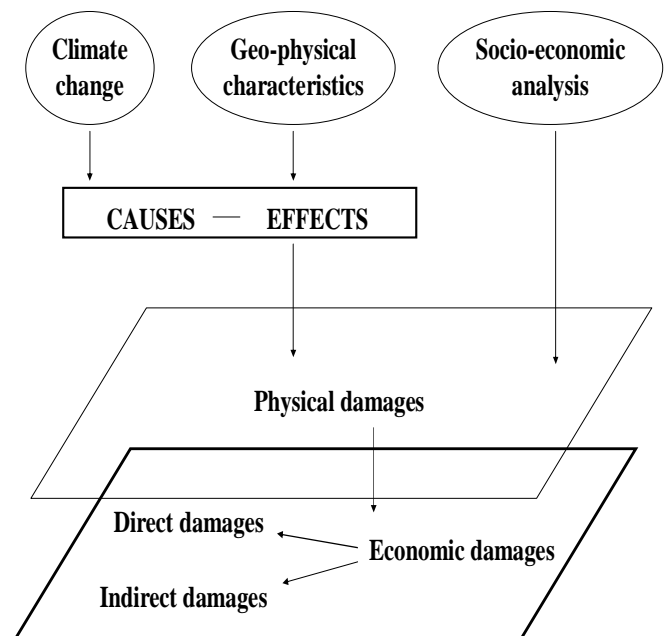


Figure 3. Methodology scheme.

The assessment of socioeconomic effects in the evaluation of consequences of natural hazards needs the contribution of physical experts who study climate and environmental characteristics. The most important characteristic of this project is the presence of different team of research, experienced in different aspects of global warming. To get to successful results, the information obtained have to be shared, and conclusions have to be drawn together. In Figure 3, the different informative levels, separately studied by the different groups, are in the circles; in the first step, the socioeconomic study is directed towards the gathering of data and the comprehension of historical series, drivers and weaknesses. The main target of the project is the characterization of the most important elements, and their role in the developing of regional economy. In the second step the conclusions drawn by the different groups are shared and all the groups together determine the physical effects. The determination of physical effects has the aim to forecast the effects on the territory with changing climate conditions. The approach used to study the economic assessment of damages and risk is the same previously used with the ALARM project: the cause - effect approach (Giacomelli 2005); while in the previous case the analysis was carried out only for a small area, a little mountain town, in this case the study is directed towards the comprehension of regional impacts, on an area with different socioeconomic characteristics. The comparison between the different working packages has produced a new informative level, the so called, "physical effects", whose results will be superimposed by those derived from the socioeconomic analysis. For this analysis it would be useful to use a GIS support, in order to better understand the connections and relationships between environmental and socioeconomic scenarios.

After the identification of physical effects, the socioeconomic analysis will help the study of the economic damages. Economic damages are divided into two categories: direct damages, defined as the cost of recovery or rebuilding of exposed elements, and indirect damages, coming from the interruption of economic activities of elements directly or indirectly involved. This distinction is important because, in case of involvement of structures that are important for the socioeconomic equilibrium, their temporary unavailability could compromise the usual activities, with economic indirect damages that may be even bigger than direct ones. It is also important to specify that indirect damages could weight upon a larger area and last for a longer period of time.

This characteristics determine the importance to analyse indirect damages.

Tourism represents more than one third of the overall added value produced in Valtellina, (3836 million euros in 2004; source UNIONCAMERE). As a matter of fact, the service sector affects for the 69.1% the total province income; this is an important result, if considered that service sector in Valtellina is tourism oriented.

The development of tourist activities in Valtellina knew his biggest growth in the second part of twentieth century. The beginning of tourist industry was tied with tourist flows coming from the plain of Lombardy. With the development of communication lines and the extension of holiday periods, people gradually chose to change their destinations and to spend their longer holidays in mountain resort far away. Weekend tourism and commuter tourism are still an important resource for Valtellina. Besides, a great number of houses are used as holiday houses, and it is not possible to gather statistical data about these tourist facilities.

As happened to the most important mountain resorts of Alpine bow, tourist activities are becoming different in the last decades; hence Valtellina started to offer to tourist demand a larger and larger number of sport activities, in summer and winter season, matching them with other attractiveness, first of all thermal tourism. Valtellina has hundreds years of experience in this field, that draws tourists every month of the year.

Another important characteristic of tourism in Valtellina is that this economic activity is not an economic system apart, but an economic integrated system with different activities; in fact the seasonal nature of tourism does not allow resident to make it their only job.

### 9.1 *Infrastructure*

Valtellina has a peculiar geomorphologic structure: a long mountain chain in direction east - west separates the large valley from the pre-alpine area. This conformation gives to Valtellina its distinctive characteristics, that make it different from the other Alpine valleys, generally settled in direction north - south.

For this reason, the State Highway SS 36 is the faster and most convenient road to reach Valtellina from Milano, the main centre in northern Italy; this highway reaches Lecco, on the eastern branch of Lake Como, and follows the eastern coast of lake up to Colico. After Colico, the road splits into two parts, one going in Valchiavenna towards the Spluga Pass, and the other entering Valtellina with the State Highway SS 38 towards Stelvio Pass.

Moreover, the only railway connection between Valtellina and the plain, passes from Colico. This

remarks help to understand the importance of this junction for Valtellina socioeconomic equilibrium.

