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Review

Water Resources Management under Climate Change: A Review

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Abstract: Climate change affects water resources through the decrease in rainfall and the increase in temperatures and evapotranspiration. An indirect impact of climate change is also the increase in water uses by human activities. In this review, 320 papers were retrieved, of which 134, spanning five continents and dealing with impacts and solutions, were selected to be used to better understand the effects of climate change on water resources, ecosystems, human health, security, and socio-economic aspects. Here, suggestions and proposals towards solutions by scientists from around the world, tips and ideas to deal with climate change, and the best solutions for future water management are presented. The main solutions highlighted concern integrated water resource management, political direction, policies, an increase in knowledge, and new technologies. Furthermore, most of the analyzed papers underline that water resource management needs to incorporate the protection and restoration of ecosystems and their services. Nature-based solutions need to be the starting point of new scientific and innovative ways to deal with climate change and look towards future climate adaptation. In this complex evolution of the water resource, the political position of Italy is also shown, illustrating what actions could be implemented for water resource management.

Keywords: climate change; integrated water research management; water resources

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1. Effect of Climate Change on Freshwater Resource Availability Worldwide

Since the early 1990s, the Intergovernmental Panel on Climate Change (IPCC) identified an anthropogenic effect on climate that caused catastrophic changes at global level (such as temperature and sea level rises, ocean acidification, etc.) [1,2] (Table S1: 79). The new models developed in this period started to incorporate the potential climate effects of human activities, including the increase in sulfate aerosols and in stratospheric ozone. In addition, a better definition of the natural variability of the climate system was developed [1,2] (Table S1: 56, 60, 81). Considering inland waters and their catchments, indirect climate change impacts can be present, with positive and negative effects on the amount of precipitation, the total riverine runoff, snowfall and snowpack accumulation, evapotranspiration, lake levels, and connecting channel flow reduction [3,4], (Table S1: 2, 12, 75, 90).

The first examination of climate change and the consequences on freshwater resource availability conveyed that there was an apparent increase in the frequency of drought periods, mainly in summer, and that probably these were a consequence of climate change [5,6] (Table S1: 12, 54, 70, 90).

Anthropogenic climate change is expected to have significant impacts on global freshwater resources. These impacts include increased evapotranspiration, resulting from higher temperatures, as well as a likely increase in the frequency and intensity of droughts, with a reduction in snowpack and changes in the timing of spring runoff (Table S1: 34). In snowmelt-dominated river systems, higher winter temperatures resulted in reduced snowpack accumulation and lower snowmelt contribution to river discharge during summer [7] (Table S1: 2, 13, 46, 67, 75). As a result, climate change affects water supply, resulting in damage to infrastructures due to floods, water scarcity related to decreasing rainfall and increasing demand, sanitation services related to declining water quality, and the distribution of water resources (Table S1: 94, 122, 129).

Moreover, climate change affects soil moisture, groundwater recharge, and the frequency of flood or drought events and groundwater levels in different areas. Studies on the socio-economic impacts of climate change, based on future scenarios and uncertainties assessment highlighted (1) the timing, magnitude, and nature of climate change; (2) the ability of ecosystems to adapt either naturally or through managed intervention to the change in climate; (3) the future increase in population and economic activities, with potential impacts on natural resources; and (4) adaptation of the human society through the logical responses of individuals, businesses, policy changes, and security [8,9] (Table S1: 12, 15, 36). Freshwater security concerns the capacity of water to support human activities, including economic, social, and health aspects together with ecosystem aspects [10] (Table S1: 105, 111). Climate change affects rainfall quantity, increasing precipitation variability with catastrophic consequences on groundwater recharge [11,12], river flow, water resource availability, agricultural production, and economic growth in several countries [13–15] (Table S1: 102, 103). Therefore, climate change, combined with intensive human activities, caused significant changes in precipitation and streamflow amounts worldwide [16] (Table S1: 40, 42, 61, 96).

In the era of climatic changes, it is clear that management approaches should also be changed, and the knowledge of the trend of rainfall temporal changes, population, and storage should be at the base of any water management: the storage trend evolves in an opposite way to the rainfall gradient [6,17,18] (Table S1: 85). Several studies highlighted that a certain amount of climate change is inevitable, and the efforts made should be towards adaptations strategies (Table S1: 5). Some of these strategies should include changes and improvements in behavior, technological solutions, laws and policies, and water resource management [14,17] (Table S1: 16, 25, 33, 44). The assessment of the availability of freshwater resources in the context of future national requirements and expected impacts of climate change and its variability is critical for national and regional long-term development strategies and suitable development [8,18] (Table S1: 82, 87, 97, 108). Physical water shortage, or lack of water probably will not be extensive, but, instead, the failure to meet multi-purpose water demands (or needs) will cause a profound water crisis due to climate change [7] (Table S1: 41).

