Impact Assessment on Environment from Transboundary Air Pollution in Italy carried out by a multi-pollutant integrated assessment model

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EXTENDED ABSTRACT

The effects of transboundary Air Pollution, at continental level in Europe, are regularly analysed by Integrated Assessment Modelling, specifically by the RAINS_Europe model, developed by IIASA (International Institute for Applied Systems Analysis, Austria). These analyses are carried out both in the UN-ECE (United Nations Economic Commission for Europe) context, in relation to the Gothenburg Protocol of the Convention on Long-Range Transboundary Air Pollution (CLRTAP), and within the EU framework, in support to the definition of the Community Environmental policies. The RAINS_Italy (MINNI Project), has been developed, in co-operation with IIASA, to perform multi-pollutant multi-effect analyses, at national level. In particular, in this paper the impact on the environment deriving from the multi-pollutant anthropogenic activities, in terms of damage on ecosystems caused by acidification and eutrophycation (excess of nutrient Nitrogen in the soil), are analysed by the RAINS_Italy Model, considering 2 different scenarios. The 1st scenario is assuming all the pollutant abatement measures, as they are planned in the Current Legislation (CLE scenario) at national and EU level, are implemented.

The second scenario, assumes the full implementation (at 100%) of the most effective technical abatement measures, at the target year 2020, to estimate the Maximum Technical Feasible Reduction (MTFR scenario), in the impact on the ecosystems. Then, comparisons are made between the 2 scenarios, in terms of effects and implemented technologies. The results show how more than 50% of the ecosystems remain unprotected from eutrophycation, in some areas in the North of Italy, namely the Po Valley, and in some west cost areas in Central Italy, even in the best case of the MTFR (Maximum Technical Feasible Reduction) scenario, at 2020.

1. INTRODUCTION

More than 30 years ago, when the acidification effects were detected in the Scandinavian lakes, the studies carried out by the scientists demonstrated the transboundary nature of a number of pollutants generated by anthropogenic activities. In 1979 the UN Convention on Long Range Transboundary Air Pollution (CLRTAP) was signed. In the frame of the Convention, the scientific community developed analytical tools for a systematic and comprehensive approach to the Air Pollution issues. After some years, it became clear that the multiple inter-connections existing among the several aspects characterizing the air pollution and its effects, needed to be addressed and analysed simultaneously, originating the concept of "Integrated Approach". As a consequence, the analysis tools, namely the simulation models, have moved in the same direction. Within the frame of the Convention, the International Institute for Applied Systems Analysis (IIASA) has been developing, in the past years, a more and more sophisticated simulation tool, taking into account techno-scientific, economic and social aspects, also to satisfy the increasing demand of a multi-purpose multi-effect approach. The RAINS Methodology (now denominated GAINS, after the recent extension to the greenhouse gases analysis) developed by IIASA, is nowadays, commonly adopted and used within the Convention and the European Union (27 Member States).

In 2002, ENEA (Italian Agency for New Technology, Energy and the Environment) started the development of a modelling system with the ultimate objective of providing a tool for scientific underpinning to the policy choices, in support to the policy makers, on the basis of the integrated approach. The MINNI (Integrated National Model to support the International Negotiation) project started, with the support of the Italian Ministry for the Environment, the Land and the Sea.

2. THE MINNI MODELLING SYSTEM

The MINNI Modelling System is aimed at providing the policy makers with scientific support in the elaboration and assessment of air pollution policies, at international and national level, by means of the more recent understandings of the atmospheric processes peculiarly characterizing the Italian territory. MINNI has been developed following a double track:

- The Atmospheric Modelling System (AMS_Italy), a Eulerian Model tool for the analysis of the pollutant dispersion and the chemistry of the atmosphere
- RAINS_Italy Model, an integrated tool for scenario analysis, derived by the IIASA Rains_Europe Model (Amman et al, 2004)

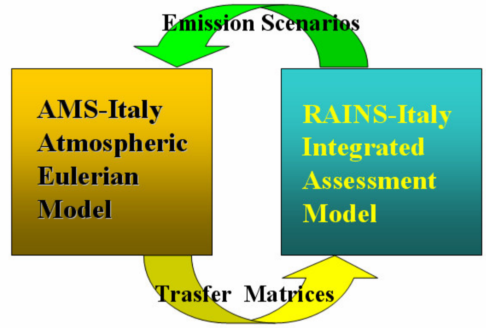

Figure 1. Functional schema of the MINNI Modelling System. The 2 main components AMS-Italy and RAINS_Italy

As shown in Figure 1, the two systems may work independently and/or together to provide a comprehensive analysis, at national and local level, comprising meteorology, emissions and abatement costs, impact on the environment and the human health. As usual, in this kind of works, where applications of the MINNI system are reported, a brief description of the two systems is given below, in order to have a comprehensive view of the whole modelling system. Details can be found in the references.

