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A New Dialectical Model of Water Security under Climate Change

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Abstract: Although Integrated Water Resources Management (IWRM) is widely accepted as the state-of-the-art rational model for improving water governance, its evaluations under climate change at national and global scales indicate that progress made in water security and ecosystem preservation is slow. The paper identifies the relationship between Humans and Nature as the main reason for that and generates a novel social component to improve Water Resources Management (WRM) following three pillars: (1) A historical review over the past 20,000 years indicating that WRM depends on the interplay between Humans and Nature. This is in constant change over time, and depending on socio-economic and climate conditions, it oscillates between two opposites: conflict and cooperation. Three clusters have been identified, showing a different timeline pattern of dominance: (a) Nature dominating Humans (Naturalistic), (b) Nature–Humans in cooperation and competition (Dualistic), and (c) Humans dominating Nature (Anthropocentric). (2) Clarification of why a WRM model can improve water security through the Governance–Policy–Science Nexus. (3) Suggestion of a novel WRM model based on conflict identification (eristic component) and dialectical conflict resolution. Two types of conflicts have been distinguished: (a) Human vs. Human and (b) Human vs. Nature when the laws of nature are not respected. The dialectical tool operates by exchanging rational arguments to unify opposite objectives for harmonizing Humans with Natural laws. A case study of flood mitigation in Crete Island illustrates the Eristic–Dialectical methodology.

Keywords: water management; climate change; humans–nature relationship; conflict resolution; dialectics

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1. Introduction

Among multiple severe environmental challenges we face today, water security under climate change is the most prevailing for humans and the future of life on our planet. According to the UN Secretary-General, climate change is “the defining issue of our time” [1]. From different interpretations of the meaning of water security provided by international and UN organizations, such as [2], we may agree that it is a goal to guarantee a sufficient quantity of freshwater of good quality for Humans and Nature, including plants, animals, and all ecosystems under climate variability and natural disasters, such as droughts and floods. More frequent catastrophic floods and extensive droughts in different regions around the world, the flow rate reduction in big rivers, aquifer depletion, and diffuse pollution indicate that water security is today at risk for several reasons. One very important reason is the overuse of freshwater resources for human socio-economic activities, mainly in agriculture, while reducing water necessary for sustaining flora, fauna, and ecosystem services. The amount of water necessary per capita is set by water utilities and the UN’s recognition of water as a human right generally to 150 l/day. This is a small portion of the total quantity of water necessary to sustain life on the planet, which is roughly estimated per capita up to 3000 l/day [3].

Concerning the risk from climate change, to mitigate negative consequences for water security, countries agreed during the UN Climate Change Conference (COP21) in Paris to cut greenhouse gaseous emissions. However, the goal set is far from being obtained mainly because of inadequate financing. Recently, the results obtained by COP27 in Sharm el-Sheikh, Egypt, 6–20 November 2022, made progress for climate mitigation and adaptation more uncertain. Concerning the goal of water security, the modification of rainfall patterns in the hydrosphere due to climate change has increased extreme floods. At the same time, droughts of extended duration and water scarcity in regions of temperate climate have threaded local economies, such as those located in Southeastern USA, and Central and Northern Europe.

This paper identifies the relationship between humans and nature as the main driver of water security being threatened by climate change. This relationship also influences the way humans use and manage natural water resources over time. Through a historical review, starting from ancient civilizations [4–7], covering the classical Greco-Roman period [8–13] and the post-industrial and modern times [14–19], we investigate possible correlations between human socio-economic activities, like agriculture, industry, and cultural achievements on the one hand, and WRM practices under natural climate conditions on the other hand. WRM models have been used at different times either in accordance or in conflict with natural laws, like the water cycle and the water flow. From the historical revision, we have distinguished three clusters having a different pattern of dominance between humans and nature, i.e., (a) Humans being dominated by Nature (Naturalistic); (b) conflict and cooperation coexisting (Dualistic), and (c) Humans dominating Nature (Anthropocentric). Anthropocentric behavior has produced multiple negative impacts on air, soil, and water and made environmental remediation very difficult, especially in ensuring water security [20].

To respond to anthropocentric WRM challenges and increase resilience in water security under climate change, global solutions have been reported in our previous papers, based on conflict resolution between Humans and Nature [21,22]. Recently, NBs (Nature-Based solutions) [23,24] and ATHs (Ancestral Traditional Hydro-technologies) [25,26] have been proposed to conciliate human activities with nature. However, the former refers to natural processes and natural material without considering the conflictual part of human behavior to nature. The latter deals with low-cost and small-scale traditional water-related technologies, which although are a good source of inspiration cannot be easily upscaled to meet the actual needs of human societies.

In this paper, the novel WRM model is explained by responding to two questions: (1) How can a “good” WRM based on Humans–Nature reconciliation improve water security under climate change? (2) What are the contents and the novelty of the dialectical WRM, how does it differ from the IWRM process or model, and how can it be implemented in policy?

The response to the former question is that a good WRM model is the main driver that influences water governance and increases water resilience through complex bilateral interactions between science, policy, and governance. Governance, Policy, and Science are interrelated in a complex process that may form an entity we call GPSN (Governance–Policy–Science Nexus).

To answer the latter question, a deeper analysis of the IWRM model is presented in Section 2.3. In connection to the historical analysis, it indicates that although very complete and theoretically sufficient, the IWRM model remains anthropocentric and technocratic [27,28]. As it is stated in [19], the IWRM idea goes back centuries. For adopting IWRM in the political agenda, the year 2000 of the Ministerial Declaration in the second WWF (World Water Forum), The Hague, could be considered a milestone. Since then, its implementation in Europe and many other countries has produced several negative environmental impacts, such as diffuse pollution, groundwater depletion, and soil degradation. To increase resilience in water security, we propose to improve the IWRM model by adding a social dimension activating stakeholder participation. This is accomplished in two steps: (a) assessing conflicts between natural laws and human socio-economic activities (Eristic

Analysis), and (b) resolving these conflicts dialectically (Dialectical Resolution), as it is explained in the following sections.

2. Materials and Methods

2.1. Historical Review of Human–Nature Interplay

Although humans are closely related to nature and are part of it, they feel it necessary to compete with natural forces to survive and improve their living conditions. This is not only for protecting themselves from natural disasters, such as floods, hurricanes, and tsunamis, but also for controlling, appropriating, and even mastering natural resources, such as water, food, and energy. This was obvious during the prehistoric period when humans struggled to survive in a hostile environment dominated by wild animals, floods, volcano eruptions, and low temperatures. During the era between 100 and 10 thousand years ago, a period scientists call the "Pleistocene", they experienced different severe climatic hazards. As shown in Figure 1, during the Late Pleistocene, i.e., between 20 and 10 thousand years ago, our planet was dominated by temperatures as low as −8 °C. During that period, securing life under severe climate conditions was a priority. Scientific developments and technical tools to manage natural resources, such as big rivers, and reduce impacts from floods were almost inexistent. During that period, humans considered cosmic forces like the Sun [4] to be Gods controlling human existence. Nature was dominating humans, and therefore, we may call that period "Naturalistic".

