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Article

Nature-Human Conflict Dialectics for Sustainable Water Security

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Abstract. The water resources policy under climate change impacts water security, which should ensure enough water of good quality for humans and nature. Integrated water management is the state-of-the-art policy support model that, after 20 years in use, failed to achieve in many countries its primary goal of water bodies' good ecological status. Here, we show that this is due to the substantial externalities the anthropocentric character of the model generates. From the historical analysis, three main results are obtained: 1) the nature-human interplay is always composed of the coexistence of two opposite behaviors of conflict and cooperation; 2) this contradiction is a dialectical, general ontological attribute; 3) on the balance of power between nature and humans, three clusters are identified: i) naturalistic; ii) dualistic; iii) anthropocentric. A novel behaviorist dialectical conflict resolution model can resolve the differences between stakeholders and natural laws. The harmonic symbiosis of humans with nature removes environmental externalities and can lead to sustainable water security. Three case studies from the literature illustrate the merits of the new dialectical model.

Keywords: water management; climate change; nature-human relationship; conflict resolution; dialectics

Economic growth, human prosperity, and the environmental quality of life in modern societies greatly depend on how natural resources, such as water, energy, and food, are managed [1]. Humans rely on natural assets that constitute the basis they develop through education, intelligence, science and technology, human values, and additional economic goods. By humans, we mean the human society composed of multiple stakeholders with different conflicting socio-economic interests. In this human endeavor for a better life that persists with ups and downs through the successive ages of human evolution, water is not only vital for human and ecosystem subsistence and for maintaining the fauna and flora on our planet [2]; it is also the raw material of all economic activities, such as agriculture, industry, tourism, and energy.

In contrast to saltwater in seas and oceans, which represent about 97% of the total water on Earth, only 3% is freshwater available in rivers, lakes, and aquifers and as a solid state in polar glaciers. Freshwater resources are limited and non-uniformly distributed around the globe in constant movement through the global water cycle [3]. Therefore, how countries use and allocate their natural water resources to various economic sectors is crucial to ensure water supply, healthy ecosystems, and socio-economic prosperity.

Climate change has recently induced unprecedented natural disasters, such as heat waves, forest fires, floods, and droughts [4], challenging the Water Resources Management (WRM) model. Since the Second Industrial Revolution in the late 19th Century, greenhouse gases have continuously increased in atmospheric concentration. The greenhouse gases have induced a constant rise in temperature and created atmospheric instabilities, the source of random precipitation patterns. Intense precipitation has been observed in restricted areas, creating catastrophic floods, although mega-drought conditions impacted neighboring river catchments. Warmer marine waters in the oceans and the Mediterranean Sea initiate more intense and frequent hurricanes with catastrophic negative impacts on human infrastructure and even loss of lives [5]. Therefore, an effective WRM under climate change has become a priority, together with the need to develop an efficient WRM model for improving water governance and security. Here, we use the term model in the sense of a

paradigm, a narrative, or a process that can take different forms, like descriptive, conceptual, numerical, or mathematical.

Although the idea of an Integrated Water Resources Management (IWRM) [6] goes centuries back, a milestone in the WRM's conceptual evolution towards a system approach is the United Nations Water Conference, Mar del Plata, 14-25 March 1977 [7]. IWRM is theoretically very attractive but complicated and very challenging to implement. It served as a general scientific framework for the European Union's (EU) policy on WRM [8]. In 2019, almost 20 years after its implementation in Europe, the EU Commission organized a general evaluation procedure concerning the fitting of the Directive, i.e., its relevance, coherence, effectiveness, efficiency, and added European value. The evaluation result was unsatisfactory as more than half of the European water bodies failed to reach a good ecological status [9].

In our view, the failure of the EU/WFD in its implementation is more radical as it is related to the way the underlying IWRM model is structured and used in the field. We support our criticism with a historical review, indicating how IWRM reflects the nature-human interaction, i.e., the human behavior against the natural world. Earlier attempts to understand and analyze its dialectical role in improving water governance and urban hydro-security suffered from insufficient theoretical background [10,11,12].