2.1. The Atmospheric Modelling System (AMS_Italy)

AMS_Italy simulates the air pollution dynamics and the multiphase chemical transformations of the pollutants, providing concentration and deposition levels, on hourly and annual basis of SO_2, NO_x, NH_3, PM_{10}, $PM_{2.5}$ and O_3, with spatial resolutions from 20km x 20km to 4km x 4km. The core of the AMS_Italy is in the three-dimensional Eulerian chemical-transport model FARM (ARIANET 2004), which is derived from STEM (Carmichael et al, 1998). The code has been developed so that different chemical schemes can be implemented; within MINNI, the SPARC90 gas-phase scheme is implemented. As for PM, two approaches are available: the AERO0 simplified PM 'bulk' module, as implemented in the EMEP Eulerian unified model (EMEP, 2003), considering the ammonia-nitric, acid-sulphuric, acid-water system, and the AERO3 Models-3/CMAQ module (Binkowski, 1999), following modal approach and including also secondary organic particulate (SOA). Atmospheric transfer matrices (ATM) for RAINS_Italy have been calculated using the first approach, while the second one has been employed for specific studies.

The reference meteorological year is 1999, for AMS-Italy calculations.

2.2. The Integrated Assessment Model Rains_Italy

The Integrated Assessment Model RAINS_Italy, developed in collaboration with IIASA, owner of the original RAINS_Europe model (Vialetto *et al*, 2005), maintains the same features of the RAINS_Europe model.. RAINS_Italy calculates emission scenarios for SO_2, NO_x, NH_3, PM_{10}, $PM_{2.5}$ and VOCs, as well as estimations of the costs associated with the implementation of the abatement technologies, and impact assessment on the environment and the human health. The 20km x 20km spatial resolution has been selected, in RAINS_Italy, as compromise with respect the expensive time computing. The two components complement each other. AMS_Italy feeds RAINS_Italy with Atmospheric Transfer Matrices (ATMs, source-receptor relationship coefficients) allowing RAINS_Italy to estimate average annual PM concentrations, SO_2 and NO_x depositions, for the purposes of acidification and eutrophication and health impact, in terms of Life Expectancy Reduction ($PM_{2.5}$) and Premature Deaths (ozone). As well, emission projections calculated by RAINS_Italy, can be used as input to AMS_Italy for accurate analyses on hourly basis.

3. THE MAIN OBJECTIVE OF THIS STUDY

The study described in this paper has been thought to provide an estimation of the impact on the environment, due to the current and expected levels of pollution, mainly in terms of deposition of acidifying substances (acidification) and eutrophication, that is, excess deposition of nutrient nitrogen on the soil. Both the effects are recognized as harmful for the ecosystems. An assessment of the emission trends, for the concerned pollutants (SO2, NH3 and NOx), in the next years, is carried out, first. Then, using the Atmospheric Transfer Matrices implemented in the RAINS_Italy model, the pollutant deposition is calculated and finally compared to the critical loads, to identify the possible exceedances and therefore risk for the ecosystems.

The hypotheses assumed for the analysis are:

- The most updated activity data, at national and regional level, concerning the anthropogenic and production activities, are used.
- The energy projection data, officially adopted in 2006 by the Italian Ministry for the Economic Activities, are used.
- All the abatement measures, in compliance with the provisions of the Current Legislation, at national and EU level, are taken into account in the CLE Scenario.
- All the most effective abatement measures, implemented at 100%, are assumed in place, at the target year 2020, in the MTFR scenario.

4. EMISSION SCENARIOS

According to the hypotheses explained above, the emission scenarios, for sulphur oxides (SO_2), ammonia (NH3) and nitrogen oxides (NO_x), as precursor substances generating acidification and eutrophication, have been calculated by the RAINS_Italy Model, in the two case scenarios, CLE and MTFR, in terms of total anthropogenic emissions, at national level. The general emission trends allow understanding the dynamic of the pollutant emissions over the next decade. Also, the trend analysis may focus the attention on the most contributing sectors and/or the most cost effective areas, where the measures should be taken, if additional actions are required to eventually reduce the impact on the environment.

