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Climate change-induced droughts and their territorial impact, the case of the 2022-2023 event in Liguria

Geography of Conflicts

Relatore

Pietro Piana

Candidato

Ivan Vianello

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Introduction

This research thesis investigates drought as a local and international phenomenon, analyzing the Liguria region and its repercussions in 2022/2023 at an environmental but also governance level. Drought today, moreover, is a phenomenon that is increasing in frequency and intensity which, seen globally, is the generative cause of numerous internal conflicts which will grow increasingly due to the projections on climate change. The choice of this topic is motivated by the desire to investigate the causes of this phenomenon which is manifesting itself in an increasingly systematic way in different areas of the world and to understand what the viable solutions and the negative implications for the environment are. This work discusses how we are about to interface with one of the greatest environmental security risks that we will not be able to predict or control, capable of long-term disastrous effects and affecting the most valuable resource for life on planet Earth: water. Despite being a very frequent phenomenon worldwide, there does not seem to be sufficient attention to it particularly in countries traditionally not affected by droughts such as temperate countries. This is the case of Liguria, a region characterized by a temperate and rainy climate which since early 2022 has been experiencing an incredibly significant drought, just like most of Italy and Europe. The main aim of this research is to analyse the drought in terms of its climatological and environmental manifestations, as well as for the implications at social and governance levels. The research consists of the analysis of the phenomenon through the analysis of meteorological and hydrogeological data and the methodology of semi-structured interviews[1] with various stakeholders involved in water management. The research methodology entailed a careful analysis of data, unveiling the urgency of a prompt intervention aimed at mitigating the effects of what already is current issue institutions must face and providing evidence that it is the moment to act at the various political, diplomatic, and institutional levels to implement prevention actions that can introduce innovations in terms of sustainability, prevention, and savings. The strong point

[1] R. Longhurst, (2003), *Semi-structured interviews and Focus Groups,* https://www.researchgate.net/publication/268036642, [Last Accessed 20/06/2023].

is precisely this: understanding that, given the current critical situation and forecast, institutions have the duty and the burden to burden too obvious deductions that no longer represent probabilistic hypotheses far from the reality, but facts now consolidated in the daily life of each of us and it is exactly there that the change starts, from our small actions up to the point of requesting a joint global effort. The present paper here is therefore divided as follows, presenting a careful inspection of world data and trying to identify the areas currently most at risk, notably Sub-Saharan Africa, a land of long-lasting droughts and conflicts. The first chapter examines the situation in the Liguria region which has been undergoing water shortage, a situation which does not seem to be improving even in winter. The last part focuses on personal communication provided by experts and local administrators and meetings that took place with the experts in question who have kindly released the permission to be mentioned and reported in this research, including the actions put in place by the political class which, as has already happened for scholars and scientists, is realizing that intervention as far as possible is now necessary given that the warnings provided by atmospheric phenomena or closely connected to them are now evidence of an ongoing process, which will strike again and abruptly.

Chapter 1
A global perspective on Drought

1.1 Definition of Drought

Drought is an event of a prolonged shortage of water supply or deficiency of precipitation over an extended period, both of an atmospheric type and therefore implies a series of rainfall below the seasonal average or of a water type, with surface or groundwater that undergoes the effects of evaporation and drying up. Generally, a drought lasts for months or a few years, but it particularly affects the summer period with the possibility of causing a serious impact on the ecosystem and agriculture of areas of the world in which the phenomenon takes place with an evident extreme impact, not only from a natural point of view but also from an economic one.[2] In tropical regions, the summer seasons, which are usually the driest ones compared to continental climates, increase the possibility that different types of fires may develop due to heat waves, extremely correlated to the phenomenon of drought, which can significantly worsen accelerating the evaporation of water from the soil.[3] Drought is a phenomenon affecting developing countries globally but is also concentrated and developing year after year in temperate zones.[4] This means that the phenomenon of drought is an event that is increasingly going to undermine the climate stability balances of areas of the globe, previously not particularly affected by this type of event. In general, drought is still a feature that often occurs in different areas of the world, however, despite this, these regular droughts have become increasingly irregular in areas of the planet where they did not occur before. The unpredictability of drought itself is therefore due precisely to climate change, which is manifesting itself in new areas and

[2] Wikipedia, *Drought*, (2022), https://it.wikipedia.org/wiki/Drought, [Last Accessed 13/10/2022].

[3] *Ibidem*.

[4] D.A. Wilhite, (2000), *Drought as a natural hazard: concepts and definitions*, a Global Assessment, Volume I, Routledge, London (UK), pp. 3-18.

regions with often intense, destructive, and extreme atmospheric phenomena of different types.

The various hydrogeological, hydrographic, and meteorological studies show that there is an annual increase in drought phenomena and that the events have already begun to change starting about 1900, to continue in the last decade systematically and more consistently, showing a precise frequency.[5] Droughts and water shortages can be categorized into mainly three groups of effects: environmental, economic, and social drought. [6] The environmental drought in question in this thesis is the type of drought that affects more and more generally temperate areas, increasing the presence of dry soil and fires with consequent loss of biodiversity. [7] Consequently, there is also an economic loss following the event and therefore we can speak of economic drought: the decrease in agricultural, forestry, game and fishing production generates an increase in food production costs and also the supply of these resources becomes increasingly difficult, including that, obviously even before food, water, in short supply for the energy and civil sector, creates critical situations for the population who is no longer able to be self-sufficient.

The social and health costs are therefore closely related to the negative effects not only on the surrounding environment but also on the health of the people who are directly exposed to the phenomenon, generating collective water stress caused by failed crops together with the high food costs that lead to the occurrence of mass migrations and serious humanitarian crises that are difficult to deal with.[8] From a human point of view, drought is not only a phenomenon that can be defined as physical, but it is also an event that marks the breaking of the balance between the natural availability of water and the consumption caused by

[5] European Environmental Agency, (2016), *Europe's environment: Second assessment*, www.eea.europa.eu, [Last Accessed 13/10/2022].

[6] D. Chan, Q. Wu, (2015), *Significant anthropogenic-induced changes of climate classes since 1950*, Nature Scientific Report, Article Number 13487, pp.1-8.

[7] ISPRA, (2019), *Rapporto sulla siccità*, www.isprambiente.gov.it, [Last Accessed 13/10/2022].

[8] D. Proietto, (2005), *Carestia e siccità in Etiopia*, www.politicadomani.it, Politica Domani [Last Accessed 13/10/2022].

human activities.[9] This disruption of the natural balance can cause considerable damage both to the ecosystem, which faces a serious loss from a natural point of view, and to the agricultural activities of the areas concerned.

1.1.1 Drought as an increasing phenomenon

Although droughts usually last many years, they can, however, be particularly intense even in shorter periods such as the case of 2022, particularly difficult in Europe and in various other areas of the planet due to extreme and somehow unexpected lack of precipitation. Since drought is a devastating phenomenon in environmental and economic terms, in many regions of the Earth it is important to use some strategies which, if adopted, include the right measures to counter it in advance. In terms of records, the world's longest-lasting drought in recorded history occurred in Chile's Atacama Desert and lasted for 400 years.[10] Throughout history, humans have always sought the causes of droughts trying to remedy them. Drought is a natural threat in the last years have been affected by human activity which, by altering the water cycles through CO2 emissions for decades, is giving way to so-called climate change.[11] However, drought is still the subject of numerous criticisms and scepticism today, as according to some scientists, the phenomenon is and remains cyclical, unrelated to any artificial activity.[12] Whether or not be a consequence of climate change, the physical causes of drought are to be found in atmospheric precipitation; these do not depend only on the presence of water vapour in the atmosphere but also on the simultaneous ascent of the air masses inside it: if one of these two phenomena is attenuated

[9] *Ibidem.*

[10] T. Spano, (2022), *È il posto più secco del mondo, non piove da 500 anni,* www.ecocultura.it, [Last Accessed 14/10/2022].

[11] H. Pörtner, D. C. Roberts, (2022), *Report Climate Change 2022: Impacts, Adaptation and Vulnerability Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Chapter 3, p. 458.

[12] E. Ragusa, (2022), *Cambiamenti climatici: un crescente scetticismo,* www.attivitasolare.com, Attività Solare, [Last Accessed 14/10/2022].

it can generate a particular situation of drought. In addition, some factors may influence such as a prevalence of high pressure which brings dry air masses instead of humid ones; the oceanic thermal cycles for which there are still numerous studies to be done, as they have not been fully understood in their complexity. Finally, deforestation reduces soil moisture and the ability to retain liquids, thus fueling global warming[13] Deforestation is strongly associated with global warming and hurts crops[14], especially in developing countries, where the phenomenon has significant consequences such as the death of livestock and a reduction in the extension of cultivated fields due to the consequent increase in desertification.

The population is no longer able to live in an environment that is hostile to human life since the phenomenon can also create, at least in some cases, sandstorms given that already desert regions are affected by erosion. The social tensions that result from drought can subsequently also lead to situations of conflict and wars, generating mass immigration which is only one of the possible effects. Indeed, conflict-related drought also depends on several crucial elements such as the vulnerability of the area affected. Where there is a type of subsistence agriculture it will is very probable that the population arises due to drought due to a lack of food resources, but the consequences also strongly depend on the social and political conditions of the country itself. [15] To deal with these problems, generally, in industrialized countries, some techniques are used to counteract the lack of water resources, such as desalinating seawater for agricultural or domestic uses. In addition, constant monitoring of rainfall levels with crop rotation can help minimize erosion and subsequent crop loss.[16] In conclusion, an efficient and organized collection and purification

[13] Climate Action, (2021), *Consequences of climate change*, climate.ec.europa.EU, [Last Accessed 14/10/2022].

[14] *Ivi*, p.12.

[15] *Ibidem*.

[16] The Economist Namibia, (2020), *The effects of rainfall distribution and intensity on agricultural production*, https://economist.com.na/57635/columns/the-effects-of-rainfall-distribution-and-intensity- on-crop-production/, [Last Accessed 14/10/2022].

of rainwater, and the construction of dams, aqueducts and canals can guarantee water supply in dry areas, despite the absence of water in certain seasons which can lead to water use restrictionssuch as those applied in Italy in the summer of 2022[17] including a limitation on the irrigation of lawns, gardens, car washing and the use of swimming pools. These restrictions can certainly help save water so that we can face the summer season, usually the most affected, without having to resort to further particular solutions, as the restrictions themselves certainly generate a water reserve that can cope with the existing crisis but unfortunately, only for a limited time and as a palliative solutions[18] Extreme weather events repeated over time still pose a major challenge for agriculture and the sector itself. The convergence of remote sensing using satellites and supervised learning can generate solutions for problems arising from drought-related climate change: through a series of available data and outputs, this function can be used to predict new phenomena. Since, as seen from the indices, the phenomena are not parametric anyway, it is not possible to extract large quantities from satellite data to capture the real relationships between climate variables present on the earthtoday but is it possible to prevent or hypothesize the event to protect the crops and to develop weather forecasting models. The agricultural index reflects on the water conditionsof the soil that influence the crops, monitoring events in terms of time to react in advance and investing resources in the best viable way to deal with them if they occur. In such a way that these approaches, however, can go to integrate satellite data. Climate change is modifying rainfall patterns and increasing their severity. The drought of summer 2022 has reduced crop yields by 40% and 50% in some countries in both northern and central Europe.[19] Drought is by far the costliest natural disaster on the earth and can have far-

[17] F. Cupellaro, (2022), *Siccità, la battaglia dell'acqua: Regioni e Comuni chiudono i rubinetti*, https://www.repubblica.it/green-and blue/2022/06/23/news/siccita_le_regioni_e_i_comuni_chiudono_i_rubinetti, The Republic, [Last Accessed 14/10/2022].

[18] *Ibidem.*

[19] Sky TG 24, (2022), *Siccità in Europa, 47% del territorio a rischio secondo uno studio dell'Unione Europea*, tg24.sky.it, [Last Accessed 14/10/2022].

reaching impacts. Notwithstanding the most important analysis of the phenomenon entered into force in 1947, there is no evidence that tolerance to water stress has improved in recent years, indeed, the perception is negative[20]. Therefore, drought forecasts are important to determine when to take emergency actions to prevent them to mitigate the risks and the impact itself. The practice of in-depth forecasting remains challenging and is however subject to great uncertainty as in part it is due to the instability of the hydrogeological cycle itself.[21] Over the years, it has demonstrated an oscillating behaviour made up of sudden changes that appear in the hydroclimate register as unexpected. One of the priorities of climate science is the development of reliable data sets for understanding climate processes on a global scale. Most of the efforts have recently been devoted to developing a global gridded dataset with various climate variables, including temperature, precipitation, and pressures across different areas of the globe.[22] Despite the usefulness of these data, there is a need to adjust baseline climate parameters and this summary information on wet and drought conditions. These are the primary data points valued by environmental, hydrological, and global change researchers and are crucial for determining possible variable effects regarding the drought. The best approach is developed through the measurement of relative humidity in different areas of the world and of dryness to calculate the highest drought indexes given by the combination of these two factors.

1.1.2 Forecast droughts through indexes

The most important indexes are the Palmer drought severity index (PDSI)[23] which is one of

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[20] G. Ondrasek, L. Ornella, G. Kruseman and J. Crossa, (2019), *Drought Detection and Solutions, Satellite Data and Supervised Learning to Prevent Impact of Drought on Crop Production: Meteorological Drought*, London (UK), Chapter 1, p. 1, [Last Accessed 14/10/2022].

[21] *Ibidem.*

[22] Integrated National Drought Information System, (2022), www.drought.gov, [Last Accessed 14/10/2022].

[23] NCAR, (2023), *Climate Data Guide*, https://climatedataguide.ucar.edu/climate-data/palmer-drought-severity-index-psi, [Last Accessed 14/10/2022].

the most used to verify the water and climate balance and considers the anomalies in rainfall and the phenomenon of evapotranspiration, the soil water retention capacity.[24] The index has reported extreme humidity and drought cases over the years, at frequencies never seen before and in rare conditions. The time scale used does not allow us to distinguish the three diverse types of droughts (economic, social, and environmental), since drought is considered a multi-scalar phenomenon, an event that can occur simultaneously on several time scales. For example, a critical short dry spell may also occur within a less intense long dry spell. Both drought and aridity indicate an imbalance in water availability, while drought is a real danger to human survival in areas prone to it. In addition, aridity is a constant climatic feature in which the potential for evapotranspiration can be assessed as a means of understanding resilience in a warming climate. Another index used and recognized internationally is the standardized precipitation evapotranspiration index (SPEI) [25] based on the rainfall present in each season.

seasons indices together are used to understand the results that emerge from the different experiences of drought and the various trends of storm phenomena in different parts of the globe with climates from humid, semi-arid and sub-humid zones. The conclusion of the detailed analysis from the year 1936[26], provided by the Journal of Hydrometeorology shows that the indices have had different and generally decreasing trends. The SPEI was not largely comparable to the PDSI in that both indices considered water inputs by precipitation and water outputs by evapotranspiration today, however, comparing the SPEI and PDSI datasets globally demonstrates that they both have a rigid time scale, and this means that the correlation exists even at the level of certified data: when a drought condition is recorded

[24] A. K. Mishra, V. P. Singh, (2010), *Prevision of Drought*, Texas (USA), Chapter 2, p. 157–175, Journal of Hydrology, [Last Accessed 14/10/2022].

[25] NCAR, (2023), *Climate Data Guide*, https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-evapotranspiration-index-spei, [Last Accessed 14/10/2022].

[26] S.M. Vincente Serrano, (2010), *Drought Global Index Database*, Volume 11, p. 1035, American Meteorological Society, Journal of Hydrometeorology, [Last Accessed 14/10/2022].

with the SPEI on a particular time scale,[27] it is possible with certainty to scientifically demonstrate and establish that the drought is caused by a cumulative deficit of rainfall and/or excessive evapotranspiration (compared to average conditions) and therefore it is possible to predict the next level of drought on a reliable time scale for 12-18 months; exceeding this period the index it would prove to be inaccurate as it is imposed only for intermediate periods, not too short or too long.[28] Although severe droughts have always occurred in some areas and have been very intense in the summer periods, it has also been possible to demonstrate that the drought conditions began to be particularly severe on a global scale around the 1940s[29], while on longer time scales these episodes were not recognized due to the intrinsic limitation of the indicators, thus deducing from that year in particular, a correlation with human activities that were increasing massive industrialization In summary, these examples show that existing drought datasets based on these two indices are too strict to identify droughts of different time scales in the short and long term, but the relative conditions of dryness and wetness can still be measured in the medium term, finding the correlations to the phenomena, and introducing actions to prevent them and therefore not just limiting themselves to predicting them. In short, due to the great complexity of the effects of drought, the Journal of Meteorological Hydrogeology[30] deals with identifying different sectors and natural systems that include a rigorous probabilistic nature. The index provides objective information on drought climatic conditions, as it is not influenced by external variables, but is based only on concrete climatic data. In any case, there would be other factors to consider such as the activity of the

[27] McKee, T.B. Doesken, NJ. Kleist, (1993), *The relationship of drought frequency and duration to time scales,* Paper Presented at 8th Conference on Applied Climatology, American Meteorological Society, Anaheim, California (USA), pp. 17-22.

[28] B. Fernandez, A. Vergara, (1998), *Risk of the scarcity of monthly precipitation and stream flows in semiarid regions*. Hydrology Science Journal, 43 (5), 759–773, [Last Accessed 14/10/2022].

[29] *Ibidem.*

[30] *Ibidem.*

vegetation in the steppe areas, in the arid cereal-growing areas of the semi-arid regions as happens in the Iberian Peninsula, for example on short time scales of 3-6 months[31] capable of influencing the drought phenomenon, while forests responded more to longer timescales but were unable to survive and cope with it in the short term if as intense as summer 2022. In Conclusion, droughts have occurred very frequently in different parts of the world and the impacts have aggravated the hydrogeological situation in all countries the water demand has grown exponentially but due to climate change, it is no longer possible to meet it with the consequence that in the temperate zones studies are focusing a great deal of attention and applying a different variety of concepts to rough modelling, ranging from simplistic to extremely complex approaches based on a multitude of data, remembering that meteorology is not an exact science, as modelling approaches have both advantages and limitations.

The various papers published in the authoritative 'Journal of Hydrology dealt with the integration of several drought concepts into previous data from 2010[32], in which recent updates on probability-based models and analysing the space-time of global climate models, increasingly focusing on probable drought scenarios to build a reliable system on terrestrial data. For efficient modelling and planning, it was found that large-scale climate indices in the temperate areas of the world appear to be promising for forecasting even long-term droughts, as the original indices with the studies seen above were only able to define predictable phenomena in the medium and short term. There have therefore been significant improvements at a scientific level in recent decades, and the use of hybrid models, which have now become crucial to the work in this regard, have seemed the best, as they include a vast amount of data that is often difficult to analyse but can give hopeful results on the applications of these models to drought, trying to identify a certain characterization of drought to understand its real effects, obviously including rainfall as a fundamental element in defining its severity for risk assessment and the adoption of

[31] A. K. Mishra, V. P. Singh, (2011), *Drought modelling – A review*, Journal of Hydrology, [Last Accessed 14/10/2022].

[32] *Ibidem.*

precautionary measures subsequently developed through a flow of useful information for users. However, climate change does not yet seem to be clearly defined, and even though the temperate zones of the world have a greater capacity to restore their natural balances momentarily, developing countries do not seem to be able to cope with the phenomena also due to the inexorable growth of the population at a global level, which has recently reached eight billion people and is mainly occurring in these very countries, the direction seems to be that of being close to environmental collapse if there isn't a sudden change. The expansion of the agricultural, energy and industrial sectors worldwide also continues to contribute to climate imbalance and the contamination of vital water resources, which are becoming increasingly scarce. Therefore, understanding the patterns and the attention paid by ecologists, hydrologists, and meteorologists to the phenomenon around the world is a priority for future joint management of resources and planning for their reuse and saving. In concrete terms, the hydrogeology variables for drought are still rainfall, temperature flows, evaporation, soil moisture, water in aquifers and their levels. Together with these variables, a rough index can be established, allowing the methodology of regression[33] models and historical probability models to be developed, which can become hybrids[34] if they are cross-referenced with additional climate data available to us such as sea temperature levels, ocean fluctuations, wind, and atmospheric pressure data. In this way, the production of data could deliver clues on the initiation and cessation of the phenomenon by understanding its nature, severity, and likelihood of recurrence. Hybrid models[35] are, however, useful for extracting drought predictions, as they have greater accuracy.

[33] V. Kumar, U. Panu, (1997), *Predictive assessment of the severity of agricultural droughts based on agro-climatic factors,* American Journal of Water Resources Association, 33 (6), pp. 1255–1264.

[34] T. Kim, J.B. Valdes, (2003), *Nonlinear model for drought forecasting based on a conjunction of wavelet transforms and neural networks*, Journal of Hydrology, Eng., ASCE 8 (6), pp. 319–328.

[35] *Ibidem.*

1.2 Meteorological Observation in temperate world areas and data conflict

The current geography of the temperate zones of planet Earth encompasses a vast geographical area between the tropics and the polar circles between latitudes 23° 27' and 66° 33' of the two hemispheres.[36] The temperate zones of the world include all four seasons and have different types of climates. In Italy, for example, the climate is of the Mediterranean type with mild winters and summers that are not excessively hot. Together with all the other European countries and other areas of the world such as the United States, they represent the temperate climate par excellence with frequent and abundant rainfall in autumn and spring that has allowed the development of complex and extremely widespread vegetation, particularly of broadleaf deciduous forests, this amount of biodiversity can be found mainly in Eurasia and North America facilitated by the constant frequency of rainfall that occurs almost daily.

It is important to remember that temperate climates have made it possible to develop even the most important agriculture thanks to the fact that the lack of water in these areas has never been a problem, at least until today. Although heat peaks also occur in temperate zones and particularly in summer periods, they have never been able to generate severe droughts such as those of recent years. The temperate zones of the world also include countries that have reached unprecedented high levels of wealth, determining the climate factor as being closely linked to economic factors[37], thanks to the abundance of available resources that have enabled them to achieve prosperity, since they have been able to make greater use of the available resources in the past, even if today, as a result of climate change and extreme phenomena such as floods, intense snowfalls and droughts even in the temperate zones of the world are beginning to intensify the disastrous effects that normally

[36] Mohamed Labidi, (2016), *Zone temperate*, www.skuola.net, Skuola.net, [Last Accessed 17/10/2022].

[37] *Ibidem.*

used to occur in some developing countries that have been coping with climate change for years, as they are in areas more prone to these phenomena.[38] Today, however, we are realising that climate change is not just a problem exclusive to a few countries with particular and critical meteorological characteristics but is a problem that must now be tackled on a global scale so that a solution can be found if time has not already run out and it is not too late to act. According to the World Meteorological Organisation, the extreme heat wave that hit the European continent, which is currently one of the world's main temperate zones, was the worst in the last 500 years[39]: the previous record happened in the year 1540.[40] In that year, an extreme heat wave hit the European continent, generating an unprecedented drought. Although there have been numerous other dreadful drought events in these since this record was so distant in the past, the summer of 2022 will go down in history because it was a very dry year even in the winter period and the summer drought has now entered record numbers, surpassing the 1540 figure. Today's figure emerges from a comparison of data obtained by the 'Copernicus satellites for the European Earth observation programme, which is also managed by the European Commission and the European Space Agency. [41] In a sequence of several images from the summer months, the satellites have revealed how vast regions went from a lush green to a barren brown during July and August 2022. The most significant damage is visible in certain European areas such as south-eastern Great Britain, parts of northern France and large areas of Germany, Poland, Italy, and eastern Europe.

[38] M. Vittoria, (2021), *Riscaldamento globale: cause e conseguenze*, www.informazioneambiente.it, Environment Information, [Last Accessed 18/10/2022].

[39] ANSA, (2022), *Nell'estate 2022 la peggiore siccità in Europa in 500 anni*, ansa.it, Rome (Italy), [Last Accessed 18/10/2022].

[40] B. Raso, (2022), *La terribile siccità del 1540 in Europa: innescata dall'ondata di caldo più estrema del 2003,* www.meteoweb.eu, Meteoweb, [Last Accessed 18/10/2022].

[41] Dozen Blogs, (2022), *Nell'estate 2022 la peggiore siccità in Europa in 500 anni*, dozenblogs.com, European Earth observation program Copernicus, European Commission, and the European Space Agency (ESA), [Last Accessed 18/10/2022].

Fig. 1, Images provided by the Copernicus project in collaboration with the European Union, showing how North-western Europe in the summer of 2022 suffered desiccation of the vegetation due to the current drought, Programme Copernicus of EU, (2022).

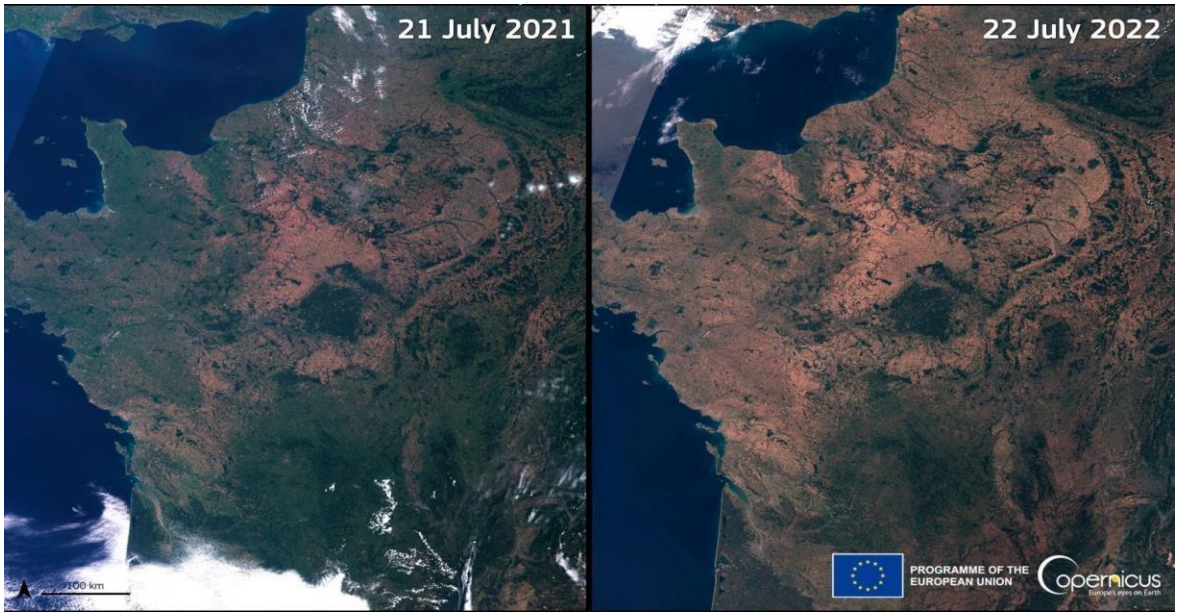

Fig. 2, Images provided by the satellites, showing an increase in drought in areas of north-western France during the summer of July 2022 compared to July 2021, with visible desiccation of the vegetation, Programme Copernicus of EU, (2022).

The data from the Global Drought Observatory, therefore, help to understand that much of Europe was in alarming straits in August: the most serious signs were the lack of moisture in the soil and the effects of extreme dryness on vegetation. In addition to the crisis at the European level, several rivers in the temperate zones then felt the effects of the extreme heat wave, lowering their average water levels in an unprecedented manner, causing severe crop damage in the clear example of the Po River in Italy. In 1540[42] the phenomenon was similar and occurred due to a situation dominated by almost persistent high pressure over western Europe, surrounded by low-pressure systems in the North Atlantic and western Russian areas. Documents of the time concerning the northeastern part of the European continent spoke of a very cold spring and frozen harvests, while information from northern Italy told of a winter with incredibly summery temperatures and an unprecedented summer.[43]

The same situation, even more extreme, occurred in the summer of 2022 in which the vegetation suffered excessively from the heat, drying out much more quickly. According to some meteorological data, the month of June 2022 in detail was only less hot than that of the year 1868, but the month of July set the first record, reaching 27.5 degrees centigrade as the average steady-state temperature for the entire month, far exceeding the measurements of 2003, another year with record numbers but more limited since the summer heat of 2022 included winter and autumn months, characterised by the total absence of precipitation. It, therefore, becomes easy to visualise a general picture: the great wave of persistent heat characterised the Italian and European summer that has just passed, with an average temperature during all three months that was not only the highest ever but also the highest in the history of observations.

As a result, the high temperatures and extreme heatwave continued to affect October 2022[44],

[42] Repubblica, (2022), *In Europa la peggiore siccità degli ultimi 500 anni vista dai satelliti*, repubblica.it, European Earth observation program Copernicus, European Commission and the European Space Agency (ESA), [Last Accessed 20/10/2022].

[43] Sky TG 24, (2022), *Siccità, l'estate 2022 è stata la peggiore per l'Europa in 500 anni*, tg24.sky.it, [Last Accessed 20/10/2022].

[44] Ruminantia ANBI, (2022), *Osservatorio Risorse Idriche: resta rosso l'allarme*, ruminantia.it, Milan (Italy), [Last

generating a series of dangerous fires, especially in Spain and Italy, where the heat persisted the most. The drought also made things worse. If we then analyse the amount of rain that fell year by year and put it about the events of 2022, we reach a second absolute negative record for the year itself: from the beginning of 2022 until October 2022, only 130.6 mm of rain fell in Italy, and in this case, the previous record belonged only to the year 2017.[45] However, these measurements were also possible thanks to the joint analysis of various European observatories, including the historical weather observatory of the University of Genoa, which began its activities in 1833[46]. In any case, the measurement for the year 2022 has broken all records, giving rise to an important deduction: climate change is indeed taking place with local and global phenomena that are scattered and complex but increasingly noteworthy because they can disrupt the climate. It remains to be seen what the further effects of these changes will be if they are irreversible, including the reactions of the population who will be faced with a phenomenon of global proportions with possible economic shocks, for which we have already risked tasting some of it in Europe in the past years.[47] Whatever the future events, however, we will have to prepare for the worst because the data currently worsening from year to year proves it. This is not the case in the temperate regions of the world where the abundance of water resources has always allowed for substantial economic development by the states in these lands. However, there are also regions of the world that are less fortunate in this respect, where the climate has not allowed for the development of water resources and crops.

Accessed 20/10/2022].

[45] *Ibidem.*

[46] D.Scafidi, G. Ferretti, R. Pedemonte, (2022), Caldo e siccità record per il 2022, Genoa (Italy), unige.life.it, Società Meteorologica Italiana, Osservatorio Meteo UniGe [Last Accessed 20/10/2022].

[47] European Union, (2018), *Weather improvements too late for crops*, https://joint-research-centre.ec.europa.eu/jrc-news/weather-improvements-too-late-crops-2018-09-17_en, [Last Accessed 20/10/2022].

1.2.1 Restrictions to Deal with Drought in Europe

In recent years, however, especially since the summer of 2022, it has been possible to observe how the world's temperate zones are also beginning to undergo climate change with extreme effects aimed at upsetting the pre-existing equilibrium.

Drought, in particular, has been the main antagonist of the summer examined here, and in such a situation it has been difficult to meet the water needs of the various countries, except by imposing certain restrictions[48]; in addition to the fact that this summer's temperatures have been low in humidity and high in heatwaves, which have necessarily imposed restrictions, as in the case of New Aquitaine, France[49], where drought crisis committees are regularly set up in the wake of these events, in particular for the drought of 2019, created specifically to limit the use of water through administrative constraints that are often unpopular and technically costly for many administrations, creating situations of discontent in rural areas but also in cities and along the coast. In summer, water consumption is mainly due to irrigation, and water resource managers consequently set up a non-linear water system in innovative irrigation pricing terms to achieve several objectives: first, limiting water consumption to meet minimum flow rates in rivers and anticipating imbalances between supply and demand before agricultural plantations are made. These operations improve distribution from a local point of view and users also participate by making the most of the resource. This is just one of the tools adopted to counter the recent drought in France and even though it has never been so intense, these measures have worked. Also, in Italy, the drought has forced them to adopt measures to contain water consumption. In the summer of 2022, many small municipalities adopted measures for water rationing, especially in Piedmont, Lombardy, Liguria, and Emilia Romagna. Now it's the turn of the

[48] E.A. Bacelar, (2006), *Ecophysiological Responses of Olive (Olea europaea L.) to Restricted Water Availability: Limitations, Damages and Drought Resistance Mechanisms*, Vila Real (Portugal) Universidade De Trás-Os-Montes E Alto Douro, 292, pp. 1–12.

[49] G. Ondrasek, J. Terreaux, M. Tidball, (2019), *Can Nonlinear Water Pricing Help to Mitigate Drought Effects in Temperate Countries,* University of Montpellier, (France), Chapter 2, p.29.

big cities, Milan is among the first to leave after the Lombardy Region has decreed a state of water emergency until 30 September. The drought alarm has found its symbol in the Po River which dried up in most of the summer period, therefore asking for water rationing in 125 municipalities[50] as the river level was 3 meters below the usual level and as the snow in the Alps had dried up, the situation was critical. Emergency measures were requested in approximately 125 municipalities[51], of which 100 were in Piedmont and 25 in the province of Bergamo, but also large cities such as Milan[52], the Lombardy Region subsequently decreed a state of water emergency until 30 September 2022. For this reason, since different European countries have to deal with water scarcity every year, it would be necessary to improve well-designed coordination of different uses of water in this sector at the European level, so that there is a welfare and economic performance such as to ensure that there is no wastage and to allow a sufficient supply of water to agricultural communities; remembering, however, that despite everything these are always short-term solutions and cannot be valid for the long term, as the forecasts predict increasingly intense droughts and related heat waves for the European summer periods.