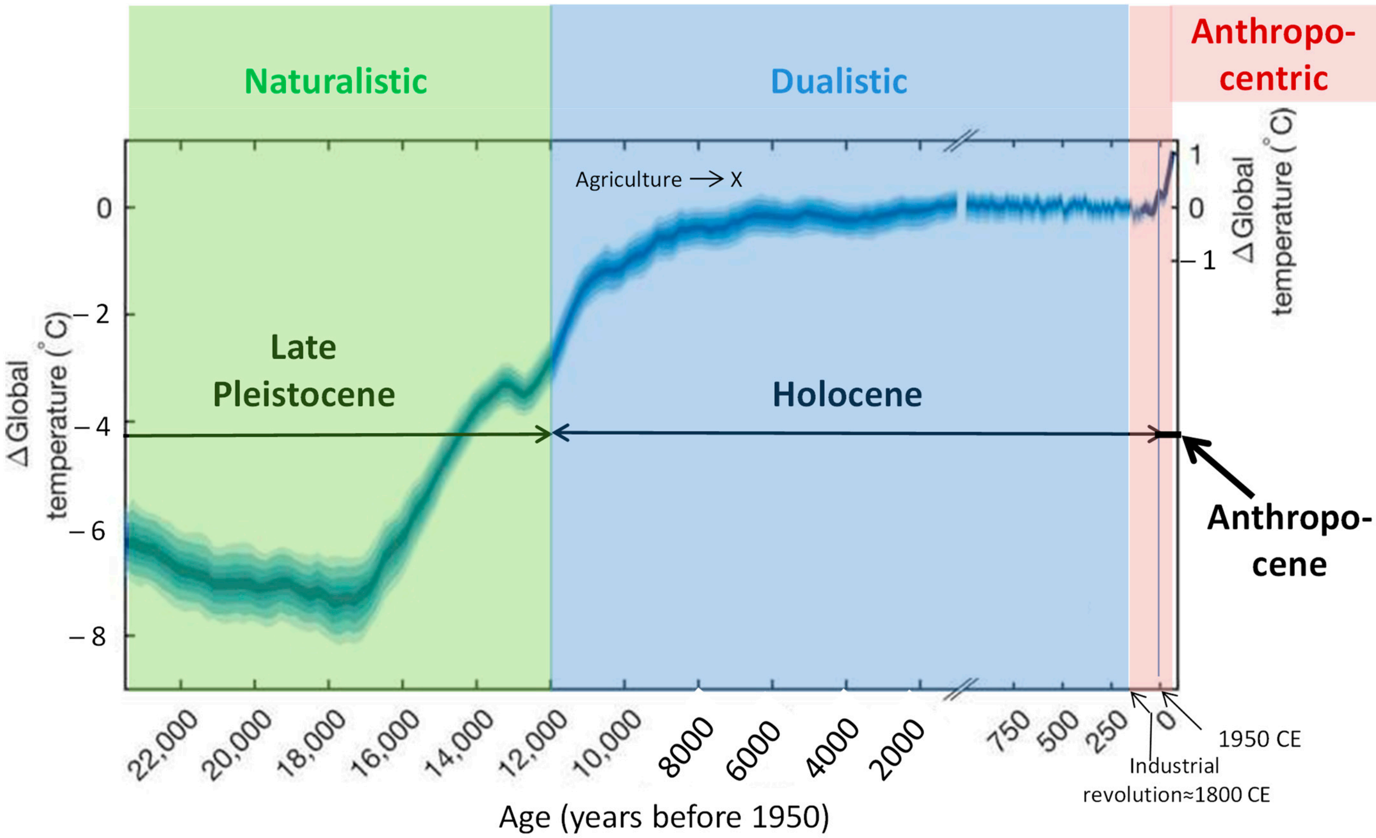

Figure 1. Humans–Nature interplay between Naturalistic, Dualistic, and Anthropocentric status over the past 24,000 years. Adapted from [5].

After the Late Pleistocene, which was the last glacial period, the global temperature on Earth was steadily increasing to reach a constant mean value around 8000 years ago, as we can see in Figure 1. The geological age that started around 10,000 years ago was particularly beneficial to humans and is called the "Holocene" or the "Age of Man".

During the Holocene period, humanity started experiencing new ways of living and developing healthy socio-economic activities, especially in agriculture and trade. Social interaction and cultural progress were facilitated by creating larger human settlements and the first important cities that flourished in places of fertile agricultural land. Extensive agriculture was developed with large quantities of irrigation water from big rivers like the Nile in ancient Egypt, the Tigris and Euphrates in Mesopotamia (Middle-East), the Indus River valley in South Asia, and similar sites in China and South America. Old cities like Babylon, located in present-day Iraq, were founded more than 4000 years ago and ancient civilizations like the Minoan [6] go back more than 3000 years. They were developed on islands and in coastal areas across the Mediterranean as nautical powers trading artifacts, potteries, and agricultural products between cultural centers like Knossos on the island of Crete and Mycenae and Pylos in the Peloponnese.

Advanced water infrastructure for drinking water supply and sanitation was found in Knossos, Crete Island, and subterranean aqueducts known as Canats for transporting groundwater by gravity were discovered and implemented in ancient Persia, Egypt, and China for water supply and irrigation. At the same time, the Norias of Hama, big circular hydraulic pieces of machinery, were invented in the city of Hama, Syria, to elevate water from the Orontes River to a higher elevation for irrigation. Norias were tall water wheels with a series of boxes collecting, by circular movement, water from the river and depositing it in the irrigated field located on higher ground. There is strong evidence that Norias were in operation under Romans in Syria at least by 350 CE.

The time from 600 BC to 600 CE is marked by the rise and fall of the Greek and Roman civilizations in Europe. As we can see in Figure 2, there is a correlation between high temperatures and the time of big achievements of these two civilizations. In the same graph, we can observe that the fall of Athens and Rome took place in periods of low temperatures. Low temperatures are also noticed with the southern expansion of the Vikings, the retreat of the Mongols from Europe, and the "Back Death" pandemic. From 480 BC to the year 400 BC, Athens, the glorious city-state in Greece, experienced the most prosperous economic and cultural growth in its history, known as the "Golden Age" of the Athenian democracy under Pericles.

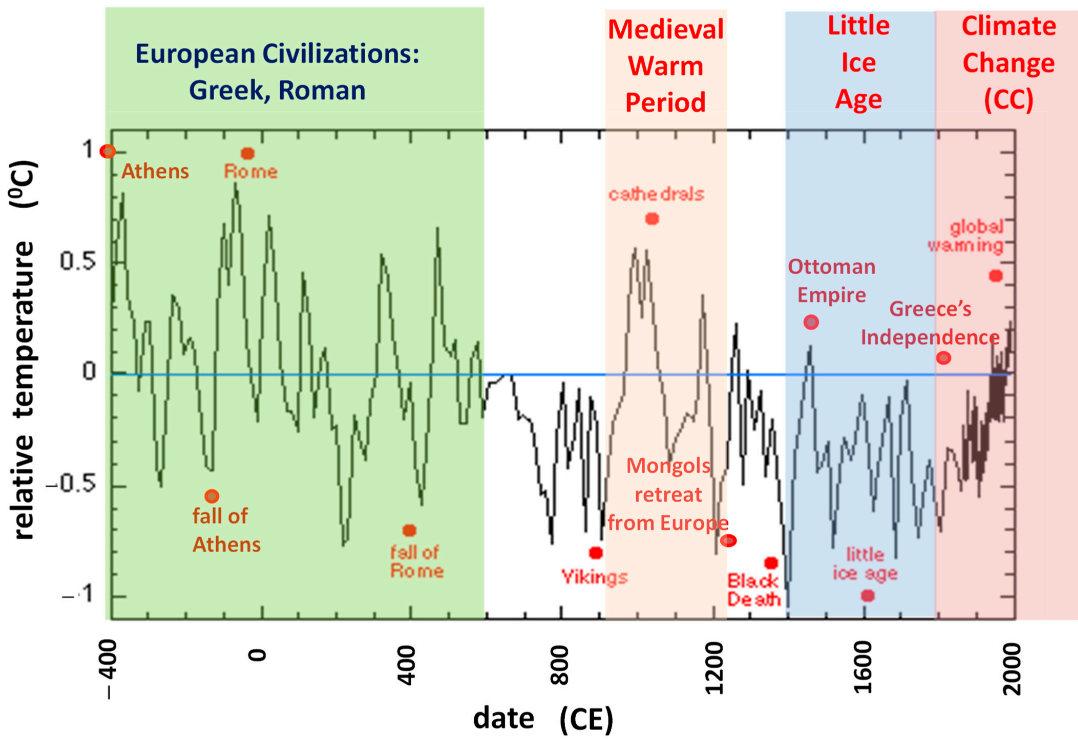

Figure 2. Humans–Temperature interaction from 400 BC to 2000 CE. Adapted from [7].

