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Centro Euro-Mediterraneo
sui Cambiamenti Climatici

Risk Analysis

Climate Change in Italy

Executive Summary

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The Euro-Mediterranean Center on Climate Change CMCC Foundation is a non-profit research institution whose mission is to investigate and model the climate system and its interactions with society to provide reliable, rigorous, and timely scientific results that help stimulate sustainable growth, protect the environment and develop science driven adaptation and mitigation policies in a changing climate.

The CMCC Foundation involves a plurality of institutions that collaborate in the multidisciplinary study and investigation activities of topics related to climate change sciences.

The CMCC draws on the extensive applied research experience of its members and institutional partners: Istituto Nazionale di Geofisica e Vulcanologia (INGV), Università degli Studi del Salento, Centro Italiano Ricerche Aerospaziali (CIRA S.c.p.a.), Università Ca' Foscari Venezia, Università della Tuscia, Università di Sassari, Politecnico di Milano, Università di Bologna, RFF - Resources for the Future.

The CMCC research network is distributed among nine research divisions that share different knowledge bases and skills in the field of climate sciences: Advanced Scientific Computing; Climate Simulations and Predictions; Economic analysis of Climate Impacts and Policy; Impacts on Agriculture, Forests and Ecosystem Services; Ocean modeling and Data Assimilation; Ocean Predictions and Applications; Risk Assessment and Adaptation Strategies; Regional Models and Hydrogeological Impacts; and Sustainable Earth Modelling Economics.

The CMCC Foundation Supercomputing Center (SCC), located inside the Campus "Ecotekne" in Lecce, provides the technological infrastructure and computational capacity required to develop highly accurate, detailed and increasingly defined simulations and climate models. The CMCC's infrastructure is recognized as one of the most important in Europe and the only one in Italy exclusively devoted to the study of climate change.

Risk Analysis. Climate Change in Italy.

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Climate change in Italy: risk amplifiers

Reduction in water resources, soil instability, forest fires, soil consumption, desertification and losses in crop and ecosystem productivity are some of the numerous risk factors that characterize the Mediterranean Basin. In addition, there are other pressures caused by ongoing climate change that act as “amplifiers” with the potential for extremely negative consequences in the coming decades if a new model of sustainable development, that reduces impacts and strengthens resilience, is not pursued.

Implementing this transformation is an absolute priority, especially in light of the ongoing sanitary, social and economic crisis caused by COVID-19. The pandemic has drawn the attention of governments and citizens to the need for ensuring greater resilience to social, environmental and economic stressors that arise from a plurality of origins.

The report “Risk Analysis. Climate change in Italy” summarizes up-to-date scientific knowledge on the main risks arising from climate change in Italy as a result of different potential levels of global warming and development models.

The CMCC Foundation focuses its analysis on certain key areas and also discusses possible impacts in economic terms. The main financial opportunities for the adoption of resilient actions, which allow for a reduction in territorial vulnerability and turn risks into new development opportunities, are also analyzed.

The report offers a base of knowledge for both policy makers and citizens, providing information and elements that support decision making and resource allocation processes, whilst creating greater awareness on the issue of climate change risk and the need to adapt our behavior and choices.

The report is structured in five sections whose contents are summarized below.

1 - Analysis of the expected climate scenarios for Italy

Climate change in Italy is linked to increases in temperature, changes in rainfall patterns and increased frequency and duration of extreme weather events.
The climate scenarios analyzed in this report show a generalized +5°C increase in average temperature in 2100 compared to the beginning of the century (worst case scenario, RCP8.5).
The precipitation regime shows significant differences throughout the region. In general, a decrease in annual precipitation values and an increase in intensity on rainy days are expected.
All the scenarios considered show an increase in the number of hot and dry days during the year.
Significant changes are also expected for the marine environment, namely surface temperature increases and sea level rise, with negative impacts on the supply of so-called coastal "ecosystem goods and services" that support the entire socio-economic system.