In this dramatic context, the European Union has developed a general water framework directive to regulate the distribution of water resources equitably.[53] Starting from the fact that drought has three pillars, economic, social, and environmental, there are still few solutions to prevent one of these parts from being left out of a crisis.[54] In general, it is not yet possible to solve the water shortage as water storage in reservoirs is no longer sufficient due

[50] Rai News, (2022), *Allarme siccità Po, richiesto il razionamento dell'acqua in 125 comuni,* rainews.it, [Last Accessed 22/10/2022].

[51] *Ibidem.*

[52] Tutto Lavoro 24, (2022), *Razionamento acqua 2022, al via Milano: ecco l'Ordinanza,* tuttolavoro24.it, [Last Accessed 22/10/2022].

[53] European Parliament, (2000), *Protection and management of water resources*, directive 2000/60/EC, [Last Accessed 22/10/2022].

[54] *Ibidem.*

to the constant lowering of their levels due to excessive evaporation.[55] Furthermore, the increase in water use in urban and rural areas and the exponential growth in world population and consumption do not allow for preventive measures capable of sustaining these rhythms. Therefore, it is clear that there is an annual imbalance between water supply and demand; the objective is therefore to make more and more use of public information and data on the level of rivers, aquifers and dams because of the importance of at least guaranteeing farmers their fair water supply with the aim therefore of creating a proper coordination of the resource and allocated to these activities responsible for social and environmental security, thus anticipating possible annual imbalances between water supply and demand.

The main objective thus always remains to avoid crises from future droughts[56] and to try to anticipate them to resolve most of the possible conflicts of interest before they are well established and the allocation of the resource in advance has failed. Finally, the various measures of the member states have in any case shown that it is possible to change the average daily volumes of water consumed at the European level by increasing citizens' awareness of wastage and by generating a lot of shrewdness, a great deal of savings can be created to ensure water availability at the right time.[57]

1.2.2 Drought in temperate zones around the World

Other studies point to complex situations in temperate areas of the world, such as the drought in the western United States in 2022, which turned out to be the worst in 1,200

[55] J. Keyantash, J.A. Dracup, *The quantification of drought: An evaluation of drought indexes*, Bulletin of the American Meteorological Society, Boston (USA).

[56] E. Ngumbi, J. Kloepper, *Bacterial mediated drought tolerance: Current and prospects,* Applied Soil Ecology, 105, pp. 109-125.

[57] Eurostat, (2022), *Water statistics*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Water_statistics, [Last Accessed 23/10/2022].

years[58], according to a study published in a well-known article called 'Nature Climate Change' and largely based on the study of tree rings. Unfortunately, in the opinion of scholars, it is thought that 42% of the drought that occurred in 2022 in the USA can be attributed to climate change. Today in the western United States there is a picture of the devastation that includes nearly dry reservoirs, dried-up lakes, and landscapes parched by wildfires, in addition to the fact that many cities, just as happened in Italy, have had to begin critically rationing the amount of water for domestic use, and often much more than in Italy, to save as much as possible as the negative effects of this drought seem to be of historic proportions. The drought has been showing its damaging effects since 2021, and in general, it can be considered that it has been raging in this area of the United States with regularity for two decades, with medium to long periods of dry weather. The US Drought Monitor Agency[59], the body in charge of monitoring drought within the country, reports that it alerted the authorities as early as 2021[60], thus declaring a year earlier a state of alert for a heat wave and consequent drought capable of causing a substantial water emergency, especially in the Colorado River, which is one of the major sources of life for the west of the country since it supplies water to some 40 million Americans; they, had to halve their use through rationing since the various lakes and reservoirs, such as Lake Mead near Las Vegas, created to meet the needs of the desert city, dropped dramatically in level and was practically dry.

Similarly, soil moisture levels in much of the western US but also other states such as New Mexico and Oregon have identified a direct link between the heat and the increase in wildfires in the region that have ravaged much of the West. Over the last few years, possible correlations between these phenomena have been possible thanks to the measurement

[58] A. G. Consolaro, (2020), *Siccità negli USA: la peggiore degli ultimi 1200 anni*, iconaclima.it, Milan (Italy), [Last Accessed 23/10/2022].

[59] US Drought Monitor, (2022), https://droughtmonitor.unl.edu/Data.aspx, [Last Accessed 23/10/2022].

[60] *Ibidem.*

indices that have once again confirmed the causal relationship between the increase in fires, lack of rainfall and extreme drought. The fires were also fuelled by the completely dry vegetation that drought and heat help to create, and given the extent of American fires, human intervention was often not enough to put an end to them, as in the great Yellowstone National Park fire of 1988[61], which was only ended by the subsequent rainy winter.

It is crucial to remember that certainly, not all droughts are due to climate change, but this excess heat in the atmosphere recorded in this part of the United States and above all the absence of soil moisture aggravates the situation more than we think. In any case, emissions in this area of the United States have always been massive[62], even if the effects are unfortunately worldwide and whereas desert climate, this can only favour drought, with a good percentage of the blame going to human activities, since exact figures do not yet exist. According to estimates based on the analysis of tree rings where the phenomenon can be traced back the past up to 800 A.D.[63] at the latest, going backwards, it is evident that droughts in the United States, which is a large country in the temperate climate belt of the planet, now have major climatic phenomena that have become more and more intense and frequent over the last two decades.

[61] National Park Services, (2022), https://www.nps.gov/yell/learn/nature/1988-fires.htm, [Last Accessed 26/10/2022].

[62] H. Ritchie and M. Roser, *Our World in Data*: *Co2 Emissions*, https://ourworldindata.org/co2-emissions, [Last Accessed 26/10/2022].

[63] *Ibidem*.

1.3 Per capita consumption and global distribution

It is also of primary importance to address the issue of water distribution in the world: water, today often referred to as 'blue gold'[64] has an unequal distribution. Most of the water on our planet is salty while only a small part is fresh but hardly drinkable or usable. In detail, a very small percentage of 3%. In numbers, there are about 10 trillion cubic metres of water on the earth, covering about 70 % of its surface[65]. A crucial source of life for humans, fresh water can also be found in large quantities in ice, glaciers, and perennial snows: they are mostly found in the south and north poles but are not exploitable even though they account for 68.9% of the total freshwater, while 29% is confined underground[66], mainly in groundwater aquifers, and it is difficult to withdraw.

Only 0.3% of the total amount of water on the planet is easily accessible in rivers and lakes with no certainty that it is drinkable, but the problem also lies in actual consumption worldwide: available fresh water is used 70% for agriculture and 22% for industry, leaving a minimal 8% for human consumption and the service sector, including numerous wastes due to poor management of facilities and non-essential services.

Due to climate change and the contamination produced by human pollution that has now manifested itself in different forms: indeed, in recent years more and more specific attention has been paid to the phenomenon of microplastics, the presence of which has also been found in the human body; they spread throughout the water, air and practically all natural

[64] V. Bruzzo, (2022), *Consumo e necessità di una gestione sostenibile delle risorse idriche*, www.ingenio-web.it, Ingenioo, [Last Accessed 26/10/2022].

[65] Group CAP, (2021), *L'acqua nel mondo: tutto quello che c'è da sapere sull'oro blu*, gruppocap.it, Milan (Italy), [Last Accessed 26/10/2022].

[66] *Ibidem.*

environments, leading to micro-pollution caused by man and capable of establishing an irrecoverable process, from the point of view of recycling and irreversible as there are no technologies capable of collecting these infinitesimal quantities of polymers, inevitably damaging the world's water heritage and consequently the natural environment. The availability of water reserves is part of an asset that is increasingly difficult to guarantee for all, as suggested by the United Nations 2030 agenda[67] and in general, to preserve. Available data show that there are still great inequalities in the management of water, which in addition to being badly distributed, cannot be relied on for governance as it is unbalanced and dependent from country to country: temperate zones today have a large availability with greater water reserves and unjustified wastage; on the other hand, in developing countries, which often have desert climates and frequent droughts, not a single drop can be wasted. Of course, one cannot generalise in some cases, certain countries in the developing world are rich in water.

The World Health Organisation (WHO)[68], in support of the work of the United Nations also promotes water as an essential public good for hygiene[69] and a real right. Ensuring clean water with unlimited access to everyone with at least 50 litres of personal daily requirement is a goal to be achieved even if it will still take many years to achieve and may never be possible due to the current climate upheavals. However, water management would still require huge investments and governance that does not fall victim to corruption and mismanagement. Therefore, it is increasingly important to introduce sustainable rules and treaties at the international level, in addition to the already existing ones, especially where water is already critically scarce.

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[67] United Nations, (2015), *Department of Economic and Social Affairs Sustainable Development*, https://sdgs.uNorg/2030agenda, [Last Accessed 26/10/2022].

[68] *Ibidem.*

[69] World Health Organization, (2022), *Infection Prevention and Control*, https://www.who.int/teams/integrated-health-services/infection-prevention-control/hand-hygiene, [Last Accessed 26/10/2022].

1.3.1 Different Water for different states

In conclusion, the availability of water is not only due to the resource itself, but also to the type of state in which it is found and how it is managed and distributed: for example, it is found in large quantities in North and South America, particularly in Canada where management is quite efficient, but in several parts of the Asian continent, it is polluted and lacks efficient infrastructure. The same happens in the states of Central and Southern Africa and the Middle East where one also must contend with the lack of even frequent rainfall. The European continent, on the other hand, has good water resources, in the territories close to the Alps where reservoirs, both artificial and natural, do not yet trigger conflicts due to their availability.

It's possible therefore distinguish between countries rich in 'blue gold', which are mainly found in South America, North Asia, and North America, and areas lacking in this respect such as Africa, the Middle East, China, Mexico and India, with availability varying from 2000 to 5000 litres of water per person per year,[70] with the situation also being critical due to the frenetic overpopulation of China and India[71], where two billion people live. Drinking water reserves are therefore still an accessible commodity for few individuals, and the claimed 50 litres per person per day seems to be rather a distant mirage and not an achievable goal considering that after intense droughts, it is not even possible to reach 5 litres of water per person per day in Sub-Saharan Africa[72], leading populations to experience critical water stress, also due to the lack of funding for major water works, which only China in the last two decades seems to have shown interest in realising through the so-called 'win-win' strategy, obtaining in return a rich subsoil for the strategic control of rare metals for the expanding technology sector. Many of these African states, particularly in the Sahel with its

[70] Group CAP, (2021), *L'acqua nel mondo: tutto quello che c'è da sapere sul blu oro*, gruppocap.it, Milan (Italy), [Last Accessed 26/10/2022].

[71] WorldoMeter, (2022), https://www.worldometers.info/water/, [Last Accessed 26/10/2022].

[72] T. Gebremariam, (2021), *Acqua pulita, ancora un sogno per l'Africa*, https://www.africarivista.it/acqua-pulita-ancora-un-sogno-per-lafrica/182663/, [Last Accessed 26/10/2022].

already extreme semi-arid and desert climates, have however been affected in recentdecades by civil conflicts, mass emigrations, absolute poverty, and political instability in addition to the major problem of water shortage.

These different situations, in countries that seem so distant from rich countries in terms of possibilities and lifestyles, are now translated into inequalities based on alarming data: to understand better today we know that an inhabitant in the United States has up to 425 litres[73] per day at his disposal, but an inhabitant of Madagascar has only 10 litres. The European average is 165 litres per person and in Africa only 20 per person. Italy reaches 420 litres per person per day, establishing itself as a country not subject to water stress except for some recent summer periods [74].

It is also important to remember that this shortage situation also reflects on the quality of sanitation and the actual health situation. In fact, according to the World Health Organisation and UNICEF[75], whose director is Bertram Denver, for the Middle East and North Africa safe water is a rare commodity whilst contaminated water causes intestinal diseases and thousands of deaths every year due to contamination; therefore, the problem is not only one of inequality and equity in the distribution of resources but also reflects a no longer negligible health problem that cannot be tackled in the short term unless huge investments are made in this direction.

1.3.2 Conflicts over shared basins

Due to the economic importance of water, poor as well as industrialised countries need potable and safe water for various necessities. This makes it important to activate public policies to limit wastage and initiate collaborative projects even with countries known to have fewer resources or which already collaborate on redistribution, as in the recent case of

[73] Following Cancun, (2022), *Average water use in the United States*, https://followingcancuNcom/en/average-water-use-in-the-united-states/, [Last Accessed 26/10/2022].

[75] UNICEF, (2022), *Water for every child*, https://www.unicef.it/media/acqua-e-hygiene/, [Last Accessed 02/11/2022].

Israel and Jordan.[76] In any case, the United Nations developed the 'Watercourses Convention' in 1997 to establish peaceful relations for the equitable, sustainable, and shared exploitation of shared basins. The 'Transboundary Waters Assessment Programme' (TWAP)[77] is a two-year project funded by the Global Facility for the Environment (GEF), which aims to conduct the first global baseline assessment of transboundary water systems. The assessment will be carried out in five components, namely transboundary aquifers and groundwater systems, transboundary river basins, transboundary lake basins, large marine ecosystems, and the open ocean It was responsible for carrying out the groundwater component of the project, assessing 199 transboundary aquifers and 43 small island developing states and it's involved in the management of data and information on the groundwater component.[78] In this project, there are 286 transboundary water basins in 151 countries worldwide, covering 62 million km2 and whose waters serve 2.8 billion people or 42% of the world's population[79]. Intuitively, more attention must be paid to these impressive figures: the management of these resources is particularly complex since international agreements and conventions are not always respected. It is, therefore, necessary to cooperate at different political and institutional levels to increasingly regulate the distribution of water in the countries that share this resource and to avoid conflicts and tensions arising from it as much as possible. Already two billion people live in water-stressed areas, and this figure will grow to four billion by 2030. Globally, however, water use continues to grow and, according to the OECD, global consumption will increase by 55% by 2050 for agricultural and energy sectors.[80]

[76] C. Nadotti, (2022), *Israele e Giordania insieme per salvare il fiume Giordano,* www.msNcom, Repubblica [Last Accessed 01/11/2022].

[77] Transboundary Waters Assessment Programme, (2016), *River Basins Component*, http://twap-rivers.org/, [Last Accessed 02/11/2022].

[78] Unesco Intergovernmental Programme, (2012), *TWAP Groundwater*, groundwaterportal.net, [Last Accessed 02/11/2022].

[79] A. Vitale, (2018), *Water resource among diplomacy and conflict*, Foundation Giangiacomo Feltrinelli, Milan (Italy), [Last Accessed 02/11/2022].

Understanding the importance of this situation will be crucial for our future: countries sharing this resource might come into conflict over its control and avoiding this future competition to secure the resource now involves the priority of preventing these situations with sustainable international projects. It is also possible to identify with some anticipation, again thanks to the TWAP study[81], a possibility of future conflicts given the current conditions of degradation and exploitation, analysing the probable scenarios related to threats to local ecosystems and the socio-economic impact of possible water shortages, adding the data on the ability of the competent authorities to cope with water crises and, if possible, resolve them through diplomatic means. Projections for 2050 point to a certain increase in the local population with a constant decrease in resources including. The transboundary water basins of the Middle East, Central Asia, Southern Africa, and the Indian subcontinent will be the four points on the planet where freshwater resources will decrease by 25% because of use for food and industrial purposes, being areas of increasing population density where local government does not currently seem able to provide concrete answers of a sustainability plan.

[80] OECD, (2015), *Principles on Governance of water, meeting of the OECD Ministerial Council*, www.oecd.org/regional/water, [Last Accessed 02/11/2022].

[81] *Ibidem*.

1.4 The conflict-environment nexus: the case of the Sahel

Climate change and its effects are certainly one of the hottest topics addressed in recent years. The United Nations has often dealt with the issue, thanks to the contribution of many experts and researchers such as Wangari Maathai, who won my Nobel Peace Prize in 2004 and thanks, during the years addressed climate change issues with the Intergovernmental Panel on Climate Change (IPCC)[82]. Also in 2007, the UN Security Council held its first conference, basing the meeting on the analysis of climate data.[83] The chair of this debate, who was the then British Foreign Secretary Margaret Beckett[84], left no doubt about the connection between climate and conflict. Many of the questions that circulated at the time centred on what really starts today's wars and how one can respond firmly if indeed most of the world's wars start because of resource conflicts and especially in fighting over the lack of water resources' the struggle for food production and the intensive use of land for exploitation.

In September 2009, the newly elected US President Barack Obama stated the same: "The threat of climate change is currently the most serious and urgent priority, and the drought figure is the key element to be combated due to the frequent crop failures in recent decades, which have generated hundreds of minor wars".[85] In a report created in 2014 by retired US

[82] O. M. Theisen, H. Holtermann and H. Bahaug, (2011), *Climate Wars assessing the claim that drought breeds conflict*, Oslo (Norway), Volume 36, N 3, p. 79, [Last Accessed 05/11/2022].

[83] United Nations, *Security Council holds first-ever debate on the impact of climate change on peace, and security, hearing over50 speakers,* https://press.uNorg/en/2007/sc9000.doc.htm, [Last Accessed 05/11/2022].

[84] The Guardian, (2007) *Climate change could lead to global conflicts, says Beckett,* https://www.theguardiaNcom/world/2007/may/11/politics.greenpolitics, [Last Accessed 05/11/2022].

[85] NY Times, (2009), *Obama's speech on climate change*, www.nytimes.com, [Last Accessed 05/11/2022].

generals and admirals, it was also recently stated that environmental security is no longer a soft policy, but the present climate change must be included as a threat as it can create instability and conflict, with global repercussions.[86] Since the growing trend was and still is that of civil conflicts, these declarations were based on sound science; in fact, environmental studies in the natural sciences reported that climate change was reporting real security implications and climate change had already gone beyond estimated limits, suggesting that the problem now had to be tackled on a global scale.

In any case, at the heart of the discourse on climate security, today is the issue of water scarcity. Indeed, this is one of the fundamental features that cause crises in the world's most vulnerable and poorest societies, threatening unavoidable independence for the massive agriculture typical of developing countries, and its success is linked to the per capita income of the population that can thus ensure food supply. From a global perspective, it has also been hypothesised for decades that global warming of the atmosphere affects precipitation and the unforeseen increase in extreme weather events with a growing trend, as they are having an increasingly frequent negative impact in many parts of the world. Some scholars as M. Sollenberg, and H. Strand[87], argue that these meteorological developments will also have major implications for peace and security in the long term related to non-democratic states; indeed, studies on collective security for example the analysis of R. Reuveny, offer various reports based on cases of armed conflict erupting due to resource competition[88], can no longer exclude climate variations. It is not yet possible to determine whether there are exceptions or whether a pattern can be depicted that clearly links resources and conflicts, but most of the conflicts that have been on the rise in recent years increasingly represent civil wars around the possession of strategic resources. The nexus of scarcity and conflict,

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[86] A. Johnson, (2014), *Retired generals, admirals warn climate change is a national security concern*, www.nationalreview.com, National Review, [Last Accessed 05/11/2022].

[87] O. M. Theisen, H. Holtermann and H. Bahaug, (2011), *Climate Wars assessing the claim that drought breeds conflict*, Oslo (Norway), Volume 36, N 3, p. 81, [Last Accessed 05/11/2022].

[88] R. Reuveny, (2007), *Climate Change-Induced Migration and Violent Conflict*, Political Geography, Vol. 26, N 6, pp. 656-673.

comparatively speaking, somewhat explicitly incorporates the role of ethnopolitical structures, although not all groups in various societies are equally vulnerable to environmental shocks. Soil and water in Africa are critically affected by droughts and are now a major phenomenon: peripheral and often neglected groups living in already degraded and vulnerable environmental conditions prefer to engage in political conflicts against the absence of government or the more affluent opposing ethnic group because they have no resources to deal with environmental and social hardships in a context of already accentuated social divisions.[89] The local implications in the short term could therefore also include a reduction of opportunities for the population and an onset of rebel recruitment that would use humanitarian aid and kidnappings to self-support and finance itself, with the enemy to be fought being identified in a more affluent social class or ethnic group or corruption in resource management in the central government, thus resorting to the use of brutal force. To assess the empirical validity of the above hypotheses, a high-resolution dataset exists, particularly for Africa, the continent that has always been subject to major droughts more than any other in the world. Over the period 1960-2004[90], geo-referenced and annualised rainfall data were combined with new data on the starting point of a civil war[91] or the political status of ethnicity and groups in government, testing a wide selection of situations and correlating both direct and conditional evidence, varying widely depending on the socio-political characteristics and intensity of droughts in different countries, it emerged that the link could be confirmed. The study provided evidence that there is a real correlation between sudden local water shortages with the outbreak of protests. This confirmation, however, required some moderation as it was necessary to further investigate and examine the phenomenon with empirical evidence of repeatable events undercurrent

[89] N P. Gleditsch, P. Wallensteen, M. Eriksson, M. Sollenberg and H. Strand, (2002), *Armed Conflict 1964-2001: A New Dataset, Journal of Peace Research*, Vol. 39, N5, 2002, [Last Accessed 08/11/2022].

[90] United Nations Environment Program, (2008), *Vital Water Graphics: An Overview of the State of the World's Fresh Marine Waters*, Nairobi (Kenya), [Last Accessed 08/11/2022].

[91] *Ivi*, p.42.

circumstances to introduce it as a guideline for climate security studies.

The IPCC instead reported that according to measurements averaged over the last 50 years, temperatures were slightly cooler than they were at the beginning of the century, but since the 2000s they have risen steadily and 2010 was recorded as the warmest year globally so far.[92] At the same time and up to the present day, there has been a drastic reduction in the seasonal extent of Arctic and Antarctic ice, while the global rate of natural disasters has increased exponentially, whereas before they were rarer phenomena. It is therefore difficult today to quantify the exact contribution of global warming, but available evidence shows an increasing trend. However, climate change is not felt in the same way in all corners of the world, since it is developing in the hemispheres as already existing phenomena increase disproportionately and more frequently. The IPCC precipitation models[93] show that the phenomena have overlapped in some areas of the world, such as some developing countries already mentioned, increasing, and changing with considerable interregional and interannual variations.

1.4.1 Climate Change in the Sahel

Africa has been hit by intense droughts in recent years that have severely impacted its subsistence agriculture free of advanced technologies; in fact, only 4% of Africa's cultivated land[94] is efficiently irrigated, making African agriculture ill-suited to withstand increasing droughts, increasing the inability to advance agricultural productivity. The models show that as much as 1/3 of the African population lives in risk-prone areas, and the reference is explicit for all the sub-Saharan countries, an area inhabited by a very large number of

[92] PHYS.org, (2019), *the* year *2010 was the hottest decade in history, says UN as emissions lengthen again*, phys.org, [Last Accessed 08/11/2022].

[93] *Ibidem.*

[94] A. Ferrari, (2019), *Anche l'Africa brucia, forse più dell'Amazzonia*, https://www.agi.it/estero/incendi_africa_savana_agricoltura-6090819/news/2019-08-27/, [Last Accessed 08/11/2022].

people, around 1,5 billion[95], increasingly subject to water stress that will become, according to the latest estimates, critical from 2025 onwards[96], although some disastrous phenomena have already been seen in recent years, such as the drying up of Lake Chad[97], a huge reservoir, fundamental for fishing for the large lake population, shared by as many as four countries and which has recently disappeared completely, leaving space for arid climate and desertification, thus identifying sub-Saharan Africa as the part of the world that is certainly most affected by climate change now.

The Sahel area used to be considered a humid climate and a kind of barrier against the heat generated by the Sahara Desert, but today it is rapidly receding, leaving room for the sand of the dunes. Some projects have recently been put in place to counter the phenomenon, such as the 'Great Green Wall Initiative', a 7,000-kilometre green belt that will be fundamental to containing the advance of the desert, providing jobs for local communities, promoting crops, and stemming drought events. However, IPCC data[98] suggests that the intra-continental trends in the Sahel area will continue, hardly giving this part of the globe a chance: in this context, the Sahel area is one of the most vulnerable areas in the world threatened by climate change.

Efforts are being made at regional, national, and international levels to address the challenges posed by climate change in the Sahel. These include initiatives focused on sustainable land management, reforestation, improved water management, and climate-resilient agriculture practices. International organizations, such as the United Nations and regional bodies like the African Union, are also providing support for adaptation and

[95] Rivista Africa, (2019), *The population of the continent is constantly increasing*, https://www.africarivista.it/la-popolazione-del-continente-e-in-incremento-costante/143162/, [Last Accessed 10/11/2022].

[96] *Ibidem.*

[97] D. Bellocchio, (2019), *Sulle rive del lago Ciad, la crisi umanitaria più complessa dei nostri giorni*, https://www.lifegate.it/lago-ciad-reportage, Lifegate, [Last Accessed 10/11/2022].

[98] IPCC, (2018), *Special Report on Climate Change and the Earth, Desertification*, https://www.ipcc.ch/srccl/chapter/chapter-3/, [Last Accessed 10/11/2022].

mitigation strategies in the region. However, the complex and interconnected nature of climate change requires a comprehensive and collaborative approach to effectively address its impacts on the Sahel.

1.4.2 Effects of Drought on Population and Governance of Sahel Countries

Another crucial piece of work was carried out by Thomas Homer Dixon[99], a Canadian researcher who analysed the emotional shocks and population effects induced by resource supply and demand. According to this school of thought, countries that are not currently as developed as industrialised countries are more likely to be subjected to endemic resource scarcity because they have neither the means nor the knowledge and skills to overcome the surrounding pressures. The absence of opportunities is more likely to cause a population to suffer collective stress than waiting for a reduction in the economic cost of raw materials, and the costly immigration and demarcation of socially excluded groups from active political participation in the country with consequent disruption of contact with political institutions generates, according to these studies, a high risk of violent reactions. The current literature on environmental security includes numerous reports of conflicts in the Sahel region[100] that are a direct consequence of resource poverty. Models and studies explain particular facts and dynamics concerning armed conflicts with the constant criticism of political ecology[101], which is the study of the relationships between political, economic, and social factors about environmental changes.[102] According to this current, transactional empirical quantitative research has not yet unanimously found convergence towards the

[99] H. Dixon, (1999) *Environment, Scarcity and Violence*, Princeton University Press, New Jersey (USA), [Last Accessed 10/11/2022].

[100] Climate Risk and Adaptation Country Profile (2011), *Vulnerability, Risk Reduction, and Adaptation to Climate Change in Sahel*, World Bank Group, pp. 1-16.

[101] *Ivi,* p.64.

[102] C. Arsenault, (2015), *Drought Expanding Deserts and "Food for Jihad" Drive Sahel's conflict*, Thomson Reuters Foundation, London (UK).

creation of a robust systemic connection between resource scarcity and civil wars[103] but prefers to keep the salute on disaggregated country studies, as each situation is different from the previous one. [104] Resource scarcity does not generally cause social injustice per se, but the link lies in the dwindling supply of self-healing resources on which a subsistence-only population relies. Finding oneself forced to relocate, as the environmental shock uproots a real cultural and local heritage in addition to forced migration, is perceived as a huge injustice inflicted on a population. Consequently, this canfoment conflict that can be defined in distinct levels of violence depending on the type of hardening of socio-economic divisions between identity groups forced to live together because of migration.

Migration is however a main antagonist, especially from a European perspective, but it is a fact that this manifestation has also often been condemned by some authoritarian African governments and is used as a motive against which to direct hatred.

Since there is no conceptual clarity and there is a complex network of migration drivers in the case studies, it was possible to demonstrate and explore the sequences of environmental migration in the different cases. The main study[105] on these phenomena provides an alternative explanation for this dilemma over the connection between scarcity and conflict that exists but is most likely simple: economic.[106] In agricultural societies, deviations from normal rainfall levels are quite significant and hurt aggregate production, thus reducing state revenues from export taxation. With a weakened state and an even poorer population, the economy can lead to an increased risk of conflict in two ways: firstly, this negative impact can reduce the government's anti-corruption capacity and interrupt the supply of

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[103] *Ivi*, p.42.

[104] T. A. Benjaminsen, (2021), *Climate change and human conflicts in the Sahel,* Encyclopedia of Ecology, 2nd Edition, Volume 4, pp.1-3, https://www.sciencedirect.com/topics/earth-and-planetary-sciences/political-ecology, [Last Accessed 04/12/2022].

[105] *Ibidem.*

[106] T. A. Benjaminsen, *Supply-Induced Scarcity Drive Violence Conflicts in the African Sahel,* Peluso and Watts, Violent Environments, Volume 45, N6, pp. 723-861, https://journals.sagepub.com/doi/epdf/10.1177/0022343308096158, [Last Accessed 04/12/2022].

public goods to cope with the emergency; secondly, the opportunities for the creation of dissident organisations with a call to arms are automatically increased by starting a power struggle, and the opportunity cost of becoming a rebel soldier for a good cause is reduced as one's people are already in a critical situation because of the drought. The latter argument, therefore, is part of the more general theory of rebellion as a criminal symbol of behaviour,in which the decision to rebel is based on the declining economic situation due to the ongoing environmental crisis. In any case, the existence of a nexus between climate change and conflict, especially in Sub-Saharan Africa where conflicts are on the rise and environmental degradation undermines diminishing access to natural resources, provides the most interesting case study for evaluating the data and analysing how the irrelevance and absence of ecological or environmental policy to support the population in these areas has only fueled violent conflicts over the years, triggered under the illusion that things can be improved in the despair of fragile socio-economic systems.

The long periods of authoritarian governance in the Sahel states have therefore also seen their authority interrupted because of the impact of conflicts determined by mechanisms influenced by changing climatic conditions. Environmental fragility is indeed the defining characteristic of this region of the world where the concept of land as a geopolitical identification was little in use until the early post-colonial times. More recently born countries have not been able to come to terms with a past of exploitation that has always limited possibilities for growth and today, a lack of prompt response to climate change has given rise to a real humanitarian crisis in the region. This environmental fragility of the Sahel is, among other things, increasingly aggravated by climate change, which every year is exacerbating the availability of resources and the ability to cope for present societies with individuals within them traditionally accustomed to alternating dry and rainy seasons in desert climates[107], but not to longer dry seasons. Originally, October to June and July to September has for centuries dictated the sequences of agriculture and pastoralism; activities that contribute to the livelihoods of the vast majority of the Sahelian population as for the

[107] I. Sesana, (2020), *Cambiamenti climatici e guerra: siccità e inondazioni minacciano la pace*, Rights Observatory, Milan (Italy), [Last Accessed 14/11/2022].

the vast majority of the Sahelian population as for the communities of Mali and Niger live largely on subsistence, and rainfall determines the organisation of this type of agriculture based on land-use rotation. However, climate change may seriously threaten the fragile balance that sustains this age-old way of life. Available evidence suggests that already the capacity and quantity of water retention in the soil is decreasing, and the variability of rainfall in these countries is progressively decreasing, giving way to increasing desertification.[108] Extreme droughts in the 1970s and 1980s[109] raisedfears that the frequency and severity of Sahelian droughts were experiencing an upward spiral, but the phenomenon only seems to have intensified in the last decade as long-term climate trends indicate that temperatures are possibly rising unevenly across the region, and fears that increased evaporation in combination with poorly designed irrigation schemes and unsustainable deforestation to meet the needs of the growing population are paving the way for massive desertification and armed conflicts. Taken together, these changes threaten to disrupt local partners in productivity, mobility, and livelihoods in different countries, generating a potential reverberation on local and international social stability as the conflict over resources in the last decade has also increased due to pressure fueled by fears of resource depletion. At the same time, the Sahel is also an area experiencing a serious political and security crisis that weakens state control, generating widespread violence and massive population displacement. In Mali, in 2012[110] following two rebellions by the population and the situation plunged into a serious political crisis, requiring the intervention of the military to prevent the general collapse of the state.

[108] C. Raleigh, (2010), *Political Marginalization, Climate Change, and Conflict in the African Sahel States,* InternationalStudies Review, Volume 12, N 1, pp. 69-86.

[109] J. R. Lee, (2009), *Climate Change and Armed Conflict*, Routledge, New York (USA).
Journal of Peace Research, (2008), *Drive Violent Conflicts in the African Sahel? The Case of the Tuareg Rebellion in Northern Mali*, Vol. 45, N 6, pp. 819-836.

[110] A. Mulas, (2013), *The crisis in Mali,* https://www.difesa.it/InformazioniDellaDifesa/Pagine/lacrisiinmali.it, [LastAccessed 15/11/2022].

but taking advantage of the country's weakness, transnational networks of organised crime and terrorism have multiplied throughout the region The internal crisis in Mali, once considered a model of democracy in Africa, erupted in January 2012 with the rebellion of the Tuaregs in the north of the country and resulted on March 22 of that year with the dismissal by the military of President Touré. The two events are linked to each other and represent the culmination of the difficult relations between the central government and the periphery. In the north, the advance of Tuareg rebels led to the declaration of independence of the Azawad region.[111] The growing presence of terrorist cells[112], however, has also progressively spread to vast areas that are victims of international instability including Burkina Faso, Niger, Nigeria, Libya, Côte d'Ivoire, and Chad; all near-bankrupt states that have no control over their territory and are testing the resilience of local societies. The shockwave of migration generated by these crises has been reflected in states across North Africa, also fueling destabilisation across the Mediterranean basin. Trans-Saharan arms smuggling between North Africa and the sub-Saharan area is now rampant, and the strong links between jihadist formations in Algeria and Mali, as well as in Libya and Niger, are well documented.