Concerning the use and management of water resources, the Greeks refined different techniques of ancient civilizations, such as the implementation of technical infrastructure for urban water supply and irrigation. To transport water from springs at higher elevations, they were able to construct subterranean aqueducts conveying with high precision water by gravity over several miles. Well known is the Eupalinos tunnel on Samos Island [8], dating back to the 6th Century BC, and in the same period the Peisistration subterranean aqueduct in ancient Athens, in partial operation until today. Furthermore, a well-known hydraulic device invented by the Greeks is the Archimedes hydrodynamic screw, which was used in Hellenistic Egypt from around 234 BC and is named after the Greek mathematician Archimedes. Also known as the Heron of Alexandria, a Greek mathematician and engineer who used to live in Alexandria, Egypt, where he discovered, following the Hellenistic tradition, the first steam-powered device and a wind-powered engine. The first legislation to control individual and public wells for groundwater supply in ancient Athens was promoted by Solon, around the 5th Century BC [9].

The Romans become famous for building the Roman Empire based on strong military power and special organizational skills. They have been distinguished as engineers and architects with special skills in building huge public temples and buildings, such as the Pantheon and the Coliseum in Rome. They also improved the construction of aqueducts in the form of strong bridges, made by a succession of rounded arcs to support open flow channels, able to transport water to cities over long distances [10].

In the Holocene period that started about 10,000 years ago (Figure 1), and then during the Western European civilization from 400 BC to 500 CE, as shown in Figure 2, mild temperatures contributed to developing a more comfortable human life and modifying the interrelation between humans and nature. However, the progress in arts and sciences was not sufficient or strong enough to support human efforts to dominate natural resources and domesticate wild living ecosystems. Not only in Europe but also in Asia, India, China, and South America, local religions such as paganism in ancient Greece and Rome [11] and the Hindus in ancient India considered rivers and streams as Gods. In the period of classical antiquity, humans were able to dam relatively small rivers to control and divert the flow for irrigation and protect their cultures from possible floods. They developed a mixed relationship with nature, oscillating between friendly and adversarial. The Ilissos River in Athens is depicted by Phidias [12] as a statue of Man-God in form of a young man on the western pavement of the Parthenon.In the same period, the mythical hero Hercules is shown in Athenian potteries fighting the River Achelous, having the form of a big snake that produced catastrophic floods in continental Greece [13].

The dual behavior of conflict and cooperation between humans and nature during the classical period can be called "Dualistic". It was continuously present during the adoption of the Christian religion in the Roman Empire and beyond it. As shown in Figure 2, during the "Middle Ages" (500–1400 CE) and mainly in "Early Modernity" (1400–1800 CE), Europe experienced a dramatic economic and cultural expansion, culminating in the collapse of the old noble regime, the French Revolution (1789), and the Industrial Revolution (1800). The idea that humans are part of nature and at the same time are placed out of it by developing their one culture was also promoted in Geneva by the French philosopher Jean-Jacques Rousseau [14].

After the years of successive industrial revolutions started in 1800, the exponential growth of sciences and technology reinforced the human belief in the possibility of mastering natural processes on a big scale. Most of the rivers in the Western World and also in the Greater South have been modified by a succession of dams to form artificial waterways for producing hydropower. A milestone of this human ability to dam big rivers is the construction in 1935 of the Pharaonic Hoover Dam in the Colorado River, USA [21]. The drainage of huge humid regions and shallow lakes for agricultural purposes has been called "reclamation work", aiming to improve the quality of human life by threatening ecosystem services and reducing water resilience. Economists have named these negative environmental impacts "externalities" and engineers thought of the ability to remediate ecological disasters. We may call this human behavior "anthropocentric", i.e., "human-centered", restricting values to human beings. This human attitude against nature has produced a strong footprint, so a group of scientists has proposed to call this period the "Anthropocene", i.e., the era of humans (Figure 1 and [22]).

2.2. The Governance–Policy–Science Nexus (GPSN)

Water governance can be defined in different ways, including that formulated by UNDP [29] as "the range of political, social, economic, and administrative systems that are in place to develop and manage water resources and the delivery of water services, at different levels of society". We may resume that water governance is a socio-economic and administrative framework that for taking political decisions combines a set of laws and policy measures with a WRM model. In democratic societies, based on the rule of law, political decisions are taken by the majority of elected representatives. This range of socio-economic systems forms a hierarchical complex, composite and interdisciplinary framework that is shown schematically in Figure 3.

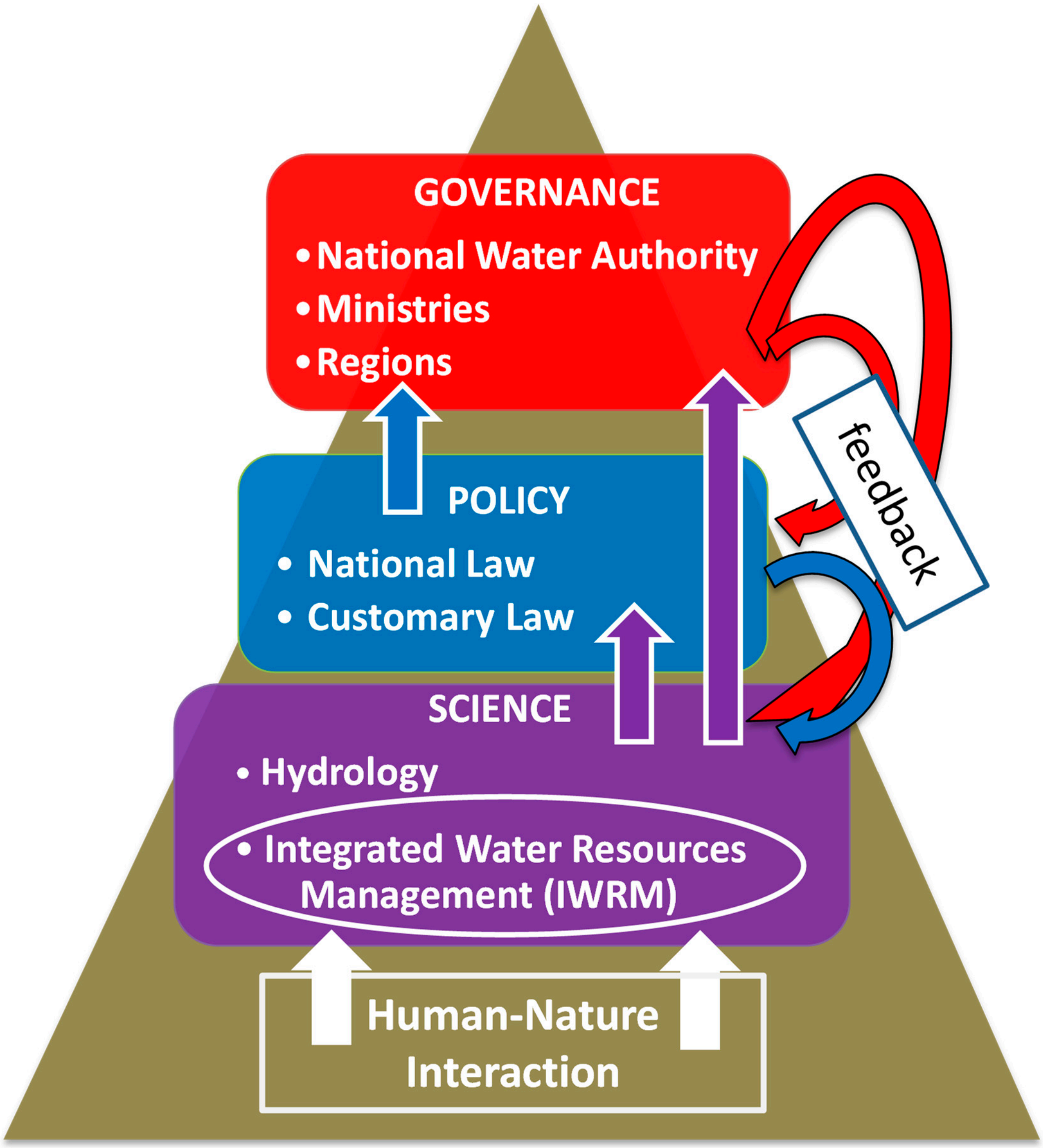

Figure 3. The GPS Nexus: from Human–Nature Interaction to Hydro-Governance.