Over time, several solutions were proposed to counteract or to adapt to climate changes, such as integration of measures of climate resilience through water safety plans and water resources management, strictly connected with policy prescriptions and new technological solutions (e.g., wastewater treatment, pumping efficiency, and renewable sources) [19] (Table S1: 16, 18, 40, 48, 69, 78). Therefore, it seemed likely that adaptive management, integrated freshwater resources management, social learning, and resilience thinking have to be the new paradigms related to political and institutional practices and national–international laws [20] (Table S1: 20, 41, 44, 47, 64, 83, 121).

Thereafter, to evaluate water resources and water resource management, a new concept has been introduced: the Terrestrial Water Storage (TWS), a natural or manmade water storage that represents the freshwater global resource availability, including both surface waters and groundwaters, strictly linked to droughts, floods, and sea level changes (Table S1: 76, 87, 116). It represents all the natural and artificial water storage present on the Earth's surface, sub-surface, and underground, such as soil moisture, root zone, groundwater, snow, ice, water stored in vegetation, rivers and lakes, reservoirs, and ponds (Table S1: 46, 100, 131). The TWS is thus the capacity given by lakes, rivers, groundwater, soil moisture, glaciers, canopy water storage, etc., to balance the hydrological cycle with ecological, environmental, and socio-economic aspects [21] (Table S1: 16, 32, 96). Recently, the Gravity Recovery and Climate Experiment (GRACE) model allowed for the evaluation of water resources; drought and floods phenomena; and, above all, the impact of human activities on the water cycle, i.e., groundwater depletion [22] (Table S1: 16, 40, 42, 48, 61).

Different adaptation measures have been under study: increasing water supply, reducing demand through water saving, or utilizing infrastructure as groundwater artificial recharge (water spread or impound on the land surface to allow infiltration and percolation to the aquifer or injecting directly water into the aquifer using wells); and increasing water conservation efforts (through rain-water harvesting, ponds, lakes, digging canals, water-reservoir expansion, and installing rain water-catching ducts and filtration systems on buildings), with lining kilometers of unpaved canals, land-use changes, crop conversion, etc. [7,13]. The increase in water storage capacity would seem to be the most viable solution: it could increase agricultural and economic productivity, contributing also to hydro-power generation and provision of water supply to commercial and industrial enterprises. This solution has strong multi-tasking roles contributing to poverty reduction, sustainable development, and adaptation to climate change [13], (Table S1: 25, 133).

The adaptation to climate change needs to be dynamic, and it is necessary to consider the socio-political contest, biodiversity and ecosystem services into integrated development-oriented processes [23], (Table S1: 17, 44, 108, 113).

In this paper, we analyze the effects of climate change (as increase in evapotranspiration, of annual runoff, and of water resources variability) on temperature, on longer drought periods, and on the total number of extreme events with decreasing snowpack accumulation, with consequences on agriculture, socio-economic development, biodiversity, and ecosystem services in each continent. An in-depth bibliographic search in support is reported Supplementary Materials Table S1.

The present overview aims to achieve the following: H1, to understand what kind of responses different governments are taking across countries (point 3: country-based solutions to water management; H2, to highlight the impact of different water management solutions on fields such as economy, society, and nature to find strategies and smarter solutions that consider also the cost–benefit ratio and environmental aspects (point 4: relevance of the main solutions on economy, society, and environment); and H3, to find out and offer to Italian policy makers possible appropriate solutions already applied in other countries to address water resource management challenges under climate change effects (point 5: proposal for the Italian territory).

2. Methodology

A total of 320 papers were retrieved from the internet using Google and Google Scholar search engines in two time steps.

The first time-step search was focused on climate change and its evolution in time and space analyzing papers from 1990 to 2022 and was performed using long-tail keywords involving more than a single word, i.e., initially “Climate change”, successively “Effects of climate change”, and then “Climate change and water resource” (Table 1).