The integrated analysis of climate scenarios for Italy shows that climate change is a determining element for risk factors, enabling new risks to emerge and/or amplifying pre-existing ones in an already critical context, directly affecting many socio-economic sectors such as agriculture and forests, health, geo-hydrological instability, and water resources. The analysis of climate projections has been carried out through the use of Regional Climate Models (RCM) with a high spatial resolution, which is particularly suitable for carrying out an assessment of climate characteristics and impacts at regional or local scale, and thus responds to the needs of policy makers, activities producing goods and services, and civil society.

The regional climate models of the EURO-CORDEX program, with spatial resolution at 12 km, and the COSMO-CLM model in the configuration developed by the CMCC Foundation for Italy, with spatial resolution at 8 km, were used in this analysis with three climate scenarios (RCP2.6, RCP4.5 and RCP8.5) of the Intergovernmental Panel on Climate Change (IPCC).

The main atmospheric variables and how they are influenced by climate change are studied in terms of both average and extreme values. The results are reported as anomalies, i.e. differences from the reference period 1981-2010.

The expected variation in the average temperature increase changes considerably depending on the scenario considered, whereas the distribution is almost uniform throughout the territory, although some differences are noticeable especially in spring and summer seasons.

The expected variation in the annual precipitation regime over the next decades indicates low differences for the Italian area among the different scenarios considered. On the contrary, the analysis at seasonal scale shows clear reductions in precipitation in central-southern Italy in summer and increases in the north especially in winter.

To analyze the variations in temperature and precipitation extremes a set of internationally developed climate indices has been used. According to the scenarios considered, an increase in intense precipitation events and periods without rain are expected. Moreover, the scenarios project a marked increase in days with intense heat in the summer season, on average up to +18 of the so-called tropical nights (in reference to days when the minimum temperature exceeds 20°C).

Analysis of the coastal and marine Mediterranean area indicates, for the period 2021-2050 under the high climate change scenario (RCP 8.5), an expected increase of about 1.2°C in surface temperature on an annual basis, with differing seasonal variations. A diversified sea level increase is also expected, with +6 cm for the Adriatic Sea and +8 cm for the Tyrrhenian Sea on an annual basis.

2 - The aggregated risk for Italy

The probability of risk from extreme events has increased by 9% in the last twenty years.
Resilience and the ability to adapt affect the entire country but southern Italy shows a considerable number of municipalities with low levels of resilience to disasters. However, even the richest and most developed regions in the north are not immune to the impacts of climate change, nor are they better prepared to deal with them.

The concept of risk is discussed considering the evolution of its definition in the context of Disaster Risk Reduction (DRR) and according to the IPCC definition where the risk of climate impacts derives from the interaction between climate-related hazards (including dangerous events and trends), vulnerability (with its components of sensitivity and adaptive capacity), and exposure of human and natural systems.

The assessment of climate risk and resilience for Italy was carried out using three indices, calculated in different contexts in order to support decision-making processes: the Climate Risk Index (CRI), the Actuaries Climate Index (ACI) and the Disaster Resilience Index (DRI).

The Climate Risk Index was calculated using climate simulations from the EURO-CORDEX regional models for two future periods (2021-2050 and 2071-2100) within the low emission scenario (RCP4.5), compared to the reference period 1961-1990. The compo-

nents of built, natural, social, and economic capital were considered in the analysis of Italy's exposure and sensitivity to climate change, whereas other indicators (expression of available economic resources, infrastructure, education, technology and quality of institutions) were used to assess the adaptive capacity. The final results of the analysis of the Climate Risk Index provide useful information for climate adaptation planning at the provincial (NUTS3) level, as well as an assessment and definition of needs and priorities for funding planning and distribution.

The Actuaries Climate Index was developed to better understand extreme weather events and the associated risks. The analysis shows that, in the period 1999-2018, the probability of extreme weather risk increased in Italy by about 9%, compared to the previous 20 years (1979-1998). If we consider sea level rise an even higher increase is expected due to the large amount of coastal areas and low altitude regions in Italy.