The Figures 2,3 and 4 show a general decreasing trend in the total emissions in the next decade. The decreasing is quite sharp for SO2, mainly due to the recent EU directives concerning the maximum sulphur content into the fuels, although a slight increase in the SO2 emissions is observed between 2020 and 2025, due to the increased energy demand. The NOx emissions are also decreasing, although the rate is lower than it should be to satisfy the more and more ambitious target aimed by the European Commission, at continental level.

The ammonia emissions show a quite stable behaviour over the next decade, mainly due to the great and stable contributions from “Cows” and “Urea” fertilizer use.

The comparison analysis between the CLE and the MTFR scenario, at 2020, a huge potential of emission reduction exist for all the pollutants concerned, although the MTFR scenario must be considered as a theoretical lower limit, by definition. Moreover, it has to be taken into account that the emission scenarios are referring to primary emissions. The final total effect will be discussed in the following paragraphs, when the pollutant deposition will be analysed, as result of the chemistry of the atmosphere, the humidity, the rainfall etc., as well as, the comparison with the ecosystem sustainability.

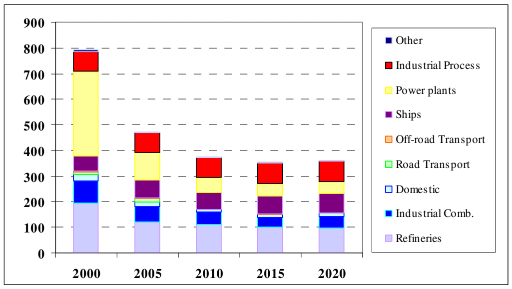

Figure 2. SO_2 emission scenario, CLE case, (kt SO_2/yr), national total emissions, calculated by RAINS_Italy. The contributions from the main sectors are shown.

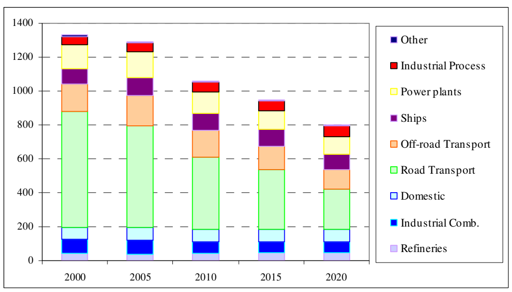

Figure 3. NOx emission scenario, CLE case, (kt NO_x/yr), national total emissions, calculated by RAINS_Italy. The contributions from the main sectors are shown.

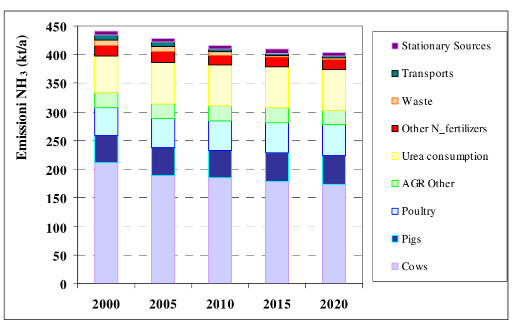

Figure 4. NH3 emission scenario, CLE case, (kt NH3/yr), national total emissions, calculated by RAINS_Italy. The contributions from the main sectors are shown

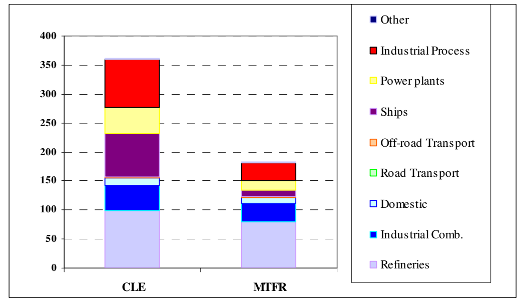

Figure 5. Scenario comparison for SOx emissions, CLE (left) and MTFR (right), (kt SOx/yr), national total emissions, at 2020, calculated by RAINS_Italy. The contributions from the main sectors are shown.

