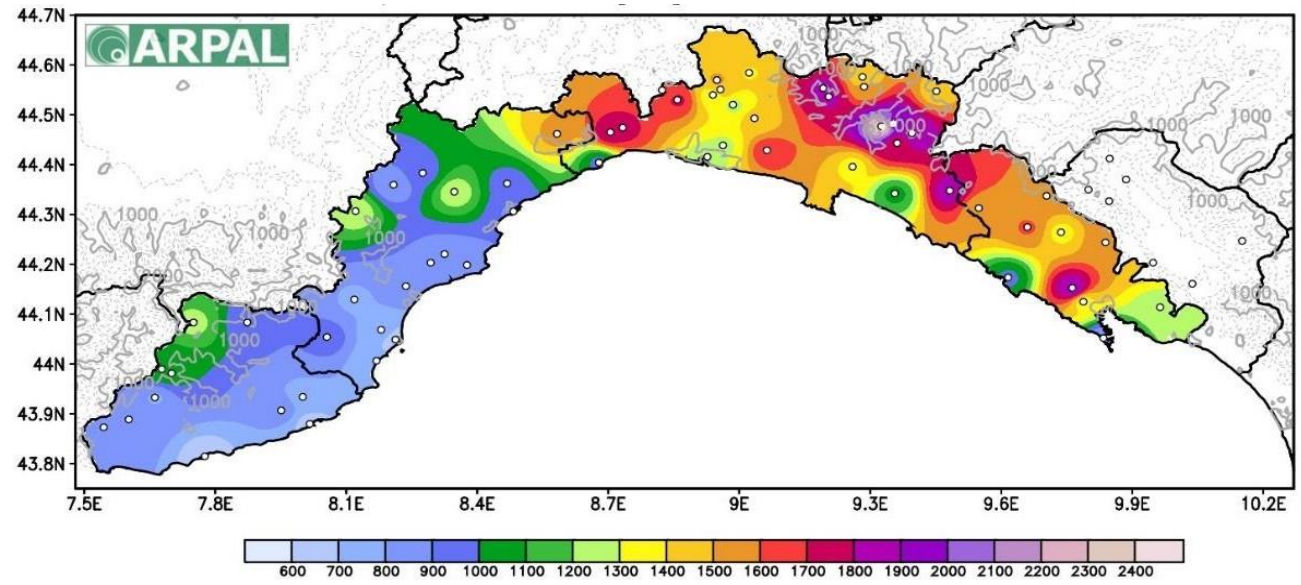

Fig. 24, Cumulative precipitation in millimetres, representation of the annual average of the 1981-2010 period, ARPAL, Cenvis, Cima Foundation and Unige-Dad, (2014).

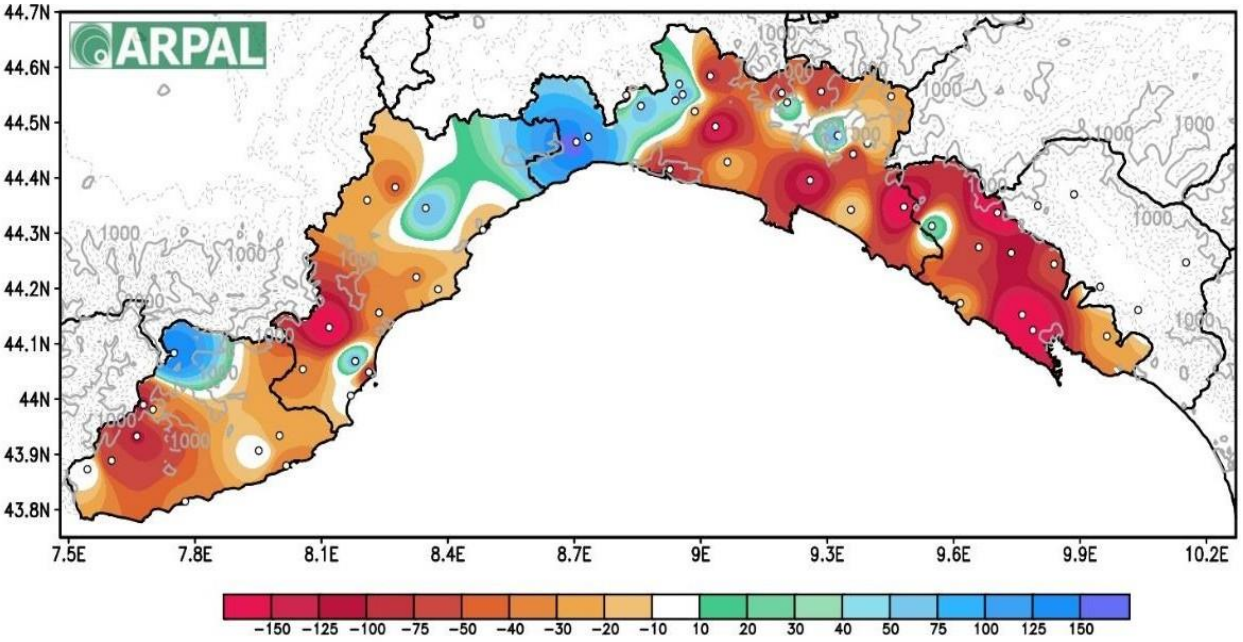

Fig. 25, Cumulative precipitation in millimetres with a variation of the annual average 1981-2010 compared to 1961-1990, ARPAL, Cenvis, Cima Foundation and Unige-Dad, (2014).

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].