The Disaster Resilience Index was calculated considering the following components: access to services, cohesion, economic resources, housing conditions, education, environmental status and institutions. The results indicate that northern and central areas of Italy show greater resilience, while southern Italy shows a considerable number of municipalities with low levels of resilience to disasters.

3 - Analysis of the expected risk for Italy: key sectors

The report focuses on sectors that are considered particularly significant in addressing and describing climate risk in Italy. For each sector the key risks, main impacts on a selection of relevant functions, and principal aspects that determine their vulnerability are analyzed.

Urban environment

Urbanized areas will suffer strong negative impacts from climate change, especially in reference to extreme climate phenomena (heat waves and intense precipitation events).
The most fragile segments of the population (children, the elderly and people with disabilities) will be the primary victims of the most negative effects.
Intense heat represents a health risk for the population.
Urban centers experience temperatures 5-10°C higher than their surrounding rural areas.
In 2019, there were 29 more days of intense heat than in the period 1961-1990. Climate projections predict an increase in these phenomena, which are exacerbated in urban areas.

There is also a strong link between temperature rise and air pollution. The foreseen increase in periods of intense heat will cause increased mortality, as well as cardiovascular and respiratory diseases.
Italian cities are also particularly exposed to the risks of heavy rainfall and flooding.
The risk analysis integrates data from climate scenarios on the expected future increase of heavy rainfall events with the current context where 91% of Italian municipalities are at risk from landslides and floods, and more than 7 million people live or work in areas defined as "high danger".

Urban centers host 56% of the Italian population. They are the main providers of services to citizens and, at the same time, are "hot spots" for climate change as geographical areas characterized by very high vulnerability and exposure. The expected intensification of extreme climate phenomena, especially heat waves and intense rainfall, for the decades to come, is one of the main amplifiers of climate risk factors in cities. Characterized by the presence of impermeable surfaces (covered with cement and asphalt) and few natural areas (soil and vegetation), the urban environment is warmer than the surrounding rural environment. The heat from solar radiation accumulated by urban surfaces and the heat produced by vehicular traffic, air conditioning of buildings and industrial activity, cause, along with other factors, the urban heat island phenomenon.

Heat waves – that are expected to increase in the coming years according to the climate scenarios analyzed – are particularly critical in urban environments, where they contribute to exacerbate public health risks.

In addition, there is a link between very high temperatures in urban environments and air quality: at the same time of the occurrence of heat waves there is an increase in hospital admissions for cardiovascular diseases and strokes, as well as an increase in respiratory diseases due to the relation between O_3 and PM_{10} concentrations and temperature.

At the Italian level, there is an increasing trend in frequency and intensity of extreme precipitation phenomena, with a consequent rise in the risk of flooding from water basins and urban floods.

Italian cities are particularly exposed to the risk of flooding for a number of specific reasons such as: the geographical and geo-hydrological characteristics of the territory that is already very fragile, poorly controlled urbanization processes, and land use characterized by the proliferation of impermeable surfaces.

In this context, the climatic risk related to floods increases in all scenarios considered compared to the present condition and affects the safety of people, infrastructure, goods and services.

As for risks related to heavy rainfall, the most exposed people are also the most fragile ones (people with low mobility, low income, the elderly, and children).

Geo-hydrological risk

Italy is an area that is strongly affected by phenomena of geological, hydrological and hydraulic instability, which pose a significant threat to the population.
Rise in temperatures and increase in localized precipitation phenomena play an important role in exacerbating the risk of geo-hydrological instability throughout the region.
Anthropic factors (soil consumption and sealing, occupation of river areas, etc.) combined with temperature rise and increase in localized precipitation phenomena play an important role in exacerbating risks.

In relation to the expected rise in temperature, the phenomenon of melting snow, ice and permafrost will worsen and affect Alpine and Apennine areas more severely in terms of both magnitude and seasonality of disruptive phenomena.

Moreover, the expected increase of intense precipitation contributes to a further increase in hydraulic risks for small basins (that during intense precipitations overflow before larger basins), and increases the risk associated with surface landslides in areas with more permeable soils.