It consists of three main elements: Governance (decision making), Policy (water laws), and Science (water management). We may call it the GPSN (Governance, Policy, Science

Nexus). To ensure the rational use of water for the community, Hydro-Governance is the upper stage of three underlying and interconnected systems. From a bottom-up approach, these are: (1) the Human-Nature interaction leading to (2) WRM models for developing (3) policy or a water regulation system.

In reality, Hydro-Governance is the overarching process integrating policy and WRM into the socio-political and socio-economic domains. WRM plans that public authorities develop and address to water utilities, and all water users, indirectly incorporate the relationship humans entertain with nature. Along the complex steps in the decision-making chain for water allocation and management, WRM plans which are based on information, data, and scientific knowledge reflect at the same time the particular interplay between humans and nature at a given historical period. In water governance, elected officials in central, regional, and local administration ask advice from water scientists on how to implement WRM plans or how to use water legislation to taking appropriate decisions. In the opposite direction, as shown in Figure 3, WRM plans and scientific information may benefit from experiences coming out from water governance and policy (feedback).

We may describe the time evolution of the WRM model as follows:

(1) At a given time, WRM planning is influenced by the Human–Nature interaction and can be distinguished by the naturalistic, dualistic, and anthropocentric historical trajectory. Diachronically, the contents of water laws for policy regulation and the way water governance is exercised depend on the conceptual framework of the WRM model.
(2) Since 2000, the WRM model has gradually become a systemic tool under the title of IWRM (Integrated WRM) [27]. The IWRM model has evolved through multiple steps initiated by many UN conferences and the corresponding UN resolutions.
(3) In 1972, i.e., 28 years before the IWRM's completion, the UN Stockholm declaration called for environmental protection,
(4) Twenty years later, in 1992, the Rio UN summit adopted the need for sustainable WRM, living in harmony with nature, together with the definition of Agenda 21 and the MDGs (Millennium Development Goals), and
(5) In 2000, at the first WWF (World Water Forum), The Hague, the IWRM systemic model resulted in the adoption of the integrated 3Es axes of sustainability: Environmental, Economic, and Equitable WRM.

2.3. Policy Implementation of the IWRM Model

The main idea of the IWRM model is that the management of water resources should address not only the quantity and quality of water for sustaining human life and maintaining all kinds of life on Earth. Water is the raw material of almost all socio-economic activities, like agriculture, industry, energy production, manufacturing, and transportation. Therefore, its use should cover all economic sectors by providing a sufficient amount of water to satisfy the demand. Furthermore, water management is a multi-disciplinary topic, involving different disciplines and many professions like engineers to deal with water infrastructure, chemists and biologists for water quality, lawyers for water policy, economists for water pricing, and general managers at different scales. This systemic approach to Water Resources Management is very appealing theoretically and very popular for educational activities. The IWRM model is described in detail by a series of technical reports [27,28], produced by the Global Water Partnership (GWP), an NGO affiliated with the World Bank.

The application of the IWRM model in policy and public water regulation is complicated [18]. After many years of experimentation in several countries, the model has resulted in partially positive results. This happened for several reasons.

Firstly, the general aim of the model implementation in the real world was very ambitious and complicated to attain. To achieve an integrated result, the model targeted not only technical and economic reliability in water management but also environmental and ecological preservation together with social fairness and social equity. However, if the techno-economic approach was feasible mainly for water infrastructure, social and environmental sustainability have been obtained only up to a certain level.

Secondly, the theoretical relationship between the use of water resources and their allocation in different socio-economic sectors, although easy to understand, has been proven almost impossible to formulate. For example, it is obvious that we need to use more energy for agricultural irrigation due to water transportation or pumping; also, more water is needed for maximizing agricultural food production. However, in the mathematical frame of multi-objective decision making, an optimum solution minimizing water and energy consumption while maximizing food production is impossible to obtain. Instead of an optimum solution, multiple feasible alternatives are possible; any choice between them depends on our preferences, either economical or environmental. An important attempt to simplify the complexity of the IWRM model is the focus on three main natural resources, i.e., water, energy, and food. Because these three elements are interrelated in a complex way, the model was named the Water–Energy–Food Nexus. If the model is used without special attention to water consumption, water security can be compromised [30].

Thirdly, the organizational setup for implementing the IWRM or the Nexus model was missing. The main advantage of the integrated approach was to profit from synergies between activities in different sectors, save natural resources, and achieve sustainable solutions. However, common administrative systems have a long tradition of working in silos. For example, governments distribute socio-economic responsibilities in ministries, dealing with particular sectors, e.g., ministries of agriculture, energy, and environment. Although in many countries the environment is associated with the energy sector, some attempts to combine agriculture, energy, and environmental issues have failed due to inadequate coordination between the three sectors and a lack of collaborative skills.

The first serious political effort to translate the IWRM model into a policy document was the adoption by the European Parliament in 2000 of the Water Framework Directive (EU-WFD) 60/2000/EC [31]. Because Europe is not a federal country but a union of independent Member-States, the Directives issued by the European Commission and adopted by the European Parliament do not have the form of federal laws. However, there is an obligation of all Member-States to incorporate them into the national law. Based on the subsidiarity principle, every Member-State could adapt the directive following national particular conditions, but failure to adopt the main principles of the Directive could bring the Member-State to the European Court. Severe fines can be imposed by the Court in case of non-compliance by the Member-State.

The EU/WFD has been the compromise between different professional lobbies, NGOs, ecologists, scientific associations, and the European Parliament. The main principles and guidelines of the directive can be resumed as follows:

(1) Water Resources Management and water allocation in different socio-economic sectors should take place at the river basin scale.
(2) National authorities should nominate the river basin organizations (RBOs) covering all national and transnational river basins or groups of them, called hydrological districts.
(3) RBOs are responsible for assessing the hydrological, chemical, and ecological characteristics of the water bodies, including rivers, lakes, and aquifers
(4) Based on the status of the water bodies and the needs for water of various socio-economic sectors, RBOs should develop river basin management plans (RBMPs), to be revised every 6 years by collecting additional data and improving the national monitoring system.
(5) In case of ecological problems and water scarcity, RBOs should propose a program of measures (PoMs) aiming to restore any environmental degradation.
(6) An economic evaluation based on the cost recovery of water services should be developed by evaluating the water cost for different uses and fixing the corresponding water pricing.

(7) Extensive public consultations should take place to correct and adopt the RBMPs and the PoMs.

Almost 20 years after the implementation of the EU-WFD by its Member-States, in 2019, the European Commission started an extensive review among all Member-States of the obtained results. More particularly, the fitting for-purpose evaluation has focused on the relevance, effectiveness, efficiency, and the European added value of the Directive [32]. In the Directive, the year 2015 was targeted as the year to obtain a "good" environmental state of all European water bodies. A "good" state is defined as an acceptable chemical and ecological status for surface water and the same for the quantitative and chemical state of groundwater. As this was not obtained in 2015, after the assessment, it was extended to 2027. The results of the fitness check show that less than half of the EU's water bodies were of good ecological status. In Greece, 30% of the rivers and 80% of the lakes failed to have a good ecological status.

The fitness check of the WFD was not a direct evaluation of the IWRM, and some of the WFD's scientific objectives were not realistic, such as the removal of nitrogen from the soil in a few years. Officially, the obtained results have been attributed not to the contents and the methodology recommended by the Directive but to the delays caused by the Member-States in implementing it. Different causes of such delays have been noticed, such as lack of sufficient funding, weak water governance, and lack of coordination between economic sectors like agriculture, energy, and transport that heavily impact the water environment.

In our opinion, apart from some particular pollutants, the main reason for not attaining the Directive's goal by 2015, and most probably by the new time horizon of 2027, is more fundamental and linked to the anthropocentric character of the IWRM model.

3. The Novel Dialectical WRM Model for Water Security

Revisiting Figure 3, we realize that the interaction between humans and nature is the main driver regulating the efficiency of the WRM model and influencing water policy and governance. From the previous historical revision of the WRM metabolism throughout different eras and various socio-economic and climate conditions, we have learned that the WRM model is in constant evolution: it takes different formulations depending on the balance of power between human societies and natural forces and is impacting not only its internal structure but also the water policy and governance.