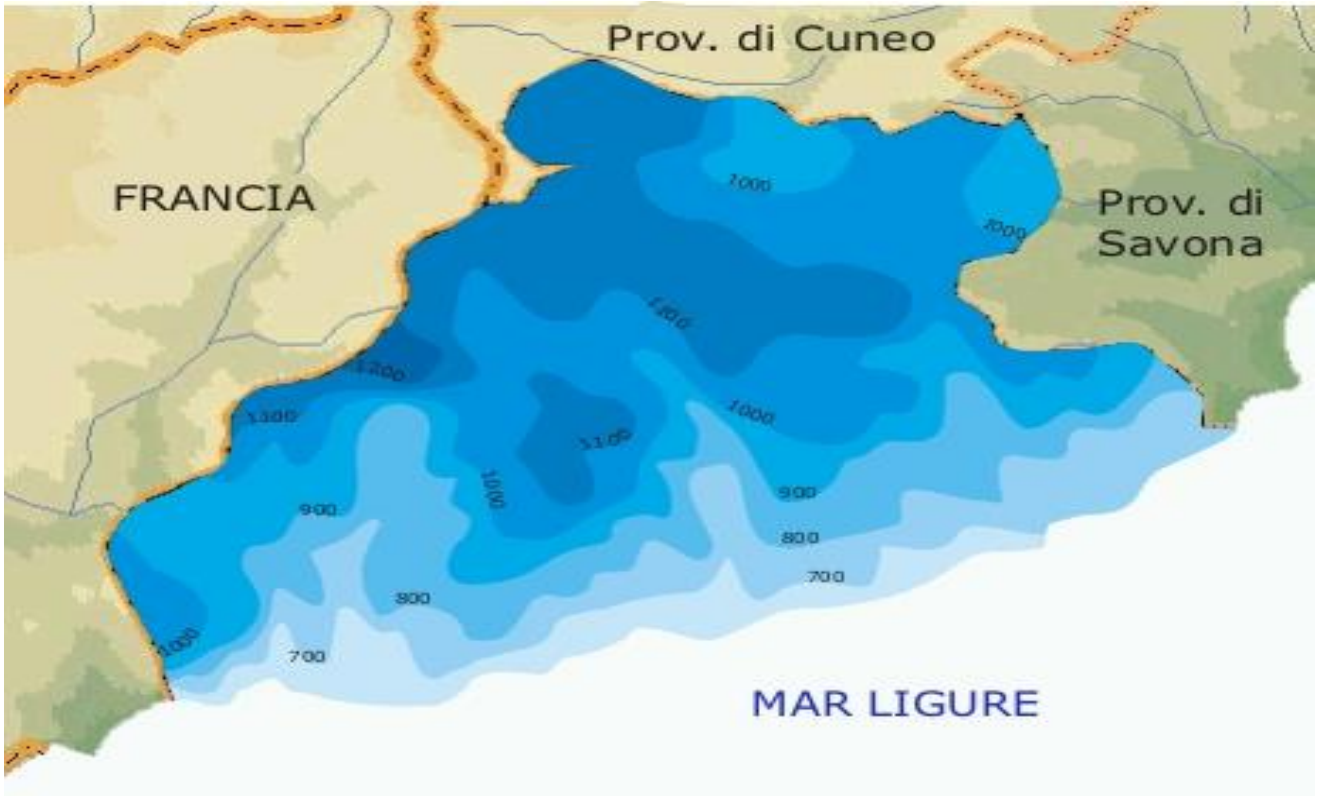

Fig. 26, Pluviometry data from the province of Imperia: on the coastal band the minimum values are measured, with annual totals that descend a little below 700 mm in the westernmost part, decreasing proceeding towards the French border. The least rainy location is Ventimiglia, with 671 mm, Rivista Ligure 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 and allocate funds to retain and utilize water effectively. Addressed chronic leaks in water pipes are 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.

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[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. Even if efforts are being made to improve water infrastructure and management, the effects of the drought of

[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].

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. 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

[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].

today a universal drought index 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 particular 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

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[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.

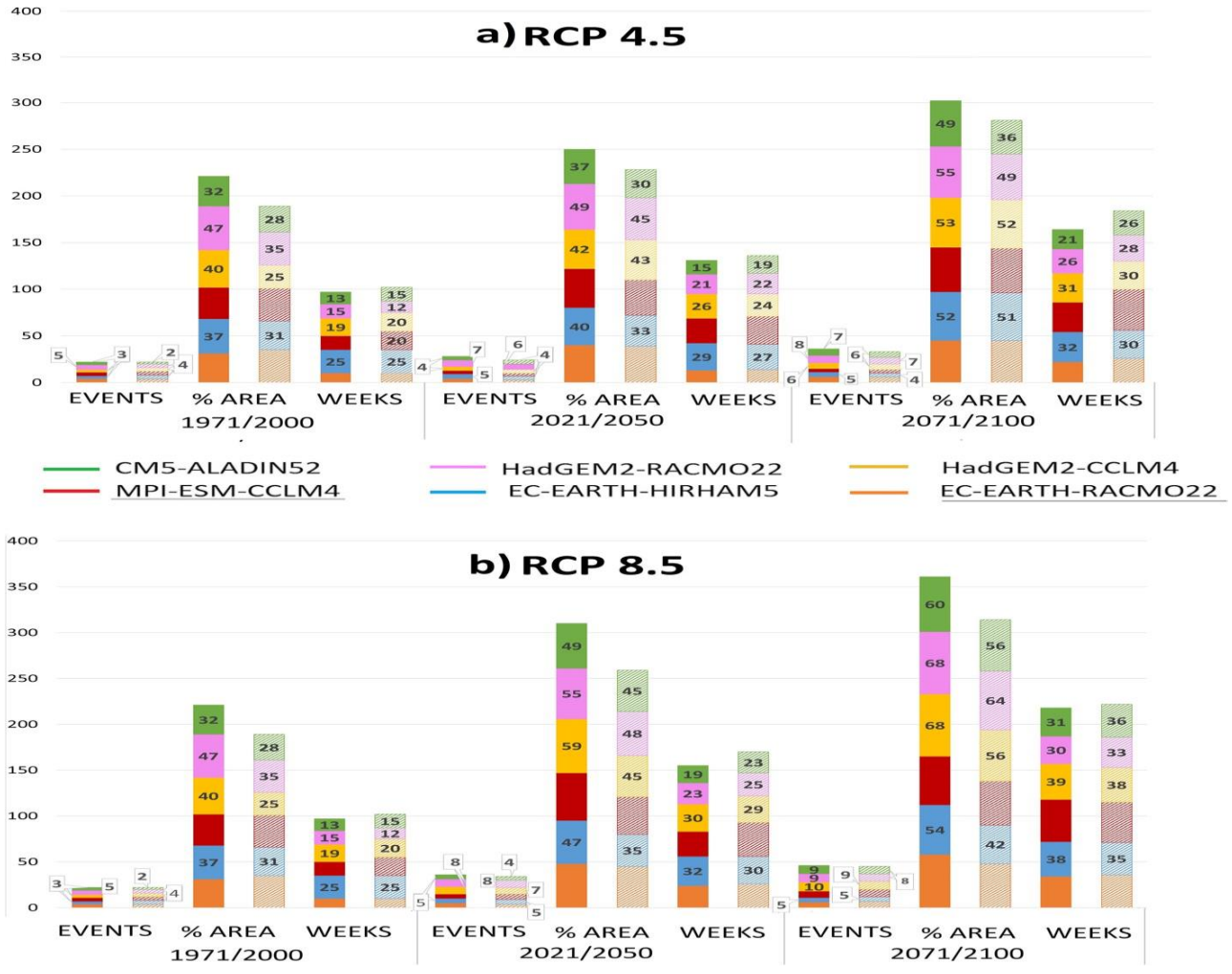

Fig. 27, Number of consecutive drought weeks expected for the baseline (1971–2000), near (2021–2050), and far future (2071–2100). The plain-coloured histogram represents 12-month SPEI

[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.

results, and line patterns indicate 12-month SPI results. [275]

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.