It is therefore no coincidence that the situation has also been framed in the broader Mediterranean space, leading to the adoption of regional and national security strategies to combat and prevent terrorist acts, now a priority for the European Union and the coasts of member states. In this context, illegal landings, and migration flow from Africa across the Sahara Desert to reach Europe are depicted as an illustration of the complex interplay between fragile environments and conflicts where livelihoods have long been precarious. The belief that there may be a direct causal link between climate change and ongoing

[111] S. Morosi, Corriere, (2015), *Mali, la storia del paese dal golpe del 2012 all'accordo di pace*, https://www.corriere.it/esteri/15_novembre_20/mali-storia-paese-golpe-2012-all-accordo-pace-2c0490ac-8f71-11e5-bb0e-f8f4aecfe338.shtml, [Last Accessed 17/11/2022].

[112] P. Genger, (2019), *A Perfect Storm: How Climate Change Contributed to the Rise of the Islamic State, Center on Terrorism, Extremism, and Counterterrorism (CTEC),* Middlebury Institute of International Studies, Monterey (USA), pp. 1-24, [Last Accessed 17/11/2022].

conflicts start explicitly from the Malthusian assumption of population[113]: disproportionate growth is eroding ecosystems, leading to unsustainable intensive exploitation of natural resources. Conflicts related to climate change are correlated with population growth, leading to environmental degradation and reduced sources of livelihood, which consequently fuels greater tensions and escalation of violence by including water stress as a main factor in conflict dynamics.

In the past, various studies have tested the validity of the conflict-drought hypothesis by drawing diverging conclusions: they have failed to demonstrate any unequivocal causal link between climatic factors and wars, as the perception of these studies mainly emphasises the role of governance, especially at the local level, its legitimacy, the effectiveness of constitutional and customary norms, the dispute resolution mechanisms of local institutions, active participation in reducing escalations of violence, and the peaceful management of these. These findings, while providing a healthy dose of scepticism by simplifying the initial conceptualisation of climate change-related conflict, are probably nonetheless influenced by methodological shortcomings.

On the other hand, the innovative research on the correlation between climate and conflict events has brought updates and wants to critically approach positivistic approaches originally conceived for economic studies that are ill-suited to the exploration of complex social phenomena. The diversity of factors has yet to capture the independent variable of climate disruption as the main cause: this is why some studies[114] are beginning to focus on precipitation levels such as variable temperature, freshwater availability, and natural disasters. In addition, most of these studies[115] are based on analysing the temporal correlation between climate events that are to be considered more and conflicts that have yet to be decoded, especially if they happen in the same year. Some more sophisticated

[113] P. Agarwal, (2022), *Teoria della popolazione malthusiana*, https://www.intelligenteconomist.com/malthusian-theory/, Intelligent Economist, [Last Accessed 17/11/2022].

[114] Damberg, (2013), *Analysis of Trends and Patterns of Droughts Using Satellite Data and Climate Model Simulations*, Lund University, Report TVVR 13/5002, pp. 1-70.

[115] M. Özger, A.K. Mishra, V.P. Singh, (2010), *Estimating Palmer drought severity index using a wavelet fuzzy logic model based on meteorological variables*, Climatology Studies, 391, pp. 202-216.

studies perform analyses to explore whether climate variation might then have a greater influence: conflict in the year immediately following a drought might suggest in this approach an implicit mechanism whereby exceptional climate variations should trigger the crisis in a short to medium timeframe.

Current political ecologism still argues that conflicts following natural phenomena are less violent even if they have sudden outbursts of ferocity, as opposed to protracted processes that intercept long-term political and social struggles resulting from a multitude of factors of discontent. But if drought were to play a predominant role for many years, demonstrating its extreme intensity in a few summer peaks that can lead to desperate violence, there would be a clear link between conflict and climate. It is therefore not surprising that analyses to date have proved unable to identify any significant link between climate events and conflict, especially if beliefs are still based on incomplete variables that do not reflect the reality of the facts. In a new 2015 'Climate for Peace' report commissioned by the UN[116], however, it was finally mentioned that brutal conflicts occur also because of pre-existing environmental vulnerabilities. Methodologically, this most recent study has increasingly reacted to the abstract approaches of the previous methodology, which were too generalisable, and is focusing on groups of case studies. These developments have indeed made it possible to illustrate the environmental factors that can be linked to the exacerbation and endurance of climatic conditions in local communities that can give rise to conflicts.

The correlation of the phenomena might suggest a new approach[117], breaking down the superficiality of qualitative studies from an illustrative point of view but not compelling revolutionising the subject matter because there is a great need to devote more attention to understanding the causal mechanism that can reasonably link violent tendencies to climatic events in conflict dynamics.

This competition can be political or, in the most acute cases, at people's level, especially in

[116] L. Rüttinger, D. Smith, G. Stang, D. Tänzler, J. Vivekananda, (2015), *A new Climate for Peace*, Adelphi, International Alert, The Wilson Center, The European Union Institute for Security Studies, Paris (France).

[117] *Ibidem.*

correlation with the economic element when supply is reduced, creating a scarcity of basic consumer goods due to a national economy with a demand that cannot meet the increase in demand. In this context, the migratory mechanism is generated: mass population movements can intensify friction and tension between local communities, which are often culturally different because sometimes migrant groups could not always coexist, once kickstarting the escalation of conflict.

This study[118] thus identifies a positive point on the overall confidence in the growing value of the climate conflict thesis, thus endorsing this hypothesis. The empirical analysis is still investigating the specific mechanisms, potentially linking the changing dynamics of climate and the outcomes of even past conflicts: between the late 1960s and the late 1980s[119], the Sahel terrain experienced a sharp decline in rainfall, causing it to fall by 15% and 25%[120], respectively, compared to the multi-year averages during the generally wet periods that preceded these events since the 1950s. As a result, the region experienced the most severe drought ever seen up to that time, and it also proved to be exceptionally long, affecting large areas of West Africa, and giving rise to numerous famine riots that followed consequently. Initial studies tended to attribute these events mainly to local anthropogenic factors, such as poor harvests, deaths due to poor management of human disease, and overconsumption of water resources in the preceding years by local communities.

Dynamics and impacts in the already notoriously arid Sahel belt have led to the realisation that there has been a further loss of biodiversity and unprecedented widespread ecological degradation, far more severe than in the 1970s. The depletion of livestock remains difficult to quantify, however, but has probably been massive for social groups with pastoralist-

[118] L. Ranieri, (2022), *Drought, Desertification and Displacement: Re-Politicizing the Climate-Conflict Nexus in the Sahel*, Institute for International Affairs, Rome (Italy).

[119] W. Robert, (1980), *Impact of drought in the Sahel Sudanese zone of western Africa: an analysis of 1910-15 and 1968-74*, Environment and Society portal, Clark University, Worcester (USA), Document N 32.

[120] *Ibidem.*

based livelihoods, particularly the Fulani[121] and Tuareg[122] ethnic groups, who have been plunged into poverty. The Sahel droughts of the 1970s and 1980s were also accompanied by the particularly acute famines of 1973 and 1985. The causal link between these two phenomena, drought, land famine and the outbreak of the uprisings, however, remains controversial to this day. However, there is little doubt that resources are being stretched by the Sahel's long-standing historical drought, which contributes to the general propensity for regional food crises, and had it not been for the contribution of exogenous political factors in the 1970s and international aid promoted by international financial organizations and institutions such as the World Bank or the International Monetary Fund, it would probably have been the most serious famine in the last 50 years.

In conclusion, the economies of states in the Sahel areas have always been weak anyway, and there is a multitude of actors with different motivations and interests for which they conduct violent actions; for example, the case of Nigerian terrorism created by Boko Haram[123] officially born in 2002 in Maiduguri. Since its foundation, the organization has obtained the approval of several Muslim families in Nigeria, becoming a point of reference for jihadists[124], and exploiting the frustration and poverty of local citizens against the central state. In the original Hausa language, the name of the organization means "Western education is prohibited", a phrase that immediately reveals the extremes and the speculative

[121] The Fulani people are one of the largest ethnic groups in the Sahel and West Africa. A third of them, around 12 to 13 million people, are pastoralists, and their ethnic group has the largest nomadic pastoral community in the world.

[122] M. Abdalla, (2009), *Understanding of the Natural Resource Conflict Dynamics: The Case of Tuareg in North Africa and the Sahel*, Institute for Security Studies, Pretoria (South Africa), Humanity United, [Last Accessed 25/11/2022].

[123] International, (2015), *Il gruppo Stato islamico e Boko Haram uniscono le forze*, https://www.internazionale.it/notizie/2015/01/12/cos-e-boko-haram, [Last Accessed 25/11/2022].

[124] W. Hansen, (2016), *Poverty and Economic Deprivation Theory: Street Children, Quranic Schools/Almajirai and the Dispossessed as a Source of Recruitment for Boko Haram and Other Religious, Political and Criminal Groups in Northern Nigeria, In Perspectives on Terrorism*, 10 (5), pp. 83–95, [Last Accessed 25/11/2022].

and forced use of Islam is considered the antithesis of the Christian world of the West.[125] Within the most likely scenario, empirical research shows how it always includes political exclusion as a facilitating factor for civil war[126], which is not a causal process but occurs in response to the increasing likelihood of triggering latent conflict under certain conditions, exacerbated by climate change. In any case, most reports of conflicts induced by the scarcity of resources therefore always concern environmental policy issues[127], to be linked with the new fact of demographic stress caused by overpopulation in particular areas of the world and the population-intensive area.[128]

[125] V.S.M. Grassi, (2022), *Boko Haram: cos'è, cosa vuole e chi finanzia il gruppo terroristico in Nigeria*, www.money.it, Money, [Last Accessed 25/11/2022].

[126] *Ivi*, p.42.

[127] *Ibidem.*

[128] M. Jones, (2020), *The Sahel Facing 3 Problems: Climate, Conflict and Overpopulation*, https://www.visionofhumanity.org/challenges-facing-the-sahel-climate-conflict-and-overpopulation/, [Last Accessed 25/11/2022].

1.5 The case study of Ethiopia

In the aftermath of ethnic cleavages, groups denied access to central decision-making usually face the exclusion of peaceful means to address their concerns: this was the case in the Tigray region of Ethiopia, which was cut off from the central government in Addis Ababa and triggered a civil war[129] to gain the right to be recognised within the Ethiopian state.

The central government, instead of meeting these demands, including the consequences of serious environmental issues such as drought in Ethiopia, has repeatedly brutally affected the country in recent years and has responded with arms and violence in turn, isolating the region and trying to control the insurgency, identifying the people as terrorists, and generating one of the most serious humanitarian crises within the Tigray ever with repeated violation of human rights.

In Ethiopia, it's important to remember that famine had already hit the country in the 80s[130] and was illustrated as a social-political effect brought about by an environmental phenomenon such as drought, and although the country had recovered within a few years, the uprising was led by the Tigray Liberation Front (TPLF)[131], which had already been active for almost a decade, as resentment against the central government was growing anyway for different ethnic reasons.

Ethiopia is a clear example in Africa of combinations of devastating climatic and environmental effects capable of leading to poor living conditions and consequent political crises which, over the years, can lead to civil wars.

[129] Global Conflict Tracker, (2023), *War in Ethiopia*, https://www.cfr.org/global-conflict-tracker/conflict/conflict-ethiopia, [Last Accessed 25/11/2022].

To counter the insurgency, the central government used as a strategy the large-scale military offensive with aerial bombardments of agricultural warehouses in the most productive areas, imposing severe restrictions on trade and preventing mass starvation migration. The solution adopted by the central government was an outright elimination of the Tigray region. The TPLF, increasingly supported by the population, also turned against the Amhara group[132], which, allied with the central government, sought to establish its influence in the neighbouring region. Until 2020, ordinary life in Ethiopia was thus characterized by constant insecurity to the exclusion of ethnopolitics, and drought was certainly not the only contextual factor that could determine whether water scarcity alone could trigger a civil war[133] in this area of already particular political tensions.

However, peace negotiations to end this tragedy have fortunately begun in November 2022.[134]

An attempt was made to find a solution between the parties to the dispute, in such a way as to avoid as much as possible a humanitarian crisis which nonetheless materialized.

In conclusion, highly adaptive societies are, however, more characteristic of developed countries, which are generally well prepared to handle excessive climatic variability and unexpected scars. Despite the adaptive capacity of small farmers, we often forget to remember that pastoralists in the African drylands still have limits to their knowledge, which is only based on experience and therefore not able to cope with something as dramatic and permanent as climate change, and that such extremes never existed in the past.

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[130] K. Reid, (2022), *1980 Ethiopian Famine: Facts, What Changed, and How to Help*, https://www.worldvisioNorg/disaster-relief-news-stories/1980s-ethiopia-famine-facts, World Vision, [Last Accessed 25/11/2022].

[131] De Wall, (1991), *Evil Days: Thirty Years of War and Famine in Ethiopia*, Human Rights Watch, New York, (USA), p.19, p.210.

[132] *Ibidem.*

[133] *Ivi*, p.42.

[134] Continent Projects, (2022), *Negoziati di pace tra Etiopia e Tigray*, https://progettocontinenti.org/7448-2/, [Last Accessed 29/11/2022].

It is also possible that in the future, the impact of climate change will be so great that it may somehow also reduce people's capacity to mobilise, as the deteriorationof living conditions and the reduced economic opportunity cost in the series of struggles may have already been exhausted, just as agrarian livelihoods have been exhausted, although there are no case studies on this yet.

1.5.1 Non-state Actors, political fragmentation, and fragile environments

Among many ethnics groups always existed, from an economic and political point of view, different disadvantages inside the various countries of the Sahel and for this, there was an increase in violent reactions as a natural mobilization in response to worsening conditions, as happened in the case with the Tuaregs in Mali[135] before mentioned and the Bedouin groups[136] in Mauritania; inside this context it was possible to observe more recruitment from a terrorist organization, becoming quickly powerful actors in fragile states. For example, in Mauritania[137], terrorism penetrated the poor Bedouin populations, recruiting, and operating within its vast areas of under-governed territory, the result of an impoverished country plagued by fragile policies, military factionalism, ethnic-racial tensions, growing economic insecurity and high levels of unemployment.

Mauritanians also represented a disproportionate number of violent extremist[138] ideologies,

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[135] Journal of Peace Research, (2008), *Drive Violent Conflicts in the African Sahel? The Case of the Tuareg Rebellion in Northern Mali*, Vol. 45, N 6, pp. 819-836, [Last Accessed 29/11/2022].

[136] M.A. Abdalla, (2009), *Understanding of the Natural Resource Conflict Dynamics: The Case of Tuareg in North Africa and the Sahel*, Institute for Security Studies, Paper 194, p.4.

[137] Counter Terrorism Project (CTP), (2023), *Mali: Extremism and Terrorism*, https://www.counterextremism.com/countries/mali-extremism-and-terrorism, [Last Accessed 29/11/2022].

[138] *Ibidem.*

and high-ranking terrorists. Mauritanians were influential and overrepresented in the Saharan branch of the GSPC, which was rebranded as al Qaeda in the Islamic Maghreb (AQIM) in 2007.[139] In these situations, multiple social structures become asymmetrical, tending to be accentuated during periods of environmental crisis. A bad harvest and a loss of pasture have implications that are certainly based on the discontent of local communities that use subsistence to survive since interventions to support sources of income that can meet agricultural concerns have never been available or available from the often bankrupt or seriously corrupt state. Protests or alliances with other hopeful terrorist organizations remain the only solution to demand justice from a state that does not help the population and therefore has no legitimacy to exist for the population itself if it's unable to cope with these problems. Understanding therefore that national incomes and the reduction of available funding amounts are threatened by climate change[140], bring to the result is that in these countries there's a growing wealth gap between the haves and have-nots, and thus between those who can depend on the regime and those have little chance of survival.
Participation in the political sphere of influence does not include the poor who are instead reduced to marginalization with unfulfilling social conditions such as a drastic economic situation and even, in the most extreme cases, a lack of food and water due to droughts. Indeed, severe water shortages should bring the greatest potential for violent protests when they affect populations already deprived of resources who are unable to pursue alternative lifestyles.

1.5.2 Final remarks on the drought-conflict nexus

[139] A. Boukhars, African Strategic Studies, (2020), *Keep terrorism at bay in Mauritania*, africacenter.org, 16th June 2020, [Last Accessed 29/11/2022].

[140] W.A. Holthuijzen, J.R. Maximilian, (2011*), Dry, Hot, and Brutal: Climate Change and Desertification in the Sahel of Mali,* Journal of Sustainable Development in Africa, University of Pennsylvania, Clarion (USA), Volume 13, N7, pp. 245-246.

In the studies carried out on the drought/conflict nexus, there are still inconclusive results, but new research approaches the link from a novel point of view, explicating and studying the long-term implication of climate with the very anomalies brought about by civil wars[141] or poor growth economics.

Drought influences and establishes the risk of latent conflicts with considerable variations depending on the World Meteorological Organisation designed a 50x50-kilometre grid system[142] capable of considering annual rainfall, an effective demonstration of the decreasing precipitation trends since the 1980s in various African countries. Data were also provided thanks to the University of East Anglia's climate and environment research unit and UNEP missions[143], analysing mainly the period 1980-2001[144]. The aggregated data on annual rainfall thus links well with the severe drought, showing statistics of rain falling at unusual times of the year. The standardised indices for each month also measured the deviation of the normal rainfall of the annual months, showing that in recent decades, various areas in Africa, even if they were in themselves very arid or in any case very hot but never drought-prone, began to be affected by cyclical drought phenomena, and crossing the dates on the outbreak of these periods, populations rose as a rebel. Thanks to the grid system of the annual rainfall of the World Meteorological Organisation and the attached data, it was possible to identify conflicts in the exact location of onset with the corresponding geographical coordinates of low annual precipitation: the most recent significant advance in support of the previous theses is that drought is an event that determines an exogenous

[141] *Ivi*, p.42.

[142] F. Tollefsen, H. Strand and H. Bahaug, (2012), *Pro Grid: A Unified Spatial Data Structure, Journal of Peace Research*, Vol 49, N 2, pp. 1-12.

[143] UN Environment Programme, *Vision, Mission, and Objectives*, https://www.unep.org/explore-topics/green-economy/what-we-do/environment-and-trade-hub/vision-mission-and-objectives, [Last Accessed 02/12/2022].

[144] B. Rudolf and Udo Schneider, (2005), *Calculation of Gridded Precipitation Data for the Global Land-Surface Using In-Situ Gauge Observations*, IPWG, Geneva (Switzerland).

relationship with the reactions of human behaviour. The climate data from the grid[145], however, speak for themselves, the climatic conditions between the patterns of precision and temperature vary for most countries, and Africa is no exception The distribution of normal annual rainfall across the continent is practically absent in the Sahara desert and the other areas are characterised by tropical and semi-arid climates rather than relative drought but the cross-activity between drought and political status since the onset of conflicts shows that on the dates of the outbreak, civil conflicts rather rare: about 1/3 of all observations are of ethnic groups in power and only 9 out of 59 conflicts[146] that broke out in drought-related causes have been identified. Hence, a civil war[147] may break out in many cases even without the effects of the phenomenon at the time, but the grid data show that in fact in most of the remaining cases, the drought was latent and had already occurred intensively in previous years, carrying the effects through to the start of the conflict, revolutionising the assumptions of previous models. Moreover, since Africa has hosted more armed conflicts than any other continually in recent decades, it constitutes an ideal test bed for the climate warfare thesis as it is the most likely environment in which systemic covariance occurs, which should be observed through drought and armed conflict models, although the research needs to be constantly updated in this respect, as in any case Africa is also experiencing a period of great change from a demographic point of view and this factor could lead to a lack of resources in the future, which, beyond the drought situation, could lead to new types of wars. In conclusion, the path of political ecology[148] has not demonstrated the most plausible link between climatic events and conflict, but the adequate

[145] *Ibidem.*

[146] F. Tollefsen, H. Strand and H. Bahaug, (2012), *Pro Grid: A Unified Spatial Data Structure, Journal of Peace Research*, Vol 49, N 2, pp. 1-12.

[147] *Ivi*, p.42.

[148] T. A. Benjaminsen, H. Svarstad, (2019), *Encyclopedia of Ecology 2nd Edition*, https://www.sciencedirect.com/topics/earth-and-planetary-sciences/political-ecology, [Last Accessed 04/12/2022].

The explanation lies in the dynamics observed in several recent average cases that need further analysis, leading to interesting innovative theoretical implications: firstly, that the possibility of a link between climate and conflict dynamics necessarily retains a political aspect to be taken into account; secondly, climate change can indeed fuel violent conflicts, especially as they contribute to disrupting the fragile socio-economic systems that underpin innumerable generative mechanisms of conflict dynamics. Thirdly, there are certain data such as demographics that are not yet fully considered and the work is in any case complex diverse situations[149]. Finally, one must include in all cases secondary factors that are in any case determinants of social upheaval, following the emergence of new resentments against industrialised countries for the lack of equal access to resources at the time of confrontation[150]; to be included in the mental shocks and frustrations related to it mentioned above. Or to the unhindered accessibility of weapons for insurgents, often supplied by non-state actors and the cause of the weakness of state security apparatuses.[151] Indeed, weapons are now all too widespread and widely available through black-market sales in the Sahel by groups often mobilised and fomented by extremist ideologies. Thus, this hypothesis is now part of an essential paradigm in the planning of international security policy and analysis and has become crucial for the organisation of the internal security of Western states.[152] In addition, even the US National Intelligence Council[153] has stated the likelihood of new future environmental wars.

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[149] H. Dixon, (1999) *Environment, Scarcity and Violence*, Princeton University Press, New Jersey (USA), [Last Accessed 06/12/2022].

[150] Climate Risk and Adaptation Country Profile (2011), *Vulnerability, Risk Reduction, and Adaptation to Climate Change in Sahel*, World Bank Group, pp. 1-16.

[151] *Ibidem.*

[152] S. Scaini, R. Bakalova, (2020), *Sicurezza e cambiamenti climatici: l'approccio della NATO a una sfida globale alla sicurezza*, https://www.safetysecuritymagazine.com/articoli/sicurezza-e-cambiamento-climatico-lapproach-of-born-to-a-global-security-challenge/, [Last Accessed 06/12/2022].

[153] O. M. Theisen, H. Holtermann and H. Bahaug, (2011), *Climate Wars assessing the claim that drought breeds conflict*, Oslo (Norway), Volume 36, N 3, p. 79.

Chapter 2

The case of Liguria

2.1 Climatic Features of Liguria

Liguria is an Italian region with the ordinary statute in north-western Italy of 1.502.943 inhabitants, with the capital Genoa. It is bordered to the south by the Ligurian Sea, to the west it bordith France, to the north wbyPiedmont and Emilia-Romagna and the south-east witbyscany. The region is part of the Alps-Mediterranean Euro-region.

The climate of Liguria is considered one of the most diverse ones in the context of Italy due to its location between the coast and mountains[154]: in fact, Liguria is located within a narrow arc belt, which includes the southern slope of the Ligurian Alps with some reliefs such as Monte Saccarello which reach up to 2200 meters[155] and other mountains of the Ligurian Alps characterized by harsh and impervious orography, while the Apennine mountains are generally more eroded and therefore with lower altitudes.

These hilly and mountainous reliefs directly reach the shore of the Ligurian Sea and only in a few stretches of the coast do some short plains open, in the province of La Spezia towards Tuscany and the plain of Albenga identifying them as the few large cultivable valleys of Liguria, while most of the territory is couch and dense forests as spontaneous vegetation on the slopes, which cover about half of the regional territory.

The hydrography and climate of Liguria are therefore extremely influenced by its morphology and the proximity to the sea which generates a diverse climatology within the region itself, placing a primary diversification according to the area, i.e., the Riviera di Ponente and the Riviera di Levante.[156]

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[154] Treccani Institute, (2006), *Caratteristiche climatiche della regione Liguria,* https://www.treccani.it/enciclopedia/liguria_(Encyclopedia-of-the-boys)/, [Last Accessed 4/02/2023].

[155] *Ibidem.*

The levels of precipitation, for example, are different even if both areas, especially due to their proximity to the sea, have a Mediterranean climate with dry and relatively hot summer, mild winter and wet autumn and spring. In the inland area, temperatures drop rapidly even during the summer and rainfall increases, especially on the hills behind the Riviera di Levante. On the northern slopes of the Apennines, the climate is that of the Po Valley area, of continental type.[157]

The Liguria Region, in detail, has therefore an extremely varied climate[158], generally of Mediterranean type but is greatly affected by the uneven morphology of its territory, largely mountainous which opens into a decidedly warm sea about its relatively high latitude.

The arched breached-back ridge towards the south, between the French and Tuscan borders, creates areas of low pressure on the Gulf of Genoa[159], that in the winter months is the cause of northern winds with heavy rains and snow low altitudes up to the shore of the Ligurian Sea.

On the contrary, in summer, thanks to the sea breezes, daytime temperatures hardly exceed 30°C, but relative humidity often remains high even in the afternoon, amplifying a muggy effect. Night temperatures, on the other hand, are cool in summer evenings, thanks to the mitigating effect of the sea.

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[156] P. Bonino, MeteoLive, (2002*), Il clima della Liguria: differenze tra Oriente e Occidente*, https://www.meteolive.it/news/I-tipi-di-clima/38/il-clima-della-liguria-differenze-tra-levante-e-ponente-/, [Last Accessed 4/02/2023].

[157] *Ibidem.*

[158] P. Bonino, MeteoLive, (2018*) Microclimi locali: Pianura Padana e Liguria a* confronto, https://www.meteolive.it/news/I-tipi-di-clima/38/microclimi-locali-pianura-padana-e-liguria-a-confronto-/72836/, [Last Accessed 5/02/2023].

[159] Centro Meteo, (2009), *Il clima della regione Liguria e le tavole climatiche per alcune località,* http://www.centrometeo.com/articoli-reportage-approfondimenti/climatologia/5410-clima-liguria, [Last Accessed 5/02/2023].

However, in general, the "dry" Ligurian season is limited to the months of July and August and only in some places on the western part of the coast. The data are therefore different from one end of the region to the other: rainfalls are less frequent in the western areas, exposing them to a greater risk of summer drought.[160] In the inland area, on the other hand, the climate is semi-continental and therefore harsher with decidedly lower average winter values, especially in some valleys of the Po catchment. As regards temperatures, the average minimum values of these localities are between -2°C and -5°C in the winter, while the expected seasonal minimum values are around -10°C, even if night-time temperatures can drop much below these values, up to some records of intense frost in particular in the highest valleys such as Val Bormida and Val d'Aveto, where during the winter of 1985 they touched - 25°C[161]. It is not uncommon for frosts in these areas to take place until mid-April. The summers of the hinterland consequently continue to remain cold, dry, and windy and it is not common to record lows of 5°C or 6°C in the valleys of the Ligurian hinterland, even in the middle of July. [162] The average rainfall also varies in this case from West to East, the latter more affected by intense summer storms. The coastal areas of the Riviera di Levante of the 5 Terre, the Golfo Paradiso and the entire province of Imperia are in any case more sheltered from the cold winds in winter deriving from the Apennine ridges thanks to their protected position They are therefore much milder in winter, where days with mild temperatures are common, while where the valleys have a particular north-south orientation and low mountains to protect from northerly winds.

[160] *Ivi, p.8.*

[161] Centro Meteo, (2009), *Il Grande Gelo del gennaio 1985: cronaca di un inverno mitico*, http://www.centrometeo.com/articoli-reportage-approfondimenti/climatologia/5410-clima-liguria, [Last Accessed 5/02/2023].

[162] *Ibidem.*

As in the cities Savona andthe Polcevera and Bisagno valleys of Genoa the winter climate can be cold; this is due to thecold Po valley's winds in the direction of the sea slopes. In conclusion ground from the southern quadrants condenses humidity through near nearby mountain ranges to form a compact layer of low to medium cloud cover, which can diffusely cover much of the coast and coastal slopes of the region giving birth to the original "Maccaja" [163] in the late autumn in the presence of the African subtropical anticyclone and related winds.

2.2.1 Interannual temperatures analysis

Opening a focus on temperatures is of crucial importance since evaluating the seasonal and annual trends of some meteorological parameters in the city of Genoa and Liguria is essential for hypothesizing forecasts of droughts for the coming years. At a national level, the data[164] is already clear: the average temperatures of Italian cities have already increased by 0.8°C, and the city of Genoa is not an exception (calculated on the average for the period 2001-2018 compared to the average for the previous thirty years). This means that the climate is changing, indeed it has already changed.[165] In Italy and in the countries bordering the Mediterranean basin, which is a closed sea, is warming at a faster rate than other seas and this affects winds, cloud formation and rainfalls. Liguria has a diverse climate and temperatures vary significantly depending on the area. Temperature records at Genoa airport from 1963[166] show a constant increase except for a short cooling phase in the 1970s

[163] Limet Centro Metereologico Ligure, (2020), *Macaia,* https://www.centrometeoligure.com/meteowiki/maccaja/, [Last Accessed 5/02/2023].

[164] R. Pedemonte, Nimbus Rivista Ligure di Metereologia (2007), *Osservatorio Clima, una nuova rubrica,* http://quiwww.nimbus.it/liguria/rlm23/osservatorio_sul_clima.htm, [Last Accessed 5/02/2023].

[165] D. Passeri, (2021), *Gli effetti (devastanti) dei cambiamenti climatici sulle città italiane non possono più essere ignorati: sempre più frequenti bombe d'acqua e ondate di calore, sono urgenti misure di adattamento,* https://www.elle.com/it/lifestyle/verde/a36045256/come-e-cambiato-il-clima-in-italia/, [Last Accessed 5/02/2023].

[166] WikiWand, *Stazione meteorologica di Genova Sestri Ponente*,

which was followed by the intent warming in the following decade with the increase in temperature in the 90s, before reaching the third millennium. In the last 10 years until 2005, the value of the average annual temperature in the city of Genoa has always been higher than the long-term average, identified at around 15.85°C, with plus 0,29°C in only the last years. (Fig. 3).

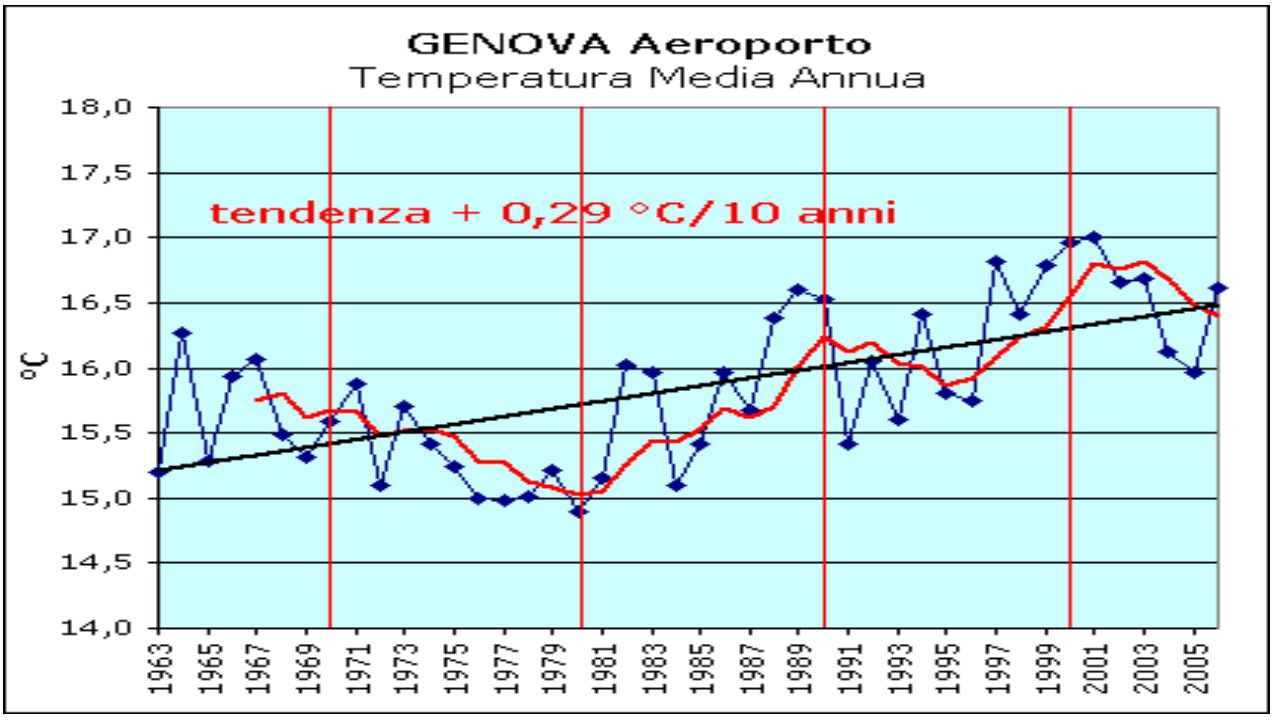

Fig. 3, Annual average temperature increases registered from 1963 to 2005, Genova Sestri Ponente Meteorological Station, (2007).

https://www.wikiwand.com/it/Stazione_meteorologica_di_Genova-Sestri_Ponente, [Last Accessed 5/02/2023].