## 10 THE VALTELLINA LANDSLIDE: EFFECT ON TOURISM

It is interesting to study statistics based on tourism in Valtellina in the last twenty - five years. The whole area is characterized by a growing trend of the number of tourist facilities, as well as an increasing number of presences. The study of tourist presences data allows to understand the impact that Valtellina landslide produced, not only on the structures involved, but also on the economy of the valley. The aggregate trend of tourist presence in Sondrio Province can be analysed in Figure 4.

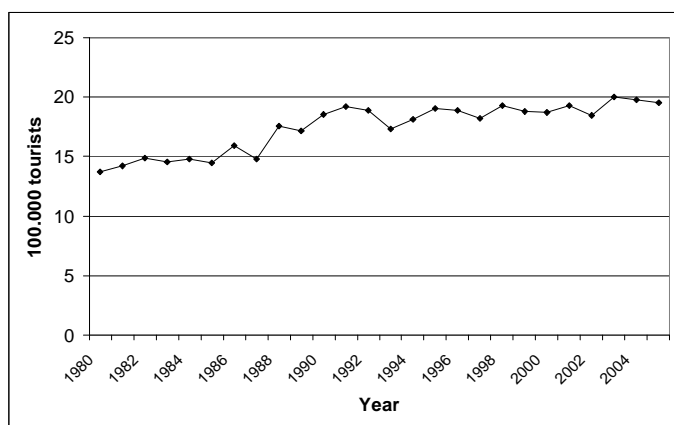


Figure 4. Tourist presence 1980-2005.

Tourist economy has been characterized by a constant growth in time in the last twenty - five years. Nevertheless, if the analysis is focused only on the two main tourist resorts situated in Alta Valtellina, Bormio e Valfurva, the result is different.

Alta Valtellina represents the most important tourist area, also thanks to Stelvio National Park and the biggest Alpine Himalayan glacier. Focusing the attention on the period elapsed between 1980 and 2005, it is possible to see that effects due to Valtellina landslide has weighted upon the Alta Valtellina more than upon Valtellina as a whole. In 1987, both Bormio and Valfurva suffered the outcomes of Pizzo Coppetto landslide in terms of decrease in tourist flow. As shown in Table 1, the greatest percentage fluctuation in the last twenty - five years is registered both for Bormio and Valfurva in 1987, but there are not evidences of the same fluctuation for Sondrio Province as a whole. The phenomenon did not weighted upon the whole province in the same way. This is due to the interruption of State Highways SS 38, that connects this important tourist area with Colico.

Furthermore, in 1988 the growing trend restored the former tendency.

Table 1. Variation ratio in tourist presence.

	Bormio %	Valfurva %	Sondrio Province %	
1980				
1981		-7	13	4
1982		2	14	4
1983		-4	-14	-2
1984		3	3	2
1985		4	9	-2
1986		4	15	9
1987		-17	-25	-8
1988		22	23	16
1989		-9	14	-3
1990		13	9	8
1991		3	-9	3
1992		-7	-6	-2
1993		-16	-1	-9
1994		40	1	5
1995		6	3	4
1996		-1	-1	-1
1997		1	-7	-4
1998		2	7	5
1999		-1	-1	-3
2000		-6	-6	-0.3
2001		2	4	3
2002		-3	-15	-5
2003		4	9	8
2004		-5	-2	-1
2005		0.2	-19	-1

This result highlights the importance of roads in the determination of indirect effects. The interruption of the most important way leading to the upper part of the valley caused the decreasing of tourist flow in Alta Valtellina.

As data show, the negative effect did not last for long. In 1988 the tourist flow already recovered the growing trend, begun in the first half of the eighties.

A first analysis has assessed that such a decreasing in tourist flow generated to Alta Valtellina nearly 3.6 million euros (2006) of indirect damages.

It is also supposed that tourist flow decreased in the whole province after Valtellina landslide, because of the fear that people developed towards such a phenomenon.

## 11 CONCLUSION

The problems related to the assessment of damages due to climate change in a mountain area has been analysed. Starting from the landslide that affected Valtellina in 1987, the effects registered on tourism has been shown.

The approach that it is used in the RICLIC project has been presented. The contribution of each work package has outlined the scenarios of climate change, studied to assess the effects. The integration between the different work packages is basic to un-

derline the weaknesses and the emergency of the physical system. Once outlined different scenarios, the assessment of direct and indirect damages will produce the economic assessment of climate change. At present, only the initial steps of the work (data collection and analysis) are being performed; this paper aims to present the approach and to collect remarks and suggestions to improve the analysis and to get better results.

The greatest landslide that affected Valtellina is taken as an example to present an ex-post assessment of economic consequences, to understand the importance of socioeconomic point of view in natural hazards assessment and management and to understand economic damages dimension. Moreover, this is an example of what could follow an intensification of extreme events in this area, even more often with climate change.

As the tourism activity produces more than one third of the whole added value, a phenomenon like the one that happened in Valtellina could seriously compromise the general economy of Sondrio Province, especially in the occurrence of climate change, that is bringing about an intensification of extreme events.

The results that will follow this analysis will contribute to hazard management and could help decision makers in the implementation of land management plan. Without a careful and effective management of territory, the increase and intensification of extreme effects could represent a significant threat to the economy and the equilibrium of these part of the valley.

## 12 PROJECT DESCRIPTION

This research is carried out in the framework of RICLIC project, funded by Università degli Studi di Milano Bicocca, Fondazione Lombardia per l'Ambiente (Lombardy Environment Foundation) and Regional Agency for Environmental Protection.

This paper has been discussed by both authors. Paolo Giacomelli wrote the paragraphs 2, 3 and 11 and Marta Brambilla wrote the paragraphs 1, 4, 5, 6, 7, 8, 9 and 10.

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