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[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.

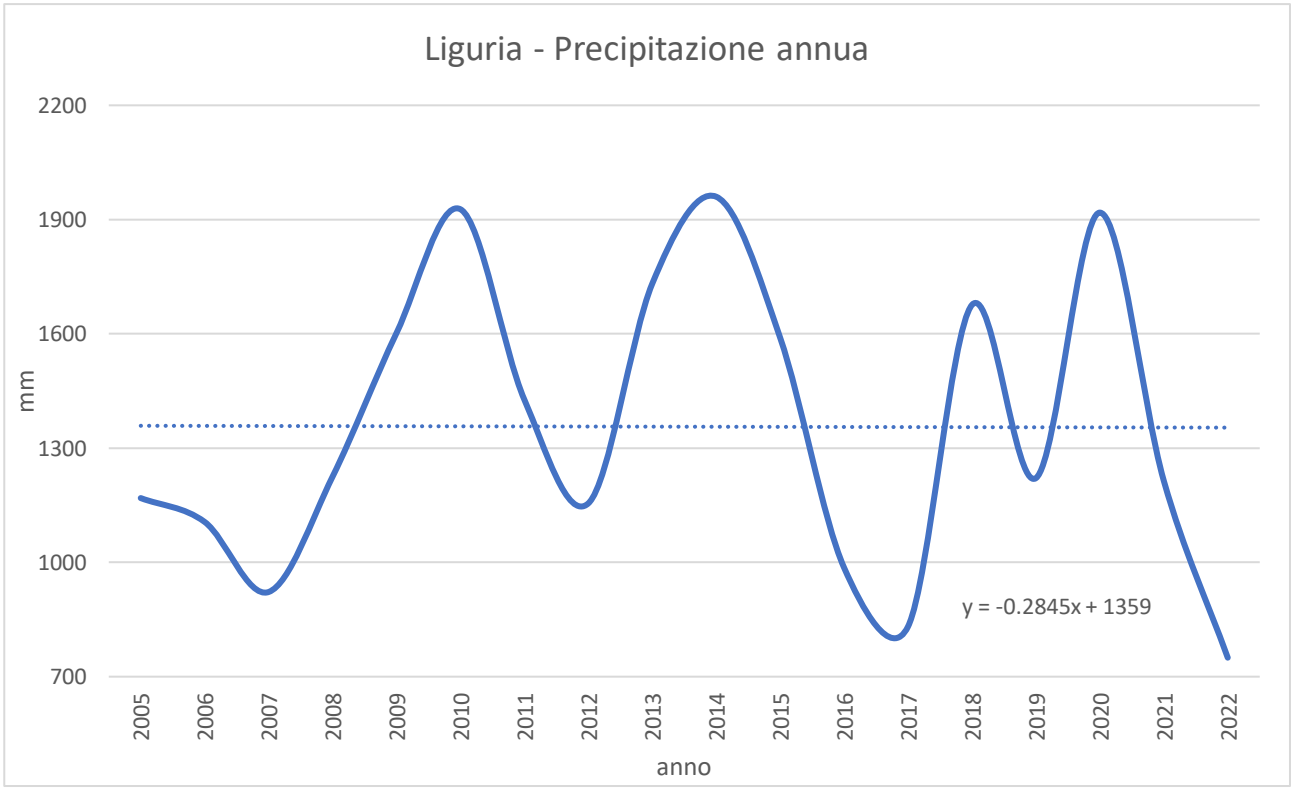


Fig. 29, Image developed by Massimo Riso to evaluate the trend of annual rainfall for the period 2005-2022 in Liguria. It is possible to notice ups and downs in the trend, identifying the variability of the fluctuations which however are negative in the serious final fallout in 2022.

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.