The second time step focused on water research management and on the solution to water scarcity, water multiple uses, and groundwater and water availability for ecosystems, considering papers from 2000 to 2022 to find the most recent research on climate change impacts and on smarter solutions to manage water resources, and it was performed using the following keywords: initially “Water research management”, successively “Climate change and water storage”, and then “Water storage” (Table 1).

We retrieved 160 references for each time step, including scientific papers, books, memorandum, and grey literature. Of the collected references, we considered only papers written in English, published in indexed international scientific journals, and fully related with the topics of interest. The exclusion criteria led to us keeping 134 relevant papers.

Table 1. Number of papers found during the first and the second search step and their relationships with the highlighted topics.

	Books/Report/e-Book	**Biology**	**Modeling**	**Economy**	**Sociology**	**Tourism**	**Medicine health**	**Natural Hazard/Geology**	**Water Resource Management**	**Not Available**
First Time-Step Search										
Climate change	19	7	1	1	3	1	0	1	16	2
Climate change effects	4	19	8	4	0	3	5	1	10	1
Climate change/water resource	3	1	11	1	0	0	0	1	37	0
Sum	26	27	20	6	3	4	5	3	63	3
	Books/Report/e-Book	Biology	Modeling	Economy	Sociology		Water Quality Health	Technology	Water Resource Management	Not Available
Second Time-Step Search										
Water research management	3	5	5	4	2		11	1	26	1
Climate change/water storage	1	6	4	2	2		4	1	28	2
Water storage	1	4	3	2	0		7	17	18	0
Sum	5	15	12	8	4		22	19	72	3

Therefore, subsequent analyses were carried out, considering both the distribution of papers per continent, and the solutions or proposals related to climate change or the adaptation to it, resulting from a different country in each continent. In the continent list, we added two elements: "More Countries", which includes papers whose studies referred to the effects of climate change on water resources and the potential solutions in more than one country or continent; and "No Country", representing papers dealing with climate change in general, without specific relation to countries or continents.

3. Country-Based Solutions to Water Management

For the first time-step search, the papers on climate change impacts on water resources were the most common and represented 39.4% of the analyzed papers, followed by papers dealing with climate change impacts on biological aspects (17.0%) and climate change modeling (12.5%). Other topics were represented by percentages lower than 5% and included economical aspects of climate change effects, climate change related to medicine and health, and climate change impacts on tourism, as well as the frequency of natural hazards, geological impacts, and sociological aspects.

For the second time-step search, the overall results showed that papers dealing with water resource management were the most common, representing 47.3% of the analyzed papers. Other topics were less frequent, with papers dealing with storage in regard to solar energy or hydro-power generation production (12.0%), and water quality status and chemical aspects related to water treatments for safe drinking water (10.0%). Papers on biological, ecological, and microbiological carbon storage, biological treatment of drinking water, modeling of changes in water availability, climate change impacts on global atmospheric circulation, and economical effects of water availability were less common (<10.0%).

The analyses considered in the second run allowed us to process the results reported in Table 2 and in Figure 1.

Table 2. Number of papers per country. Middle East includes Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Saudi Arabia, Qatar, Syria, United Arab Emirates, and Yemen. No country: not geotargeted general aspects.

Continent and Countries	No. of Papers
North America and Canada	21
South America	3
Northern Europe and UK	11
Central Europe	3
Southern Europe	8
Africa	8
Asia	23
Australia	3
Middle East or Saudi Arabia only	3
China and Korea	6
India	6
Central Asia or Himalayan region only	8
More Countries	47
No Country	7

Most of the selected papers (35.1%) targeted multiple countries debating climate change effect across Asia and Eastern Europe or in developing countries or into arid, alpine, or glacier zones. In the Americas (17.9%) and in Asia (17.2%), massive research activity was devoted to climate change effects on water resources; water management; groundwaters; and social, economic, and environmental aspects. Overall, 62.5% of the papers concerning the Americas dealt with impacts, effects, and solutions concerning the United States, and

21.7% concerning Asia addressed climate change effects on water resource management in China and India. Europe, the third most referred to continent, accounted for 16.4% of the papers, dealing mostly with climate change impacts on agricultural and economic aspects, introducing proposals for shared legislations and management planning activities. Papers related to Africa only represented 6.0% of the total production, equally distributed between North and South Africa, and they mainly debated changes in water resources and social and political implications. Conversely, papers referring to Australia (2.2% of the total) covered topics such as future climatic change scenarios and expected impacts on water resource management.