In general, on the Italian territory, the expected impacts of climate change will contribute to intensify pressure on geo-hydrological instability, amplifying and aggravating a situation that is already very complex.

Therefore, the analysis of climate risk for Italy highlights the need for an effective and efficient adaptation strategy based on the combination of mitigation (intended, in the hydrological field, as the reduction of river flows to the ridge and, in the geological field, redesign of defense works for the different types of disruption), and adaptation actions (aimed at increasing resilience in the social system).

Water resources

The foreseen changes in climate (prolonged periods of drought, extreme events and changes in the rainfall regime) present risks for the quality and availability of water resources in Italy.
Risks are more evident in the summer months and in semi-arid areas.
High competition between sectors (civil consumption, agriculture, industry, energy, tourism) for water, especially in the hot season, requires greater planning and coordination to increase efficiency of resource use and ensure sustainable development.
The inadequacy of infrastructure (water losses up to 50% in the agricultural sector) represent a clear vulnerability and an important factor for risk management.

Water security is a fundamental requirement for sustainable development that guarantees fair growth, competitiveness of companies and protection of the natural environment.

This challenge is made more difficult by climate change, which affects the hydrological cycle with a consequent increase in the risks associated with it.

The analysis, carried out at district and river basin level, shows a reduction in both quantity and quality of water resources due to climate change.

In the coming decades, the increase in average temperature, evapotranspiration and low rainfall will contribute to a significant decrease in flow rate: a 40% reduction by 2080.

A further decrease in flow rates of 10-15% is expected as a consequence of anthropogenic activities, such as an increase in water withdrawals.

Strong competition for water resources between sectors (such as civil use, including tourism, industry, power generation, and agriculture) may be exacerbated by the impacts of climate change on water quality and availability. The need to maintain a balance between water demand and water availability is a major challenge today and will become increasingly important in the decades to come.

Conflicts between these sectors are particularly evident in the summer season, when demand for water resources increases in the months when they are most limited.

Outdated and inadequate infrastructure highlights the need for further efforts to improve water resource management, not only for human needs but also for maintaining an adequate percentage of water flow to ecosystems.

As a result of prolonged dry periods (increasing in Italy according to the analysis carried out on climate change scenarios) negative effects on water quality, flow rate reductions and inflow velocities are expected. These phenomena contribute to eutrophication, i.e. an increase in aquatic plant biomass that worsens the quality of the resource. In addition, drought phenomena and the consequent reduction in flow rates, combined with conditions of over-exploitation of water resources, make watercourses and coastal groundwater reserves (especially in lowland areas) more exposed to the action of sea level rise, with consequent intrusion of salt water and increased salinity in the freshwater reserve.

Finally, sudden floods and runoffs, linked to the expected increase in heavy rainfall in Italy, increase the supply of nutrients and contaminants from agriculture and livestock farming.

Agriculture

The risk posed by climate change for the agricultural sector in Italy is relevant for both plant-based and animal-based production.
Crops respond to the forecasted increase in average temperatures with: changes in the duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes, where better conditions for growth and development can be expected.
In the future, Italy can expect decreases in the productivity of spring-summer crops, especially if non-irrigated.
There is also a potential shift in arable land towards the north of Italy for species such as olive trees and grapevines. However, the expected increase in extreme events may limit this expansion.
The increase in temperature affects the welfare and quality of livestock under heat stress for long periods of the year, with consequences on the productivity of the sector.

The report analyzes the main projected impacts on crop and animal production through both an analysis of existing literature and model simulations that evaluate yield variations for cereal crops, evaluating the uncertainty related to climate projections and the direct effect of an increase in atmospheric CO_2 concentrations in offsetting the negative impacts of climate change. For the livestock sector, expected projections for the Temperature Humidity Index (THI), which expresses the combined effect of temperature and humidity and allows to evaluate possible impacts on animal welfare, were evaluated.

A reduction in irrigated corn yields of up to 25-50% compared to current values is expected in the coming decades, in some areas, according to the analyzed scenarios.