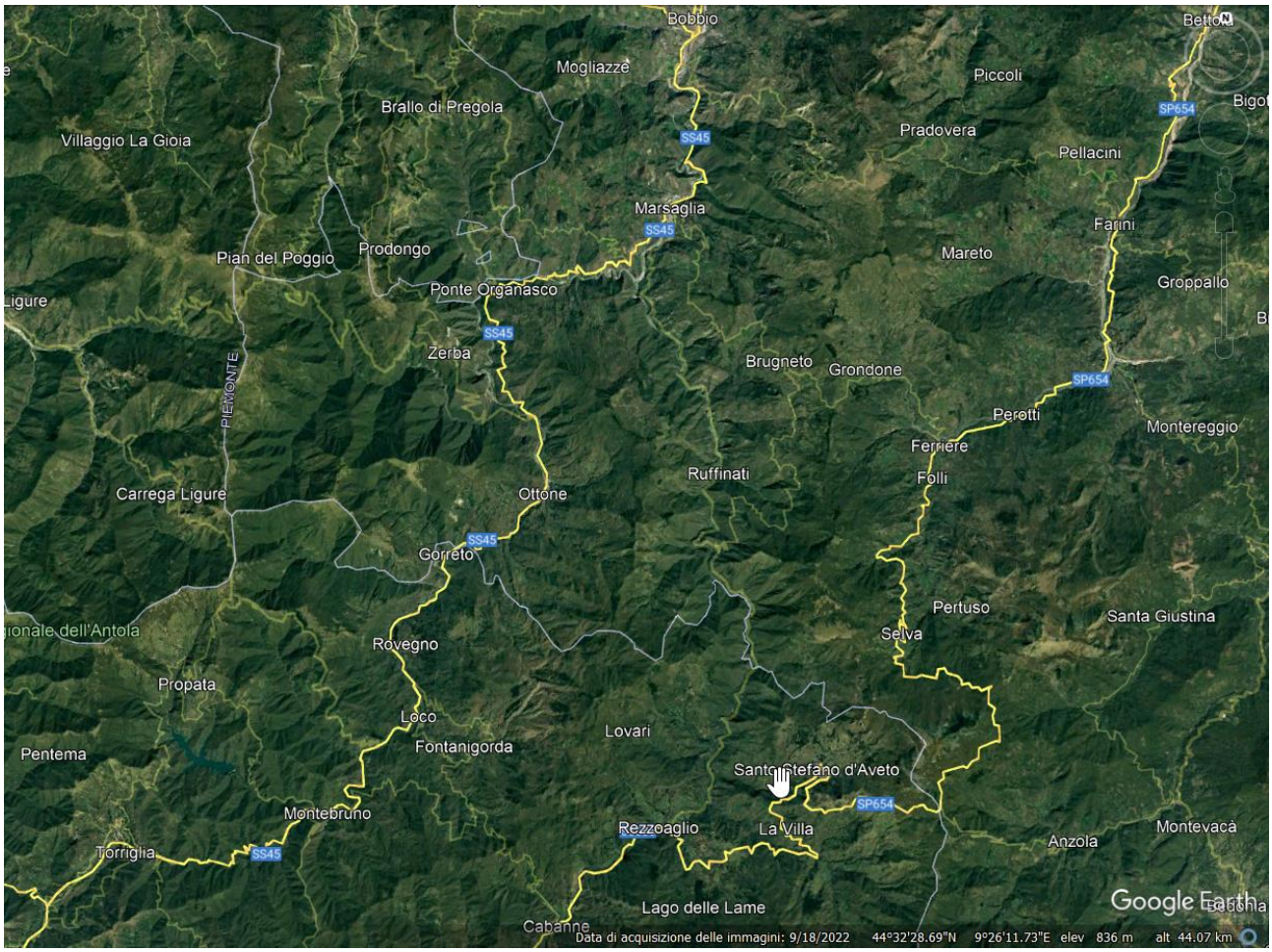


Fig. 30, Image showing the Trebbia valley where the Trebbia River begins near Torriglia and the valley ends near Bobbio, up to Piacenza following the SS45 Street, Google Maps (2023).

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.

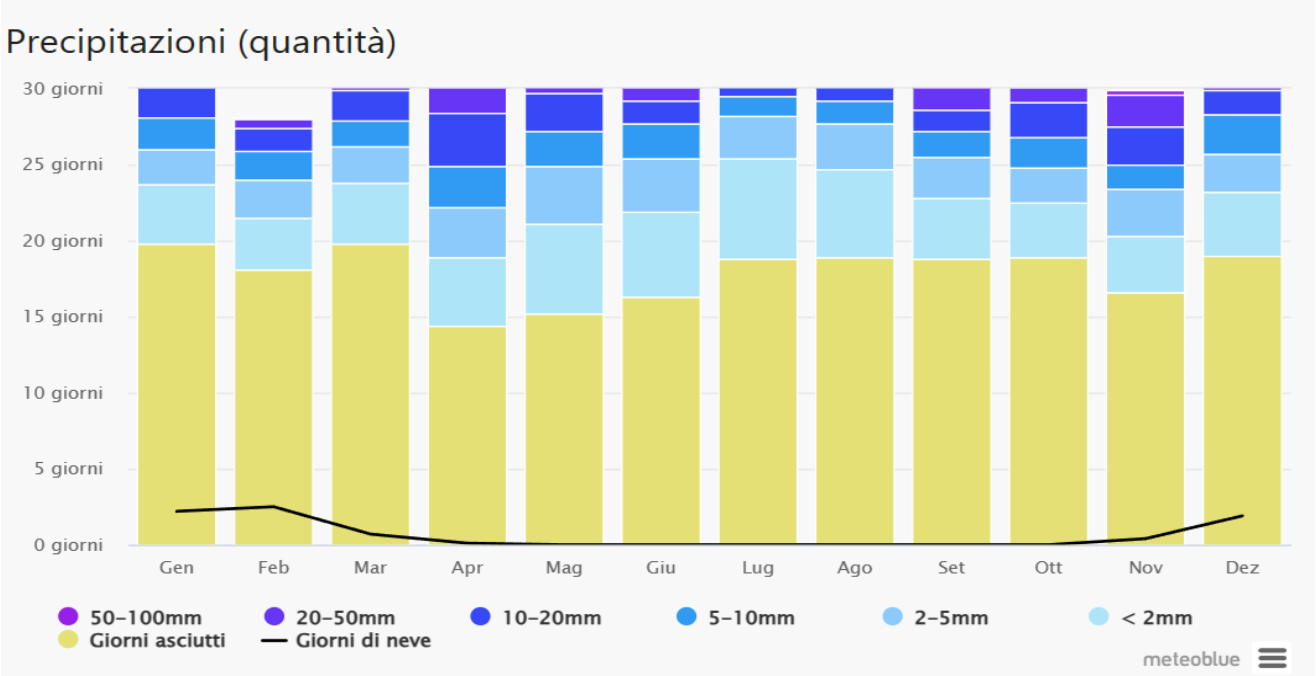
their sustainability. With higher consumption due to the increase in tourist activities, there is no longer compatibility with resource availability. In the urban plans, this is very evident: there is no adequate and updated design on how to develop the water supply in the western areas. The expansion 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]