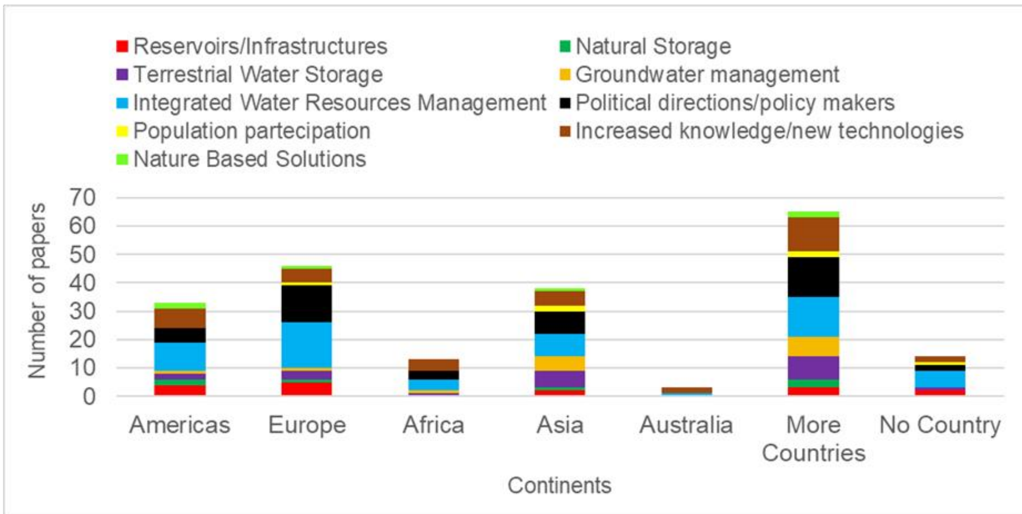

Figure 1. Solutions proposed to adapt or deal with climate change, by continent.

The selected papers, in addition to addressing climate change issues on water resources, also proposed solutions to achieve sustainable water resource management (Figure 1). Solutions frequently included both reservoirs and Terrestrial Water Storage (TWS), or they included political directions and popular participation in politics, or enhanced knowledge and groundwater management. Groundwater management was sometimes presented as the universal solution to achieve an Integrated Water Resources Management, while the enhanced knowledge was seen as an investment bringing remarkable improvements to any other addressed solution.

Natural Storage and Nature-Based Solutions were viewed as innovative solutions and were therefore little treated and considered as a separate topic.

In general, the most frequent proposal was based on Integrated Water Resources Management (27.8%), followed by political directions or decisions (21.2%), and by enhanced knowledge or new technologies (17.5%). Innovative solutions were poorly represented; therefore, Terrestrial Water Storage, reservoirs/infrastructures, and groundwater management were addressed only in less than 10.0% of the papers. Natural storage, popular participation, and Nature-Based Solutions were even less considered (<5%; see Figure 2).

In Europe, Asia, and "More Countries", all the analyzed solutions ("Reservoirs/ Infrastructures", "Terrestrial Water Storage", "Integrated Water Resources Management", Population Participation", "Nature-Based Solution", "Natural Storage", "Groundwater Management", "Political Directions/Policy Makers", and "Increase Knowledge/New Technologies") were considered. In the Americas, "Population Participation" and "Groundwater Management" were not considered as individual solutions, but they were included in the "Integrated Water Resources Management" category, representing the 19.0% of all the papers, versus 27.0% in Europe, 13.6% in Asia, and 7.0% in Africa.