This paper shows that historically, the nature-human interplay has always been in dialectic confrontation. By dialectics [13], we mean the internal contradiction of exchanging logical arguments by counter-arguments. In our case, nature is represented by the natural laws and the nature-human relationship by the coexistence of two opposite human behaviors, i.e., conflict and cooperation. Depending on the balance of power between human capacity and nature's environmental state in different historical periods, we have identified three clusters: *naturalistic*, *dualistic*, and *anthropocentric*. A breakthrough in the human attitude against nature started after the Second Industrial Revolution when scientific and technical achievements made humans believe they could dominate and modify nature to maximize socio-economic benefits [14]. This anthropocentric human behavior is reflected in the IWRM model's structure, and for us, it is the main reason for producing substantial adverse environmental impacts that economists call "externalities" [15].

Here, we suggest a new IWRM behaviorist model aiming to reduce and even exclude environmental externalities. We analyze stakeholder behavior for harmonizing human activities with natural laws through a dialectical conflict resolution approach. The various steps of the new model describe how tuning the opposites (conflict and cooperation) may produce zero externalities by harmonizing human sustainable growth with environmental laws.

Nature-Human Dialectical Interplay

Earth has constantly evolved since approximately 4.5 billion years after its formation [16]. The continents are slowly but permanently drifting apart, volcanoes frequently erupt, and the climate has experienced several changes as it constantly evolves. It has moved periodically from warmer to cooler periods, including the formation and melting of glaciers in different long-lasting periods. The history of all these changes describes the timeline of nature's evolution. The chemical and biological characteristics of flora and fauna left their footprint on fossil deposits in rock formations. Geological strata of variable composition, thickness, and depth correspond to different periods, which paleontologists call geological epochs. Around 6 million years ago, the human species first appeared in Africa and continuously left signs of interacting with nature in various geological formations [17]. The timeline of human footprint provides data showing the interaction between natural conditions and human socio-economic development. In this complicated historical journey, it is of particular interest to analyze the role of water and its use by humans to survive and develop different socio-economic activities.

Analysis of historical data indicates that the coexistence of two opposites, i.e., fighting and friendship, is the basis of the water-human relationship. It is interesting to notice here that the coexistence of conflict and cooperation is also the case in the transboundary water resources hydro-hegemony literature. However, no convincing explanation is reported for this apparent contradiction

[18]. In the timeline variation of the two opposites, their relationship fails to be harmonious when one prevails, and negative impacts may occur either on the nature or the human side.

Here, we define the water-human contradictory coexistence as *dialectical*. This definition means a relationship between two opposites with the potential to overcome their differences by a logical synthetic methodology. The dialectical interplay between humans and water is variable over time, and its dialectical nature is admitted here as an *ontological* rather than an *epistemological* principle. We suggest a dialectical conflict resolution model based on exchanging contradictory arguments, leading to the union of the opposites, i.e., between human activities and natural laws. From the historical review, we draw valuable lessons on improving the IWRM model in our times of climate change and reducing drastically negative environmental impacts.

Historical Analysis of Water-Human Interaction

For many reasons, water is the most appropriate environmental indicator to characterize the relationship between nature and humans. First, it is essential for human survival and all life forms on Earth. Second, as a primary driver for agricultural irrigation, it is the main driver for food production. The third reason is that water constitutes the raw material for all socio-economic activities, such as energy production and tourism. Fourth, water and sanitation play a significant role in enhancing public health and quality of life; fifth, as a negative indicator, water may cause natural disasters such as floods and droughts [19].

Climate variability on Earth generated a time series of atmospheric temperatures in different geological epochs. Data on oxygen isotopes in Greenland ice cores [20] indicate the Earth's climate changes. As shown in Fig. 1, ~800 kyr ago over the late Pleistocene, also called the Ice Period, the climate varied in ~100-kyr glacial cycles [21]. In the interglacial Eemian period, humans benefited from relatively warmer temperatures [22]. During that period, migratory movements are reported from Africa to Australia and South Asia to Europe [23] (Fig. 1).