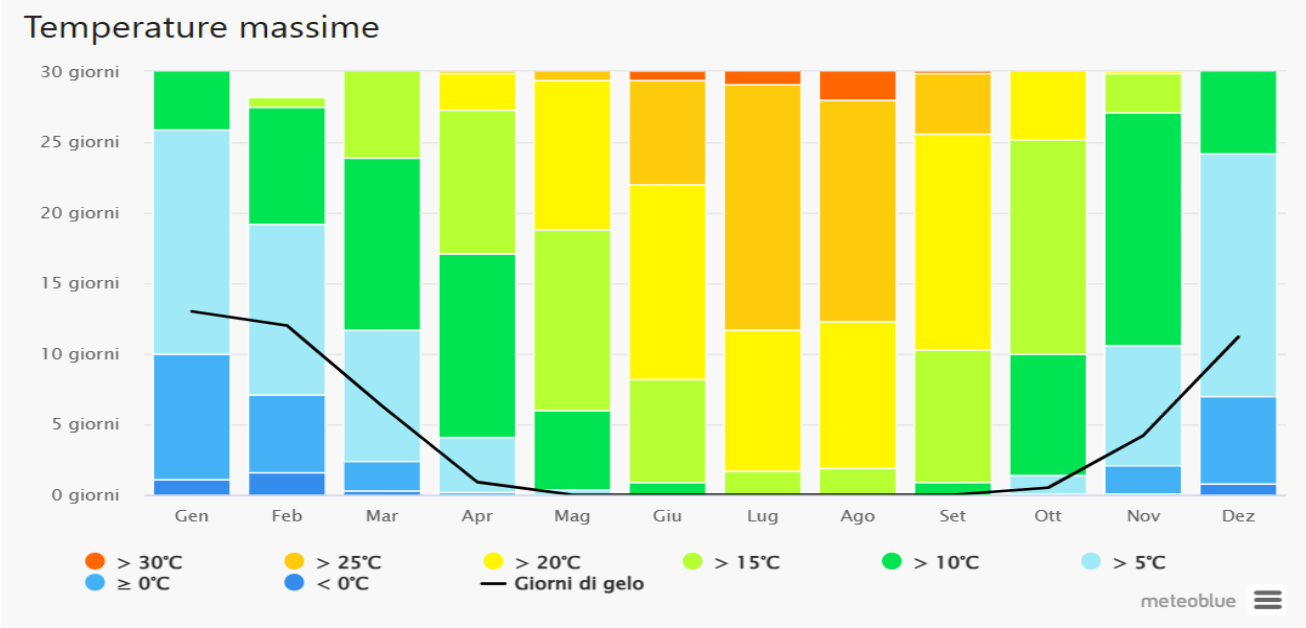


Fig. 32, precipitation diagram of Torriglia, one of the most important towns in Valtrebbia.[291]

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.*

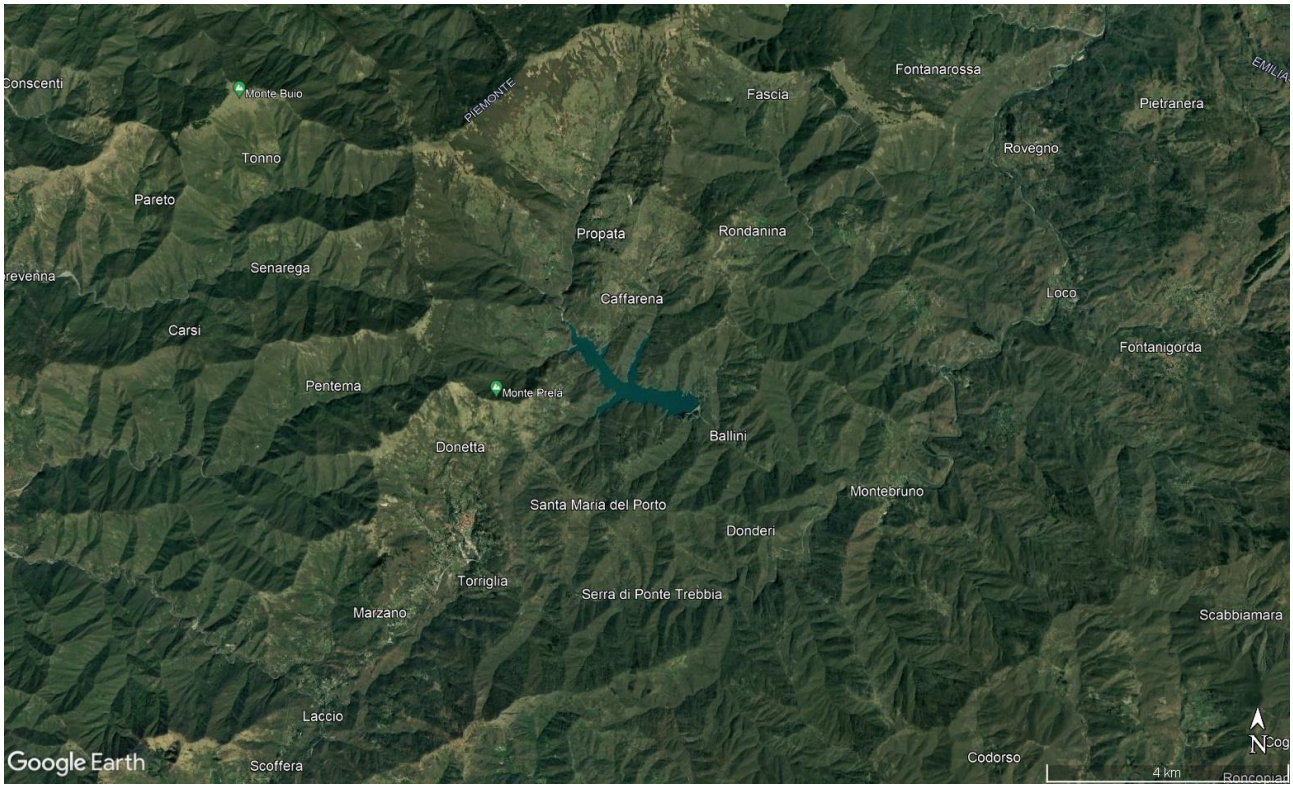


Fig. 33, Image showing the Brugneto Lake and its artificial dam. The natural flow of the water would flow towards the Trebbia River, carrying the water towards Piacenza and then Emilia-Romagna towards the Po, but it is mainly directed towards the city of Genoa every year. Google Maps, (2023).

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.

Bibliographical references

Bibliography

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].

A. F. Tollefsen, H. Strand and H. Bahaug, (2012), *Pro Grid: A Unified Spatial Data Structure, Journal of Peace Research*, Vol 49, N 2., p. 366.

A. Fernandez, A. Vergara, (1998), *Risk of the scarcity of monthly precipitation and stream flows in semiarid regions*. Hydrology Science Journal, 43 (5), 759–773.

A. K. Mishra, V. P. Singh, (2010), *Revision of concept of Drought*, Journal of Hydrology, Texas (USA), Volume 391, Numbers 1–2, September 14, 2010, pp. 202-216.

A. K. Mishra, V. P. Singh, (2011), *Drought modelling – A review*, Journal of Hydrology, Texas (USA), pp. 157–175.

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

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

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

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].

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

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

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

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

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].

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.

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

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

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.

European Parliament, (2000), *Protection and management of water resources*, directive 2000/60/EC.

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].

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, 122, pp. 619–634, [Last Accessed 28/02/2023].

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.