In the state-of-the-art IWRM model, ecological issues for environmental sustainability are mainly defined as goals and targets. They also include indicators aiming to assess the progress made in attaining the goals. In the EU/WFD, specific monitoring activities are described aiming to classify the ecological status of surface and groundwater bodies. Five main water quality classes are distinguished, i.e., high, good, moderate, bad, and poor, with the ultimate goal to obtain "good" status for all European waters. However, the WFD was unable to achieve its goal completely, mainly due to its anthropocentric formulation.

The technocratic view of the IWRM model and the EU/WFD is based on the underlying assumption that humans can manipulate nature positively or negatively by producing negligible collateral environmental damage.

Goals and targets aiming to achieve sustainability are also described in detail in the 2030 Agenda for Sustainable Development, adopted in New York in September 2015 [33]. Enumerating 17 SDGs (Sustainable Development Goals) and 169 targets, the new UN Agenda demonstrates its ambition to achieve environmental sustainability by 2030. Concerning the SDG.6 on Clean Water and Sanitation, six different targets with 10 indicators are described: 6.1 Drinking Water, 6.2 WASh (Water and Sanitation Hygiene), 6.3 Wastewater and Water Quality, 6.4 Water Use and Water Scarcity, 6.5 Integrated WRM and Transboundary Surface and Groundwaters, and 6.6 Water Ecosystems.

Although setting ambitious goals and targets is important, more crucial is to set up the framework and describe the steps to follow to achieve them. The experience we have from the past is that the time frame for reaching goals is usually not achieved. Different reasons and new interpretations of data are given to explain why that happened. For example, the 1992 Rio Declaration, Agenda 21 setting the Millennium Development Goals (MDGs) to be achieved by the year 2015, has given limited results and was revised in 2015 by the SDGs. The main reason for this UN inefficiency is the fact that the diversity of the UN member states makes the needed abstraction and standardization of a common action plan very difficult. Concerning the fate of SDG 6.5 on IWRM, it is anticipated that its mid-term review in NY, 22–24 March 2023, will have, as in the case of the EU/WFD, only partial good results.

To reduce environmental pressures and limit externalities up to acceptable levels, it is necessary to redefine the conceptual WRM framework and the underlying theory based on a revised Humans–Nature relationship. The solution is not to come back to older models of naturalistic or dualistic view but to articulate a new conceptual relationship and an underlying theoretical and methodological approach. Two recent approaches have initiated a revival of interest. These are (a) the so-called NBs (Nature-Based solutions), and (b) the upscaling of ancestral ATHs (Ancestral Traditional Hydro-technologies).

An interesting discussion has been recently animated in the specialized literature concerning the use of NBs as a new WRM model. First coined during the 2016 World Conservation Congress organized by the IUCN (International Union for Conservation of Nature) [23], NBs were defined as "actions to protect, sustainably manage and restore natural and modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". In recent times, several initiatives from civil society have emphasized the need to introduce NBs for protecting urban ecosystems and water streams for ecological reasons, climate change adaptation, and to increase biodiversity and the quality of life [24]. In Athens, Greece, a strong debate has been initiated between local authorities, professional organizations, and NGOs for protecting and stabilizing the banks of urban streams with the use of NBs, like plants and bio-engineering materials. Ecological associations went to the Greek Supreme Court of Justice and won against local authorities and public contractors who used to protect against floods and stabilize open water streams with concrete material or stone-made gabions. NBs can be used as an alternative with the aim to increase green areas, protect ecological services, and integrate water areas into the urban landscape. However, if NBs are efficient on a small scale, upscaling them is questionable and their application cannot be considered a panacea.

More recently, in connection with NBs and climate adaptation, traditional ancestral hydro-technologies and tribal water management techniques have regained public interest [26]. During the recent Int. Conference on Ancestral Hydro-Technologies, Barcelona, Spain, 16–17 February 2023, many case studies on ATHs (Ancestral Traditional Hydro-technologies) were presented. The main drawback of ATHs is the social context in which they have been efficient. The actual socio-economic environment is quite different from the historic rural societies. This makes the return to the past a utopia rather than an innovative solution for facing actual environmental challenges.

Before introducing the novel dialectical model for WRM, it is interesting to briefly discuss the economic dimension of WRM. The balance of power between Humans and Nature can be evaluated and compared in monetary terms [34]. At different time and space scales, we may distinguish between (a) natural capital, (b) human capital, and (c) produced capital. Human societies use natural assets that can be renewable, like water, forests, crops, solar energy, and wind energy, and non-renewable, such as oil and gas. Natural capital has long been considered for granted and used as free. However, when humans return to nature pollution at a rate that the Earth cannot recover, natural assets are threatened (Figure 4).

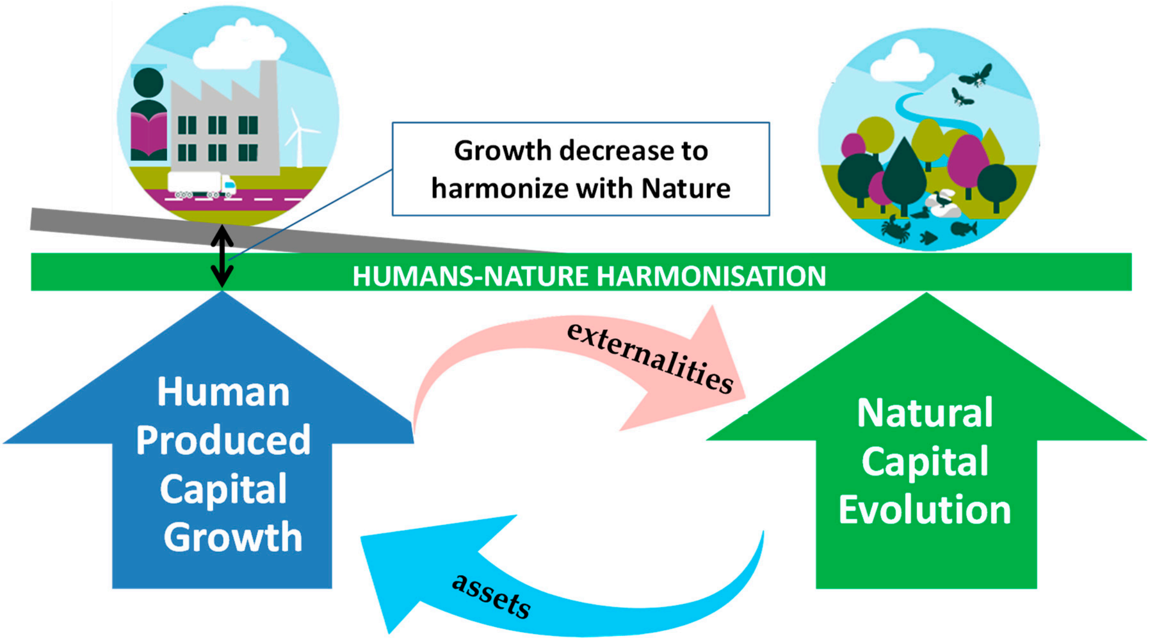

Figure 4. Humans–Nature capital inequality and possible harmonization (adapted from [34]).

Humans use natural capital in terms of goods and ecological services to produce income, such as water supply and sanitation, housing, transportation, and infrastructure. This is the produced capital through different tools related to education, labor, and technological innovation. By increasing this capital, humans return to nature, which economists call externalities that threatens the natural capital (Figure 4). According to [34], the economic estimation during the period 1992–2014 indicates that the globally produced capital per head increased by 100% while the value of the natural capital per head declined by 40%. This capital inequality as shown in Figure 4 can be reduced in two ways:

(a) Consent to decrease the level of our socio-economic conditions.
(b) Increase the natural capital with human interventions, like planting new trees, cleaning our rivers and lakes, and changing our agricultural practices. Decreasing social growth and human welfare means a reduction in our actual GDP (Gross Domestic Product), which is socially unacceptable. On the other side, increasing the natural capital by restoration and conservation needs many generations time and is very difficult to be implemented socially, especially in the Greater South.

The new model we suggest for improving IWRM is based on a dynamic, open-ended methodology—that avoids a one-dimensional approach, such as technical, social, or physical. It unifies positive and negative attitudes, e.g., conflict and cooperation, by exchanging contradictory arguments [35] to find the best solution (dialectical logic). It was first formulated philosophically by Heraclitus [36], fully adopted in the 19th Century by the German philosopher Hegel [36–39], and served as the basis of the dialectical materialistic theory of Karl Marx and Friedrich Engels.