Yield reductions are also expected for wheat, especially in southern Italy and Italian islands, whereas in some areas of central and northern Italy increases are projected.

Higher atmospheric concentrations of CO_2 can promote photosynthetic activity and the efficiency of crop water use, but at the same time can negatively affect the nutritional quality of the products, reduce the protein content of cereals, quality of wheat baking and iron and zinc concentrations, with significant consequences on the nutritional aspects. However, further research is necessary to investigate the effect of increased CO_2 atmospheric concentration and its effect on crop productivity and food quality.

The results of the analysis reveal a higher risk condition for southern Italy, with potential higher costs related to crop irrigation, due to lower water availability, which will increase conflict between sectors for the use of water resources, putting productive processes at risk particularly in the areas downstream of the main water basins.

Climate risk assessment for irrigated agriculture due to climate change is strongly related

to the specific crop requirements and climatic conditions of each area and also requires a careful assessment of the vulnerability and resilience of water supply systems to meet increased demand for crop water.

Negative impacts of climate change are expected for livestock, related to the health status, production and reproduction of most species, with a greater vulnerability for dairy cattle and pigs, medium vulnerability for poultry, and low to medium vulnerability for beef cattle. For the entire agricultural sector, the challenge is to implement a profound transformation through appropriate political and economic choices. A key role will be played by the ability to create and disseminate information to improve the awareness of producers and consumers in order to increase the resilience and sustainability of production, to guarantee the quality of agricultural products, environmental protection, food safety and consumer health.

Forest fires

The increased occurrence of extreme climate events interacts with socio-economic and land use changes. This condition may exacerbate specific components of fire risk, with negative impacts on people, goods and ecosystems. An increase in atmospheric emissions of greenhouse gases and particulate, with significant consequences on human health, is also expected.

Forests constitute 35% of the national territory and play a fundamental and multifunctional role, providing both economic and environmental benefits to the community. Production activities related to forestry, wood, pulp and paper industry contribute up to 1% of Gross Domestic Product.

The wide range of ecosystem services offered by forests includes supporting services (such as soil formation, productivity and nutrient cycle); preparatory to regulatory services (such as hydrogeological protection, water cycle regulation, carbon absorption capacity, biodiversity conservation); and cultural services (related to tourism and recreation, sports, environmental education). These ecosystem services are threatened by the effects of current and future climate change.

In Europe, the damage caused by forest fires is estimated at about 3 billion euros per year.

As a result of the increase in mean temperatures, the intensification of dry periods and the decrease in precipitation throughout the year a further exacerbation of specific components of fire risk are expected.

Climate factors exacerbate fire risk by interacting with the effects of abandonment of cultivated areas, pastures and managed forests; the strong exodus towards cities and coastal areas; and increasingly efficient monitoring, prevention and active fighting activities.

In the report, risk is assessed by analyzing elements such as forest fire danger, the lengthening of the fire season, and the increase in number of days with extreme danger, which may result in an increase in burned areas.

In Italy, an increase in fire risk of more than 20% is projected in all climate scenarios and a lengthening of the fire season between 20 and 40 days is expected in the coming decades. These phenomena may induce an increase in burned areas between 21% and 43%, depending on the scenario considered.

The increase in burned areas will also lead to an increase in vegetation fire emissions (CO_2 and particulate), negatively affecting air quality and human health on a local scale. This situation may also have an important impact on the atmospheric budget and the carbon cycle at regional and global scale.

4 - Costs, instruments and resources

The costs of climate change impacts in Italy increase rapidly and exponentially as temperatures rise in different scenarios: from 0.5% of current GDP per capita to 7-8% at the end of the century in the worst-case scenario.
Climate change widens the economic gap between richer and poorer regions: economic impacts tend to be higher in less developed areas.
All sectors of the Italian economy are negatively impacted by climate change. The greatest losses occur in the country's networks and infrastructure (as a result of the intensification of disruptive phenomena), in agriculture and tourism in both summer and winter seasons.
Climate change will require numerous investments in the future and represents an opportunity for Italy to invest in sustainable development, recognized by the European Green Deal as the only viable model for future development.
This is the best time for ensuring that both local and national companies and public entities promote new ways of doing business so as to include sustainable land management in their portfolios.