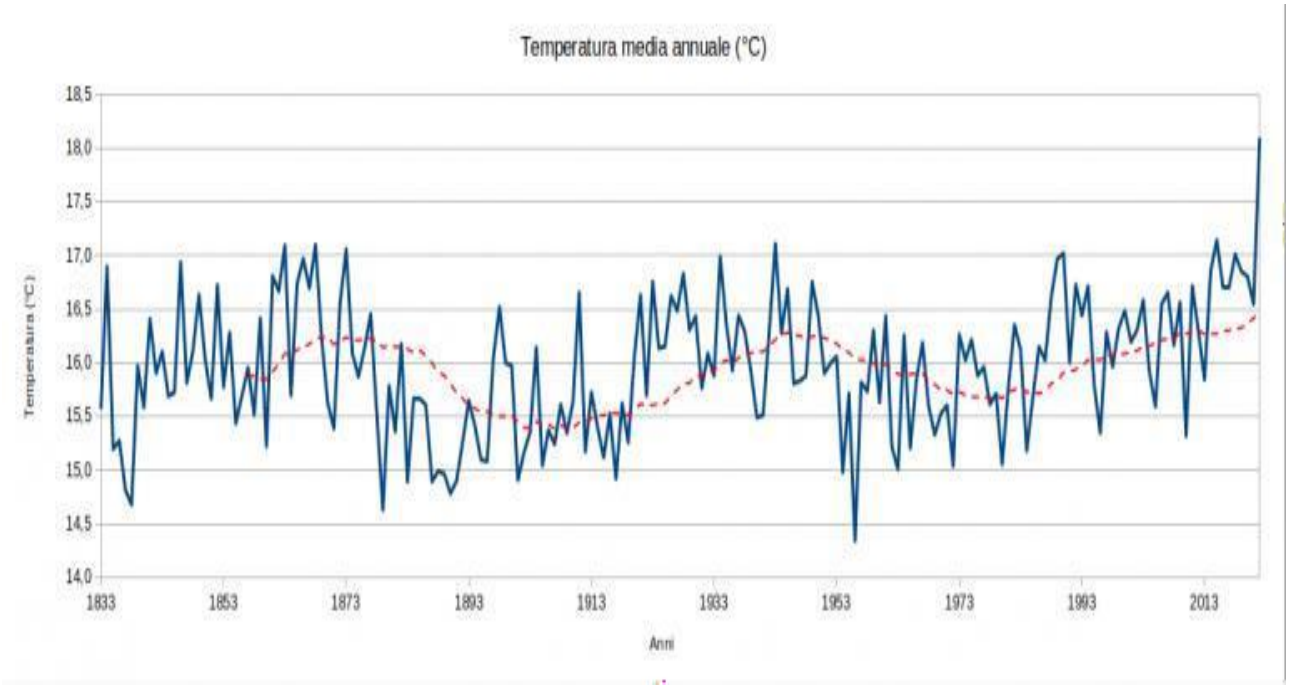

Fig. 4, The same data reworked over several years up to 2022 and therefore more recently shows how the year 2022 was a record for the climate in Genoa: it was the hottest year overall in the historical series since the start of registrations, Via Balbi Meteorological Station, (2022).

With the second image, the annual average turned out to be 18.1 °C in 2022.[167] The average annual temperature measured in 2022 turns out to be one degree Celsius higher than the previous record of 17.1 °C.[168] Based on the information provided, it seems that the autumn season in Liguria has started to resemble its annual trend. However, it's important to note that the highest values for each season were observed between 2002 and 2004. After the year 2000, there was a decrease in winter and spring temperatures, which became more extreme and sporadic but remained above the long-term average with some regularity. Regarding the average temperature of the individual months, September and October exhibit a similar trend. The temperatures in these months in recent years resemble those of the second half of the 1980s, with more summer-like temperatures extending into the autumn season. This trend seems to persist up to the present day. Overall, temperatures have progressively

[167] Unige.life, (2022), *Il 2022, un anno di record per il clima anche a Genova*, https://life.unige.it/2022-record-caldo-genova, [Last Accessed 01/06/2023].

[168] *Ibidem.*

increased, creating critical environmental situations correlated to the drought of the year 2022, an exogenous factor caused by high temperatures and the combined absence of rainfalls.[169]

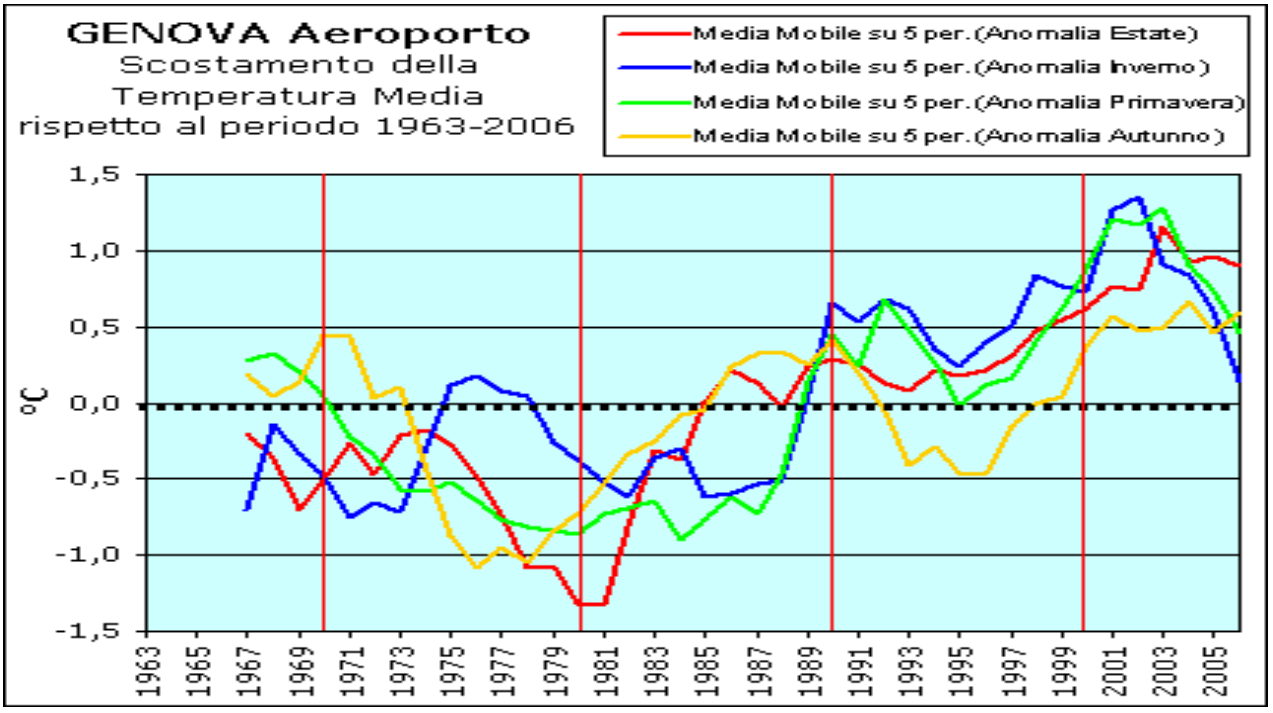

Fig. 5, Deviation of the average temperature concerning the period 1963-2006, registered from 1963 to 2005, Genova Sestri Ponente Meteorological Station, (2007).

[169] Coldiretti, *Siccità 2022, l'anno più caldo di sempre -45% di precipitazioni,* https://www.coldiretti.it/economia/siccita-il-2022-lanno-piu-caldo-di-sempre-45-pioggia, [Last Accessed 5/02/2023].

2.2 Extreme Weather Events

Liguria is not exempt from an extreme phenomenology growing in recent years: the summary image shows the number of extreme events recorded by ARPAL Liguria, the agency dedicated to Ligurian meteorological studies including the events recorded as heavy rains, strong thunderstorms, floods[170], tornadoes, storm surges and heatwaves (Fig. 14).[171] Among the statements of the interdepartmental working group of the Liguria Region it emerged that we are witnessing a greater frequency of intense rainfall events and extreme events, in general, such as the extraordinary storm of 2018[172] and the others that occurred in recent years (1999-2000-2006-2016-2019). For heat waves, one of the most important years to mention was that of 2003[173], in which we witnessed how drought and extreme heat affected a vast temperate zone not only in Italy but throughout Northern and Western Europe, with repercussions on the territory of Liguria at the local level. In addition to the mention in chapter one, the work of the ISPRA Institute[174] has also been fundamental in updating drought reports and developing some maps that have shown how summer drought periods must be assessed first through indices such as Standardized Precipitation Index (SPI)[175], andon calculated time scales.

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[170] V. Ntegeka, P. Willems, (2008), *Impatto dei cambiamenti climatici sugli estremi idrologici lungo i fiumi e i sistemi di drenaggio urban Analisi statistica delle precipitazioni storiche e andamento delle serie di flussi fluviali e cicli*, Belgian Science Policy—SSD Research Programme, Technical report CCI-HYDR project by Katolic Universiteit Leuven, Lueven (Belgium)—Hydraulics Section & Royal Meteorological Institute of Belgium, Vol. 11, pp. 5-46.

[171] M. Piccarreta, A. Pasini, D. Capolongo, M. Lazzari, (2013), *Variazioni delle precipitazioni giornaliere estreme nel Mediterraneo dal 1951 al 2010: la Basilicata Italia meridionale*, 33, pp. 2-21.

[172] Repubblica, (2018), *Liguria, mareggiata e mareggiata, una donna morta ad Albisola. Genova il Comune ci ripensa,* https://genova.repubblica.it/cronaca/2018/10/29/news/allerta_rossa_genova_con_il_fiato_sospeso_preoccuano_le_mareggiate-210274863/, [Last Accessed 19/02/2023].

[173] L. Lombroso, (2020), *Storia meteo: la calda e terribile estate 2003*, https://www.ilmeteo.net/notizie/attualita/meteo-storia-la-rovente-e-terribile-estate-2003.html, [Last Accessed 20/02/2023].

This index can quantify the surplus or deficit of precipitation that determines the drought factor. Compared to the studies[176] of a geographical area, the SPI index indicated the relationship between the amount of precipitation falling over a given period and its climatology, thus leading to the definition of whether a locality is affected by drought conditions or is a perception of a short and transient period. The analysis of wet conditions that do not favour drought phenomenon began for the ISPRA Institute, in December 1989, through four-time scales of 3, 6, 12 and 24 months. In general, however, the calculation of the SPI refers to a very long time series because it shows greater statistical robustness of the indicator and therefore less uncertainty about the estimatioN By the World Meteorological Organization, in 2012 it was stated[177] that it is still necessary to consider timeseries with at least thirty years of continuous monthly rainfall.[178] The bulletins shown here display the most obvious years in terms of drought in 2003, 2016 and 2017. The table below helps you to understand how the SPI can determine whether a drought is normal, moderate, severe, or extreme. The SPI index, up to August 2003 shows rather severe and, in some cases,extreme drought in the western parts of northern Italy, very severe on the island of Corsica. In the regions of Liguria and Piedmont, particularly in the western part on a 12-month timescale, the index showed that drought had decreased somewhat, considering it as moderate.

[174] ISPRA, Higher Institute for Environmental Protection and Research, *Bollettini sulla siccità*, https://www.isprambiente.gov.it/pre_meteo/siccitas/index.html, [Last Accessed 20/02/2023].

[175] M. Svoboda, M., Hayes, M., Wood, (2012), WMO–World Meteorological Organization, *Guida per l'utente dell'indice di precipitazione standardizzato*, Geneva (Switzerland), N 1090, p.23.

[176] *Ibidem.*

[177] Swiss Confederation, National Center for Climate Services, *Cos'è il clima,* https://www.nccs.admiNch/nccs/it/home/climate-changes-and-impacts/information-of- climate-base/things-the-climate-.html, [Last accessed 20/02/2023].

[178] World Meteorological Organization, (2006), *Monitoraggio della siccità e allarme rapido: concetti, progressi e sfide future*, N 1006, Geneva (Switzerland), p.24.

At the annual level, the same data were then analyzed in the situation of 2017 in which a worsening was also evident in a scale of analysis of 12 months.[179] Returning to our days, in July 2022 the same work was done for the months and the data were equally serious, as in this case, Southern Italy was also particularly affected.

Of course, alarming results are shown in the eastern Adriatic area of the Balkans, but at the level of annual precipitation thesituation, although it has remained in a negative condition, attests to the drought as moderate, since on the 12-month time scale the anomaly has been apparently and partially re-established.[180]

This figure is incomplete since the 2023 data is missing, so there is a need to see the next updates of the bulletins to assess the real effects of last summer's drought oncurrent water resources, mostly if it's continuing in winter.[181] The decrease in precipitation taken into analysis is as a reduction in cloud cover and consequent greater insolation remains worrying as the data on future water availability for 2023 and knowing that values affect the entire water cycle, in the final analysis, thanks to these maps is however clear the real intensity of climate change that it's not only visible in Liguria but in a national context that suffers the same effects, sometimes worst.

[179] S. Mariani, G. Braca, E. Romano, B. Lastoria, and M. Bussettini, 2018: *Linee guida sugli indicatori di siccità e scarsità idrica da utilizzare nelle attività degli osservatori permanenti per gli usi idrici*, publication within the CReIAMO PA project, p.66.

[180] ISPRA, Higher Institute for Environmental Protection and Research, *Bollettini sulla siccità*, https://www.isprambiente.gov.it/pre_meteo/siccitas/index.html, [Last Accessed 20/02/2023].

[181] G. Rossi, M. Benedini, G. Tsakiris, and S. Giakoumakis, (1992), *Sulla stima e l'analisi della siccità regionale, la gestione delle risorse idriche*, pp. 249–277.

Years and connected extreme events in Liguria.

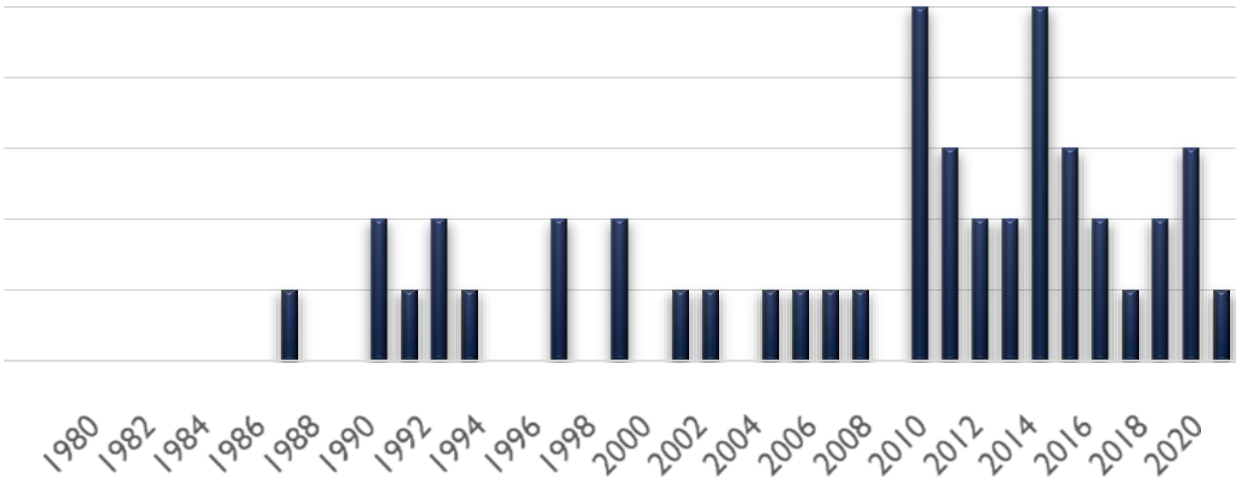


Fig. 6, Levels of extreme events and years data from 1980 to 2020, ARPAL Liguria, (2020).

–1.0 < SPI < 1.0	In the norm
–1.5 < SPI ≤ –1.0	Moderate drought
–2.0 < SPI ≤ –1.5	Severe drought
SPI ≤ –2.0	Extreme drought

Fig. 7, Levels of the Standardized Precipitation Index (SPI) related to the severity or non-severity of an ongoing drought, ISPRA, (2003).

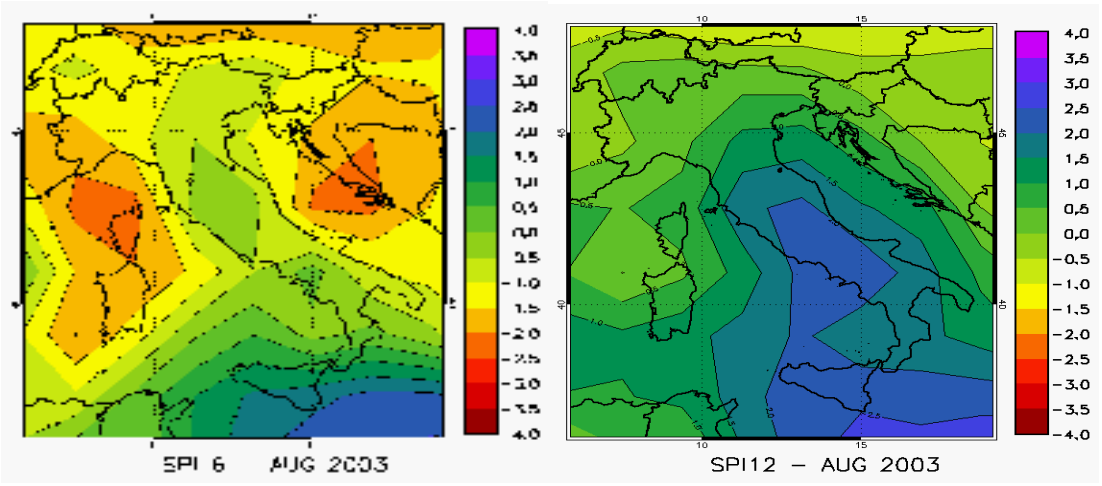


Fig. 8, The situation in August 2003, drought bulletin, SPI 6 & 12 months, ISPRA,(2003).

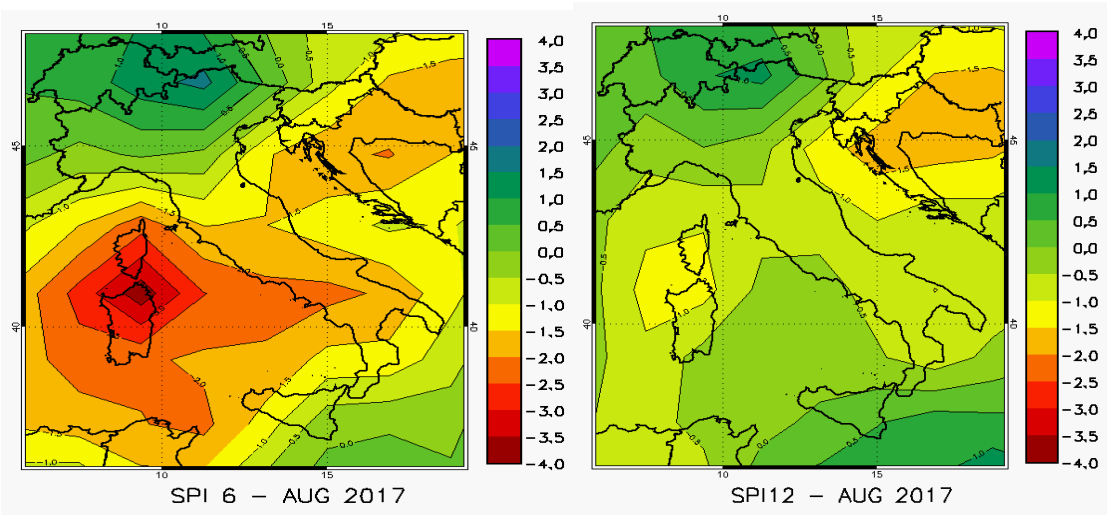


Fig. 9, The situation in August 2017, drought bulletin, SPI 6 & 12 months, ISPRA,(2003).

2.2.1 Historic floods

As mentioned previously, the Liguria region has not only been affected by drought over the years, but it is important to remember that the aspects of drought are extremely linked to other types of extreme weather events of other nature: floods.[182] The region itself has constantly been subject to major floods, particularly its capital, the city of Genoa.[183] These floods are important to mention as they have largely determined the history of the city of Genoa and other Ligurian locations. This is evident from a historical catalogue of hydrogeological events that have caused direct damage to the population due to excess rainfalls.[184] In all four provinces of Liguria, storms have caused at least 284 deaths known in

[182] S. Turci, (2022), *Siccità e inondazioni sono facce della stessa medaglia*, https://www.iconaclima.it/italia/clima/perche-si-passa-dalla-siccita-alle-alluvioni/, [Last accessed 20/02/2023].

[183] Polaris, (2010), *Popolazione a rischio frane e alluvioni in Italia: Liguria una storia di alluvioni*, https://polaris.irpi.cnr.it/liguria-una-storia-di-alluvioni/, [Last accessed 20/02/2023].

[184] *Ibidem.*

the last years on a basis of 245 locations distributed in 96 municipalities, identifying Liguria as an area of high flood risk.

Among the most tragic and important historical events, we have the flood of August 19, 1858, when in the Savona area there were about 50 victims among the occupants of some flooded houses. For the metropolitan area of Genoa, the most significant events hit the city itself[185], with the flood of October 7, which caused numerous damages, being the most disastrous event. Among the most recent cases, we have the floods of 1992 and 1993, then the storm of November 4, 2011, up to the evening of October 9, 2014, when, as the last flood so far, the count of deaths for these disasters stood on 50 dead in the city of Genoa alone.[186] In the flood of 1970, for which there is a particularly large historical memory, some very intense and localized rains[187] reached about 900 mm in 24 hours and corresponded to 90% of the average annual rainfall. In 1993 the event was located mostly in Val Varenna near the Genoa Pegli district, and it caused a total of 4 deaths and hundreds of displaced people. The flood of November 2011 caused 7 deaths, all victims of a self-regenerating storm system. Such a storm was preceded by a similar event on October 25 in Val di Vara and 5 Terre[188] with 13 casualties and a total amount of 472 mm of Rain. A few days later in Genoa in six hours more than 500 mm of rain was measured, an exceptional and tragic figure at the same time. In the whole of the region, 15 people died in 2011.[189] The flooding of the rivers Bisagno and Ferreggiano and the flooding of the Sturla, Scrivia and Entella streams generated

[185] P. Crivelli, (2014), Blasting News, *Tutte le alluvioni di Genova negli ultimi 44 anni,* https://it.blastingnews.com/ambiente/2014/10/tutte-le-alluvioni-a-genova-degli-ultimi-44-anni, [Last accessed 20/02/2023].

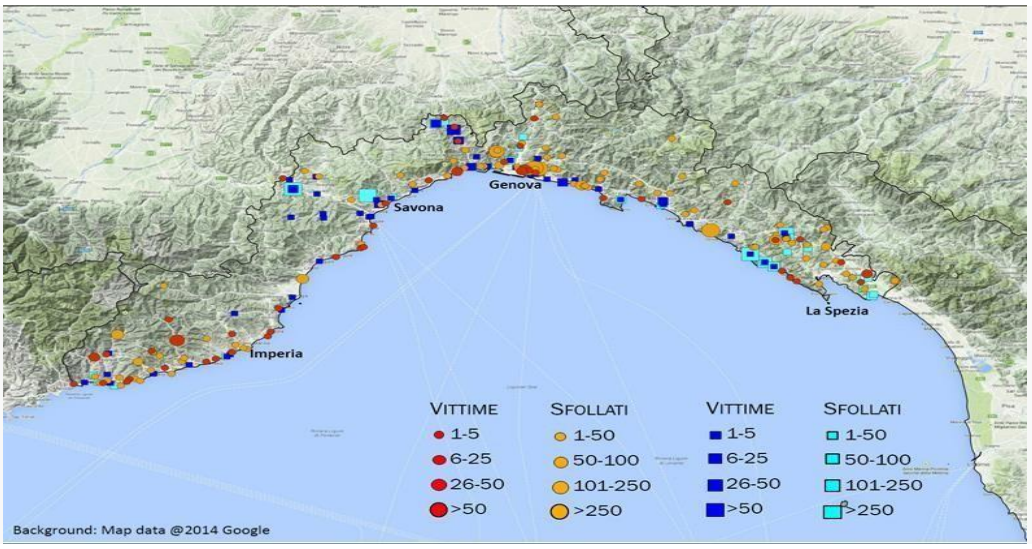
[186] *Ibidem.*

[187] IconaClima, (2019), *Temporale autorigenerante: cos'è e come si forma*, https://www.iconaclima.it/meteo/temporale-autorigenerante-cos-e-come-si-formano/, [Last accessed 22/02/2023].

[188] CinqueTerre.com, (2011), *Alluvione nelle Cinque Terre foto e video,* https://www.cinqueterre.com/alluvione-alle-5-terre-foto-e-video, [Last accessed 22/02/2023].

[189] *Ibidem*.

flooding at the mouth of the catchment areas now of limited size, where large quantities of mud and debris were collected, creating an obstacle to the natural flow of water.[190] The map (Fig. 15) shows the geographical distribution of the extreme weather events in question. The analysis of the phenomenon of self-healing storm systems and the importance of the northerly wind (Tramontana) on the Ligurian Gulf can partly explain extreme floods of this type.[191] This factor must be included in the relationship that drought maintains with flooding: the capacity to absorb water in now-dry soil is reduced and this is the risk for two years like 2022-23. Self-healing thunderstorms rely on the presence of two concomitant factors, the south-easterly wind called Scirocco and Tramontana; the latter is occurring less frequently in the last decades. However, there's no relationship with the drought phenomena.[192]



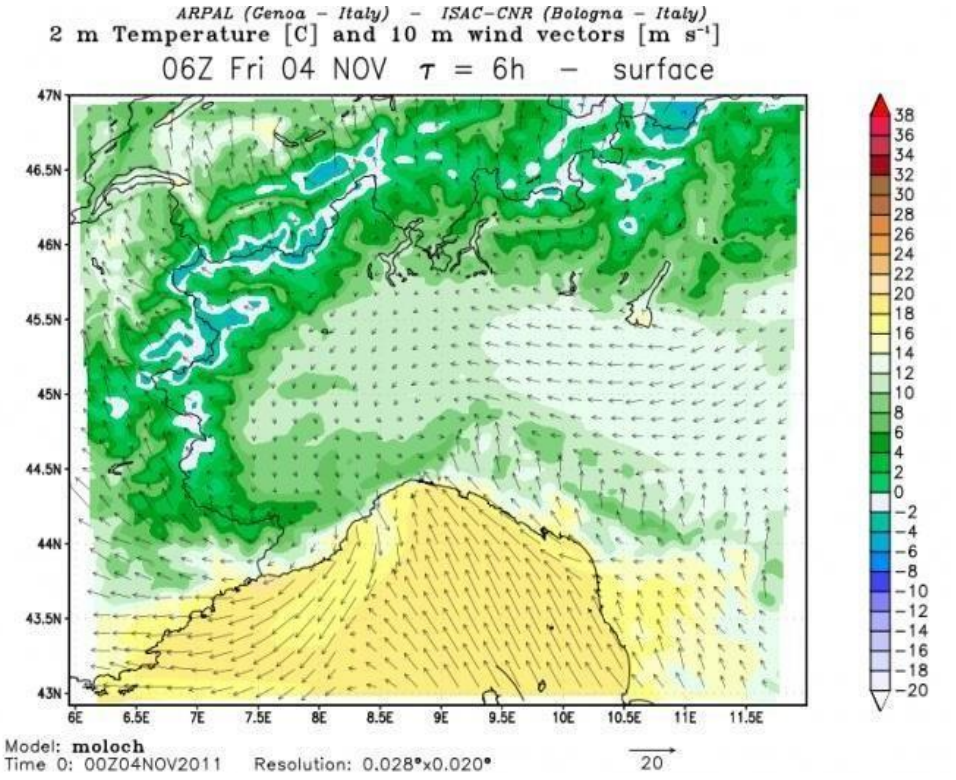
[190] District watershed authority of the Northern Apennines, (2011), *Le alluvioni di Genova,* https://www.appenninosettentrionale.it/itc/?page_id=8244, [Last accessed 22/02/2023].

[191] D. Ingelmi, (2012) *La tramontana: il famoso vento ligure che accompagna i travasi di aria fredda padana verso il golfo di Genova, portando persino la neve sulle coste*, https://www.meteoweb.eu/2012/11/la-tramontana-il-famoso-vento-ligure-che-accompagna-i-travasi-di-aria-fredda-padana-verso-il-golfo-di-genova-portando-persino-la-neve-sulle-coste/161575/, [Last accessed 20/02/2023].

[192] A. Colombo, (2022), 3BMeteo, *Alluvioni in Liguria: l'importanza del vento di punta sul Golfo Ligure nella modulazione dei temporali autorigeneranti*, https://www.3bmeteo.com/giornale-meteo/le-alluvioni-in-liguria, [Last accessed 20/02/2023].

Fig. 10, The map shows the geographical distribution of geohydrological events with damage to the population in the period 1646-2014. The red and orange dots refer to landslides, and the blue and light blue squares to floods of victims and displaced persons, National Research Council Research Institute for Hydrogeological Protection, (2014).

Most of the phenomena affect the central-eastern part of Liguria while the Province of Imperia is partly protected[193]. Storms come in the form of stationary thunderstorm systems[194]**,** which are a necessary condition for the accumulation **of** abundant amounts of rain which are poured onto the mainland in amounts like the precipitation in millimetres which are generally reported annually. The passage you provided describes the typical characteristics of Ligurian rivers and their relationship with rainfall patterns in the Liguria region during the summer, the rivers tend to be dry due to the lack of rainfall, while in autumn and winter, they can experience heavy water flow due to the rainy season.



[193] *Ivi*, p.8.

[194] *Ivi*, p. 30.

Fig. 11, Confluence between the Tramontana and the Scirocco, along which the alluvial storm was generated over Genoa on 4 November 2011, ARPAL, (2011).

The slopes of the Ligurian Riviera contribute to rapid water outflow. Liguria is prone to heavy rainfall and the most likely period for floods in Liguria is during the autumn season from September to November. The stability of the summer season, which traditionally favours the entry of Atlantic disturbances, is diminishing. However, the Ligurian Sea continues to provide energy contribution, reaching its highest temperature between late summer and early autumn, maintaining warm values until November and December. This can contribute to the occurrence of floods. The alternating episodes of floods and droughts in Liguria make it an important area of study for understanding these phenomena and their correlations. In recent years, there has been a decrease in floods, but this is closely related to the increasing average temperatures in the Po Valley area over the last few decades. However, the lack of rainfall leads to drought, which poses a significant threat to urban centres and the biodiversity of Ligurian flora and fauna. In addition to physical geographical factors, significant reasons for such disastrous floods are also to be found in recent human activities in urban centres: since the nineteenth century most of the urban basins have been subject to significant landscape changes due to a demographic increase that has pushed, even in Europe, various urban centres from the rural economy and to the industrial economy.[195] The intensive use of land and the remodelling of cities for urban reasons have also shaped the city of Genoa, accentuating hydrogeological risk.[196] The river of Bisagno has always been affected by these phenomena, also due to the intense urbanization of the last century. The implementation of sustainable management policies is now essential for adopting specific urban planning and reorganization measures to mitigate

[195] F. Faccini, G. Paliaga,P. Piana, A. Sacchini, C. Watkins, (2016), Il *bacino idrografico del torrente Bisagno (Genova, Italia) e le sue grandi piene: variazioni geomorfiche e di uso del suolo negli ultimi tre secoli,* https ://www.semanticscholar.org/paper/The-Bisagno-stream-catchment, [Last accessed 22/02/2023].

[196] Fonte ufficiale, (2022), *Perché siccità e inondazioni sono collegate*, https://fonteufficiale.it/ambiente/perche-siccita-e-alluvioni-sono-connected, [Last accessed 22/02/2023].

flood risk.

The current total population of about 580,000 inhabitants[197], does not represent the period of the great industrial Genoa when the population was 850.000 people and being a regional capital restricted between sea and mountains, the only outlet spaces for the construction of residential buildings and industries were the two large Val Polcevera and Val Bisagno. [198]

[197] All of Italy, (2021), *Popolazione di Genova 2001-2021, Andamento demografico negativo della popolazione residente nel comune di Genova dal 2001 al 2021. Grafici e statistiche su dati ISTAT al 31 dicembre di ogni anno*, https://www.tuttitalia.it /liguria/45-genoa/statistics/population-demographic-trend/, [Last accessed 23/02/2023].

[198] F. Silvestro, N Rebora, F. Giannoni, A. Cavallo, L. Ferraris, (2015) *L'alluvione improvvisa del torrente Bisagno del 9 ottobre 2014: una "sfortunata" combinazione di scale spaziali e temporali*, Journal of Hydrology, http://dx.doi.org/10.1016/j.jhydrol.2015.08.004, pp. 50-62, [Last accessed 24/02/2023].