The question about the role of time in the appearance of opposite or contrary statements is very important and needs to be clarified in the paper. If we consider that two opposites (e.g., conflict and cooperation) may occur at the same time, this is against the formal logic. According to the law of "excluded third", i.e., no third option, both cannot be true at the same time. Only one of them must be true. Therefore, in the dialectic WRM model, we should consider the opposites at distinct times.

However, according to the doctrine of constant flux (panta rei), the opposites should be considered over time, and their unity means perfect harmony on time. To understand the process, Heraclitus gave two simple examples:

(1) To obtain the best melody from a violin or a lyre, we should tune its strings by turning the pegs in a way that the tension on a string becomes equal and opposite to the force on the pegs.
(2) A bow becomes functional and a weapon of death when the tension on its resistant string is equal and opposite to the pressure that is applied to the bow.

Another simple example is the building of a dam on a river for electricity production. The dimensions of the dam and the turbine machinery are designed for maximizing energy production. This anthropocentric view faces environmental consequences such as the blocking of fish traveling upstream from the dam, which is considered an externality or collateral damage.

An Eristic–Dialectical approach recognizes first the conflict between damming the river and the hydraulic and ecological laws of free river flow and fish migration. The dialectical solution is to unify the two contraries: (1) electricity production for humans, and (2) fishes' free migration upstream. In Europe and the USA, the special design of dams and turbines allows fish like salmon to travel through the dam and continue their journey in the river. This simple case illustrates the fact that the EDIWRM model is not based on a compromise between alternative technical solutions aiming to minimize externalities but is a harmonic symbiosis between humans and nature by unifying the opposites: energy production for humans and free migration for fish. This kind of balance between two opposite forces is shown schematically in Figure 5.

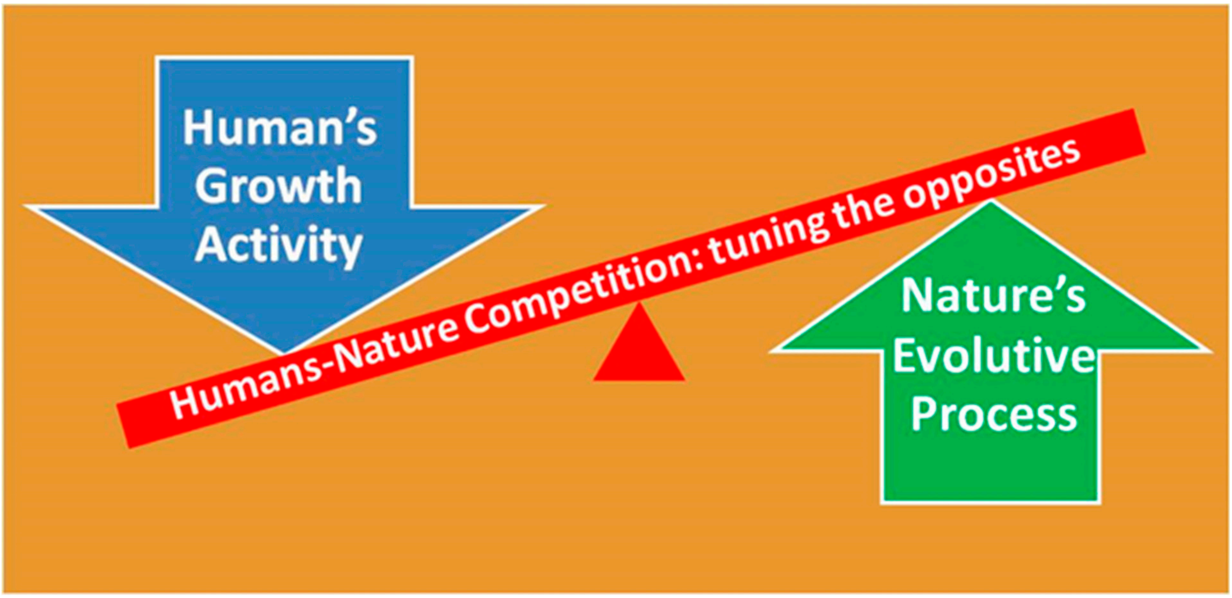

Figure 5. Dialectical Human–Nature conflict resolution by tuning the opposites.

Our Eristic–Dialectical model of IWRM has been applied in more complicated cases, including Integrated Flood Management (EDIFM). It is illustrated in the case study [40], adopted by GWR in its Toolbox [41]. The successive steps to follow for the EDIWRM implementation are shown in Figure 6 and can be described as follows:

(1) Setting the scene by detecting all surface and groundwater bodies at the watershed scale;
(2) Stakeholder consultation for developing a Joint Action Plan (JAP);
(3) Eristic analysis of conflicts between stakeholders and natural laws;
(4) Dialectical conflict resolution between human different activities and the natural laws;
(5) Establishing Eristic–Dialectical Integrated Management Plans;
(6) Revision and new planning.

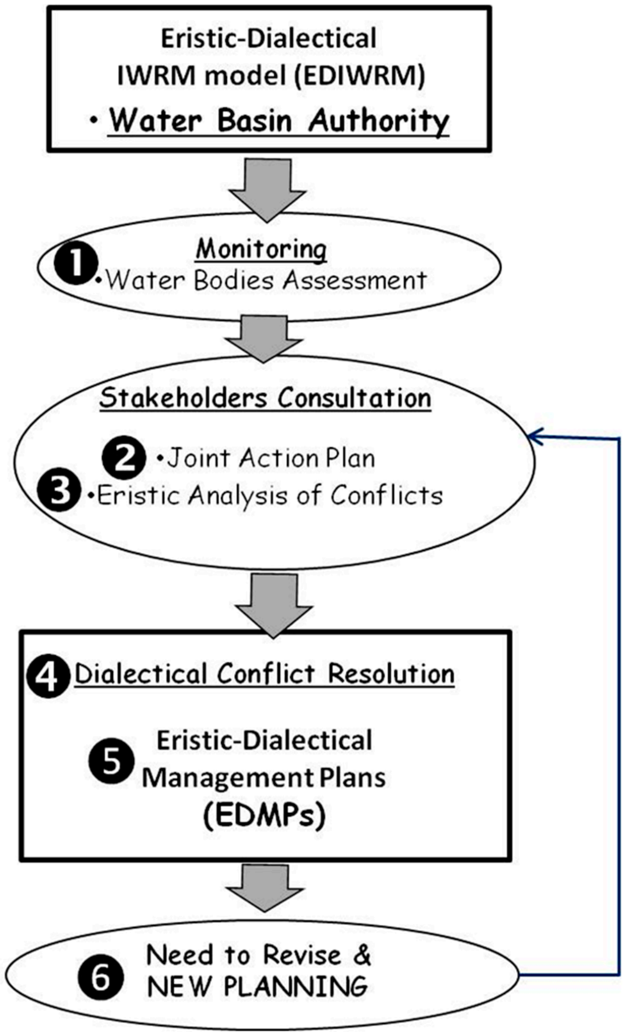

Figure 6. Steps for application of the EDIWRM (Eristic–Dialectical IWRM) model.

4. A Case Study of Eristic–Dialectical Integrated Flood Management (EDIFM) [40,41]

In recent years, on Crete Island, Greece, floods have become frequent and catastrophic under climate change. In the case of the Giofyros River flowing through the city of Heraklion (Figure 7), to complement an Integrated Flood Management (IFM) plan, a social component has been added. The new model is based on conflict resolution between human activities and the hydrological/hydraulic/natural laws. The model uses the fact that historically, water–human interactions have been and remain contradictory, i.e., at the same time conflicting (urban use of the flood plain) and cooperative (developing green areas around the river). To increase flood security, first, the conflicts were assessed and analyzed; second, by unifying the opposite Nature–Human interactions, a dialectic flood-resilient solution was obtained. It has been proven to be resilient to date to newer flood hazards.