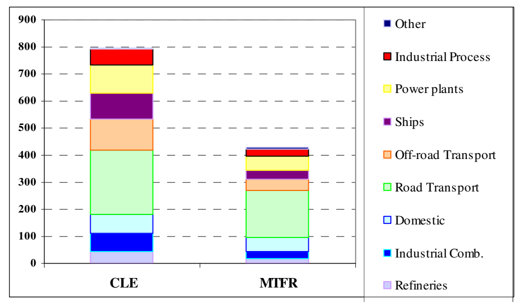

Figure 6. Scenario comparison for NOx emissions, CLE (left) and MTFR (right), (kt NOx/yr), national total emissions, at 2020, calculated by RAINS_Italy. The contributions from the main sectors are shown.

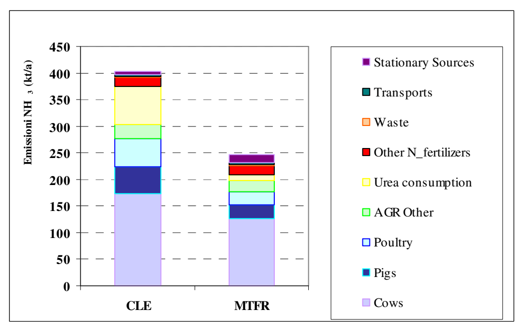

Figure 7. Scenario comparison for NH3 emissions, CLE (left) and MTFR (right), (kt NH3/yr), national total emissions, at 2020, calculated by RAINS_Italy. The contributions from the main sectors are shown.

5. METHODOLOGY FOR THE ESTIMATION OF IMPACT ON THE ENVIRONMENT

As explained in the paras 2.1 and 2.2., once the emissions are calculated, for a given year, the Atmospheric Transfer Matrices (ATM), elaborated upon the results of the AMS Eulerian Model, provide the annual average value of deposition of the substances responsible for acidification and eutrophication, coming from the primary emissions dispersion and the products of the chemical reactions in the atmosphere. The calculations are carried out for each one of the 20km x 20km cells, within the calculus domain. Then, comparing the calculated deposition levels with the Critical Loads (CLs), previously elaborated for the ecosystems, cell by cell, the Unprotected Ecosystem Percentage is plotted on the map, as indicator of impact on the environment. More precisely, since a number of different ecosystems and related CLs are associated with each cell, the CLs, sorted by magnitude and keeping the ecosystem area they represent, are processed to create the so-called Cumulative Distribution Function (CDF), which is finally compared to the average acidification/eutrophication level in the cell.

6. DEPOSITION MAPS

In the figures 8 to 10, the deposition maps for Sulphur Oxides, Oxidized Nitrogen and Reduced Nitrogen, calculated by RAINS_Italy, at the years 2000 and 2020, are compared for the CLE and the MTFR scenarios. As mentioned above, SOA is not included.

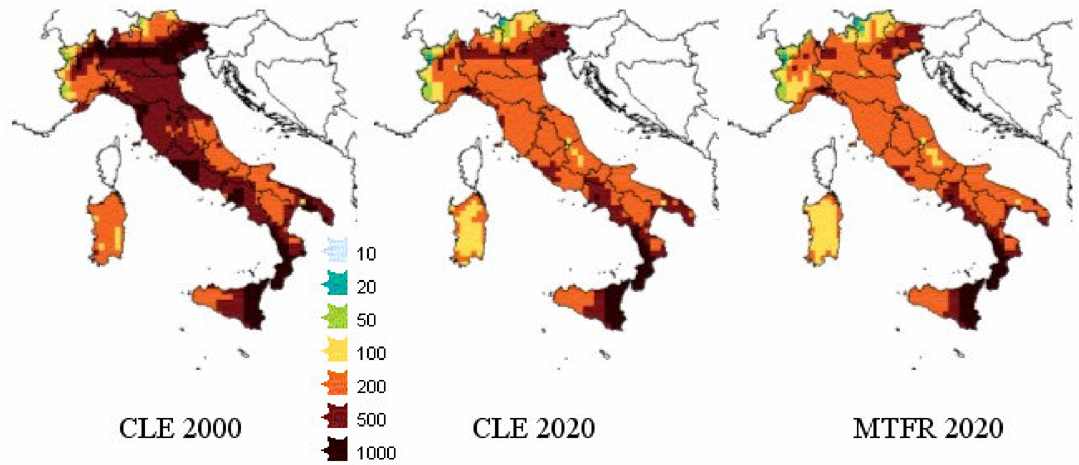

Figure 8. Deposition of Sulphur Oxides (mg/m^2/yr), calculated by RAINS_Italy. Comparison CLE Scenarios 2000 (left) and 2020 (middle) with MTFR 2020 (right).