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, pp. 14-27,[Last accessed 22/02/2023].

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].

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].

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.

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.

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.

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.

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, Volume 541, Parte A, pp. 146-157, [Last Accessed 01/06/2023].

H. Dixon, (1999) *Environment, Scarcity and Violence*, Princeton University Press, New Jersey (USA).

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.

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.

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

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.

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].

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].

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

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).

M. Abdalla, (2009), *Understanding of the Natural Resource Conflict Dynamics: The Case of Tuareg in North Africa and the Sahel*, Humanity United, Institute for Security Studies, Pretoria (South Africa).

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

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.

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.

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.

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.

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.

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].

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.

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].

O. M. Theisen, H. Holtermann and H. Bahaug, (2011), *Climate Wars assessing the claim that drought breeds conflict*, Oslo (Norway), Volume 36, N3, p. 79.

O. M. Theisen, H. Holtermann and H. Bahaug, (2011), *Climate Wars assessing the claim that drought breeds conflict*, Oslo (Norway), Volume 36, N3, p. 81.

O. M. Theisen, H. Holtermann and H. Bahaug, (2011), *Climate Wars assessing the claim that drought breeds conflict*, Oslo (Norway), Volume 36, N3, p. 105.
Oxford University Press, London (UK), pp.1-25.

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.

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].

P. Piana, (2022), *Water and environmental security lesson's slides*, University of Genoa.

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].

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].

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

R. Pedemonte, Nimbus Rivista Ligure di Metereologia (2007), *Analisi climatiche: contributo alla classificazione dei climi della Liguria,* http://www.nimbus.it/liguria/rlm11/climatologia/stampa_clima_liguria.htm, [Last Accessed 7/02/2023].

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].

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

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].

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

R. Rosso, D. Padoan, Gli stati generali dell'acqua, Catelvecchi Editore, Milan (Italy), https://www.castelvecchieditore.com/prodotto/gli-stati-generali-dellacqua/, Last Accessed 7/02/2023].

S. M. Vincente Serrano, (2010), *Drought Global Index Database*, American Meteorological Society, Journal of Hydrometeorology, Boston (USA), Volume 11, p. 1035.

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.

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].

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].

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.

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

United Nations Environment Program, (2008), *Vital Water Graphics: An Overview of the State of the World's Fresh Marine Waters*, Nairobi (Kenya).

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.

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.

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].

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.

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.

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.

World Meteorological Organization, (2006), *Monitoraggio della siccità e allarme rapido:*

concetti, progressi e sfide future, N 1006, Geneva (Switzerland), p.24.

Sitography

A. Colombo, (2022), *Alluvioni in Liguria: l'importanza del vento di punta sul Golfo Ligure nella modulazione dei temporali autorigeneranti*, 3BMeteo, 26th October, https://www.3bmeteo.com/giornale-meteo/le-alluvioni-in-liguria, [Last Accessed 20/02/2023].

A. G. Consolaro, (2020), *Siccità negli USA: la peggiore degli ultimi 1200 anni*, Icona Clima, 21th April, https://www.iconaclima.it/estero/siccita-negli-usa-la-peggiore-degli-ultimi-1200-anni/, [Last Accessed 23/10/2022].

A. Boukhars, (2020), *Keep terrorism at bay in Mauritania*, africacenter.org, African Strategic Studies, 16th June 2020, https://africacenter.org/spotlight/keeping-terrorism-at-bay-in-mauritania/, [Last Accessed 19/06/2023].

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

A. Johnson, (2014), *Retired generals, admirals warn climate change is a national security concern*, National Review, 14th May, https://www.nationalreview.com/corner/retired-generals-admirals-warn-climate-change-national-security-concern-andrew-johnson/, National Review, [Last Accessed 05/11/2022].

A. Mulas, (2013), *The crisis in Mali*, Ministero della Difesa, https://www.difesa.it/InformazioniDellaDifesa/Pagine/lacrisiinmali.aspx, [Last Accessed 15/11/2022].

A. Vitale, (2018), *Water resource among diplomacy and conflict*, Foundation Giangiacomo Feltrinelli, 14th November, https://fondazionefeltrinelli.it/risorsa-acqua-tra-diplomazia-e-conflitti/, [Last Accessed 19/06/2023].

ANSA Liguria, (2022), *Siccità: Coldiretti, in Liguria produzione foraggera in calo di 1/3*, Redazione Ansa, 28th July, https://www.ansa.it/liguria/notizie/2022/07/28/siccitacoldiretti-in-liguria-produzione-foraggio-calata-di-1/3_9cb5d28d-2cd9-43c5-a4af-0bd62fb90d34.html [Last Accessed 27/02/2023].

ANSA, (2022), *Nell'estate 2022 la peggiore siccità in Europa in 500 anni*, Redazione Ansa, 6th Septmber, https://www.ansa.it/canale_scienza_tecnica/notizie/terra_poli/2022/09/06/nellestate-2022-

la-peggiore-siccita-deuropa-in-500-anni-_bab737df-97c3-4b4a-933a-bd820cf06764.html, Rome (Italy), [Last Accessed 18/10/2022].

ANSA, (2023), *C'è allarme siccità in Liguria, il Brugneto come nel 2022*, Redazione Ansa, 2nd March, https://www.ansa.it/liguria/notizie/2023/02/28/e-allarme-siccita-in-liguria-il-brugneto-come-nel-2022_d97d24b1-1a39-4217-ba56-2ab178ad6352.html, [Last Accessed, 1/03/2023].

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 28/02/2023]

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].

Autorità distrettuale spartiacque dell'Appennino settentrionale, (2011), *Le alluvioni di Genova*, https://www.appenninosettentrionale.it/itc/?page_id=8244, [Last Accessed 22/02/2023].

B. Raso, (2022), *La terribile siccità del 1540 in Europa: innescata dall'ondata di caldo più estrema del 2003*, Meteoweb, 1st July, https://www.meteoweb.eu/2022/07/ondata-caldo-siccita-europa-1540/1811973/, [Last Accessed 18/10/2022].

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 28/02/2023]

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].

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

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].

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

C. Nadotti, (2022), *Israele e Giordania insieme per salvare il fiume Giordano,* Repubblica, 18th November, *https://www.repubblica.it/green-and-blue/2022/11/18/news/inquinamento_fiume_giordano_accordo_israele_giordania-375067126/*, [Last Accessed 01/11/2022].

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].

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].

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].