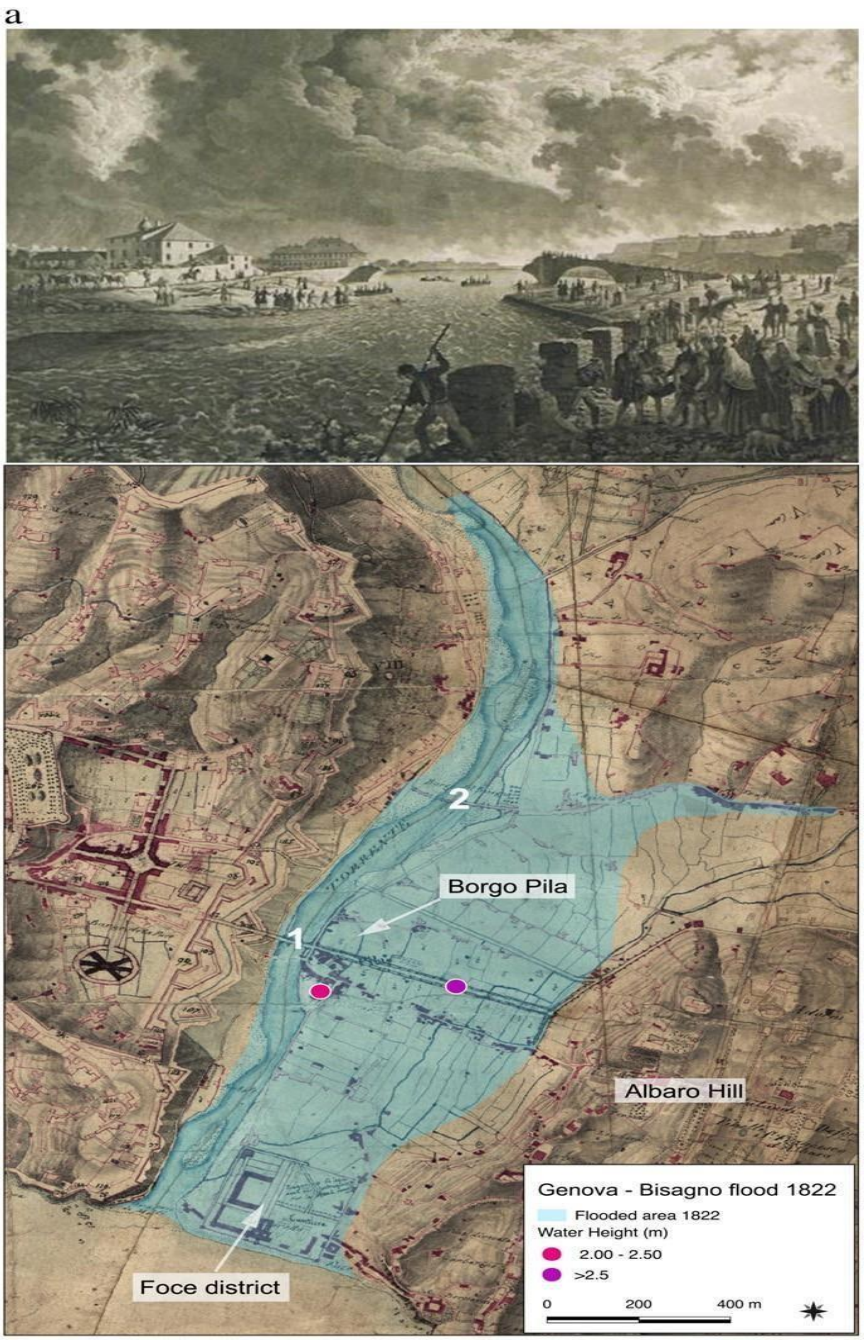


Fig. 12, The Genoa flood of 1822 the Bisagno stream flooded the natural alluvial plain designated to it which had not yet been urbanized and is now unrecognizable. On that day, 812 millimetres of rain fell in 24 hours.[199]

These areas in the twentieth century were progressively industrialized to accommodate the

[199] F. Faccini, G.Paliaga, P. Piana, A. Sacchini, C. Watkins, (2016), *Il bacino idrografico del torrente Bisagno (Genova, Italia) e le sue grandi piene: variazioni geomorfiche e di uso del suolo negli ultimi tre secoli,* https://www.sciencedirect.com/science/article/pii/S0169555X16306560, *[Last Accessed 19/06/2023]*

growth of the Genoese population. By constructing buildings at the mouth of two rather unstable floodplains[200] in the and where the average rainfall varies from 1100 to 1000 mm[201] per year with peaks in autumn, the risk was already announced with the addition of a climatic regime usually characterized by long and dry summers, following from short and intense rainfall events that would have generated flash floods in areas with high population density. The bed of the Bisagno River in the first part of the valley has also been severely restricted in the last 200 years and buried in the last 100 years[202] to facilitate the road connection with a new main road to the centre of Genoa, which today is Via XX September, through the Ponte of Pila. The area in question was raised for natural reasons and houses were also lowered to a higher risk level to smooth out the buildings at the same level, making them more flooded.

In 1822,[203] on October 25, the Bisagno plain had not yet been urbanized, but it gave rise to flooding, since 812 mm fell that day in a few hours, generating an incredible deluge, as mentioned in the study by Piana and Faccini[204]. There were, however, substantial differences between the flood of 1822 and the most recent in the nineteenth century: the plain was separated at the centre catchment area by a hill that remained until the end of the century, not allowing the water to expand towards the West. In conclusion, anthropogenic changes in land hydrography provide evidence of how human activity have been crucial for

[200] F. Faccini, F. Luino, A. Sacchini, L. Turconi, J.V. DeGraaf, (2015), *Rischi geo idrologici e sviluppo urbano nell'area mediterranea: un esempio da Genova (Liguria, Italy*), 2National Research Council, Research Institute for Geohydrological Protection, 15, pp. 2631–2652.

[201] G. Saffioti, (2022), *L'ignorante meteorologo, Genova il torrente Bisagno,* https://www.ilmeteorologoignorante.it/webcam/torrente-bisagno-genova/, [Last accessed 25/02/2023].

[202] *Ibidem.*

[203] *Ivi*, p. 37.

[204] P. Piana, F. Faccini, (2023), *Il 'Diluvio' del 25 ottobre 1822 a Genova, Italia,* pp. 3-6, https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/wea.4388, [Last Accessed 01/06/2023].

increasing risks in an area already prone to flooding for pre-existing environmental reasons.

2.3 Climate Change in Liguria

Droughts are not an unknown phenomenon in Liguria; knowledge of events of the past allows a better understanding of the 2022/23 drought which is probably unprecedented in terms of intensity. Historical dataset archives of meteorological analysis are particularly useful, for example, the collection of research data of the Hanbury's Botanical Gardens[205] near the border with France. This area of Ponente was the object of particular interest from meteorological research developed by English nobles who had taken the Ligurian coast of Ponente into great consideration from a tourist point of view and precisely because of the mild climate they came to stay in areas such as that of the gardens Hanbury, but also others such as Bordighera, where numerous weather reports were produced.[206] The data analyzed climate variations over a period that lasted 40 years, from 1900 to 1940. The registers are now digitized and statistically analyzed to evaluate their reliability to study the trends and variations of the Ligurian climate in the past: in particular, air temperature, wind direction, precipitation, and their interrelated extreme values. In terms of temperatures, there was a decreasing trend of the average annual temperature of about 0.2°C per decade, caused by a decrease in maximum air temperature, while annual cumulative precipitation was at a rather stable level, with an increase of 65.2 mm per decade of precipitation during the study period, highlighting a temperate climate, unaffected by today's climate changes**.**

This analysis also showed a decrease in summer temperature, particularly in the period of

[205] Greta V., L. Cutroneo, D. Gandolfi, G. Ferretti, D. Scafidi, M. Capello, (2017), *Recupero, validazione statistica e analisi di un dataset meteorologico storico raccolto presso i Giardini Botanici Hanbury* (Liguria, northwestern Italy) from 1900 to 1940, https://link.springer.com/article/10.1007/s00704-018-2524-3, [Last Accessed 01/06/2023].

[206] L. Bagnoli, (2022), Turisti e meteorologi nella Riviera italiana: il Journal de Bordighera (1883-1935) come fonte per lo studio del clima locale, https://www.sciencedirect.com/science/article/abs/pii/S0305748821000086, 75, pp. 24-41, [Last Accessed 01/06/2023].

the first 20 years, until the considerable drought developed in 1921, one of the first mentioned with these scientific data recorded in Liguria.[207] One possible explanation for these phenomena has been sought over the years in the negative phases of the phenomenon of the North Atlantic oscillation[208], a model of atmospheric circulation (also called the motion of variability at a low frequency of the atmosphere) located in the northern Atlantic Ocean and characterized by the cyclical fluctuation, an oscillation of the pressure difference at sea level between Iceland and the Azores, capable of adversely affecting the climate under analysis.[209] These meteorological data were crucial in laying the foundations for the greatest changes observed on the ground today and show that the climate began to change more than a hundred years ago. In this historical analysis data are safe, thanks to the confirming study developed to assess the reliability of this historical research, by D. Camuffo[210] in 2002, while the second approach to test the accuracy of the data was developed in the same year by M. Maugeri.[211]

Despite some shortcomings in the first approach, which involved the analysis of metadata with objective information relating to the instruments and times of observation, the strictly geographical characteristics of the Hanbury Botanical Gardens located in an arched morphology of the territory from the orography due to the proximity of the Ligurian Alps to the Ligurian Sea, however, could not be satisfactory to describe the entire territory or its

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[207] E. Frittoli, (2017), L'Italia senza acqua le più gravi siccità nella storia del paese, https://www.panorama.it/news/litalia-senza-acqua-le-piu-gravi-siccita-nella-storia-del-paese, [Last Accessed 01/06/2023].

[208] L. Bellagamba, MeteoNetwork, *Oscillazione Nord Atlantica*, https://www.meteonetwork.it/sites/default/files/NAO%20parte%201.pdf, pp. 7-32, [Last Accessed 12/02/2023].

[209] T.J. Osborn, (2011), *Winter temperatures 2009/2010 and a record North Atlantic Oscillation Index*, Volume 66, pp. 19-21.

[210] D. Camuffo, (2002), *Cambiamenti climatici: correzioni di errori sistematici e omogeneizzazione dei dati nella temperatura giornaliera*, Padova series (1725– 1998).

[211] M. Maugeri, T. Nanni, (2002), *Variazioni di temperatura e precipitazioni in Italia dal 1866 al 1995, Teoria dell'applicazione climatologica*, p. 165–174.

climatic diversity. Anyway, the meteorological influence processes of this area have helped to highlight the situations of meteorological instability and have encouraged the study of the development of atmospheric circulation processes also for the meteorology of the following years, thus remembering this work carried out by Hanbury Botanical Gardens as a climatic heritage of historical importance.

Other historical data show[212] that in previous years the driest periods were those of 1953 with 100.8 mm and 1896 with 125.5 mm for the first 5 months of the year, recorded at the meteorological observatory of the University of Genoa. Thus, in the past, there were already great examples of winter drought however very serious, with considerable time intervals. However, if we extend the research from the beginning of the hydrological year, or from the first day of September 2016, until May 31, 2017, the millimetres of water collected by the rain gauge of Genoa University Observatory was 376.8 mm[213] (without any snowfall in that period) and in this case, it is an exceptional value because it is the lowest quantity recorded in the period September-May since the beginning of the measurements or rather, since 1833.[214] In second place of fallen millimetres, there was only the period 1921/1922, when 439.1 mm fell, remembering that 1921 was the year in which in many European locations the absolute record of the minimum amount of precipitation was measured, including Genoa with 543.4 mm. Returning to the recent situation, for 2022 the situation might seem like the present biennials taken into consideration, not necessarily highlighting the persistence of a prevailing drought, but the winter situation of the first months of 2023[215] does not bode well and since 2022 is already the year of records in this sense two-year period

[212] R. Pedemonte, Nimbus Rivista Ligure di Metereologia (2017), *drought editorial,* http://www.nimbus.it/liguria/rlm61/editoriale.html, [Last Accessed 13/02/2023].

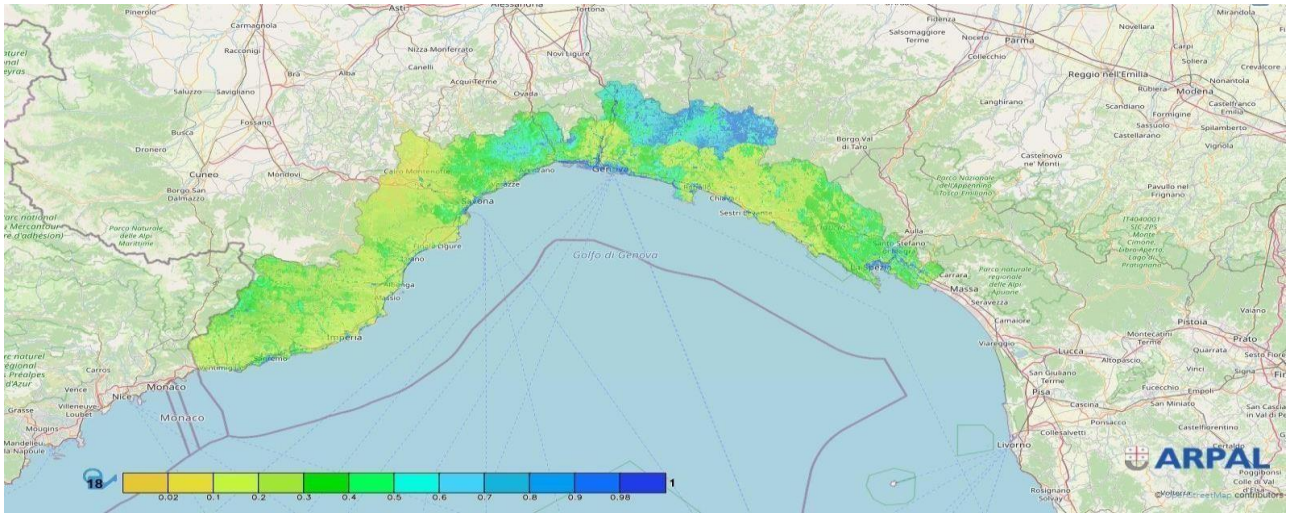
[213] Historical Weather Observatory of the University of Genoa, (2022), *L'estate del 2022 è stata la più calda della città dal 1833*, https://www.ilsecoloxix.it/genova/2022/09/17/news/genova, [Last Accessed 14 /02/2023].

[214] *Ivi*, p.15.

[215] ANSA, (2023), *C'è allarme siccità in Liguria, il Brugneto come nel 2022*, https://www.ansa.it/liguria/notizie/2023/02/28/e-alarm-siccita-in-liguria-il- brugneto-come-nel-2022, [Last Accessed, 1/03/2023].

will likely follow the same record trend numbers. The situation in 2023 is already critical: the reservoir of the main reserve today is at the same level as in July 2022, so a situation gives the signal of how prominent the theme is. On 28th February 2022, this was announced by the regional Councillor for Civil Protection of the Liguria Giacomo Giampedrone responding to a question in the Regional Council.[216] Considering that the artificial basin of Brugneto is the largest lake in Liguria and the main water reserve of the city of Genoa, the summer emergency has already begun in the winter of 2023. Faced with this evidence, we know that it is first necessary to have the numbers of the coming months and therefore fundamental to underline the secular value that represents the drought in progress even if it will report the worst data ever for the region. However, drought cannot be limited to the summer period in general because despite being the season with few spots of rain for excellence, the most serious cases of drought have affected our territory even during the winter periods: exactly as happened for the summer of 2022.

The problem of a winter drought resides in the fact that these periods represent the time when subsoils and groundwaters should be supplied with water to allow communities to cope with the normal absence of rain and summer heat. At the same time, snow is crucial for this balance of water compensation in the summer months as it accumulates in the mountains to release water more slowly during melting phases.



[216] *Ibidem.*

Fig. 13, Report N300, in March 2022 drought was the protagonist phenomenon, ARPAL, (2022).

2.3.1 Temperatures variations

The year 2022 and so far, 2023 have been characterized by two aspects, average high temperatures and overall low rainfall. As regards the rain that fell in 2022, the annual record does not however belong to the coastal areas, such as that of Genoa, but within Liguria. The data[217] report to the weather station of the small village of Barbagelata in the province of Genoa, which has accumulated only 1572 mm of rain fell in the 12 months of the year, while in areas towards the western part of Liguria, notoriously drier, such as in Cairo Montenotte located in the Savona area the record it is negative with just 377 mm of rainfall, further highlighting the gap between the two areas[218]. In the other Ligurian provinces, there was instead in Imperia 444 mm, about 581 mm in Savona and in the capital of Genoa, 469 mm of rainfall.[219] The values are among the lowest ever recorded. The most consistent daily rainfall was instead recorded on the 29th of 2022 September in Busalla with 141 mm in 24 hours.[220] The other element worthy of note is that of the temperatures, largely always reported by the military aeronautical station of Genoa Sestri Ponente, located in the airport which has always used historical data[221] as a comparison model and recorded an average annual temperature for 2022 of 17.7°C, exceeding the previously mentioned average values. This

[217] SNAP, National system for the protection of the weather environment, (2023) *in Liguria un 2022 tra caldo e poca pioggia*, https://www.snpambiente.it/2023/01/04/meteo-in-liguria-un-2022-tra-caldo-e-poca-pioggia/, [Last Accessed 9/02/2023].

[218] Ivi, p.6.

[219] *Ibidem.*

[220] IVG, (2022), *Il bilancio in Liguria nel 2022 alte temperature, scarse precipitazioni, record al Cairo, con solo 377 mm di pioggia in un anno*, https://www.ivg.it/2023/01/in-liguria-nel-2022-temperature-elevate-e-precipitazioni-scarse-record-a-cairo-con-soli-377-millimetri-di-pioggia- in a year/, [Last Accessed 10/02/2023].

[221] *Ivi*, p. 5.

marks the year 2022 as the warmest on record since 1963 when measurements began. At the regional level, the highest temperature in 2022 was recorded on 18 July in Padivarma[222], near the city of La Spezia, at 39.4°C, and the month of July was certainly the hottest of the summer.

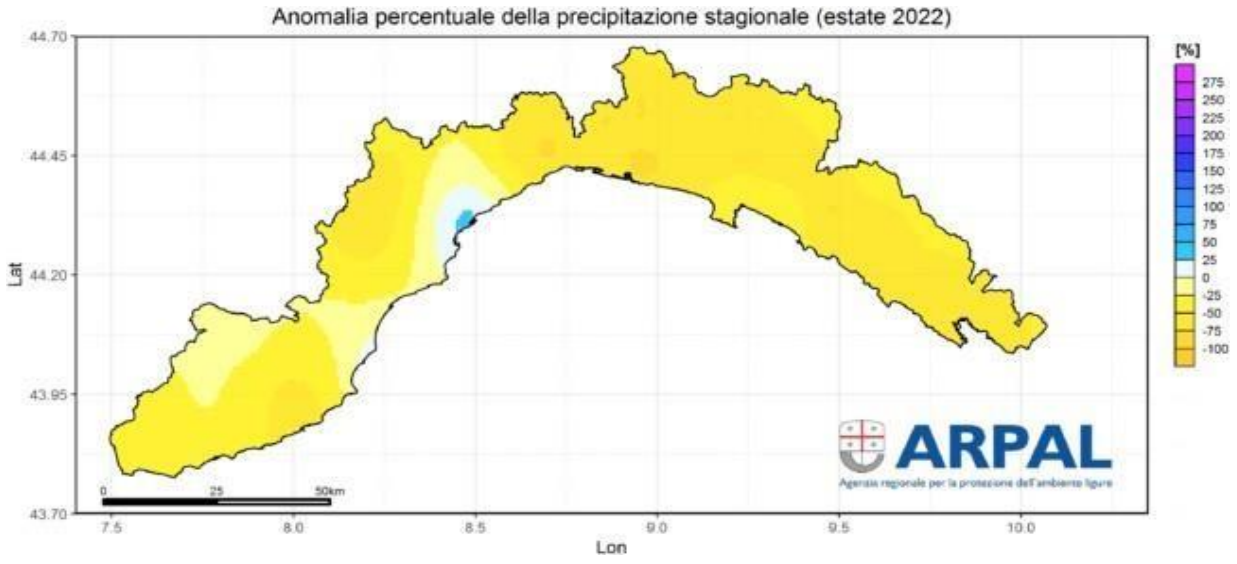


Fig.14, Liguria's seasonal report 2022, absolute seasonal precipitation percentage anomaly in summer 2022, ARPAL, (2022).

The temperatures in Genoa reached the maximum of 35.5°C and 37°C in Savona[223], but it is necessary to see them better in detail. In the city of Genoa, summer 2022 will go down in the annals to be remembered as the hottest since there have been constant and rigorous measurements of the meteorological parameters of the whole city, also thanks to the work of important observatories such as the University of Genoa which since 1822 has continued to monitor the situation in the Liguria Region and the city[224].

[222] ARPAL Liguria, (2022), *I dati meteo più significativi del 2022 in Liguria*, https://www.arpal.liguria.it/articoli/focus-home/i-dati-meteo-piu-significati-del-2022-in-liguria.html, [Last Accessed 9/02/2023].

[223] *Ibidem.*

[224] Historical Weather Observatory of the University of Genoa, (2022), *L'estate del 2022 è stata la più calda della città dal 1833*, https://www.ilsecoloxix.it/genova/2022/09/17/news/Genova, [Last Accessed 9/02/2023].

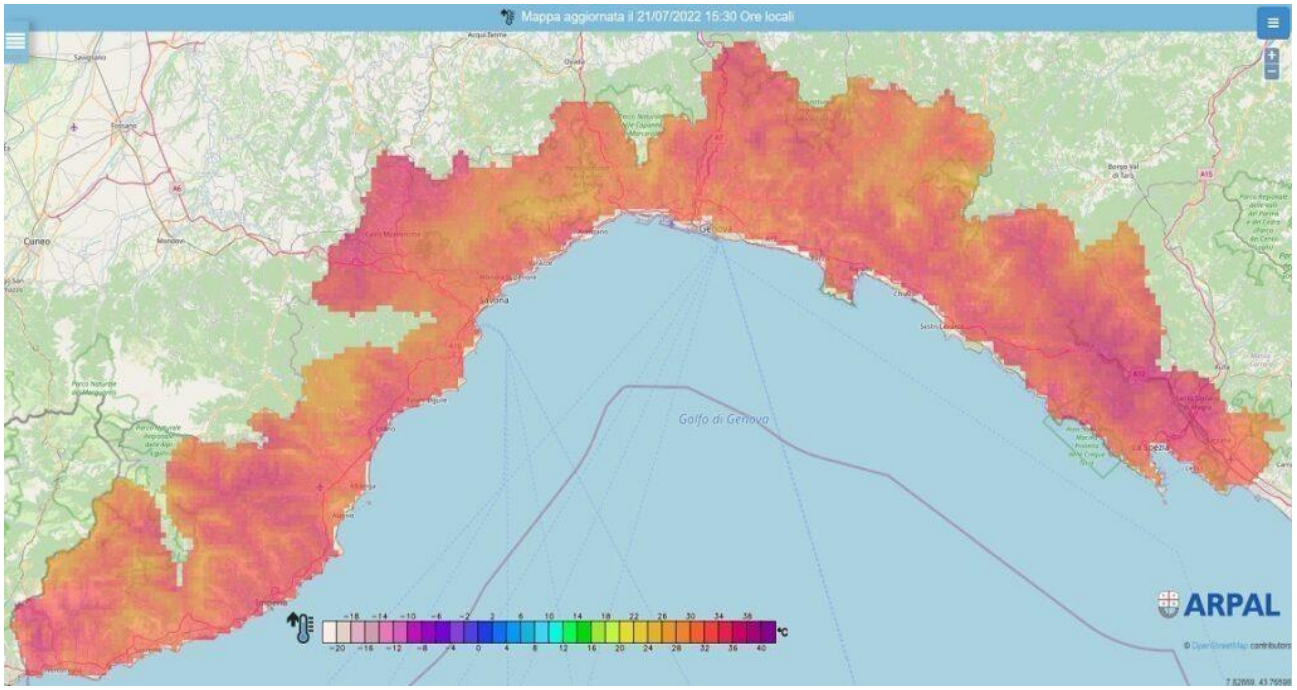


Fig. 15, Map showing the high temperatures of the Liguria region on July 21st, 2022, with the temperature's details extremely high along the coast but unusually also towards the hinterland, ARPAL, (2022).

What we can underline as fundamental data for 2022[225], is that the average temperature of the three summer months starting from June up to August, was 26.44°C. It abundantly exceeds the previous record set in 2003 of 25.69°C and therefore turns out to be 3.16°C higher than the average of the entire previous period analyzed, even starting in 1822, and therefore ending in 2021. The temperature was also 2.92°C higher than the thirty-year climatological average for the period 1991-2020.[226] So much heat was due to the average maximum and minimum daily values, the average of which was decidedly higher than any previous summer ever recorded: it was around 29.2°C, with a historical average of 26.2°C and exceeding as well as the previous 1937 record of 28.4°C. For the average concerning the minimum daily temperature, the figure stands at 23.7°C, while the minimum historical

[225] Rivista Ligure di Metereologia, (2022*), Notizie rilevanti riguardanti l'estate del 2022 e dati connessi di temperature record estreme*, http://www.rlmet.it/notizie_attualita.htm, [Last Accessed 9/02/2023].

[226] *Ibidem.*

average was 20.5°C, thus once again exceedingly even the year 2003, which was stuck at the unbeatable figure of 23.4°C. Furthermore, the minimum temperature of the summer period considered was 19°C and once again the highest ever, considering that the value in previous years had reached a maximum of 18.4°C, recorded in the summer of 1846. Another important piece of information to add is the number of days in which the thermometer exceeded 30°C, which was 32 days; this value was also recorded in 1873, but 2022 had the longest number of days with temperatures above 20°C, in particular 88, even higher than 2003 (86 days) for a higher number of days than in the past it did not drop to below by 2022, so, surpassing the previous record.[227] In detail for the city of Genoa, the highest temperature peaks were measured in the month of July in the Genoa Staglieno station with 37.9°C at 16:00 on 18th July 2022. The previous record, also this time overturned, was recorded on July 18, 2010, it was 35.9°C. Also, for the day 27th May there was already 33.1°C but the previous record was 32.2°C and dated back to 25th May 1953.[228] Throughout 2022 in the reference stations of the provincial capitals, the thermometer never dropped below zero allyear.[229]

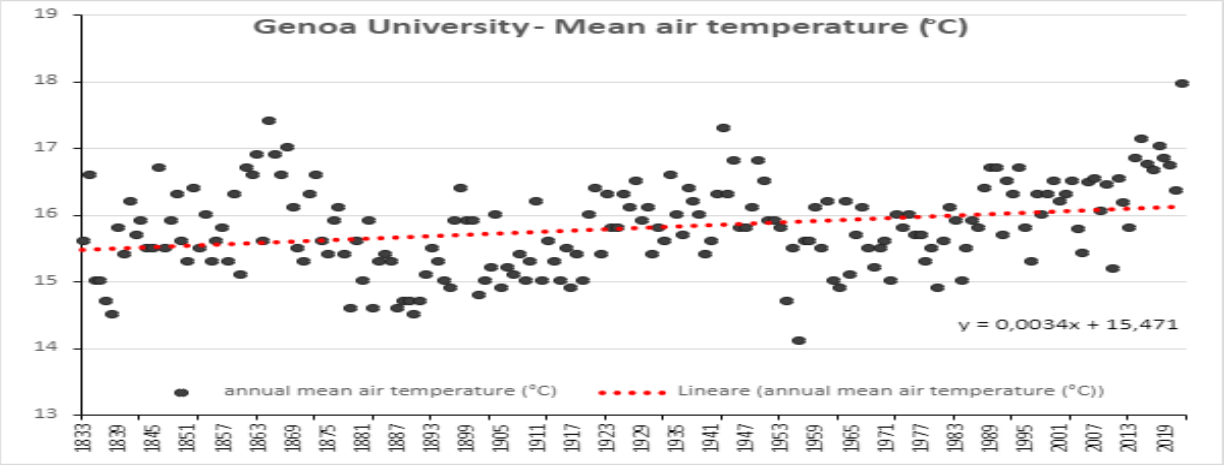


Fig. 16, Image showing the average annual temperature from the beginning of the recordings in 1833 to 2019, Via Balbi Meteorological Station, (2019).

[227] *Ibidem.*

[228] Climate Data, (2022), *Il clima di Genova su scala annuale*, https://www.genova24.it/2023/01/clima-il-2022-un-anno-record-per-caldo-e-siccita-a -genova-lo-studio-delluniversita-332180/, [Last Accessed 11/02/2023].

[229] *Ibidem.*

2.3.2 Rainfall variations

The drought shows no signs of ending, promising bad repercussions also for the following year, as despite some rainfall from October to January 2023, for Liguria and the coastal cities it was not particularly considerable.[230] The critical Ligurian situation can also be seen in the maps at the national level: the weather bulletins for November and December 2022[231] showed a still critical situation, despite the winter period, for the standardized precipitation index (SPI).

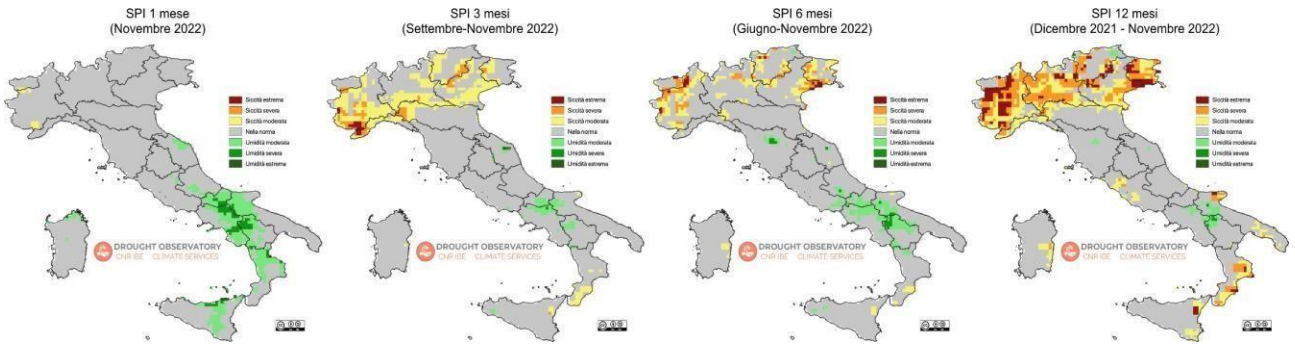


Fig. 17, CNR IBE Climate Services, Italy's Standardized Precipitation Index (SPI) weather report, November 2022, Drought Observatory 2018-2023.

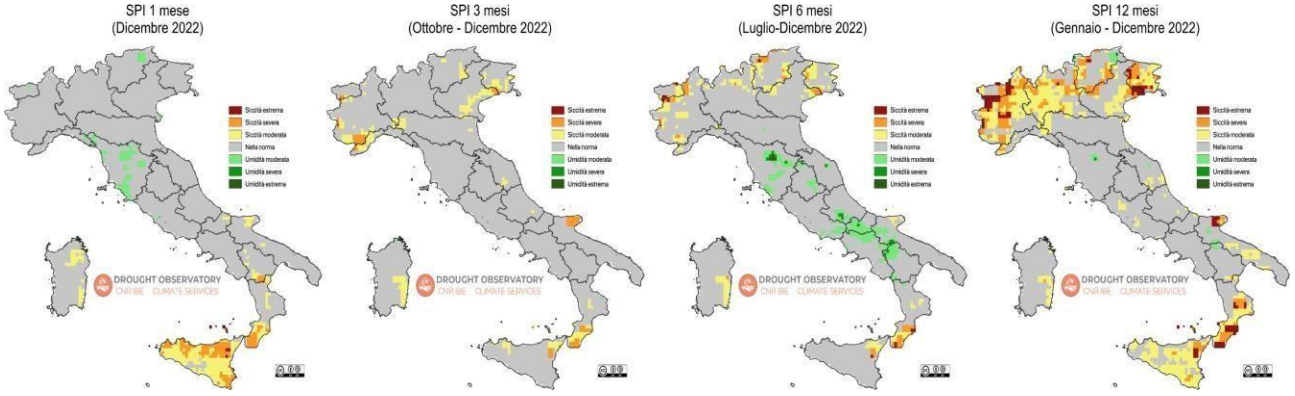


Fig. 18, CNR IBE Climate Services, Italy's Standardized Precipitation Index (SPI) weather report, December 2022, Drought Observatory 2018-2023.

[230] *Ivi*, p.22.

[231] Drought Observatory CNR IBE Climate Services (2022), *Situazione di siccità*, Meteorological bulletins of the year, https://drought.climateservices.it, [Last Accessed 11/02/2023].

The data[232] highlighted, returning to rainfalls, by the graphs are clear: the rainfalls in December 2022 had a very short positive impact on the 3 months, reporting the values on average almost everywhere. Only the island of Sicily and part of the region Calabria had below-normal rainfall. In the medium and long term, however, the situation is almost identical to that highlighted in November 2022, with the regions of Northern Calabria and Sicily affected by moderate to extreme drought. Compared to the second half of 2022, some Apennines areas have a surplus of rain that persists, although in more limited areas than in the last 3 months of the year.