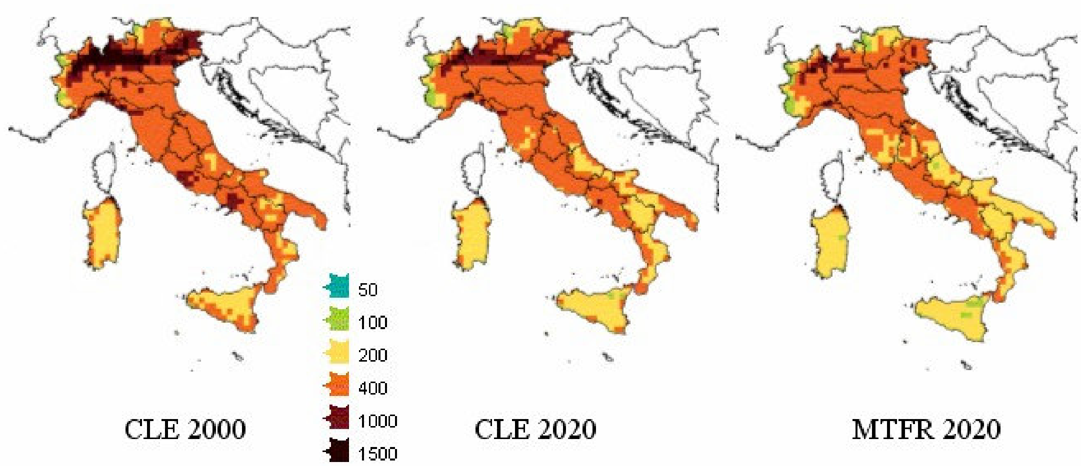

Figure 9. Deposition of Nitrogen Oxides (mg/m^2/yr), calculated by RAINS_Italy. Comparison CLE Scenarios 2000 (left) and 2020 (middle) with MTFR 2020 (right).

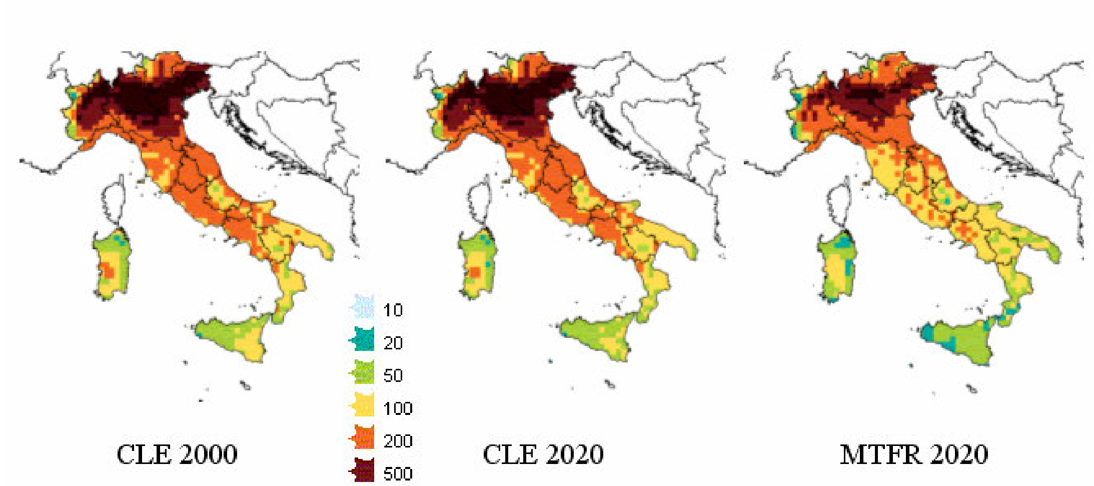

Figure 10. Deposition of Reduced Nitrogen (mg/m^2/yr), calculated by RAINS_Italy. Comparison CLE Scenarios 2000 (left) and 2020 (middle) with MTFR 2020 (right).

The Figure 8 shows a great improvement between 2000 and 2020, simply by the application of the measures foreseen by the Current Legislation, mainly due to the strong eduction of sulphur content in the fuels, while no significant better results are observed in the case of the MTFR at 2020 compared to CLE 2020. Deposition from the volcanos is also included in Sicily and the Naples' area.