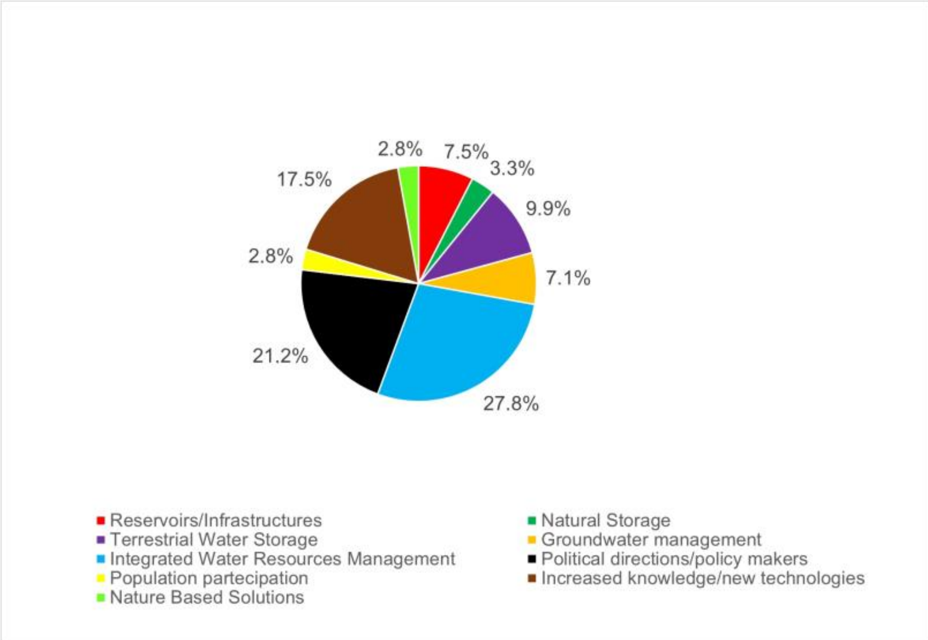

Figure 2. Percentage frequency of the most common proposals and approaches.

In Africa, the performed analyses were quite comprehensive, including "Terrestrial Water Storage", "Groundwater Management", "Integrated Water Resources Management", "Political Directions/Policy Makers", "Increased Knowledge/New Technologies" (representing <10.0% of the total amount of papers).

In Australia, we found only papers dealing with "Integrated Water Resources Management" and "Increased knowledge/new technologies".

In Asia, the suggested solutions included "Reservoirs/Infrastructures" (5.3%), "Terrestrial Water Storage" (15.8%), "Groundwater Management" (13.2%), "Political Directions/policy makers" (21.0%), "Population Participation" (5.3%), "Increased Knowledge/New Technologies" (13.2%), and "Nature-Based Solutions" (2.6%).

Clearly, for countries historically experiencing water scarcity (such as in Africa and Asia), the most efficient way to manage water was reported to be the distribution of water in larger areas through artificial or natural canals (thinking about "Groundwater Management" or "Terrestrial Water Storage") and the involvement of the public and of stakeholders in decision making on the water resource management process.

In all countries, the options "Integrated Water Resources Management" and "Increase Knowledge/New Technologies" (since 2000 and 2004) were recognized as the most effective and efficient solutions. Increased knowledge was reported as pivotal to implement the awareness of the impact of climate change on water resources and on ecosystem services, with cascading effects also on social and economic aspects. The increase in knowledge was reported also to contribute to understanding that "Integrated Water Resources Management can be a key solution to tackle climate change and to be more resilient to it.

"Nature-Based Solutions" appeared as a topic in 2009 in the United Kingdom, and later in 2018, in China; 2019 and 2021 in the United States; and in 2020 in "More Countries". In Italy, the suggested solutions were different, with diverse directions: "Integrated Water Resources Management", "Political Directions", and "Natural Storage and Reservoirs".

In summary, the results obtained showed that the options "Integrated Water Resources Management", "Political Directions", and "Increased Knowledge/New Technologies" are the most proposed solutions, mainly in Europe and in those papers including more countries. This suggests that such solutions have been studied and subsequently adopted in many parts of the world. Considering the different solutions analyzed over time, the previous solutions ("Integrated Water Resources Management", "Political directions", and

"Increased knowledge/New Technologies") have been the most important since 1996. Moreover, in the Americas and Asia, the use of Terrestrial Water Storage is a recent solution, dated back to 2017. Studies developed over time highlight the need to use all possible options to best store, retain, and distribute the available water resources, not focusing on a single solution. In addition, the option "Nature-Based Solutions", proposed and adopted in the Americas, Europe, and Asia represent innovative solutions since 2008, namely the right way to solve the water resource management to preserve the human future.

4. Relevance of the Main Solutions on Economy, Society, and Environment

Generally, studies on climate refer to the average long-term changes over the whole planet and to climate variability as a model system. In this way, a complete view of climate-change effects on biological assemblages and human society cannot be reached. These impacts are significantly underestimated and little considered as costs for the population, such as increasing food insecurity and pest disease [24]; and decreasing streams, groundwater, and lake water quality [25,26] (Table S1: 134). Changes in precipitation and temperature have significant effects on the quality of surface waters, and these effects go beyond the tolerance level of ecosystems, inducing water quality degradation (Table S1: 34, 65, 108, 113). It is therefore crucial to implement new adaptation strategies to warmer climate that take into account local ecological thresholds rather than average annual climatic conditions (Table S1: 11, 44, 46, 81).