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

Dozen Blogs, (2022), *Nell'estate 2022 la peggiore siccità in Europa in 500 anni*, European Earth observation program Copernicus and the European Space Agency (ESA), 6th September, https://dozenblogs.com/nellestate-2022-la-peggiore-siccita-deuropa-in-500-anni/, [Last Accessed 18/10/2022].

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

D. Scafidi, G. Ferretti, R. Pedemonte, (2022), *Il 2022, un anno di record per il clima anche a Genova*, Unige.life, 30th January, https://life.unige.it/2022-record-caldo-genova, [Last Accessed 01/06/2023].

D. Scafidi, G. Ferretti, R. Pedemonte, (2022), *Caldo e siccità record per il 2022*, Società Meteorologica Italiana, Osservatorio Meteo UniGe Unige.life, 16th September, https://life.unige.it/record-caldo-siccita-2022, [Last Accessed 20/10/2022].

D. Bellocchio, (2019), *Sulle rive del lago Ciad, la crisi umanitaria più complessa dei nostri giorni*, Lifegate, 25th July, https://www.lifegate.it/lago-ciad-reportage, [Last Accessed 10/11/2022].

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*, Meteo Web, 5th November,

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].

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,* ELLE, 13th May, https://www.elle.com/it/lifestyle/verde/a36045256/come-e-cambiato-il-clima-in-italia/, [Last Accessed 13/10/2022].

D. Proietto, (2005), *Carestia e siccità in Etiopia*, Politica Domani, 1st March, https://www.politicadomani.it/pdov/index.html?main=Pagine/Giornale/Num45/Carestia%20Siccita.htm, [Last Accessed 13/10/2022].

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].

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

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].

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].

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

E. Ragusa, (2022), *Cambiamenti climatici: un crescente scetticismo,* Attività Solare, 8th December, https://www.attivitasolare.com/cambiamenti-climatici-un-crescente-scetticismo/, [Last Accessed 14/10/2022].

E. Frittoli, (2017), L'Italia senza acqua le più gravi siccità nella storia del paese, Panormama, 26th June, https://www.it/news/litalia-senza-acqua-le-piu-gravi-siccita-nella-storia-del-paese, [Last Accessed 14/10/2022].

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].

Fonte ufficiale, (2022), *Perché siccità e inondazioni sono collegate*, https://fonteufficiale.it/ambiente/perche-siccita-e-alluvioni-sono-collegate, Fonte Ufficiale, 23th August, [Last Accessed 22/02/2023].

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

F. Zavatti, (2017), *Il MOI, Mediterranean Oscillation Index*, Climate Monitor, 6th September, http://www.climatemonitor.it/?p=45748, [Last Accessed 28/02/2023].

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

Group CAP, (2021), *L'acqua nel mondo: tutto quello che c'è da sapere sull'oro blu*, Gruppo CAP, 24th September, https://acquadelrubinetto.gruppocap.it/ambiente/acqua-nel-mondo/, Milan (Italy), [Last Accessed 26/10/2022].

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

Historical Weather Observatory of the University of Genoa, (2022), *L'estate del 2022 è stata la più calda della città dal 1833*, Il Secolo XIX, 17th September, https://www.ilsecoloxix.it/genova/2022/09/17/news/genova-l-osservatorio-meteo-storico-dell-universita-l-estate-2022-e-stata-la-piu-calda-in-citta-dal-1833-1.41677190, [Last Accessed 14 /02/2023].

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

IconaClima, (2019), *Temporale autorigenerante: cos'è e come si forma*, Reazione Icona Clima, 15th June, https://www.iconaclima.it/meteo/temporale-autorigenerante-cos-e-come-si-formano/, [Last Accessed 01/03/2023].

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,* Il Secolo XIX, 22th June, 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].

I. Sesana, (2020), *Cambiamenti climatici e guerra: siccità e inondazioni minacciano la pace*, Rights

Observatory, 14th January, https://www.osservatoriodiritti.it/2020/01/14/cambiamenti-climatici-e-guerre-migrazioni-tema-conseguenze/, [Last Accessed 12/01/2023].

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

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

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

ISPRA, (2019), *Rapporto sulla siccità*, https://www.isprambiente.gov.it/pre_meteo/siccitas/index.html, [Last Accessed 13/10/2022].

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].

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].

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].

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].

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

K. Reid, (2022), *1980 Ethiopian Famine: Facts, What Changed, and How to Help*, World Vision, 3rd November, https://www.worldvisioNorg/disaster-relief-news-stories/1980s-ethiopia-famine-facts, [Last Accessed 25/11/2022].

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

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].

L. Lombroso, (2020), *Storia meteo: la calda e terribile estate 2003*, Il Meteo, 4th August, https://www.ilmeteo.net/notizie/attualita/meteo-storia-la-rovente-e-terribile-estate-2003.html, [Last Accessed 20/02/2023].

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].

M. Labidi, (2016), *Zone temperate*, Skuola.net, 25th August, www.skuola.net, [Last Accessed 17/10/2022].

M. Vittoria, (2021), *Riscaldamento globale: cause e conseguenze*, Informazione Ambiente, 8th May, https://www.informazioneambiente.it/surriscaldamento-globale-cause-conseguenze/, [Last Accessed 18/10/2022].

M. Jones, (2020), *The Sahel Facing 3 Problems: Climate, Conflict and Overpopulation*, Vision of Humanity, 20th January, https://www.visionofhumanity.org/challenges-facing-the-sahel-climate-conflict-and-overpopulation/, [Last Accessed 25/11/2022].

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

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

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

NY Times, (2009), *Obama's speech on climate change*, New York Times, 22nd September, https://www.nytimes.com/2009/09/23/us/politics/23obama.text.html, [Last Accessed 05/11/2022].

N. Campini, S. Origone, (2018), *Liguria, mareggiata e mareggiata, una donna morta ad Albisola. Genova il Comune ci ripensa,* Repubblica, 29th October,

https://genova.repubblica.it/cronaca/2018/10/29/news/allerta_rossa_genova_con_il_fiato_sospeso_preoccupano_le_mareggiate-210274863/, [Last Accessed 19/02/2023].

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

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].

Polaris, (2010), *Popolazione a rischio frane e alluvioni in Italia: Liguria una storia di alluvioni*, Polaris, 10th October, https://polaris.irpi.cnr.it/liguria-una-storia-di-alluvioni/, [Last Accessed 20/02/2023].