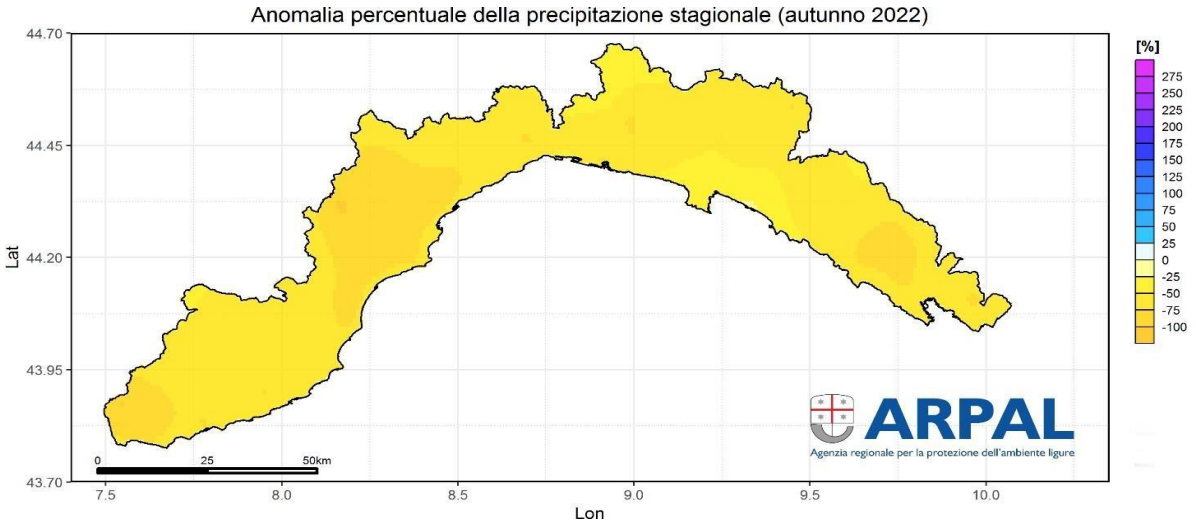


Fig. 19, Seasonal Report 2022, Absolute seasonal precipitation anomaly in autumn 2022, ARPAL, (2022).

ARPAL (Ligurian agency set up to monitor and forecast the climate) has also developed this map highlighting that in autumn 2022, as showed in the image, there was widespread precipitation anomaly throughout the region[233] (Fig. 11). In addition, the amount of precipitation that fell from January to August was also very low, 130.6 mm, remaining far

[232] *Ibidem.*

[233] ARPAL Liguria, (2022*), Pubblicazioni di anomalie percentuali assolute durante le stagioni 2022*, https://www.arpal.liguria.it/tematiche/meteo/pubblicazioni-bis/rapporti-stagionali/rapportistagionali2022.html, [Last Accessed 11/02/2023].

below the previous record of 2017 of 188.4 mm. Furthermore, some images were developed by doctoral students at the University of Genoa's meteorological station of Via Balbi, concerning the rainfall, starting from a set of data from 1883 up to today. The sharply decreasing precipitation rates are evident as are the precipitation days.

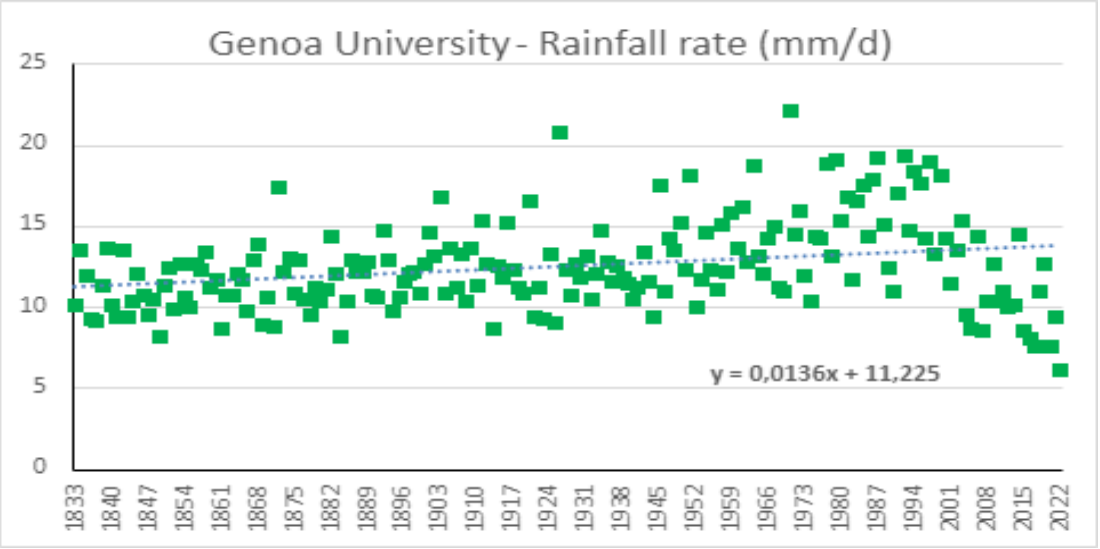


Fig. 20, This image shows the rainfall rate from the beginning of the meteorological station in 1833 until the observation of the decrease in 2022, Via Balbi Meteorological Station, (2022).

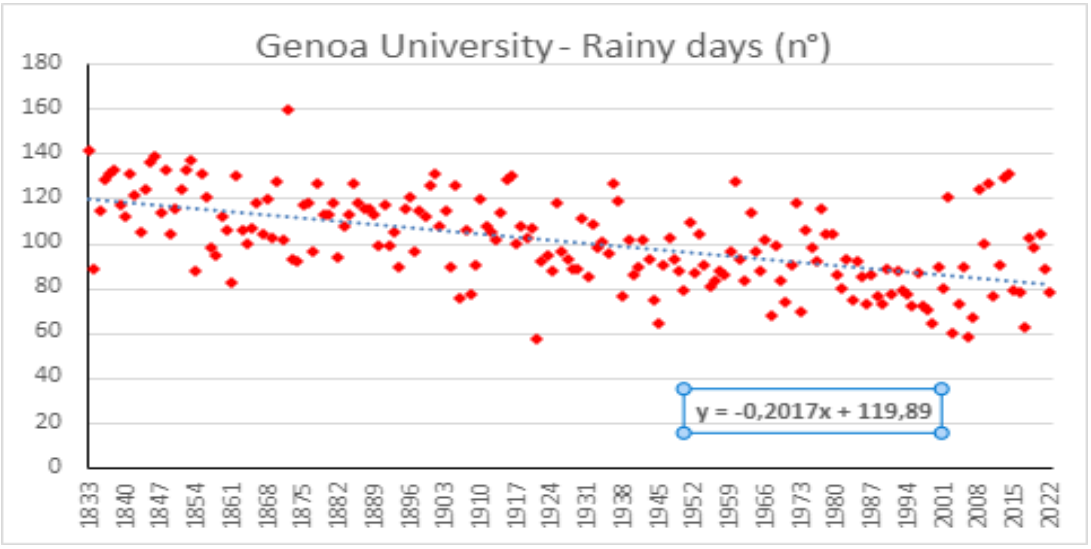


Fig. 21, This image shows the rainy days from the beginning of the meteorological station in 1833 until the observation of the decrease in 2022, Via Balbi Meteorological Station, (2022).

2.3.3 Rainfalls analysis

Focusing on rainfalls, the amount of rain in Liguria usually follows a historically increasing trend, proceeding from West to East and from the coast towards the interior of the region, even if the latter is less regular due to the action exerted by the complex orography on the air masses which determine and bring various types of precipitation,[234] sometimes more intense, sometimes scarcer depending on the year.

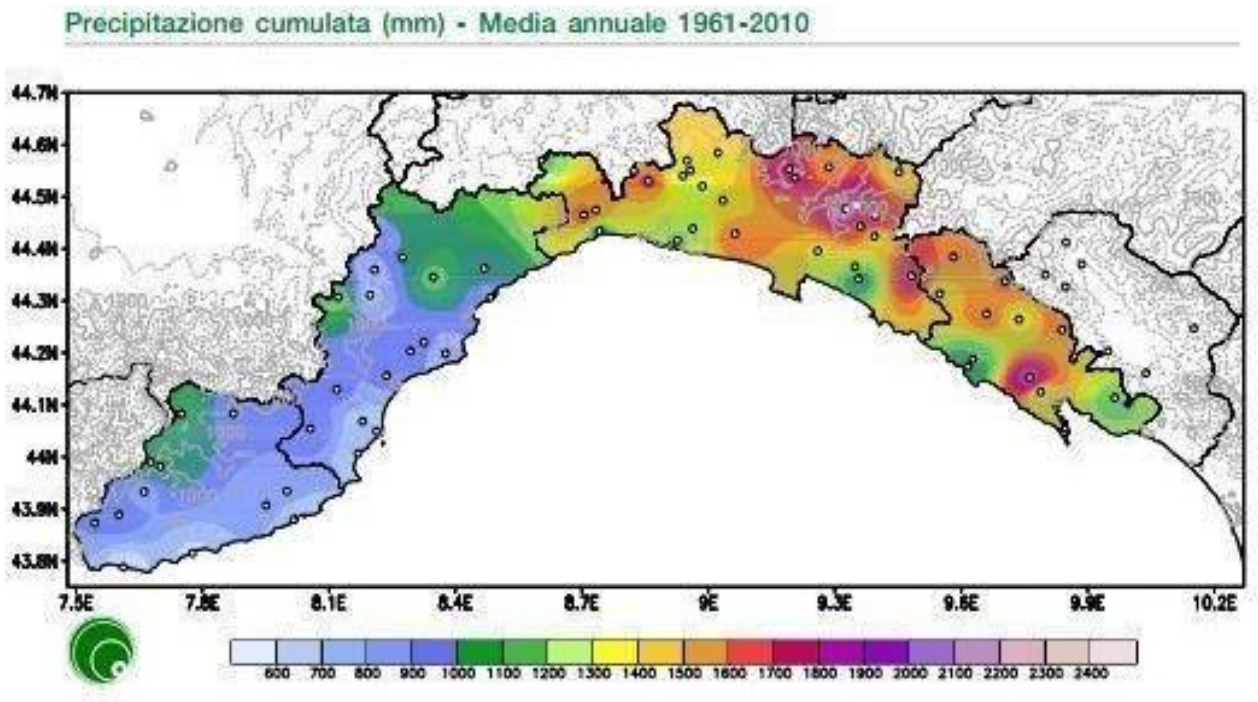


Fig. 22, Cumulative rainfall of the annual average in the period 1961-2010. Average pluviometry data elaborated by ARPAL, (2014).

The Metropolitan City of Genoa has the most diverse distribution of rainfall from 874 mm per year of the Sanctuary of the Madonna delle Grazie near Genova Voltri to 2233 mm[235] of Palazzuolo, in the upper Val d'Aveto: alongside the latter, Val Trebbia is another area

[234] *Ivi, p.2.*

[235] R. Pedemonte, Nimbus Rivista Ligure di Metereologia, (2005), *Analisi Climatiche: Distribuzione geografica delle precipitazioni annue III parte in provincia di Genova,* http://www.nimbus.it/liguria/rlm11/climatologia/stampa_clima_liguria.htm, [Last Accessed 7/02/2023].

affected by high yearly rainfalls. Moreover, as possible to see in the image the coastal areas with the total highest rainfall are in the northernmost part of the Riviera di Levante, in the province of Genoa, and the inland areas close to the latter are those that receive the largest annual quantity of the entire region. (Fig. 7)

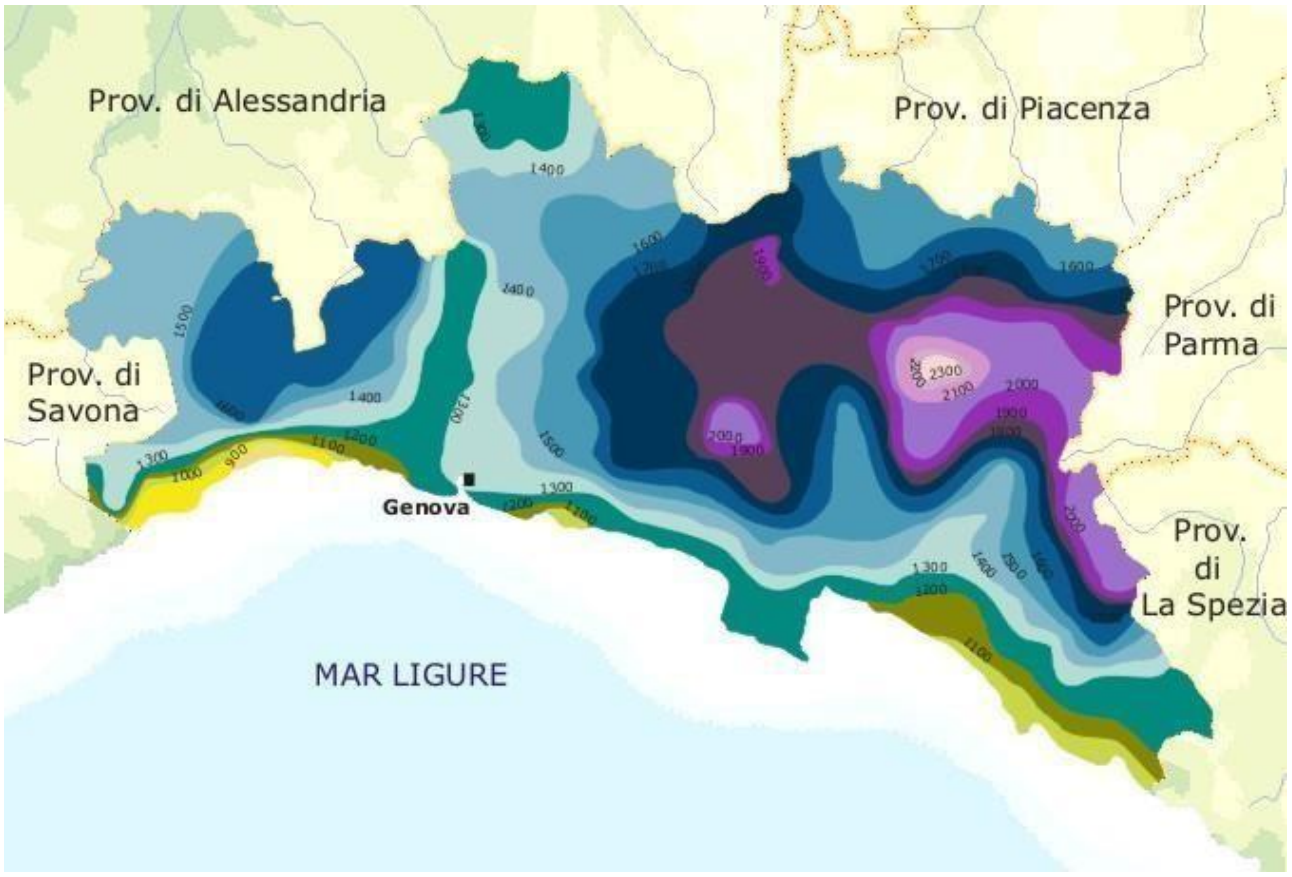


Fig. 23, Image that represents the geographical distribution of annual rainfall highlighting the situation of the Val Trebbia and Val d'Aveto as the rainiest in the province, Rivista Ligure di Metereologia, (2005).

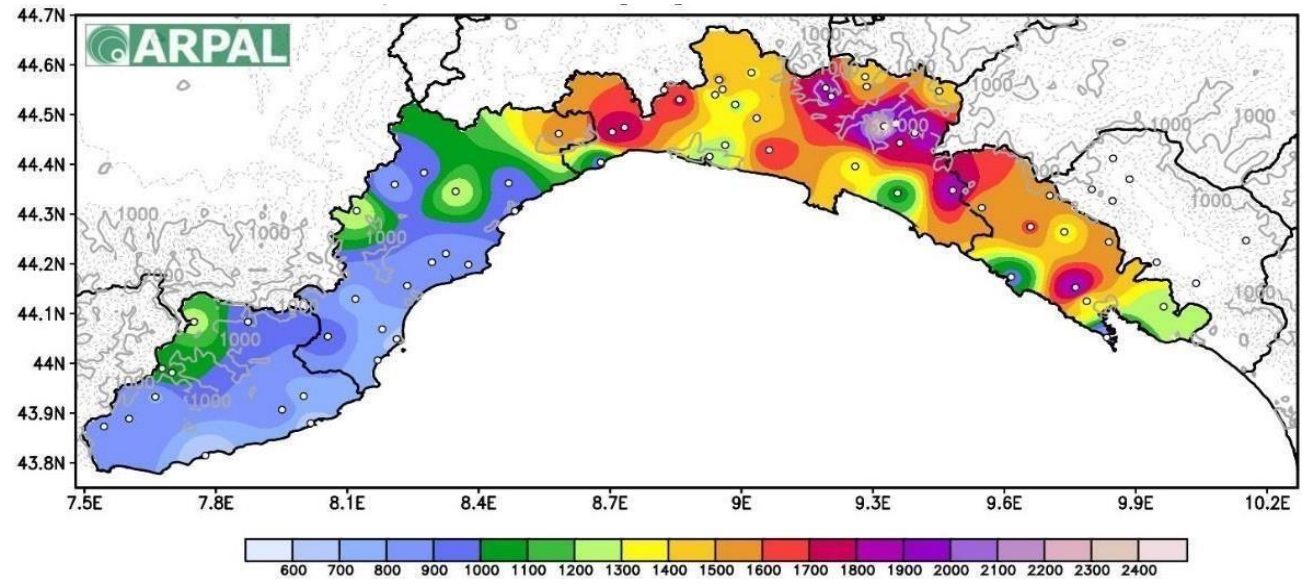


Fig. 24, Cumulative precipitation in millimetres, representation of the annual average of the 1981-2010 periods, ARPAL, Cenvis, Cima Foundation and Unige-Dad, (2014).

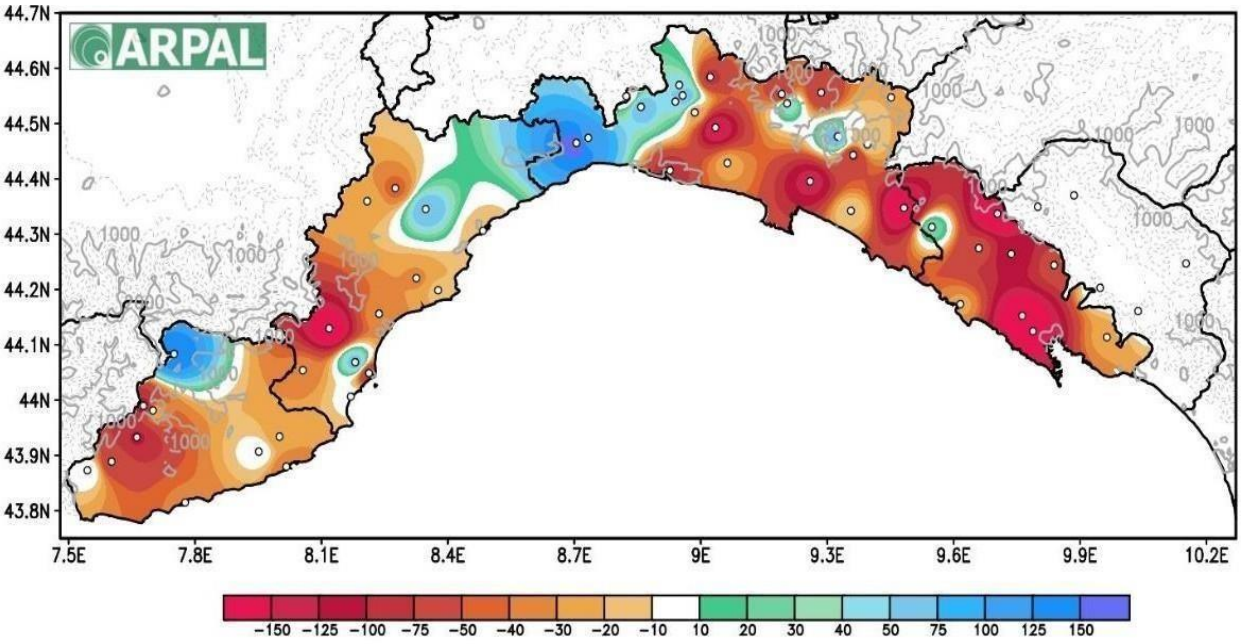


Fig. 25, Cumulative precipitation in millimetres with a variation of the annual average 1981-2010 compared to 1961-1990, ARPAL, Cenvis, Cima Foundation and Unige-Dad, (2014).

Overall, there is a historic variation of the annual cumulative precipitation with widespread decreases, approximately -10% more significant in the West with stable negative trends in the East, while considerable increases are found in the border area between the province of

Savona and Genoa (Campo Ligure, Masone) and part of the alpine area of the province of Imperia (Monesi di Triora, Mendatica).[236]

The interesting data analysis of rainfall of Liguria over the years 1961-2010 in which one emerges a change in the distribution of seasonal precipitation, while the annual rainfall does not experience other great changes. Indeed, autumn ones are increasing and in the rest of the year. From a historical point of view, this data analysis shows a particular trend of increase in rainfall which is limited to the first autumn period for the last thirty years, contrary to the remaining period of the year (of 8 months) which shows a reduction in rainfalls. Overall, in the entire typical Ligurian year, the increase and the decrease compensate for each other, highlighting annual quantities that are practically unchanged or slightly decreasing depending on the station. In the winter months of the thirty years 1961-1990, there was a decrease in rainfalls especially in the central-Western part, a trend that seems to have been confirmed in recent years as well. In the autumn months, on the other hand, there was an increase: therefore, over the course of the whole year, so until 2010 no big variations in the amount of rain have been observed compared to the past, but this was a limited view, given that the upheaval came with the year 2022 with a clear decrease in precipitation terms in four seasons, as we will see later. However, although for thirty years, from 1991 to 2019, it seems that the situation has been stable and perhaps even there has been a slight increase in rainfalls, the situation seems to have relapsed from 2020 onwards. In detail, here below are the differences in fallen rain between the various meteorological stations to explain the current situation. The coastal stations of Arenzano instead collect less than 1000 mm a year, while that of Mele and Fiorino, the latter placed respectively at 2.2 km and 4.8 km from the coast, add up between 1600 mm and 1650 mm[237] each year, thus highlighting that it is necessary to move further inland to have more rainfall and it is enough just to refer to popular wisdom without completely denying the said farmers to understand

[236] Cenvis, Cima Foundation, Unige-Dad, (2021), *Tendenze climatiche e scenari dei cambiamenti climatici in Liguria,* https://parconaturalealpiliguri.it/wp-content/uploads/2021/11/Formazione-CEA.scenari-e-impatti.pdf, [Last Accessed 7/02/2023].

[237] *Ibidem.*

that in the locality of Masone in fact, it rains about 1661 mm per year thus becoming the rainiest inhabited area in Liguria, as well as representing a geological border between the Alps and the Apennines. Continuing, once you have passed the Alpine and Apennine watershed and gone up again in the direction of the Po Valley, the amount of rainfall then undergoes a decrease. The synoptic situation favours the greatest rainfalls in areas where the low pressure that stabilizes on the Gulf of Genoa remains present both on the ground and at high altitudes. The coastal areas that totalize the highest rainfalls are in any case located in the northernmost part of the Riviera di Levante, still in the province of Genoa and concern the inland areas close to the latter which receive the largest annual quantity of the entire region of rains. Instead, the phenomenon of inversion of precipitation[238] could explain some isolated irregularities of precipitation in the Riviera di Ponente and especially in the Province of Imperia. These events, which do not occur in the central area of Liguria are of greater significance proceeding towards the extreme edges of the region and especially towards these areas where it was developed in a study by Dagnino, Flocchini and Palau in 1979. [239]

[238] *Ivi*, p.11.

[239] Dagnino, Flocchini, Palau (1979), *Inversione delle precipitazioni, Studio meteorologico basato sullo studio dei fattori meteorologici per identificare il processo di inversione delle precipitazioni, al fine di comprendere le situazioni di precipitazioni medie basse all'anno nell'estremo Ponente della Regione Liguria*, www.nimbus.it/liguria/rlm11/climatologia/stampa_clima_liguria.htm, [Last Accessed 7/02/2023].

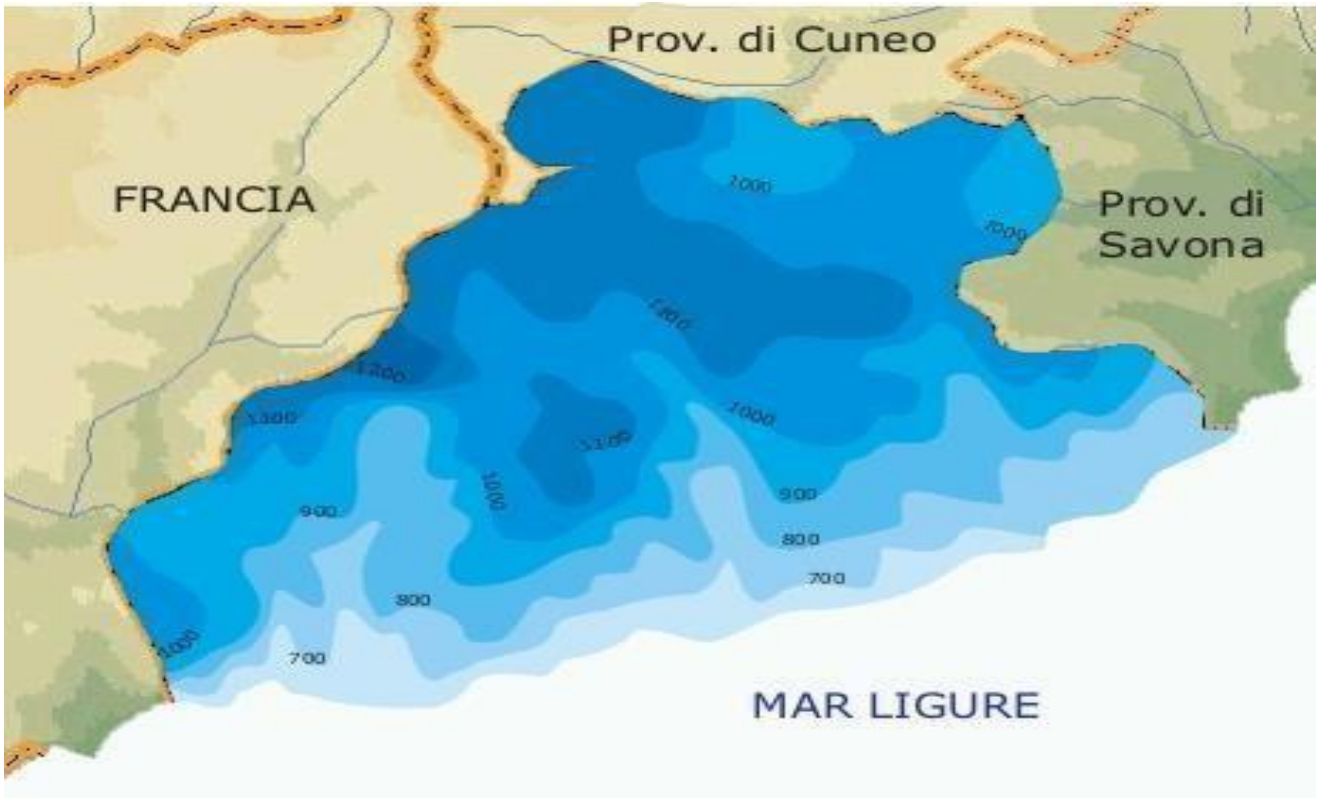


Fig. 26, Pluviometry data from the province of Imperia: on the coastal band the minimum values are measured, with annual totals that descend a little below 700 mm in the westernmost part, decreasing proceeding towards the French border. The least rainy location is Ventimiglia, with 671 mm, Rivista Ligure di Metereologia, (2005).

In this analysis, 7 out of 10 cases of precipitation inversion took place, the latter with the circulation of winds on the ground of northern origin combined with a situation of low pressure on the Ligurian Sea or the northern Tyrrhenian Sea and high pressure in the Po Valley. This combination of factors creates weak circulation at high altitudes and a lack of jet streams. Expanding the survey, it was possible to ascertain that these inversion phenomena are also found simultaneously in the south of France, on the western side of the Maritime Alps. This could explain the lack of consistent rainfall in the province of Imperia for most of the year due to this atmospheric condition which tends to repeat itself frequently.

2.4 The Drought of 2022-23

The Liguria Region in Italy faced 2022 a critical water situation, particularly in the Western areas, due to a lack of significant rainfall since the autumn of 2021.[240] The situation has been worsened by the summer season connected to higher temperatures and due to increased consumption during the tourist season and lower water flow rates in watercourses. To address this water scarcity, the Liguria Region has implemented measures to limit the use of water for non-potable and non-productive purposes. These measures included the prohibition of irrigation, watering gardens and lawns, washing courtyards and squares, washing motor vehicles, and filling private swimming pools, ornamental fountains, and garden tubs.

The Liguria Regin worked with the National Department and other regions to establish a national state of emergency 241, experiencing the maximum level of severity for the northern Apennines basin. These measures were necessary to prevent the situation from worsening and to avoid water rationing and inconveniences for residents and tourists in the summer months. Rainfalls in Liguria were significantly below average, and the levels of aquifers, primarily phreatic ones, decreased. The Brugneto reservoir, one of the main dams able to provide the biggest part of water to Genoa was the first lake that suffered water shortages. Local administrations emphasized the need to rethink actions in terms of soil protection andallocate funds to retain and utilize water effectively. Addressed chronic leaks in water pipesare also considered a significant issue that needs to be tackled. Overall, the Liguria Region took proactive measures to manage the water scarcity situation and sought collaboration with the national government and other regions to address the ongoing drought emergency.

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[240] Il Secolo XIX, (2022), *Siccità, la Regione Liguria ai Comuni: "Divieto di innaffiare giardini e prati, riempire piscine e lavare le auto". Le linee guida,* https://www.ilsecoloxix.it/liguria/2022/06/23/news/siccita-la-regione-liguria-ai-comuni-divieto-di-innaffiare-orti-e-giardini-riempire-piscine-e-lavare-le-auto-1.41532093, [Last Accessed 01/06/2023].

[241] *Ibidem.*

The desalination of seawater was considered in 2022[242] as a potential solution to address the water scarcity issue in Liguria. Utilizing seawater for various purposes was seen as a possibility worth exploring. However, the immediate focus was on implementing civil protection measures to tackle the situation. In any case, the feasibility of implementing desalination projects will depend on the timeframe and urgency of the need, as well as compatibility with other measures being implemented. It is suggested that desalination could be considered as a measure to be implemented by 2026, based on the National Recovery and Resilience Plan Securing these funds would greatly assist in addressing the water scarcity issue in the region. It was recognized also that the effects of climate change and the forecasts for future years make water management an ongoing and recurring challenge that will require sustained attention and investment. The water scarcity issue in 2022 was seen as a premonition that will require long-term efforts and planning to contrast the phenomena.

The water crisis of 2022 has been particularly significant for farmers in Liguria and Northern Italy in general. Such an emergency started in the winter of 2022 and by mid-2023 the situation has not improved, and many rivers and reservoirs are missing substantial volumes of water. It is the case of the Trebbia River[243], between Liguria and Emilia-Romagna and of many artificial lakes in Northern Piedmont and Lombardy.[244] Given this situation, it is expected that 2023 will be worse than the previous one.

[242] *Ibidem.*

[243] Local Team, (2023), *Meteo in diretta: (Video) Piacenza, il fiume Trebbia asciutto come d'estate, le immagini drammatiche*, https://www.ilmeteo.it/news/meteo-cronaca-diretta-video-piacenza- the-river-trebbia-dry-as-in-summer-the-dramatic-images-150248, [Last Accessed 27/02/2023].

[244] M. Evangelisti, (2023), *Siccità, cosa sta succedendo, laghie fiumi: è già un'emergenza. Centrali elettriche a rischio di arresto,* https://www.ilmessaggero.it/italia/siccita_cosa_sta_succedendo_davvero_fiumi_laghi_caldo_anomali_centrali_elettrici-7247255.html, [Last Accessed 27/02/2023].

2.4.1 Economic losses

For 2022 Coldiretti (National Farmers Organization) has estimated about 332,000 agricultural companies affected by drought with an amount of damage that exceeds 3 billion euros,[245] affecting circa 11% of Italian farms. According to Coldiretti,[246] 2022 is confirmed to be the worst year from a climatic point of view, between drought and bad weather since the total estimate of losses is around 6 billion euros, equal to 10% of national production, the highest for twenty years. The Council for Research and Agriculture, which was responsible for developing an analysis following this situation for the Italian agricultural economy, then stated that the reduction in Italian agricultural activity, due to the drought phenomenon in 2022, represents about 1/3 of the national total of production. The percentages show a considerable increase in prices at the national level due to damage to crops and livestock due to the water crisis not counting the 100% increase in diesel, for the transport of products. Some sectors of production are just jumped the production of summer fruit such as watermelon, but also corn and soybeans have dropped by 30% or 40%, as they need large quantities of water for irrigation. [247] According to ANSA on 28 July 2022,[248] Ligurian agricultural production, even if very limited, had dropped by 1/3 compared to the average of the period; also, olive and basil production suffered this crisis, which represents the

[245] Verità & Affari 2022, *I danni della siccità regione per regione: ecco come il caldo ha distrutto l'agricoltura,* https://www.veritaeaffari.it/cronaca/danni-siccita-regione-italia-agricoltura-17-luglio-2022/, [Last Accessed 27/02/2023].

[246] Coldiretti, (2022), *Maltempo: è previsto contro la siccità ma provoca danni,* https://www.coldiretti.it/meteo_clima/maltempo-e-atteso-against-la-siccita-ma-causa-danni, [Last Accessed 27/02/2023].