For this reason, we focused on studies describing scientifically and technically feasible solutions to better address primarily climate change and its effects on water resources, but also on ecosystems, socio-economic aspects, health, and food security. The whole list of references used is reported in Supplementary Materials Table S1. Furthermore, we provide a broad panoramic view of several forms of managing water resources in the world so as to offer scientific bases for future political and social decisions, which the ministries and the also Italian Government will have to take into account in the field of water resources.

4.1. Reservoirs/Infrastructures

Several papers [15,27,28] highlighted that the construction of new, large dams in industrialized countries is not feasible due to the lack of adequate sites and of the current legislation for environmental sustainability. Large dams have social and economic benefits but, at the same time, have negative environmental and social impacts [13] (Table S1: 33, 104, 117), such as an increased habitat for disease vectors, increased evaporation, and increased flood-related damages (Table S1: 51, 118). Furthermore, they are subject to eutrophication, salinization, and siltation (Table S1: 16, 18, 64, 84, 92).

Several papers proposed to improve the efficacy of reservoirs using water storage solutions based on auxiliary infrastructures, such as the height elevation of an existing dam, or with volume optimization, or with an aquifer recharge system based on the artificial recharge of groundwater. Other solutions can be based on improving the management of reservoirs and their distribution network [13].

4.2. Terrestrial Water Storage/Natural Storage

Terrestrial Water Storage represents all the water storage present on the Earth, natural and artificial, that is, soil moisture, root zone, groundwater, snow, ice, water stored in the vegetation, rivers, lakes, reservoirs, ponds, and small tanks. This represents all the water storage on the Earth's surface, subsurface, and underground that can balance the hydrological cycle, as well as ecological, environmental, and socio-economic aspects [16] (Table S1: 32, 69). Natural Storage represents Terrestrial Water Storage but only for the natural elements such as wetlands, soil moisture, groundwater aquifers, and ponds [13] (Table S1: 129). Small tanks represent a water supply solution in developing countries, even if their use for drinking water may create quality problems [29].

Other papers show the importance of increasing groundwater reservoir capacity in local aquifers [30] (Table S1: 110, 112, 116, 118) to manage aquifers as natural storage reservoirs, thus preventing evaporation losses and ecosystem impacts related to the presence of large reservoirs [31] (Table S1: 51, 118).

4.3. Groundwater Management

Groundwater management must consider groundwater and its relationships with surface water in order to reduce human vulnerability to climate change, maintaining or increasing water storage capacity, of both natural and artificial origin [32] (Table S1: 74, 105). These different water supplies can have different origins, with different annual variability and availability, and they need to integrate a large number of demands and supply sources and to answer to different drought periods and purposes, such as an increase in water for ecosystem health [33] (Table S1: 104). The amount of water can be stored and then used depending on the permeability of the rock; groundwater can be considered a multi-year storage which can assume seasonal variability. This capacity can be reduced by changing the rainfall intensity, and land cover and can be polluted by salt intrusion in coastal areas (Table S1: 13, 16, 18, 84). A better use of groundwater resources, i.e., through specific allocation systems, can also be found thanks to new legislative policies [34].

4.4. Increased Knowledge/New Technologies

Increased knowledge and new technologies can make groundwater recharge more efficient or support the increase in water storage, for example, using biodegradable hydrogel materials [35].

In addition, remote sensing can also be used to map the elevations of surface waters for deriving changes in water storage (lakes, reservoirs, and wetlands) and trends in major rivers flows [36] (Table S1: 102, 116) to give indications for improved water management.

New technologies, for example, related to improving irrigation management efficiency, waste and saline waters treatments, changes in agricultural practices, or the introduction of specific genetic cultivars (Table S1: 16, 20, 46, 74, 111), solicit deep research and the modeling of water quality, water uses, changes in agricultural practices, or the introduction of drought-tolerant cultivars to minimize the negative effects on crop [37], (Table S1: 29, 111), on human health, and on the environment due to overirrigation and salt intrusion [38] (Table S1: 18, 64, 92). Also, they can be useful to create additional groundwater stores to collect excess monsoon runoff or underground reservoirs capable of storing large quantities of water (Table S1: 8, 41, 101).