The macro-economic impacts of climate change in Italy are discussed in the report taking into account two methodological approaches to evaluate the use of macro-economic models and econometric techniques.

The results show that the majority of Italy's economic sectors will face negative impacts due to climate change and economic inequality between regions will worsen. Moreover, negative economic impacts tend to be higher in relatively poorer areas.

All the analyzed studies are consistent in projecting contained GDP losses with a rise in temperature lower than 2°C, whereas losses are expected to increase exponentially if temperatures rise above this level.

With regards to economic impacts on specific sectors, Italy is the European country with the highest economic exposure to flood risk. In a 3°C temperature increase scenario by 2070, the direct costs in terms of expected loss of infrastructure capital would be between 1 and 2.3 billion euros per year in the period 2021-2050, and between 1.5 and 15.2 billion euros per year in the period 2071-2100.

As far as sea level rise and coastal flooding are concerned, in the worst-case scenario costs of up to 900 million euros by 2050 and 5.7 billion euros by the end of the century are expected.

For the agricultural sector, particularly exposed to reductions in yields due to drought and water scarcity, a decrease between 87 and 162 billion euros in the value of agricultural land in Italy is expected by 2100.

The tourism sector, which is also sensitive to climate change, can expect a contraction in overall Italian demand that could reach 9% and direct losses for the sector are estimated at 17 and 52 billion euros respectively under two temperature increase scenarios (+2°C and +4°C).

Moreover, it is estimated that with an increase of 4°C only 18% of ski resorts operating in the Italian Alps would have adequate natural snow cover to guarantee normal winter season activities.

The overview of the main adaptation programs available for the elaboration of adaptation policies includes the European Adaptation Strategy, the document that outlines the framework for individual countries. The Italian path is based on the National Climate Change Adaptation Strategy (SNAC) and the National Climate Change Adaptation Plan (PNACC).

The integrated analysis of climate change scenarios for Italy, the resulting risk and the collection of the main sources of funding for adaptation at European and Italian level, highlight the need to use all the available resources at European and national level to support and encourage companies and public administrations towards a transformation consistent with the sustainable development goals.

5 - Adaptation initiatives

The management of risk from climate change requires adequate adaptation initiatives that, in light of the information provided by the analysis of climate change expected in Italy, can be designed and implemented at all levels and in different sectors, following the example of adaptation initiatives currently underway.

Adaptation is both a necessity and an opportunity to respond to the effects caused by climate change. Following the national effort, with the development of the National Climate Change Adaptation Plan (PNACC), which is still in the approval process, important adaptation initiatives have been implemented at a regional and local level. These activities have contributed to the strengthening and promotion of information, guidelines, tools and processes to support the development of adaptation strategies and plans and the identification, through a number of criteria, of the necessary adaptation actions, at different levels of government, to address the most urgent and specific risks.

At the urban level, for example, the Interreg-ADAPT project has defined a common adaptation pathway against urban floods from a local to cross-border scale.

The Life MASTER-ADAPT project, on the other hand, has worked to meet the needs of local authorities through the identification, verification and dissemination of multi-level governance tools to integrate climate change adaptation into sectoral policies (mainstreaming process).

At a regional level, a successful example is represented by the Regional Climate Change Adaptation Strategy (SRACC) of the Sardinia region. This Strategy, through the identification of the close link between the proposed adaptation objectives and actions and sustainable development objectives, won the “Premio PA sostenibile, 100 progetti per raggiungere gli obiettivi dell’Agenda 2030” as best project in “Environment, energy, natural capital”. Many other initiatives in recent years have focused on specific sectors, such as forestry or agriculture, with the aim of providing concrete solutions for adaptation to new climate conditions. Some examples, such as tools and approaches for risk assessment and decision support in agriculture (e.g. Life ADAPT2CLIMA) or for innovative and effective forest planning in a context of changes (e.g. Life AForClimate) are presented.

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