[247] *Ibidem.*

[248] ANSA Liguria, (2022), *Siccità: Coldiretti, in Liguria produzione foraggera in calo di 1/3,* https://www.ansa.it/liguria/notizie/2022/07/28/siccitacoldiretti-in-liguria-production-forage -fall-of-1/3.html, [Last Accessed 27/02/2023].

leading sectors of Ligurian agriculture. The plants, with evident water stress, have begun to suffer intensely in the summer period because of their need for increasing and continuous irrigation. The same thing happened for 2023 during the winter period when there were few rainfalls, and the first months of 2023 were alarming from a water point of view. The rainfall levels in Liguria during the December-February period have been significantly below historical averages.[249] Only the province of Imperia has seen rainfall levels comparable to the historical average, while the provinces of Savona, Genoa, and La Spezia have experienced lower levels. Climatologists have classified the province of Genoa as "dry," while Savona and La Spezia are considered "moderately dry".[250] The situation regarding water supply in Liguria is however today not critical but not yet alarming according to IREN[251], the company responsible for managing the reservoirs and aquifers that supply the region's capital. There has been a decrease in available water compared to previous years and the issue of reusing purified water for non-sanitary purposes remains open, and investments are being made to improve infrastructure, especially in western Liguria. The Regional Government has passed specific laws and approved guidelines for water management, and infrastructure works are planned with funding from the National Recovery and Resilience Plan (PNRR) and the government. The Liguria Region has moreover requested for this year the acceleration of the approval process for PNRR funds, particularly for water infrastructure projects, including the Roja and Ponente wells. In summary, Liguria is experiencing below-average rainfall levels, for the city of Genoa[252], leading to water scarcity and increased water costs for the population.

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[249] A. Palmesino, S. Pedemonte, (2023), *Liguria, siccità da record nei primi due mesi del 2023*,https://www.ilsecoloxix.it/liguria/2023/03/09/news/liguria_siccita_record_primi_due_mesi_2023_acqua_tariffe_crescita_del_25_genova-12683606/, [Last Accessed 01/06/2023].

[250] *Ibidem.*

[251] *Ibidem.*

[252] F. Acquaotta, F. Facchini, S. Fratianni, G. Paliaga, A. Sacchini, (2018), *Internsità delle precipitazioni nell'area metropolitana di Genova: variazioni e conseguenze,* https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/wea.3208, pp.1-5, [Last Accessed 01/06/2023].

Even if efforts are being made to improve water infrastructure and management, the effects of the drought of 2023 are evident in various sectors but first in agriculture.

2.5 Future Implications and Forecast

A group of experts funded by the European Union have analyzed the continent's history of drought phenomena to draw up a series of forecasts of future dangers. This initiative has led to the creation of a database on the consequences of drought, as well as a Europe risk vulnerability map, to develop solutions for the efficient management of the emergency. [253] The history of Europe testifies to its past various scenarios of widespread drought, in addition to a gradual tendency to dry up the soil in its southern areas and beyond, as visible from the satellite images previously shown[254] These phenomena have had a profound impact on agriculture, fires and water availability. The EU-funded DROUGHT-R&SPI project sought to identify possible future trends in drought emergencies to reduce vulnerability. The results led to the creation of a database including events up to 2009 in addition to information from indirect data[255] stored between 1500 and 1950. The study underlined a growth of drought phenomena in southern European countries such as Italy and Greece. The research has also shown that the sector most at risk in Europe is agriculture[256]. Food Insecurity will be a possibility deriving from droughts; it significantly impacts agricultural production leading to food shortages and increased food prices.

[253] European Commission, Cordis Executive Summary - DROUGHT-R&SPI, *Promuovere la ricerca europea sulla siccità e l'interfaccia tra scienza e politica,* (2015), https://cordis.europa.eu/project/id/282769/reporting, [Last Accessed 27/02/2023].

[254] *Ivi*, Chapter 1.

[255] *Ibidem.*

[256] European Union, Agriculture (2017*), Zone rurali dinamiche e prodotti agricoli di qualità*, https://european-unioNeuropa.eu/priorities-and-actions/actions-topic/agriculture_it, [Last Accessed 27/02/2023].

Vulnerable populations, such as the poor and marginalized communities, are often the most affected by these variations. The study has also underlined that it is not yet possible to have today a universal drought index is for forecasting events in this sense.

2.5.1 Projections of Drought

According to Baronetti et al. (2021), droughts during the rainy seasons have a significant impact on agriculture and the economy, requiring a massive use of surface water and groundwater to counteract the impact, as happens in the northwestern Italian regions. [257] In Northern Italy, the total runoff of ice surfaces is expected to decrease significantly over the next thirty years and the total decrease is expected by the end of the twenty-first century. As for the trends or possible future scenarios, considering the possible short, medium, and long-term impacts of climate change on the hydrological cycle and in particular on the availability of water resources, the situation that emerges from an assessment carried out by ISPRA[258] underlines a potential future critical situation. In fact, from a first analysis conducted by this agency[259], it is expected that due to climate change, there may be a reduction in availability at the national level of water resources of about 10% in the short-term projection if an aggressive mitigation approach is adopted in reducing greenhouse gas emissions, as shown by the IPCC RCP 2.6 scenario.[260] In the long-term projection of the IPCC RCP 8.5 scenario, it is estimated that the loss of water availability will reach up to 40% with

[257] A. Baronetti, V. Dubreuil, A. Provenzale, S. Fratianni, (2021), *Siccità future nell'Italia settentrionale: proiezioni ad alta risoluzione con insiemi EURO-CORDEX e MED-CORDEX*, [Last Accessed 03/03/2023].

[258] ISPRA, higher institute for environmental protection and research, national system for environmental protection, (2021), *Report sugli indicatori di impatto dei cambiamenti climatici. Edizione 2021*, https://www.snpambiente.it/2021/06/30/rapporto-sugli-indicatori-di-associazione-dei-cambiamenti-climatici-edizione-2021/, [Last Accessed 28/02/2023].

[259] *Ibidem.*

[260] A. Baronetti, V. Dubreuil, A. Provenzale, S. Fratianni, (2021), *Siccità future nell'Italia settentrionale: proiezioni ad alta risoluzione con insiemi EURO-CORDEX e MED-CORDEX*, [Last Accessed 03/03/2023].

peaks of 90% for southern Italy,[261] assuming however that the growth of greenhouse gas emissions maintains the current rhythms, without reductions in terms of emissions. Also, thanks to the work of the CIMA Foundation, in detail here we see the situation in the Liguria Region: in these future scenarios, for the climate scenario IPCC RCP 8.5, in the medium term (2038-2068) temperatures could undergo a further increase of about +2°C, with peaks of + 2.5°C in mountainous areas, especially in winter. It is also expected a decrease in days with minimum temperature in the same areas with about - 45 days per year. The precipitations in the Riviera di Ponente will continue the trend of decrease with critical decreases in summer while for precipitation in the Riviera di Levante, the situation will instead be more complex in winter, given that there will be possible increased precipitations in Beigua Geological Park and Val d'Aveto. The intensity of extreme precipitation will however increase by 15% compared to the past throughout Eastern Liguria and around La Spezia the days of rainfall above 20 mm will also increase.[262] In conclusion, the drought will continue with the increase of rain-free days throughout the territory, with larger increases on the coasts for about 24 more days per year.

From 2071 to 2100, considering it a period of distant and long-term projection, in the different scenarios[263] there will be a rapid change in the climate typical of this area of Northern Italy. Climatically, however, the Liguria region is not excluded from this situation: although the Apennine reliefs will mitigate this drying up for the near future, the scenarios[264] indicate that the Alpine chain will be significantly affected by global warming and the Apennine chain consequently. The eastern Ligurian Alps, in fact, already have

[261] V. Radić, A. Bliss, A. Beedlow, (2014), *Proiezioni regionali e globali dei cambiamenti di massa dei ghiacciai del ventunesimo secolo in risposta agli scenari climatici dei modelli climatici globali*, https://doi.org/10.1007/s00382-013-1719-7, Volume 42, pp. 37–58, [Last Accessed 04/12/2022].

[262] Cenvis, Cima Foundation, Unige-Dad, (2021), *Tendenze climatiche e scenari dei cambiamenti climatici in Liguria*, https://parconaturalealpiliguri.it/wp-content/uploads/2021/11/Formazione-CEA.scenari-e-impatti.pdf, [Last Accessed 28/02/2023].

[263] N Zimmermann, E. Gebetsroither, J. Zuger, et al (2013) *Clima futuro delle Alpi europee e strategie di gestione per adattare le foreste spaziali alpine ai rischi dei cambiamenti climatici*, In Tech, Rijeka, Croatia, pp. 27–36. https://doi.org/10.5772/56278, [Last Accessed 28/02/2023].

[264] *Ibidem.*

rather worrying rainfall anomalies. The anomalies for the future period mentioned above will lead to a possible stabilization between 4°C and 6°C, preventing the formation of perennial snows and glaciers, while the thermal anomalies along the Ligurian coast could exceed 3°C. As for the forecast for future rainfall, the portion of the Alps expected to record an increase in precipitation of about 40 mm will be in the area of the Corniche and Julian Alps, while the western Alps will be affected by a decrease in precipitation opposite, with an anomaly of -40 mm, with the intensification of this trend to -80 mm in the western Alps, by the scenario defined IPCC RCP 8.5.

In the period 2001-2050, the forecasts for Liguria and the surrounding areas will then foresee an increase of 20% in extreme droughts based on the IPCC RCP 8.5 scenario, with an average of 5 to 8 extreme drought events. The comparison of the characteristics of the future drought with the reference period of 1971-2000 shows that the events appear to be increasing because they are linked to a higher-than-normal evaporative demand and this is presumably linked to significant increases in temperature observed by Acquaotta in 2015[265] for the period 1961-2010, especially in Piedmont.

Also, for Northern Italy, similar results were obtained for the near future, in the 2000-2050 range, by Marcos Garcia in 2017[266], who suggested that the increase in global temperature will play the most important role in future drought episodes in the first half of this century. Identifying the real trends of this study[267] it will be possible to see the entire Alpine arc characterized by greater rainfall despite the increase of drought in the IPCC RCP 4.5 scenario, correlated with an increase of more than 2°C in global temperature. This scenario

[265] F. Acquaotta , S. Fratianni, D. Garzena, (2015), *Variazioni di temperatura nelle Alpi italiane nord-occidentali dal 1961 al 2010*, https://doi.org/10.1007/s00704-014-1316-7, [Last Accessed 28/02/2023].

[266] P. Marcos-Garcia, A. Lopez-Nicolas, M. Pulido-Velazquez, (2017), *Uso combinato di index relativi alla siccità per analizzare l'impatto dei cambiamenti climatici sulla siccità meteorologica e idrologica in un bacino del Mediterraneo*, Volume 554, pp. 292-305, https://doi.org/10.1016/jjhydrol201709028, [Last Accessed 26/02/2023].

[267] A. Baronetti, V. Dubreuil, A. Provenzale, S. Fratianni, (2021), *Siccità future nell'Italia settentrionale: proiezioni ad alta risoluzione con insiemi EURO-CORDEX e MED-CORDEX*, [Last Accessed 03/03/2023].

provided it is more limited to the previous one for the future period, would still lead to substantial degradation of the permanent ice, affecting the quality of surface water, erosion, and slope instability, as defined by Colombo in 2019.[268] An extremely long climate change of this kind could begin with evidence, precisely starting from a climatically tragic year like 2022. If this theory is correct, consecutive long droughts will occur with a significant widespread reduction in crop yield, as defined by Raymond in 2019 in Northern Italy.[269] The explanation for this prediction lies in the fact that due to the influence of the North Atlantic oscillation and the Mediterranean oscillation index[270], associated with the propagation gradient North-South resulting from the study of Baronetti[271] in 2020. These events will be able to rationalize a future with the extended decrease in precipitation for the last decades of the century. Concluding, to explain better these results and forecasts discussed, the spatial markers inserted in the plain-coloured histograms represent the SPEI and SPI indexes results and outcomes. These are the combination of Regional Climate Modeling (RCM)[272] and General Models of Circulation (GMC). The Regional climate modelling (RCM)[273] is based on the output of GCM simulations, providing a high level of fidelity between the synoptic scale of GCM fields and the associated mesoscale resolution fields

[268] N. Colombo, (2019*), Influenza del permafrost, dei ghiacciai rocciosi e ghiacciati sulla chimica degli stagni di alta quota (Alpi italiane nord-occidentali)*, https://doi.org/10. 1016/jscitotenv201906233, [Last Accessed 28/02/2023].

[269] F. Raymond, A. Ullmann, Y. Tramblay, P. Drobinski, P. Camberlin, (2019), *Evoluzione dei periodi di siccità estrema mediterranea durante la stagione delle piogge sotto i cambiamenti climatici, il cambiamento ambientale regionale*, pp. 1-13, https:// doi.org/10.1007/s10113-019-01526-3, [Last Accessed 28/02/2023].

[270] F. Zavatti, (2017), *Il MOI, Mediterranean Oscillation Index*, http://www.climatemonitor.it/?p=45748, [Last Accessed 28/02/2023].

[271] A. Baronetti, J. González-Hidalgo, S. Vicente-Serrano, F. Acquaotta, S. Fratianni, (2020), *Una distribuzione spazio-temporale settimanale degli eventi di siccità sulla Pianura Padana (Nord Italia) negli ultimi cinquant'anni*, https://doi.org/10.1002/joc6467, [Last Accessed 28/02/2023].

[272] C. Teutschbein, J. Seibert, (2012), *Correzione della distorsione delle simulazioni dei modelli climatici regionali per il clima idrologico studi sull'impatto del cambiamento: revisione e valutazione dei diversi metodi*, https:// doi.org/10.1016/jjhydrol201205052, Journal of Hydrolology, 456– 457, pp. 12–29, [Last Accessed 01/03/2023].

[273] *Ibidem*.

simulated by the RCM. GMCs are mathematical models capable of representing physical processes of the atmosphere and ocean to simulate the response of global climate to the increasing greenhouse gas emission[274]**.** The figure reports the total number of increasing events, the percentage of affected areas of North Italy and the duration of the drought events for each 30 years scenario considered. The evidence is the increasing levels of the phenomena.

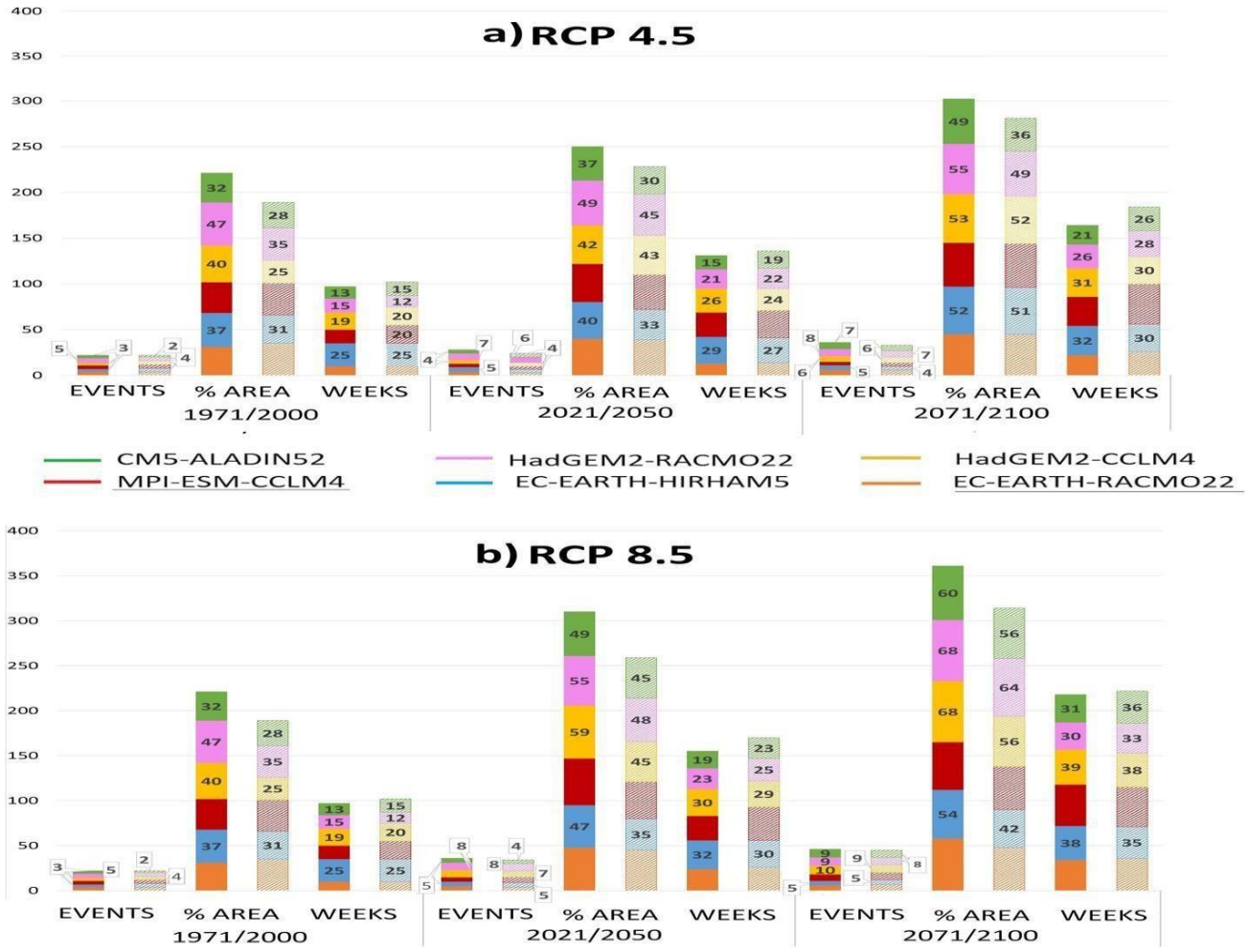


Fig. 27, Number of consecutive drought weeks expected for the baseline (1971–2000), near (2021–2050), and far future (2071–2100). The plain-coloured histogram represents 12-month SPEI results and line patterns indicate 12-month SPI results. [275]

[274] IPCC, 2022: Summary for Policymakers, H. Pörtner, D. Roberts, E. Poloczanska, *Climate change 2022: impacts, adaptation, and vulnerability. Contribution of the Working Group, Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Working Group II Technical Support Unit, Chapter 4, p.551.

Chapter 3

The perspective of experts and local administrators

The reality of drought in Liguria in 2023 is today a particular situation: we have seen large heavy rains in short periods that occurred in past years that have worried the local population given the extent of the phenomenon, today something has changed. The winter situation in early 2023 was different as the usual flood events never took place; for what concern Liguria it is not predictable whether the drought will stop or will continue in the next months and years. In this chapter, it will be fundamental to understand if water experts and meteorologists will be able to give a partial explanation of what is happening to understand the world around us. The various stakeholders interviewed, the technical experts and the local administrators of Val Trebbia share that the period 2022-2023 has been unusual. The focus on Val Trebbia is also extremely interesting since the area is one of the rainiest areas in the entire Liguria Region. It is necessary, therefore, to explain why in such an area, there is today concern about the absence of water and how all this has come about. After all the scientific data of the previous chapters, it is also right to talk about human perception of seasonality and climate or an aspect that has always distinguished Ligurian popular culture.

[275] A. Baronetti, V. Dubreuil, A. Provenzale, S. Fratianni, (2022), *Siccità future nell'Italia settentrionale: proiezioni ad alta risoluzione con insiemi EURO-CORDEX e MED-CORDEX,* https://www.researchgate.net/publication/361014193_Future_droughts_in_northern_Italy_high-resolution_projections_using_EURO-CORDEX_and_MED-CORDEX_ensembles, 172, Chapters 3-4, p.12., [Last Accessed 19/02/2023].

3.1 Opinions and Thoughts of the Expert

Renzo Rosso[276] is a full professor of hydrology and hydraulic construction at Politecnico di Milano and dean of the water science and engineering section. The commitment of the professor related to drought and the enhancement of a fundamental resource such as water was recently published in a book in which he collaborated, "Gli stati generali dell'acqua", blaming human unawareness in a more global perspective on the phenomena of consumption of the resource; in fact, in the preface Rosso argues: "We listen to dry rivers waiting for it to rain, we fear storms, melting glaciers and rising seas, and meanwhile we absentmindedly open the taps of our homes, consume billions of bottles of mineral water, ignore where water comes from, what underground roads it crosses, how it regenerates and flows, the way it is distributed, wasted, polluted, violated, sold, made a commodity in a world increasingly thirsty and wounded by intolerable inequalities". [277]

Indeed, in the twenty-first century, water is one of the most serious and urgent issues to deal with given that about two billion people in the world do not have safe access to drinking water and about 1.7 billion[278] do not even have basic sanitation. In poor countries, talking about a water emergency is also an oxymoron, since the issue is permanent, effective, and absolute. Last summer, however, laid bare the growing vulnerability of advanced areas of the planet, such as California and northern Italy.

On the other hand, mitigating drought risk requires a medium and long-term vision that politics and economics, media narrative and civil society lack. About Italy and the Liguria region, Rosso argues that in addition to hydrogeological instability, more attention should be given to events like the drought: at the end of January, the water equivalent of the Lombard snowpack was less than half of the recent historical average, as well as the volume

[276] The interview took place on 16th March 2023 in Genoa.

[277] R. Rosso, D. Padoan, Gli stati generali dell'acqua, https://www.castelvecchieditore.com/prodotto/gli-stati-generali-dellacqua/, [Last Accessed 03/06/2023].

[278] *Ibidem.*

of the pre-Alpine lakes and the dams, less affected by the prolonged dry period, still occupied only 70% of the norm. The situation in Piedmont was already critical, indeed the pluvial and snow deficit was even heavier. Therefore, water scenarios like those observed in 2022 cannot be excluded, at least for North-Western Italy in the future. It is not possible to resume the causes just talking of a question of climate change: the deficit of reservoir capacity linked to the lack of planning of storage works, and the absence of sustainable balances between food and energy related to groundwater pollution are just some of the causes.

From a historical point of view, to better analyze the relationship between water and the Liguria Region, Professor Bobbio[279] a university professor at the Department of Architecture and Design of the University of Genoa argues that the relationship that exists between Liguria and in particular its capital or the city of Genoa with water has lasted for centuries from the urban point of view and is however a historical tradition because the land available has always been limited and pending, therefore, it has always been very difficult to carry out public works.

The whole historical centre of the city is built in this way, so it is no coincidence that the consequent water problems have always existed in the past since the streets were built on pre-existing streams. Another concrete example of invasive urbanization due to a harsh territory is the Cinque Terre area: in the old photos of Riomaggiore, but above all in the maps of the area dating back to the pre-industrial period streams are not covered by roads and concrete. In the capital of Liguria, the urban expansion was uncontrolled since the 60s and 70s, coming to build over real streams with buildings and streets, often burying historic waterways in the centres of the villages and medieval settlements outside the city of Genoa.

Particularly significant is the case of Sestri Ponente: the stream Chiaravagna was subject in the 50s to the construction of buildings above its riverbed. The Chiaravagna then flooded

[279] The interview took place on 15th March 2023 in Genoa.

successively on several occasions including the last event of 2010. A specific building has been successively demolished.

These buildings and structures created did not make for a sustainable relationship between waterways and cities. In recent years several works were promoted, including the widening of the flow section of the Bisagno, considered .it was strategic for national security. These topics are connected to the drought. In 2022 it was exceptional, both during the winter period and during the summer months but even if the phenomenon no longer leads to the flooding of watercourses, it generates the opposite problem. Dry soil is not good for anything and anyone. Even if Professor Bobbio didn't consider himself an expert from the climate point of view, he said that it must be considered a fact that this drought could become somehow structural and not occasional. In that case, it will be necessary to pay close attention to our situation: now, there isn't the presence of a real strategy available to act, given that we have now completely lost contact with some portions of the territory regarding the water system, since today water from aqueducts is principally used for massive irrigation of crops, no longer using local tanks. The water today arrives in the countryside from far without real proximity management that has now been lost; it is too late to talk today about efficiency, but it's necessary.

3.1.1 The Drought of 2022-23

To explain the Ligurian drought of 2022-23 it is possible to deduce from the data available of the last 18-year period from 2005 to 2022 and compared them with the period 1961-1990 which shows unexpected respect to the common thought, that most stations recorded higher annual precipitation, but several factors need to be considered. These data were provided by Roberto Pedemonte and Massimo Riso[280] two experts that have been monitoring the Ligurian climate for years and periodically updating the Ligurian Journal of Meteorology.

[280] The interview took place on 20th March 2023 in Genoa.

Many of the data published by them have been used for this research work as they represent one of the most reliable sources for the analysis of climatic variations in Liguria.

Today's rainfalls are rarer and more intense than in the past but moreover, there were no stations of the latter period twenty years ago; therefore, many are new, but we have included in our data only those that have a real and reliable comparison with previous data. Even the administration of the weather stations has changed: it is necessary to consider that for stations of the past, even if they were managed by the national hydrographic service, the interventions were entrusted to various local figures such as parish priests and non-expert farmers who could therefore provide incorrect data, whereas today they have been completely automated. The hottest and the driest confirmed years in Liguria at the annual level were, even if there were ups and downs in trends, the years 2017 and 2022.

It's pivotal to consider this last set of data to be very reliable, assuming that there have been no and too many shortcomings. The interesting fact, however, is that the two Genoese stations of the University of Via Balbi and the one located in the Foce district and managed by the ARPAL agency have confirmed a concrete decrease in rainfalls compared to the period 1961-1990, while others stations on the regional territory have not reported anomalies of this type. The pluviometry monitoring concerning Genoa is indeed below 10% deficit: even if the causes of this localized anomaly are not clear, the city of Genoa, for a little part, negatively influenced the drought alarmism of 2022. Probably it exists for the city pluviometry wave given by the direction of the winds that have triggered this deficit for years, but further studies are needed, there is always partly true and so much alarmism, but looking at the data present here, it's possible to assert that in Liguria drought exists only in a reduced form.

- Meteorological Station of Genoa Via Balbi, Period 1961-1990, recorded annually about 1340 mm of rain against 959mm in the period 2005-2022.

- Genoa Meteorological Station of the ARPAL Functional Center, Period 1961-1990, recorded annually 1262mm against 982mm in the period 2005-2022.

Fig. 28, Comparison of two meteorological stations of Genoa provided by the analysis developed by Roberto Pedemonte. The big difference between the period 1961-1990 and the period 2005-2022 is the anomaly of the rainfall deficit in the city of Genoa, highlighted as about -10%.

In addition to the work of these two experts, one of the fundamental personal communications was moreover provided by Ulderica Parodi[281], currently an experienced and technical administrative employee of the Liguria region. What came from this communication was that generally, the opinion regarding the drought in the first months of 2023 in Liguria is confirmed as negative: to evaluate the situation in Liguria in 2023 it's necessary to observe the data and there's a very serious phase, worse than last year, because, from a hydrological point of view, the trend of March and April was like that of June 2022, some months in advance.

It is hoped for spring rains, but due to nearby dry years, there is no real possibility of recovering the reservoirs up to normal levels of availability. Indeed, in the months of May and June 2023, the situation fortunately remained in the rainfall average, as a large part of the experts hoped but all this does not seem to mark a reversal of trend, nor to have resolved the situation, but only certainly raised some problems. Liguria's region will therefore face the summer with fewer resources than last year. The most critical situation at the regional level is greater in the part of Imperia and Savona since they do not have reservoirs to mitigate water recharge scarcity; however, it is not possible to make up for the shortages with coastal aquifers because they are now subject to salt intrusion and therefore non-

[281] The interview took place on 24th March 2023 in Genoa.

potable water, as in the Andora's area. The only palliative solution adopted so far has been that of tankers in the summer of 2022.

It's important to analyze the role of the salt intrusion and how it aggravates drought in these provinces: in past years, the biggest mistake has been to continue drilling the land to find new aquifers in these areas to exploit them, but no serious budget assessment has ever been made, leading in recent decades to a rapid intrusion of saline water in areas with a high tourist vocation that suffers in summer overexploitation of groundwater. The water of the aquifer, notoriously lighter, is "crushed" by the more thought and saline seawater that leads to a new hydrostatic balance no longer mitigated by the pressure of fresh water, increasing the salt wedge that carries sea water for several kilometres in the valleys. In addition, because of its return, fresh water is no longer drinkable since the salts remain impregnated in the soil for years, causing serious decreases in quality.

The limitation of consumption cannot be a simple solution for the short term: from the cultural point of view in the areas in question and more generally in the temperate zones, water is assumed as an infinite resource and only raising awareness of climate change or more specifically of a more sustainable life could avoid in future years a reality made of a persistent scarcity.

3.1.2 Implications of climate change and global warming

Related to the widespread topic of climate change it was possible to explain through the experts that today the Ligurian climate is warmer, consequently, there is less, short, and more intense rainfall. It is not said, however, that this change is part of global warming, still controversial and that needs further study, but it could also be only part of a temporary period. Massimo Riso developed an observatory on global warming on his website. Precisely it's not still today clear if the local climate of Liguria is suffering from global effects; however, the temperature worldwide is having unexpected ups and downs in the last year and not exclusively due to global warming according to his studies. Even if the topic is political, further studies are necessary to understand better the real phenomena. However,

in Liguria surely regional periods of intense and prolonged rainfall occurred around the 1970s when the temperatures were much colder, and it was common to observe rainfall peaks above 80-100mm per day. From the graphs it is then possible to see the current negative trend for two years; however, there have been positive changes for considerable rainfalls from 2005 to today found thanks to the average of all the stations considered, even if for 2023 the precipitation trend is evidently in a sharp negative decline at the regional level. The main question in the current situation is the idea connected to the role of several future water crises for this summer. We need to bear in mind that droughts have always existed and therefore the situation could stabilize as early as next year; however, today's intensive water use once did not exist and the effects were very different. The evolution of society in terms of water has led us to be more vulnerable; in addition, there's the fact there here are huge percentages of losses for Italian aqueducts. It can therefore be concluded that it is precisely by analyzing the comparisons on precipitation that at least for our region in some areas it rains even more, but the human and natural factors mentioned here critically reduce water availability and consequently increase the impact of drought.

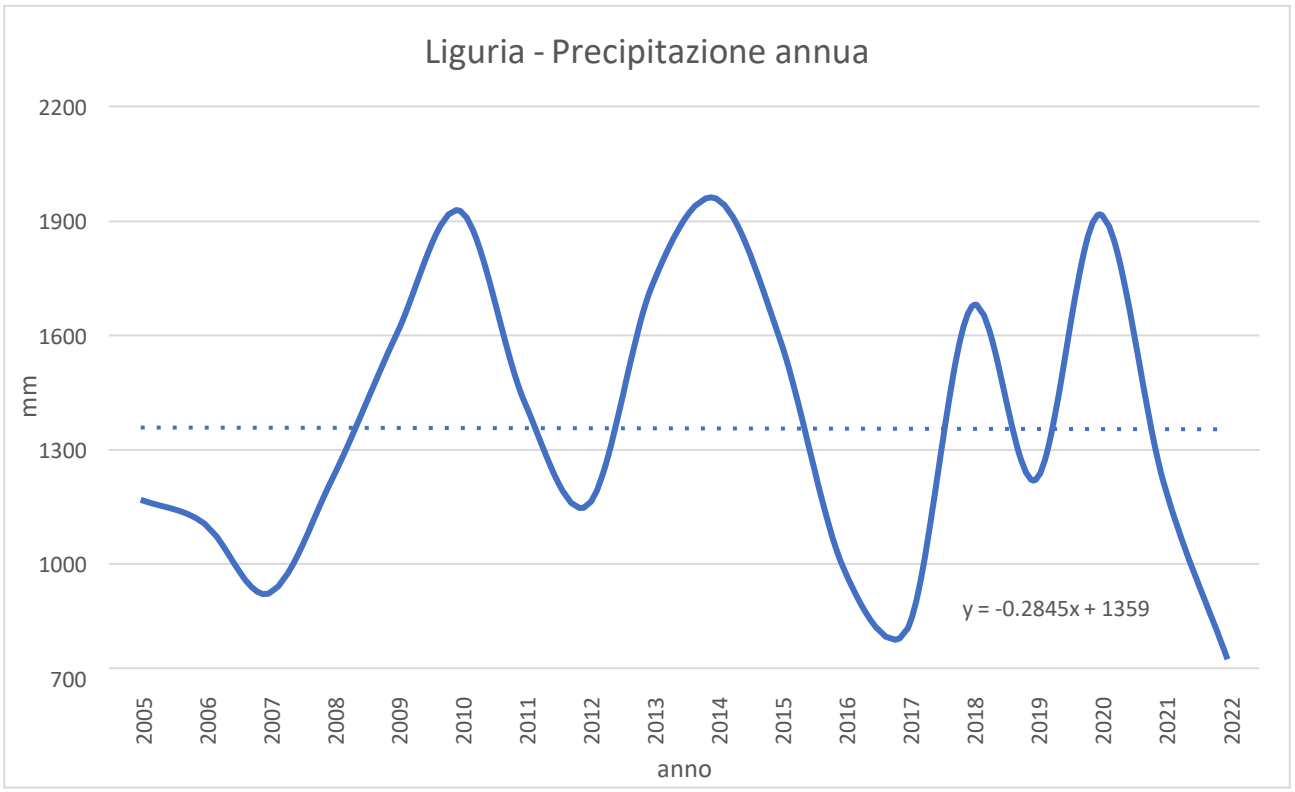


Fig. 29, Image developed by Massimo Riso to evaluate the trend of annual rainfall for the period 2005-2022 in Liguria. It is possible to notice ups and downs in the trend, identifying the variability of the fluctuations which however are negative in the serious final fallout in 2022.