4.5. Integrated Water Resource Management

The above-described technical solutions can help in improving resilience to water shortage, but it becomes evident that climate change emphasizes the urgent need of a new paradigm to the management of water resources and of goal-oriented management plans, with special attention to mitigation and adaptation strategies [39] (Table S1: 60, 66, 81, 109). It is important to highlight that increasing storage capacity alone, in the context of climate change, is not sufficient for water resources management: it is crucial to act on water demand and uses [7,33] (Table S1: 74, 104).

Water Resource Management with integrated strategies needs to be implemented and supported from a holistic point of view with different adaptation strategies, such as water storage and green infrastructures, agricultural practices, water governance and policies, disaster risk reduction, and economic diversification [40] (Table S1: 24, 102, 116); programs to optimize the use of hydroelectric energy and energy mixes that combine energies (i.e., hydroelectric, solar, and wind energy) [41], distribution efficiency, leakage control, and pressure management; and influencing demand where physical, biological, chemical, and socio-economic aspects and their interconnections are taken into consideration [16,20,21] (Table S1: 32). Integrated Water Resources Management also has the purpose to avoid the degradation of natural resources and ecosystems to obtain sustainable development with long-term productivity for the economic growth and in support of ecosystem services. The management plan should also take into account regional differences because each country has its own characteristics and issues to deal with, such as coastal and inland areas, islands, or desert regions [42,43] (Table S1: 53, 120).

However, Integrated Water Resources Management is also a political process of decision making [44] (Table S1: 3, 66, 80), which includes the four pillars of sustainability—social, economic, environmental, and institutional areas—and must consider physical, biological, chemical, and socio-economic aspects and their relationships [45], (Table S1: 6, 47, 54, 83, 95, 101).

4.6. Political Directions/Policy Makers

Political directions and policy makers have to address mitigation strategies to minimize the impacts of climate change and adaptation actions to look at how to reduce the negative effects that climate change imposes and how to exploit the opportunities that arise (Table S1: 3, 76, 88, 97, 124, 128, 134).

Mitigation strategies balancing global water availability and water demand can reduce the vulnerability of people (at risk for poor health), of society, and of ecosystem services [46] (Table S1: 60, 66, 81). Adaptation measures should incorporate climate considerations into long-term planning and management, and monitoring and advanced modeling to reduce waste to use and reuse water more efficiently for protecting and restoring biodiversity and natural habitats [26] (Table S1: 15), reducing demands, increasing the amount of water when expanding reservoir size, reducing water transport outside the catchment, and increasing pumping rate to the reservoir [47], (Table S1: 16, 64, 71). These adaptation strategies require political work to coordinate risks and uncertainties, to exchange information internationally, and to increase public awareness of the impacts of climate change [48] (Table S1: 66, 80). To plan water resource management, it would be useful to adopt a multi-criteria decision support system, i.e., an inclusive and dynamic decision-making process that takes learning and social involvement into account [44] (Table S1: 127).

4.7. Population Involvement

Therefore, by considering a population participatory approach to the planning and management of water resources, it is possible to minimize the impact and to improve our resiliency to climate change [49]. This is particularly important to prevent rural populations, especially in less developed countries, where the economy is based on natural resources such as forestry, agriculture, water, and fishing, from remaining excluded from decisions regarding natural resources [50], with repercussions on food security because no effective adaptation and mitigation policies and strategies are present (Table S1: 78). A bottom-up assessment of vulnerability holds promise as a means of responding to local priorities and complexities [23].

4.8. Nature-Based Solutions

Finally, recent studies [51] (Table S1: 11, 125) on Nature-Based Solutions on natural and semi-natural ecosystems show decreasing climate change impacts and supply support to people adaptation [49]. Protected, restored, and well-managed natural or semi-natural ecosystems have positive effects on the local economy, supporting the public adaptation to climate change and creating climate-resilient communities [52]. An example of a new strategy to solve water management issues in an urban context, where rapid urbanization, waterlogging, water pollution, and ecosystem degradation have caused severe problems, is the Sponge City [53]. This is a holistic integrated urban water management approach using Nature-Based Solutions, a starting point for new scientific research to deal with climate change in an innovative way.