The figures 9 shows a significant improvement, according to the CLE Scenarios, between 2000 and 2020, especially in the urban areas of Rome and Naples, while high deposition levels still remain in part of the Po Valley (North Italy). The MTFR scenario at 2020 indicates potential of reduction even in the Po Valley. In the Figures 10, the deposition maps of the Reduced Nitrogen, which also contributes to eutrophication, are shown. Keeping in mind the stable trend of NH3 emission, the Reduced Nitrogen deposition levels remain quite stable too, between 2000 and 2020, according to the CLE scenarios. The MTFR scenario shows potential for reduction in the whole country, with the exception of the Po Valley (North of Italy) where high levels of deposition still remain. It should be reminded that intense agriculture activities are located in the Po Valley.

7. PROTECTION OF THE ECOSYSTEMS

According to the methodology explained above the impact on the environment, in terms of percentage of Unprotected Ecosystems, due to exceedance of the calculated deposition levels, has been estimated by the RAINS_Italy Model. In the Figures 11 below, the eutrophication effects are reported for 3 cases: the CLE scenarios at the year 2000 and 2020, compared with the MTFR scenario at the year 2020.

The Figures 11 shows a clear improvement of protection in the Po Valley, between 2000 and 2020 CLE scenarios, while in the most of the country, the unprotected ecosystems remain stable ranging between 25% and 60 %, posing serious risks of loss of biodiversity, especially in the forest areas. The MTFR scenario shows persistent area of unprotected ecosystems, over 50 %, in the Po Valley and on the western coast in Central Italy. No ecosystem affected by acidification is found by the analysis performed by RAINS_Italy.

8. CONCLUSIONS

In the light of the results reported above, we may conclude that, according to the analysis of the impact on the ecosystems, carried out by the MINNI Integrated Modelling System, in a wide area in the North of Italy, namely the Po Valley, and in some west cost areas in Central Italy, more than 50% of the ecosystems are still unprotected, even in the best limit case, the MTFR scenario, where all the most efficient abatement technology are assumed to be fully implemented. As a consequence, since the abatement technologies seem to be insufficient, alone, to guarantee the ecosystem protection, alternative non technical solutions, based upon lower nitrogen content at the source, should be investigated. Similar analyses, carried out at continental level, confirm the eutrophication as a persistent problem, even in the rest of Europe. The acidification seems not be a problem, in Italy, especially after the entering into force of the European Union Directives on the maximum sulphur content in the fuels.

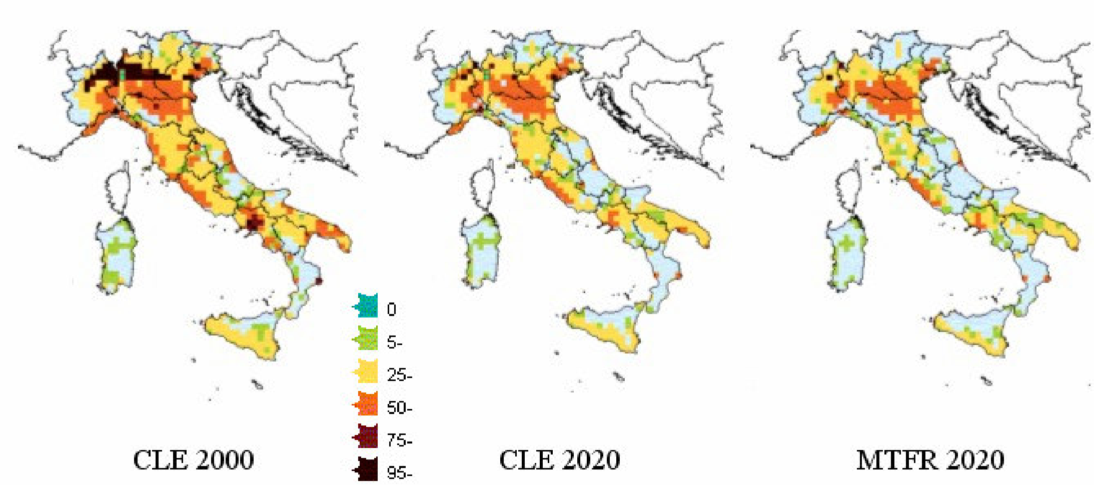

Figure 11. Ecosystems unprotected due to eutrophycation (%), calculated by RAINS_Italy. Comparison CLE Scenarios 2000 (left) and 2020 (middle) with MTFR 2020 (right).

9. REFERENCES

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