Progetto Continenti, (2022), *Negoziati di pace tra Etiopia e Tigrai,* Progetto Continenti, 31th October, https://progettocontinenti.org/7448-2/, [Last Accessed 29/11/2022].

P. Bonino, MeteoLive, (2002*), Il clima della Liguria: differenze tra Oriente e Occidente*, Meteo Live, 8th July, https://www.meteolive.it/news/I-tipi-di-clima/38/il-clima-della-liguria-differenze-tra-levante-e-ponente-/, [Last Accessed 4/02/2023].

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

P. Crivelli, (2014), Blasting News, *Tutte le alluvioni di Genova negli ultimi 44 anni,* Blasting News, 13th October, https://it.blastingnews.com/ambiente/2014/10/tutte-le-alluvioni-a-genova-degli-ultimi-44-anni, [Last Accessed 20/02/2023].

P. Agarwal, (2022), *Teoria della popolazione malthusiana*, Intelligent Economist, 2nd Febraury, https://www.intelligenteconomist.com/malthusian-theory, [Last Accessed 17/11/2022].

Rai News, (2022), *Allarme siccità Po, richiesto il razionamento dell'acqua in 125 comuni,* Rai News, 15th June, https://www.rainews.it/articoli/2022/06/allarme-siccit-del-po-chiesto-razionamento-dellacqua-in-125-comuni-0af916a5-b7cb-4a49-ae5b-45a27bfbf924.html, [Last Accessed 22/10/2022].

Repubblica, (2022), *In Europa la peggiore siccità degli ultimi 500 anni vista dai satelliti*, Repubblica, 06th September, https://www.repubblica.it/green-and-blue/dossier/siccita--gestione-acqua/2022/09/06/news/copernicus_satelliti_siccita_peggiore_ultimi_500_anni-364454343/, European Earth observation program Copernicus, European Commission and the European Space Agency (ESA), [Last Accessed 20/10/2022].

Rivista Africa, (2019), *The population of the continent is constantly increasing*, Rivista Africa, 7th July, https://www.africarivista.it/la-popolazione-del-continente-e-in-incremento-costante/143162/, [Last Accessed 10/11/2022].

Rivista Ligure di Metereologia, (2022*), Notizie rilevanti riguardanti l'estate del 2022 e dati connessi di temperature record estreme*, Rivista Ligure di Meteorologia, 4th September, http://www.rlmet.it/notizie_attualita.htm, [Last Accessed 9/02/2023].

Ruminantia ANBI, (2022), *Osservatorio Risorse Idriche: resta rosso l'allarme*, Ruminantia, 24th August, https://www.ruminantia.it/osservatorio-anbi-risorse-idriche-lallarme-resta-rosso-litalia-e-climaticamente-schiacciata-tra-siccita-e-bombe-dacqua/, Milan (Italy), [Last Accessed 20/10/2022].

Sky TG 24, (2022), *Siccità in Europa, 47% del territorio a rischio secondo uno studio dell'Unione Europea*, Sky TG 24, 23rd August, https://tg24.sky.it/mondo/2022/08/23/-siccita-europa-studio-ue, [Last Accessed 14/10/2022].

Sky TG 24, (2022), *Siccità, l'estate 2022 è stata la peggiore per l'Europa in 500 anni*, Sky TG 24, 06th September, https://tg24.sky.it/ambiente/2022/09/06/europa-siccita-estate-2022, [Last Accessed 20/10/2022].

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].

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].

S. Morosi, (2015), *Mali, la storia del paese dal golpe del 2012 all'accordo di pace*, Corriere, 20th November, 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].

S. Turci, (2022), *Siccità e inondazioni sono facce della stessa medaglia*, Icona Clima, 5th October, https://www.iconaclima.it/italia/clima/perche-si-passa-dalla-siccita-alle-alluvioni/, [Last Accessed 20/02/2023].

S. Scaini, R. Bakalova, (2020), *Sicurezza e cambiamenti climatici: l'approccio della NATO a una sfida globale alla sicurezza*, Safety & Security, 10th June, https://www.safetysecuritymagazine.com/articoli/sicurezza-e-cambiamento-climatico-lapproach-of -born-to-a-global-security-challenge/, [Last Accessed 06/12/2022].

The Economist Namibia, (2020), *The effects of rainfall distribution and intensity on agricultural*

production, The Economist Namibia, 30th November, https://economist.com.na/57635/columns/the-effects-of-rainfall-distribution-and-intensity-on-crop-production/, [Last Accessed 14/10/2022].

T. Gebremariam, (2021), *Acqua pulita, ancora un sogno per l'Africa*, Africa Rivista, 22nd March, https://www.africarivista.it/acqua-pulita-ancora-un-sogno-per-lafrica/182663/, [Last Accessed 26/10/2022].

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

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

Tutto Lavoro 24, (2022), *Razionamento acqua 2022, al via Milano: ecco l'Ordinanza*, Redazione Tutto Lavoro, 26th June, https://tuttolavoro24.it/2022/06/26/razionamento-acqua-2022-parte-milano-ecco-lordinanza/, [Last Accessed 22/10/2022].

Tutta Italia, (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].

T. Spano, (2022), *È il posto più secco del mondo, non piove da 500 anni,* Eco Cultura, 21st Febraury, https://www.ecocultura.it/deserto-atacama-siccita/, [Last Accessed 14/10/2022].

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].

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

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

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

United Nations, (2015), *Department of Economic and Social Affairs,* https:// doi.org/10.1016/jjhydrol201205052, [Last Accessed 01/03/2023].

United Nations, *Security Council holds first-ever debate on the impact of climate change on peace, and security, hearing over 50 speakers,* https://press.uNorg/en/2007/sc9000.doc.htm, [Last Accessed 05/11/2022].

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

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

V. Bruzzo, (2022), *Consumo e necessità di una gestione sostenibile delle risorse idriche*, Ingenio, 1st March, https://www.ingenio-web.it/articoli/risparmio-riuso-e-incentivi-fiscali-per-la-tutela-della-risorsa-idrica/, [Last Accessed 26/10/2022].

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

WikiWand, *Stazione meteorologica di Genova Sestri Ponente*, https://www.wikiwand.com/it/Stazione_meteorologica_di_Genova-Sestri_Ponente, Last Accessed 20/10/2022].

World Bank (2011), *Vulnerability, Risk Reduction, and Adaptation to Climate Change Mali: Climate Risk and Adaptation Country Profiles*.

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].

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

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