A further example of a Nature-Based Solution is the natural water retention pond, which was developed as a solution to the assessment of water management in agriculture [50]. Ponds showed positive effects on the agricultural landscape, on water availability, and on environmental quality. The presence of ponds increases water availability for irrigation during the dry season, adding secondary economic benefits and improving the product quality under a climate-change scenario [54].

In detail, water resource management cannot be delegated to political decision makers alone, but it must be defined through social participation and sharing because different choices lead to different scenarios. Only a choice shared by all stakeholders can lead to positive scenarios of adaptation, safety, and health with the awareness that if stakeholders have taken part in the decisions, they will be more inclined to adopt them.

Agriculture, including large companies and small farmers, needs water as much as large or small cities, just as rivers and lakes can only exist thanks to water. Considering the large number of ecosystem services and the stakeholders involved, it is important to define the role of policy makers, scientists, and the whole society. From a technical point of view, detailing the value of ecosystem services at the local scale; evaluating uncertainties; communicating with non-scientists; and interacting with local communities, stakeholders, and policy makers are important steps in planning adaptation measures [55].

Only an Integrated Water Resources Management approach which takes social, economic, and ecological aspects into consideration in an egalitarian way, through the use of every possible source of water storage (in particular Terrestrial Water Storage), is able to address climate change and direct human activities towards adaptation supporting us to water saving, sharing and higher respect for the environment and ecosystems. To correctly address water resources management in the context of climate change and fill the gaps that still exist, it is therefore necessary to consider improving knowledge on the possibilities of storing water resources in aquifers, on the use of nature-based solutions to deal with extreme rain and drought, and on the efficient use of technology to better understand climate evolution, effectively distribute the resource, and make crops more resistant to heat and drought. In conclusion, the idea shared by all countries is there is no single solution, but there is a single way of proceeding: knowing, studying, sharing, involving, using technology and, above all, putting ecosystems front and center in water planning. This is the only way to manage water resources without impacting populations, the natural system and economy.

5. Proposal for the Italian Territory

A practical example can be found in Italy, where the impact of climate change, both in the Alpine and Mediterranean areas, is posing serious problems for water resource management [54]. Artificialization is posing great problems for the aquifer recharge and for the management of extreme events of both intense rainfall and drought. Water is left to ecosystems only after other needs have been satisfied. The restoration of the natural hydrological balance, which favors a better ecological state of rivers and lakes and a higher supply of aquifers, is not so contemplated. Considering the territorial features of Italy, nature-based solutions could be the most effective actions to address water scarcity and floods events. The possibility to define floodplain areas or ponds along rivers, so as to distribute the water resource as much as possible, can help to store water when abundant and to use it when scarce. Consider groundwater and its management as distributed storage, improving the infiltration for counteracting saline intrusion in territories close to the sea. The political direction, an important element with which to define future actions and solutions to be adopted at the government level, should be more aimed at sharing and evolving towards an Integrated Management of Water Resources to better address climate change and preserve ecosystem services, biodiversity, and our future.

6. Concluding Remarks

Worldwide, due to the increase in population and in water demand for human purposes (e.g., agriculture, industry, hydro-power generation, and tourism), the water crisis is a problem even in those areas characterized by a high precipitation amount. In some countries, drought and water scarcity are characteristic, affecting human distribution and causing devastating problems due to the consequences they have on human well-being and health. Therefore, it becomes crucial to highlight solutions, methods, and approaches to better respond in a sustainable way to water scarcity, to food security and health, and to ecosystem and biodiversity protection in support of governments and their political decisions. Water resource management under climate change is a complex issue.

H1—Across the world, climate change's effects and impacts on water resources have different consequences on the environmental, social, and economic aspects. Scientists from different countries suggested several strategies and solutions according to the physical, morphological, social, and political characteristics of their territories.

H2—Most of the papers we collected also highlight that the management of water resources must take into account not only the economic and social point of view but also, or above all, ecosystems and their services. All together, they agree that Integrated Water Resources Management, political and planning process, increasing knowledge, and applying new technologies are the best approaches to deal with the problem of water resource sustainability. Climate change and the low availability of water resources require a radical change in the management of water resources, where ecosystems and their services must be placed at the core of the system. Only by respecting the recharging capability of the Earth's natural resources will we have the possibility of a sustainable and long-lasting future.

H3—This is even more true regarding Italian natural resources, water, and biodiversity, where only a new enlightened vision of territorial planning could be the solution to water resource management.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/su16093590/s1, Table S1. List of analyzed references divided per country, topic, and proposed solutions.

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