In this context, it's possible to say that climate change is a real and current problem[282]. However, this is not always presented correctly to the public opinion, not to mention the role of some climate change denialist scientists who cannot always be considered especially if they do not bring convincing scientific data. Public opinion can only express its idea on the subject if there has been a real comparison with these specific data since they already vary only considerably depending on the area of northern Italy. Moreover, it's important to add that regarding climate change, the scientific opinion does not have a uniform idea: even if according to evident and confirmed scientific data we saw an increase of 1.2°C compared to the industrial era and therefore with an atmosphere composed of higher concentrations of CO2. The greenhouse gases therefore particularly affect the temperature capable of varying the water cycle in some areas of the globe where it already manifests itself more intensely due to the sum of various and certain climatic conditions. It is no coincidence that the "climatic eras" have already existed[283], i.e., periods unknown from the climatic point of view for us today. In these long periods extremely hot or extremely cold, a climate very adverse to man and not influenced by the latter, has nevertheless allowed the possibility, even without modern means, to survive. Not only these but there are also enormous differences in the climates of the very remote geological eras that involved climatic upheavals today unthinkable and dating back millions of years ago, thus reminding us that the climate must be observed, monitored, and feared and that it will always change by its very nature.

[282] Ivi, p. 122.

[283] Giorgio Temporelli, personal communication, 16th March 2023.

3.1.3 Governance and potential solutions

Ulderica Parodi has moreover dealt with drought from a technical point of view[284], developing a permanent regional observatory to define the degree of water severity and hydrographic stress levels, which is one of the elements that civil protection at the national level uses to assess whether the situation is really at a level of severity such as to have to undertake rapid solutions for deficiencies or if you are faced only with management inefficiencies often aggravated from each other. In this context, the role of climate change is not related to drought: while this single event cannot be blamed for natural causes, annual oscillations have always existed. What is also evident and observed is a rise in winter temperatures with double melting peaks compared to previous years. It is also not yet clear whether, for a future dictated by water scarcity, it will be more convenient for governance to build many small reservoirs or a few large ones from the point of view of technical efficiency: certainly the latter alters the territory in an evident way and their construction and maintenance is not a quick intervention; these technical checks must be done in a reasoned manner because they do not produce immediate returns in the short term that deserve the investment, especially if built during periods like these of limited rainfall. A possible solution to the crisis could be concrete work in every impacting sector, without necessarily blaming agriculture: to live in Liguria means abiding in a strongly anthropized territory with a high historical and cultural value, but it's necessary to change crops and make irrigation more efficient. Precipitation will not always be favourable; therefore, the governance system must adapt if we are close to a drying up on our coasts, especially because it is now clear as already said the increase in temperatures from data; while on precipitation the short and intense flood peaks seem more evident than the norm and longer periods of drought even if we have few historical versions. If in the period there will be significant hydrological impacts with better rainfall processes, even in terms of retention this amount of water will not necessarily be preserved with the soil now so dry. In any case,

[284] Ivi, p. 113.

supplying a city like Genoa is no longer possible without reservoirs able to mitigate seasonal shortages: even if the population has decreased, consumption is very high, and the resource is scarce. The relationship with the bordering province of Piacenza, which shares with Genoa the area of Bisagno, is complicated; the situation is even worse today and the need to sell it is now a problem that could lead to new disputes for this reason, the system must be rethought because it can no longer be mitigated with a drought emergency plan that includes only tankers. Investments are crucial to improve distribution intervention and the reduction of losses is a pressing necessity.

At the level of the water system[285], however, there cannot be as the only solution the construction of new reservoirs as these only partly solve this problem provided that the roughing progress is not structural, but the priority would be to reactivate instead those that are now in disuse. Even if the city of Genoa has a system that is still oversized compared to the demographic needs because there is no longer a heavy industry and the local government could rethink the water system, before arriving at the restrictions solving the problem about it could be possible only if there was a plethora of better-coordinated entities to improve the urban and regional distribution, provided that healthy strategic investments are allocated.

[285] Ivi, p. 109.

3.2 Governance and implications at the local level: the case of upper Val Bisagno and Val Trebbia (Genoa Metropolitan Area)

Val Trebbia is a valley in the Ligurian Apennines formed by the river of the same name, a right tributary of the river Po; the Trebbia originates at the foot of Mount Prelà, in the metropolitan city of Genoa, and then flows between the provinces of Pavia, limited to a short stretch, and Piacenza. It was interesting to analyze an area like Val Trebbia because since it is one of the areas with the greatest rainfall in Liguria, drought is today an element of great discussion.

Fig. 30, Image showing the Trebbia valley where the Trebbia River begins near Torriglia and the valley ends near Bobbio, up to Piacenza following the SS45 Street, Google Maps (2023).

Currently, opinions are conflicting, and it is not known how to act against this phenomenon.

For 2023, what is hoped is the intervention of the spring rains of May and June. Today in June 2023 this fortunately happened, and they were able to partially counteract the drought of the winter months which did not even allow heavy snowfalls. The role of local administrations has been fundamental in a research thesis like this to ascertain the impact of the phenomenon in these areas since they experience it carefully every day.

For Mirko Bardini[286], the Mayor of Montebruno, the main problems for a local administrator in the upper Trebbia Valley are connected to the fact that drought emergency is a real alarming problem: although industrial activities in the municipality are almost non-existent and there is no real problem for the economic impact, the concern of summer drought remains high more than anything else for local agriculture: that the farmers' gardens in this area of the upper Trebbia Valley are all irrigated through the public aqueduct system: there are no alternatives but to use drinking water for these activities. Although the population has been steadily decreasing for years and consumption has fallen, water stress is now a recognized fact. In 2022 there were very few summer storms compared to past years and the winter rains of the first months of 2023 were scarce. In addition, the same has noticed over the years a sharp decrease in snowfall that does not allow us to see noteworthy levels in the verifiable water availability of the same Trebbia River that flows along the village of Montebruno. The collective perception is confirmed negative. To counteract the problem unfortunately there are no decisive actions for the village, except to make the aqueduct itself more efficient or to diversify the sources even though it is difficult to do so in the short term. Moreover, there is no type of emergency plan for these situations since this type of decision is not taken only at the municipal level; to be unprepared in this way is still to start at a disadvantage: we need a reduction and waste first by those who already live in Montebruno.

[286] The interview took place on 27th March 2023 in Genoa.

3.2.1 Public aqueducts management

Giorgio Temporelli[287] is an expert technician in the field of hygiene, regulations, and technology for water treatment and Genoese aqueducts. It was possible to discuss with him the aspects inherent in the current Genoese water system. The situation in Genoa and Liguria related to severe drought is connected to the positive fact that our water system is extremely resilient, as it is supplied by the historic springs and lakes that our regional territory possesses. The main water part is supplied by artificial reservoirs and in addition, the water system of the city of Genoa underwent a unification of the pipelines in 2010 for efficiency; in particular, the Galliera and Nicolay aqueducts have been set up to improve the water availability of the city of Genoa. We are currently observing critical situations due to the ongoing drought: the lowering of the river Po is dramatic. In Liguria, however, we cannot yet speak of an emergency because we are not yet in a critical phase and we do not know if the trend of the summer will worsen due to the unpredictability of this science, but it is obvious that the levels of reservoirs and waterways worry experts in the field, especially regarding the historicity of the event. The situation is quite serious, but not an emergency, as it could also be partially restored in the coming pre-summer months. In our region, we also have deactivated dams, such as Lake Badana, whose reactivation has been under discussion for years and there are also new and concrete projects for the installation of innovative latest-generation purifiers on the coast to move towards truly more sustainable reuse of wastewater. An example of total unsustainability is golf courses: the reuse of water would avoid irrigating these water waste centres with drinking water. Even if the region in terms of efficiency is at a good level, the infrastructures in Italy are now obsolete or unsuitable, thus requiring a policy-aware that the renewal of this system must be of priority interest. In the end, regarding how is it possible to improve the water system of Liguria, the management part is also crucial from a scientific point of view. At the time of large urbanizations, concessions were issued in the region for inefficient wells that did not assess

[287] The interview took place on 16th March 2023 in Genoa.

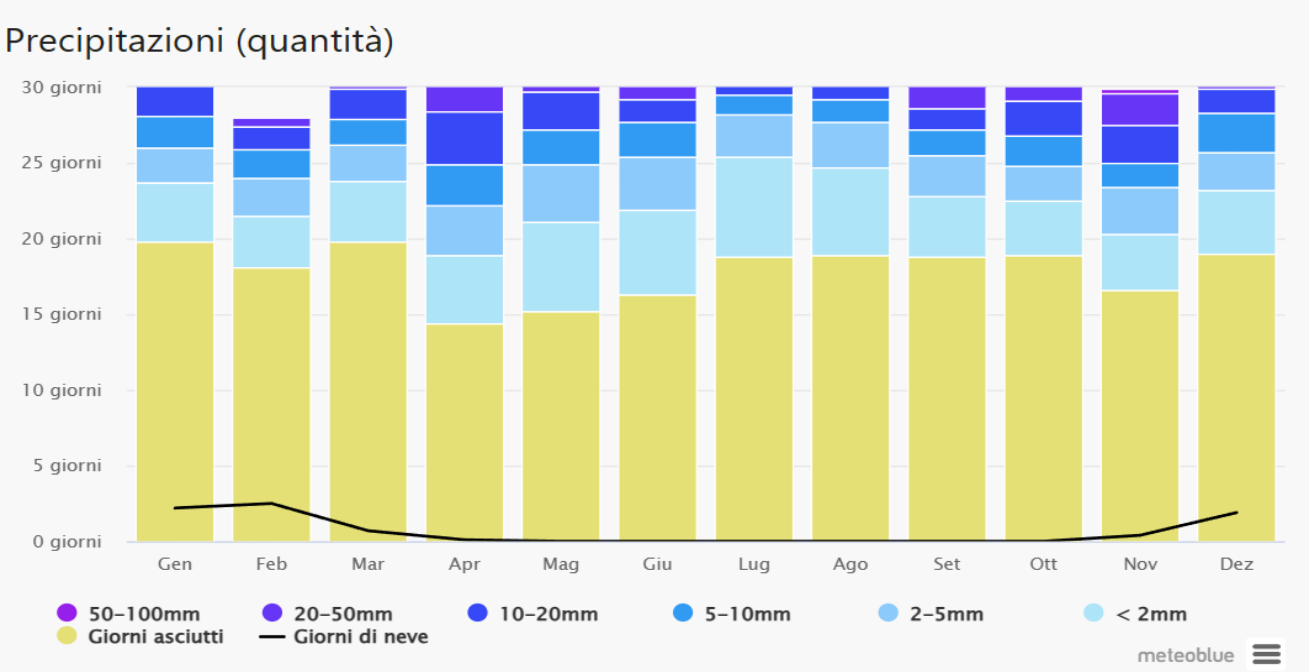
their sustainability. With higher consumption due to the increase in tourist activities, there is no longer compatibility with resource availability. In the urban plans, this is very evident: there is no adequate and updated design on how to develop the water supply in the western areas. The expansion of consumption cannot lead to imbalances but must be reasoned. Otherwise, it's possible to see situations like the one we are experiencing more and more: unfortunately for us, there could be an unprecedented water scarcity for this summer of 2023, also due to these factors. For another local administrator, Maurizio Beltrami[288], the mayor of Torriglia, the management of water for the administrators of the Trebbia Valley becomes a very difficult task since there is no real distinction between the civil use of the water systems and the use of the irrigation of the fields and gardens of the valley. The main risks concern the fact that the aqueduct is one and this is a problem because we know that this already happens in other neighbouring municipalities but now there is no emergency plan to combat a future drought in 2023 even if the restrictions will be gradually applied towards the summer period if necessary. Some drastic solutions could be adopted in Torriglia and its surroundings, like what happened when agreements were made with the old company that managed the aqueducts, called AMGA, the old water management company, bringing water to large rationing to counteract the phenomenon temporarily.

3.2.2 The drought of 2022-23 in Val Trebbia

It is impressive to observe how in one of the rainiest regions in Italy, including Liguria, in one of the rainiest valleys in Italy, such as Val Trebbia, starting from 2022, there are problems connected with drought. It is difficult to understand how this phenomenon can somehow influence these territories. Starting from the year in question, 2022, the rainfall has been lower than the norm, as confirmed by the data in the previous chapters. As a result, rivers and lakes are consequently less ready to withstand a summer drought since their water flow is visibly reduced. However, the role of local administrations remains weak in terms of

[288] The interview took place on 4th April 2023 in Genoa.

decision-making, even if various ideas are in the field in collaboration with the central bodies of the Liguria Region and the city of Genoa to counter the phenomenon. Together with the water shortage, what is quite evident now is only the perception of the local population that looks to the future with various concerns, as confirmed by the statements of the mayors mentioned here. For Sergio Casalini,[289] mayor of Bargagli, the administration will have another time to deal with drought in the summer of 2023. The town is just outside the city of Genoa and even in the last year of 2022, the local population suffered a great water shortage as in the city of Genoa; in any case, there's a widespread collective perception that climatic times are changing. In any case, Bargagli still has spring waters that local farmers use, thus saving water from Lake Brugneto. However, the drought alert cannot yet be seriously considered because spring showers and rainfalls could still occur, and they could regenerate the underlying aquifers. In any case, sustainable use of the resources would be necessary a sustainable, particularly in the summer months.



[289] The interview took place on 8th April 2023 in Genoa.

Fig. 31, Temperature diagram of Torriglia, one of the most important towns in Valtrebbia.[290]

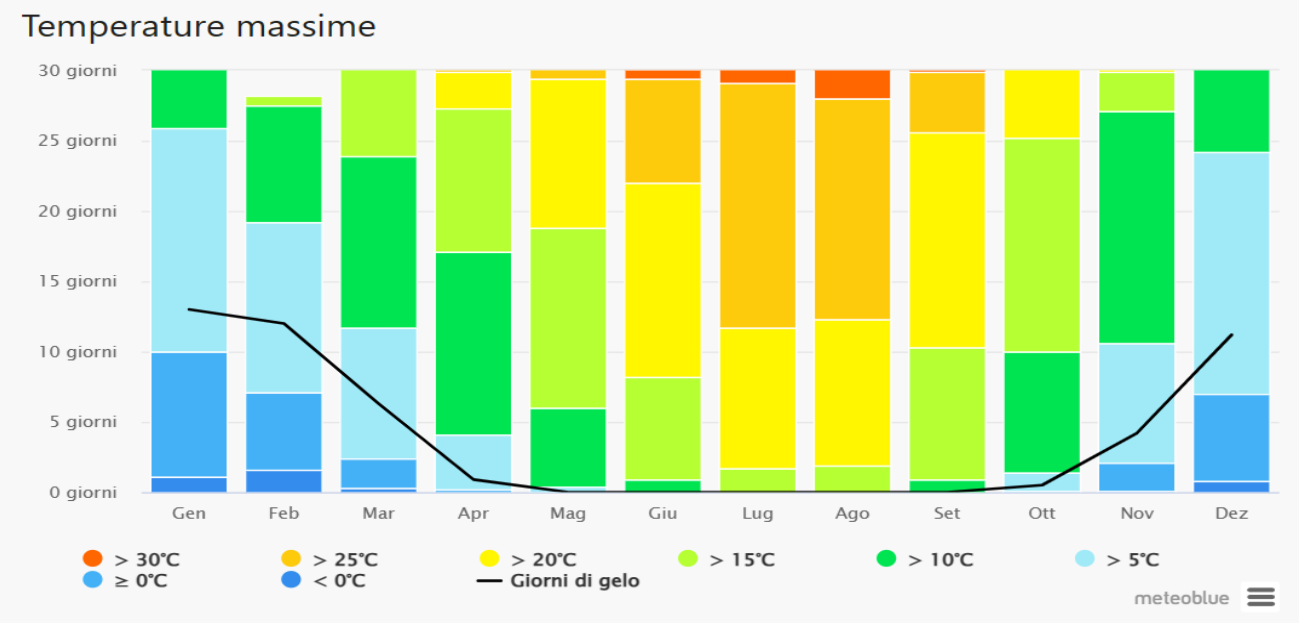


Fig. 32, precipitation diagram of Torriglia, one of the most important towns in Valtrebbia.[291]

3.2.3 The Brugneto dam

Lake Brugneto is an artificial lake located in the regional natural park of Antola in the High Trebbia Valley in the municipalities of Torriglia, Propata and Rondanina and it is the largest lake in Liguria. The lake consists of an artificial basin built in 1959 by the Municipal Gas and Water Company of Genoa as a barrier to the Brugneto torrent of the same name, a tributary of the Trebbia River. It is located at an altitude of 775.8 meters above sea level and, with a maximum capacity of 25.13 million cubic meters of water, it constitutes the main water reserve of the city of Genoa and in part of Piacenza.

[290] MeteoBlue, (2022), *Dati climatici e meteorologici storici simulati per Torriglia,* https://www.meteoblue.com/it/tempo/historyclimate/climatemodelled/torriglia_italia_3165392, [Last Accessed 20/06/2023]

[291] *Ibidem.*

Fig. 33, Image showing the Brugneto Lake and its artificial dam. The natural flow of the water would flow towards the Trebbia River, carrying the water towards Piacenza and then Emilia-Romagna towards the Po, but it is mainly directed towards the city of Genoa every year. Google Maps, (2023).

For Lake Brugneto the situation of Winter 2023 was particularly serious as highlighted before, and it would be essential to take care of the watershed in terms of efficiency, for example by dredging the lake, one of the interventions discussed for years. Moreover, due to the agreements with the province of Piacenza for irrigation, the situation should at least be reviewed. In particular, the reservoir contains about 25 million cubic meters of water and the agreement provides that, annually, 20% (4 and a half million) is released downstream, in the space of two weeks for a period optional, requested by the irrigation consortia only when the rivers are dry; it is important to note that this agreement may be revised as needed and expires. So, if we expect a worse summer than the previous one, even to avoid the possibility of a sort of water conflict. Indeed, regarding local water conflicts, the situation of constant conflict with the city of Piacenza already took place in 1989. The sharing of water in the areas of Piacenza for irrigation was exacerbated by the water crisis of 2022, reopening

the debate on the agreement of the million cubic meters ceded to Piacenza and probably will be the same for the summer of 2023. Recent precipitations in April and even more in May and June have certainly helped to relieve the emergency, but the situation is still critical. In any case, the local administrations do not seem to have emergency plans to deal with drought because, for example, the municipality of Bargagli will adapt to the provisions of the metropolitan city of Genoa. The summer crisis will require administrations also to prevent the installation of prefabricated pools that reduce water availability by thousands of litres in towns that already exponentially increases consumption in the summer due to the presence of tourists. Limiting enormous waste of this kind will gradually become crucial to counteract future water crises in Trebbia Valley's municipalities. Furthermore, Lake Brugneto supplies also water to Montebruno and even if the water levels are quite low, following an earthquake that took place in September 2022 and had its epicentre in Bargagli, a few kilometres from the village of Montebruno, the panic was triggered due to fear of a series of possible leaks or collapses of the dam itself since the fact that the town of Montebruno resides right at the mouth of the lake drainage valley. Fortunately, the dam was not affected. In any case, beyond this kind of event, the confirmation is that the situation is unusual, and the local population lives with great concern about the possibility of summer cuts or a great lack of water availability, which would lead to the total closure of any remaining agricultural activity in the valley. The dam being still at half of its level does not yet represent a great tangible problem even if the concern of the population is also high for the economic impact that the phenomenon may have. For this reason, Lake Brugneto will be constantly monitored to promptly anticipate the restrictions in the event of a drought alert and the first necessary prohibitions that will eventually be taken in the summer will be those of irrigation and car washing, even in the town of Torriglia.[292]

[292] Ivi, p. 123.

Conclusion

The initial hypotheses in this research thesis, made on drought and its relationship with the Liguria region, have only been partially explained, given that the phenomenon is currently difficult to understand given the multitude of variables, with different socio-economic, environmental, and climatological impacts. Droughts are a chronic problem in many parts of the world, particularly in several areas of Africa, such as the Sahel, where climatic and political aspects seem to be linked by a spiral of perpetual instability, due to the scarcity of resources, including water. The temperate climate in Europe, in Italy and especially in Liguria, is also experiencing a principle of these changes due to the emergency of drought phenomena and potential issues at an economic and societal level.

The experts interviewed were able to provide a rather clear opinion, arguing that in every scientific field, it is primary to observe only scientific data. It is not possible to make risky predictions and only move towards adaptation, if possible, is the only possibility.

Today's adaptation could be possible thanks to political intervention, a largely non-existent collective awareness, and a destination of resources for the efficiency of our water distribution and recycling systems. If the heat waves of 2022 have already been particularly impactful in Europe, summer 2023 will be a new test and will certainly put a strain on the water system that will necessarily have to be reviewed.

Realizing that global change is taking place is the first step in understanding what to pay attention to and focusing public attention on this future crisis. This research thesis has revealed the aspects that we simplistically reduce to well-defined events are part of a multitude of factors together. This is the key that every social scientist who approaches a new subject should do, and considering the results leads today to affirm that we are facing a new reality that will have to be constantly monitored. The interpretation of the new data and the evaluations for future studies must be a priority element for the protection of our environment and first for the awareness that our lifestyles must be changed since they are not in line with the very nature of the climate.

In conclusion, based on these findings, we can argue that drought represents an evident environmental security risk at an international and national level. It calls for immediate action to protect water resources and mitigate the devastating effects of droughts. The study underscores the responsibility of institutions to implement preventive measures and advocates for a global effort to combat the impacts of drought and climate change, while the research findings reveal that the Liguria region is facing an unprecedented challenge in terms of water scarcity and drought in 2022. Despite being traditionally considered a temperate region with ample water resources, Liguria is experiencing an ongoing and worsening water shortage situation also during 2023. The recognition of Liguria's unprecedented challenge serves as a call to action for local administrators, experts, and stakeholders involved in water management. It highlights the need for innovative approaches, sustainable practices, and proactive measures to mitigate the effects of drought and secure a reliable water supply for the region.

Overall, the research emphasizes the criticality of addressing the unique and unprecedented water situation in Liguria, urging immediate intervention and long-term strategies to ensure the region's water security and resilience in the face of ongoing climate change impacts. The study highlights the necessity for a global effort required for the importance of collective action in addressing the escalating problem of drought, emphasizing the need for cooperation, and coordinated measures to ensure a fair and sustainable future for humankind.

Abstract

Questa tesi di ricerca del corso magistrale di Security and International Relations si è occupata di esplorare il fenomeno della siccità, introducendo nella prima parte gli impatti decennali di quest'ultima nei paesi in via di sviluppo, fino ad arrivare alle aree temperate del globo, oggi soggetti ad una seria influenza del fenomeno, soprattutto a seguito degli eventi siccitosi estremi del 2022, avviando infine un'analisi approfondita sul caso di studio della Regione Liguria e sulle sue strategie di governance per la mitigazione degli effetti, in aggiunta alle possibili ragioni scientifiche dei fatti in oggetto. Indagare e analizzare il fenomeno della siccità, caratterizzata da una prolungata e diffusa carenza di approvvigionamento idrico in grado di colpire sempre di più anche le zone tradizionalmente più temperate del mondo, ha necessariamente richiesto la ricerca anche di possibili soluzioni, grazie alla partecipazione e alle dichiarazioni nel lavoro di alcuni esperti. La tesi di ricerca sostiene prima di tutto che la siccità rappresenta un rischio significativo per la sicurezza ambientale, con effetti disastrosi a lungo termine determinati verosimilmente dal cambiamento climatico sulla risorsa più vitale del pianeta: l'acqua. Nonostante sia un fenomeno diffuso a livello globale, non sembra esserci un'attenzione sufficiente nei paesi che storicamente non sono stati colpiti da tali condizioni, come nel continente europeo. Pertanto, la ricerca prova anche ad aumentare la consapevolezza e sottolineare l'urgenza dell'affrontare questo problema, evidenziando e promuovendo di conseguenza il ruolo delle azioni individuali, in vista di un possibile aumento degli effetti devastanti di questo mutamento climatico in corso.

La metodologia utilizzata nella ricerca ha previsto l'analisi dei dati meteorologici e idrogeologici, nonché la conduzione di interviste semi-strutturate con vari attori coinvolti nella gestione idrica e negli studi climatici, in grado di rilasciare comunicazioni personali ed inedite sulla base delle loro conoscenze. Combinando questi approcci, la tesi mira quindi soprattutto a fornire una comprensione completa della manifestazione del fenomeno nel caso di studio della Regione Liguria, territorio locale analizzato in questo progetto, poiché

influenzato da una siccità estrema e senza precedenti nel 2022; ad ogni modo sempre parte di un quadro comune di un territorio europeo sofferente. Date le implicazioni per le comunità locali, il lavoro di ricerca sottolinea la necessità di un intervento tempestivo per mitigare gli effetti della siccità in un lavoro congiunto di sinergie con le istituzioni politiche e gli enti gestionali, che dovranno adottare misure proattive per introdurre idee innovative di sostenibilità, prevenzione e conservazione della risorsa idrica.

La tesi di ricerca è così divisa in tre capitoli: nel primo si introduce un'analisi della prospettiva globale sulla siccità, evidenziandone le conseguenze economiche e umane. Si restringe poi sul punto di vista locale nel secondo capitolo, concentrandosi sulla Regione Liguria, che ha sperimentato carenze idriche anche durante l'inverno del biennio 2022-2023, ipotizzando la ciclicità di un evento siccitoso mai visto prima. La parte finale della tesi è incentrata sulle interviste con gli esperti e gli amministratori locali, esplorando grazie ai loro studi, analisi e percezioni, le azioni intraprese fino ad oggi per affrontare il problema. Qui di seguito il riassunto dettagliato dei capitoli di questa tesi di ricerca:

Capitolo 1: Una prospettiva globale sulla siccità

Questo capitolo evidenzia la siccità, come fenomeno ambientale caratterizzato da una prolungata carenza idrica determinata da più fattori metereologici e che può avere gravi conseguenze per gli stati colpiti, in un contesto di cambiamenti climatici. L'area di studio interessata è stata in particolar modo quella del Sahel e dell'Etiopia, zone sottoposte da decenni a gravi perdite di reddito agricolo, conflitti regionali, migrazioni forzata di milioni di profughi e carestie.

Capitolo 2: Il caso della Regione Liguria

Questo capitolo si concentra sulla manifestazione della siccità nelle regioni temperate, in particolar modo analizzando l'area della Regione Liguria. In questa parte si riscontra nei

dati la gravità della siccità nel 2022, considerata la peggiore degli ultimi anni e che ha portato a una riduzione dell'umidità del suolo con effetti negativi sulla vegetazione e la conseguente diminuzione dei livelli delle acque dei fiumi a causa di importanti deficit precipitativi. Il capitolo sottolinea la necessità di un'analisi completa della minaccia, così da poter valutare gli effetti crescenti degli eventi estremi futuri nella regione e introdurre le adeguate azioni preventive.

Capitolo 3: La prospettiva degli esperti e degli amministratori locali

Questo capitolo sottolinea l'importanza delle opinioni degli esperti e delle intuizioni degli amministratori locali, in particolar modo di una delle aree più piovose della Regione Liguria, la Val Trebbia, per ottenere una comprensione più profonda dei complessi aspetti della siccità. Riconosce l'inevitabilità di un aumento della crisi idrica dovuto al multi-annuale deficit stagionale nelle precipitazioni e delle ondate di calore riscontrabili nelle temperature fuori da qualsiasi media. L'importanza del lavoro degli esperti nell'analizzare i dati meteorologici è stato cruciale per comprendere prima di tutto che cosa sta avvenendo, dato che la confusione collettiva sull'argomento è ancora diffusa. Il capitolo discute poi le criticità e l'assenza di concrete nuove soluzioni per una gestione locale in grado mitigare gli effetti della siccità; tutti elementi che sembrano caratterizzare la Regione Liguria di oggi a causa di una concomitanza di fattori e svantaggi strategici. Ad ogni modo, i principali risultati che emergono dall'analisi del clima ligure nella ricerca sono:

Aumento della frequenza e dell'intensità: è stato osservato che la siccità si verifica più frequentemente e con maggiore gravità a seguito di eventi estremi come le ondate di calore e l'assenza prolungata di precipitazioni che si possono poi scatenare successivamente in fenomeni pseudo alluvionali, anche se ormai più rari. Questa tendenza, per quanto in Liguria necessiti di ulteriori studi, si osserva già ai fenomeni legati ai cambiamenti climatici globali.

Impatti agricoli ed economici: la siccità può avere implicazioni significative per l'agricoltura, portando perdite produttive e rese ridotte per gli agricoltori. Per quanto la Regione Liguria non sia importante per l'agricoltura, l'aumento del turismo estivo e la necessità di cedere acqua alla Pianura Padana mostra un grande rischio nei periodi secchi dato che l'offerta disponibile, dal 2022 fino ad oggi, non garantisce di poter soddisfare la domanda idrica, soprattutto nei periodi estivi.

La diversificazione delle fonti è un tema politico attuale ma non attuato: non sembra esserci l'interesse nell'avviare investimenti concreti in un sistema più efficiente e completo, diversificando le fonti civili da quelle per l'irrigazione; le difficoltà sembrerebbero gli enormi costi degli interventi legati poi ad un dibattito di tipo tecnico sulla creazione di nuovi bacini più piccoli e numerosi, rispetto alla creazioni di nuovi pochi grandi, in particolar modo nelle aree di Ponente, quelle più colpite dalla mancanza d'acqua nei periodi estivi e ormai non solo.

Conseguenze ambientali: la siccità ha un impatto negativo sugli ecosistemi, portando a una diminuzione della biodiversità, habitat alterati e ad una maggiore vulnerabilità agli incendi. Può anche contribuire al degrado del suolo e alla desertificazione; nel primo caso il dissesto idrogeologico rappresenta una vera e propria criticità territoriale della Regione Liguria, un territorio prevalentemente collinare e montuoso.

Strategie di adattamento e mitigazione: gli esperti hanno evidenziato varie strategie per adattarsi e mitigare gli impatti della siccità, portando alla conclusione che fare qualcosa è assolutamente possibile. Queste possono includere pratiche di conservazione dell'acqua, tecniche di irrigazione migliorate, varietà di colture resistenti alla siccità e migliori politiche di gestione pubblica. Tutto ciò sarebbe quindi parte degli sforzi concreti per la mitigazione dei cambiamenti climatici.

È importante notare, a seguito di questi risultati che queste affermazioni specifiche sono

parte di uno studio sulla siccità nella Regione Liguria integrato da più fonti e dipendono dai dati e dalle analisi rilasciate dai ricercatori coinvolti in questa ricerca.

Le conclusioni del lavoro di ricerca nel suo complesso sono poi riassunte qui di seguito:

La siccità è una minaccia significativa per ogni stato anche storicamente escluso: la ricerca evidenzia la siccità sia un fenomeno sempre più intenso e frequente a livello globale, ma anche nelle regioni tradizionalmente temperate, assenti però da una qualsiasi iniziativa di una massiccia azione collettiva in grado di affrontare questo rischio per la sicurezza umana.

Conseguenze ambientali e socioeconomiche nei paesi in via di sviluppo: la siccità ha conseguenze di vasta portata, tra cui perdite di reddito agricolo, degrado degli ecosistemi, aumento del rischio di nuovi conflitti per il controllo risorse idriche in grado di instaurare escalation di violenza a causa della diffusione di ideologie estremiste tra le popolazioni locali, in particolar modo nelle aree Sahel; senza contare carestia e fame diffuse, tra le conseguenze peggiori.

La Regione Liguria, in quanto area temperata europea non è stata in grado di sviluppare soluzioni innovative ma solo palliative, dimostrando che la governance politica è ancora piuttosto inesperta sulle azioni da intraprendere a livello locale, come nel caso della Val Trebbia, una delle aree regionali più piovose. Nonostante ciò, l'argomento siccità è parte del dibattito politico anche di quest'area, ma le amministrazioni locali attendono un coordinamento della città metropolitana per l'azione, dato che non possiedono piani idrici di emergenza pronti e tempestivi. Le comunità locali sembrano essere tuttavia molto influenzate dalla stagionalità inusuale delle piogge, sempre più brevi ma intense, comprendendo quindi il rischio e la conseguente preoccupazione riguardo al fenomeno. La presa di consapevolezza si sta fortunatamente concretizzando sempre di più.

Impatti sulle risorse idriche: la siccità ha implicazioni sostanziali per le risorse idriche,

influenzando sia la disponibilità di acque superficiali che sotterranee; pone grandi sfide alla gestione dell'acqua, alla sostenibilità e agli sforzi di conservazione che non sembrano essere però soddisfatti dagli attuali acquedotti in uso nella Regione Liguria, dati i sistemi sì resilienti, ma tecnicamente obsoleti e che necessiterebbero di ulteriore manutenzione e innovazione.

Nel complesso, la tesi di ricerca prova a contribuire alla comprensione della siccità come una pressante preoccupazione ambientale globale, sottolineando l'importanza di misure proattive e collaborazione internazionale senza esclusioni per mitigare i suoi impatti e garantire un futuro sostenibile per l'umanità nella lotta al cambiamento climatico.

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