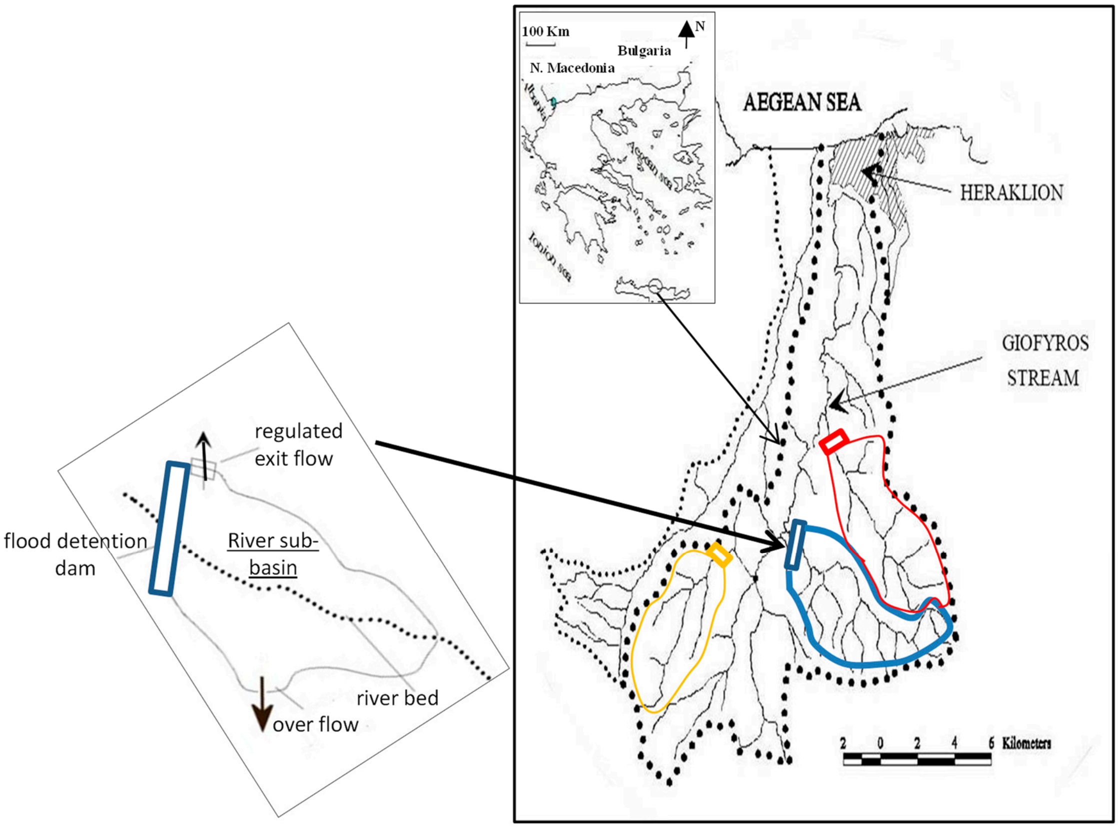

Figure 7. Location of the Giofyros River Basin (dark dotted line) and flood detention reservoirs upstream.

4.1. Summary Description

Following the steps indicated in Figure 6, the new Eristic–Dialectical Integrated Flood Management (EDIFM) model was implemented as follows.

(1) Assessment of the initial situation.

The Regional Agency for the Development of Eastern Crete (OANAK) located in the city of Heraklion was responsible, together with the city's local authorities, for developing an Integrated Flood Management Plan (IFP) after a catastrophic flood that took place on January 1994 [40,41]. OANAK invited the expert team from the Aristotle University of Thessaloniki, led by Prof. J. Ganoulis, to assess the situation and establish an Integrated Flood Risk Management (IFM) Plan.

(2) A Joint Action Plan (JAP) with local stakeholders.

The main water users and responsible authorities were identified as citizens who lost their property during the 1994 historical flood, OANAK, and the city's elected authorities. The main water-related actors and stakeholders who took an active approach were distinguished as follows:

(a) University staff and local researchers: The team was composed of two university professors from the Aristotle University of Thessaloniki and local scientists working in OANAK.
(b) City institutions: Local elected authorities and water responsible agents. The staff of the city's wastewater treatment plant played a major role because their utilities suffered huge losses of some millions of euros during the devastating 1994 flood.
(c) Private professionals: Companies responsible for waterworks such as the construction of levees and flood detention reservoirs.

(d) Civil society: NGOs and city organizations sensitive to green areas and the city's environmental protection.

The main purpose of the JAP was to identify not only natural hazards but also how humans have conflicted with nature by occupying part of the riverbed to develop properties. The consultation aimed to define the natural conditions generating floods, i.e., the river's boundaries with variable flow rates, the hydrological and solid transport characteristics of the river, and the marine coastal currents near its delta that are influenced by Coriolis forces.

(3) Eristic analysis of conflicts (EAC).

In the EAC process, conflicts were identified between land use for urban interests across the river and the riverbed extension for different return periods of flooding. The river's boundaries have been identified for a 20-year return period. To resolve conflicts of land use and other violations of natural laws, hydrological characteristics have been analyzed, such as the hydraulic conductivity of the river for different rainfall intensities, the transportation capacity of solid and suspended material, and the coastal currents near the mouth of the river. As a result, humans were identified to violate the riverbed's flood boundaries, and in exchange, the river used to flood urban areas up from a certain flow rate with negative consequences for human property.

(4) Dialectical conflict resolution (DCR).

4.2. Natural Laws

The hydraulic and hydrological investigation at the basin scale has produced the following results:

- *The Hydraulic Law*: Under the existing riverbed characteristics, the flow capacity without flooding the urban area was 300 m^3/s for a T = 20-year return period. For higher flow rates, water overflows the river and produces urban floods [40].
- *The Coriolis Forces*: Because of the Earth's rotation in the case of low tidal forces, like in the Mediterranean Sea, the river deltas show most of the time a dextral deviation of the river's mouth. This is the case in the Northern Hemisphere, while the opposite deviation may occur in the Southern Hemisphere [41].

4.3. Conflict Resolution

(a) The dialectical model for resolving conflicts is based on the unification of contraries, which in our case are (1) humans occupying part of the riverbed, violating the hydraulic and hydrological laws and increasing their proper benefits, and (2) the river responding by inundating their property when the flood water exceeds the river's flow capacity. The best solution is to retain upstream not all the volume of the flood but only the volume of the peak floodwater, i.e., the volume of water that exceeds the flow capacity of the river. In harmony with natural laws, the dialectical solution in the Giofyros basin has provided a series of flood detention reservoirs, i.e., small artificial lakes with an outlet pipe up to a certain level. In the detention reservoirs, only the peak flood volume is stored, and the rest of the flood is safely directed into the sea (Figure 7).

(b) To facilitate and reinforce the dextral deviation of the Coriolis Forces around the mouth of the river, an inclined jetty has been constructed, facilitating solid transportation into the sea and reducing the maintenance cost of cleaning the riverbed (Figure 8).

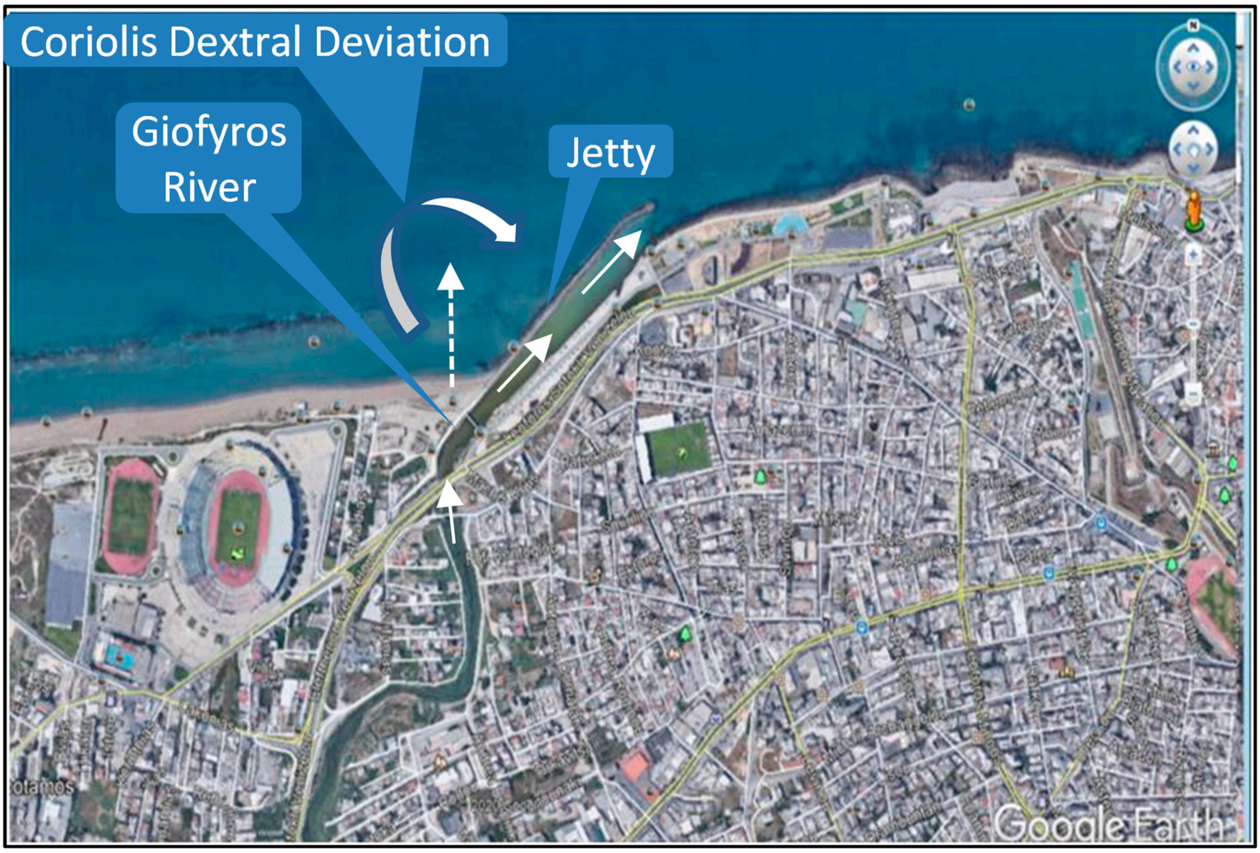

Figure 8. The jetty for a Coriolis dextral deviation of the Giofyros mouth.

4.4. Lessons Learned

4.4.1. Activating Stakeholders

Flood resilience is increased by adding a social component to the IFM model. This has been achieved by the Eristic–Dialectical EDIFM model that proceeds in two steps: (1) assessing conflicts between stakeholders and natural/hydrological/hydraulic laws and (2) resolving these conflicts by unifying opposite issues to obtain environmental sustainability.

4.4.2. Flood Detention Reservoirs

Flood resilience at the watershed level is increasing by retaining only the peak of the flood instead of storing its total volume. Flood detention reservoirs are adequately designed among the river's sub-catchments to avoid the accumulation of tributary flows that may cause an overflow downstream. Water volumes stored in detention reservoirs can be used for irrigation.

4.4.3. Solid Transportation by Coriolis Forces

Coriolis forces were used to facilitate solid transportation from the river's mouth into the sea. This can be achieved by preserving the natural dextral flow deviation with an inclining jetty. The inertial forces prevent possible obstruction of the river's mouth and reduce maintenance costs. This is illustrated in the case study and was proven reliable.

4.4.4. Keep Urban Streams Uncovered

Urban water streams, such as the Giofyros River, can enhance green areas, reduce temperature increases due to climate change, and absorb air pollution. Public authorities used to cover water streams because of the lack of water flow in summer and the activation of garbage and mosquito colonies. Flood detention reservoirs can provide sufficient water to sustain summer ecological flows.

4.4.5. Flood Governance

Hydro-Governance is the integration of water management and policy in the political field. It is exercised at different levels, such as national, regional, and local. Flood governance at the local level, consisting of the city's elected authorities, the public organism for water management (OANAK), and the university team as scientific advisors, was proven very efficient in practice.

5. Discussion

The model we suggest is needed to complement the IWRM model and improve water governance through the GPS (Governance–Policy–Science) Nexus analyzed in this paper. After 20 years of application in Europe, IWRM has shown many operational deficiencies. The novelty of our model consists of (a) the historical recognition of the anthropocentric character of the IWRM model, based on the idea that humans can control and dominate nature; (b) the fact that in the Humans–Nature relationship, the violation of natural laws by humans derives during the interplay between two opposites, i.e., conflict and cooperation; and (c) the introduction of a "dialectical methodology" for conflict resolution, based on a logical confrontation of opposite arguments that can lead to a sustainable solution unifying two opposites: the human appropriation of natural resources (eristic component) and nature's remediation following natural laws (dialectic resolution).

6. Conclusions

At times of climate crisis, water security could be achieved by establishing effective water governance that can lead to water security. The analysis of the GPS (Governance–Policy–Science) Nexus presented in this paper indicates that the best way to improve Hydro-Governance is to reformulate the existing IWRM model (scientific approach) and reinforce its communication to law experts (Policy) and decision makers (Governance).

The novel WRM model we suggest was established along three main issues. (1) The first responds to the need for harmonizing water-related human activities with nature. The historical review (Section 2.1) of Human–Water interaction indicates that the state-of-the-art IWRM model is anthropocentric and technical-oriented. Its policy implementation has produced huge environmental externalities. (2) As shown in Section 2.2, improving WRM is the main scientific and technical driver for improving water governance and, therefore, for increasing resilience in water security. (3) One novelty of the suggested WRM model is the identification and subsequent resolution of conflicts between human activities and natural water laws. This is different from Human vs. Human conflicts of socio-economic origin. We call "eristic" or conflictual the way humans use and manage natural water resources and we introduce "dialectics" as a tool for a sustainable reconciliation of Humans with Nature (Figure 9). The dialectical tool is an open-ended exchange of opposite arguments to reach an agreement. The best solution is not a compromise between alternative solutions, but the unity of opposite issues between Humans and Nature, i.e., the unity of conflict and cooperation. The new Eristic–Dialectical model may be used as an additional component of the IWRM process, as shown in Section 4. It adds a social dimension by involving stakeholders to act in harmony with nature. By exchanging logical arguments, it develops a dynamic, multi-disciplinary framework of conflict resolution away from one-dimensional ideological approaches, such as technical, anthropocentric, neo-liberalistic, or capitalistic.

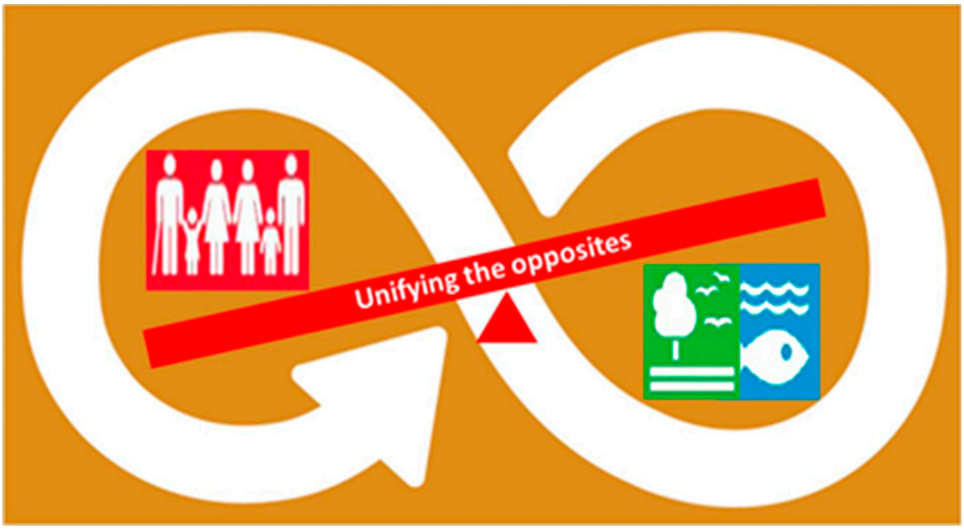

Figure 9. The Eristic–Dialectical model of sustainable conflict resolution: balancing Human-Nature opposite interests.

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