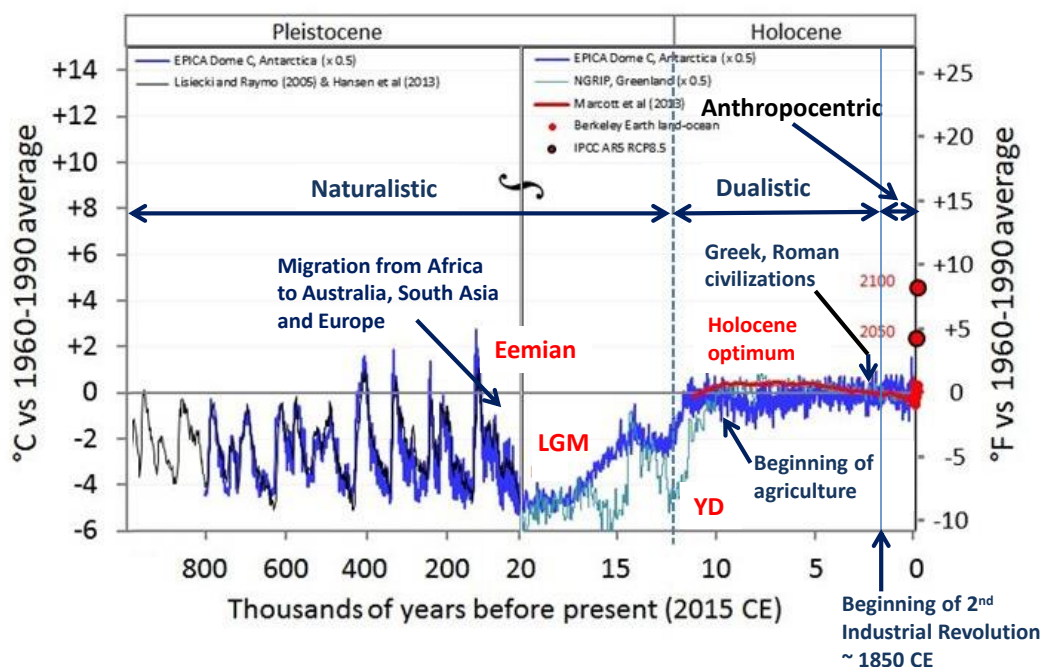


Figure 1. Nature-human interplay since ~800 kyr ago, modified from [22].

After the Eemian period, we entered the Latest Glacial Maximum (LGM) with almost low temperatures attributed to possible changes in the orbital parameters of our planet. We can observe a significant rise in temperature by the end of the LGM in the so-called Younger Dryas (YD) period. It happened approximately 12 kyr years ago, before attending an almost steady temperature

favorable to human activities (Holocene optimum). In the Pleistocene, the fight for survival against wild animals and adverse natural conditions was a priority for humans. While water use was empirical without any technical support, the humans being a part of nature, they contemplated the forces of nature in the form of natural disasters, such as floods and volcanic eruptions. Settled in caves and places offering natural protection, nature dominated humans.

The Aborigine population in Australia and the primitive population in Africa, Eurasia, and South and North America used to live as nomad hunters, looking for security in caves or precarious homes [24]. Without advanced technical equipment, they used water for survival, fighting against natural forces, hostile animals, and natural disasters. Natural phenomena like the sun's sight and the moon's variations were signs of supernatural entities and even Gods [25]. Rivers and streams had divine characteristics; the same was true for the volcanoes. A volcano eruption or a catastrophic flood was God's punishment.

About 3000 years ago, the Holocene's optimum temperatures created natural conditions favorable to human socio-economic development. It first happened in regions with abundant water resources, big rivers, and fertile plains. The first human civilizations developed extended agricultural activities in fertile valleys of big rivers, like the Nile in Egypt, the Tigris and Euphrates in Mesopotamia, the Indus River in India, and the Yellow River in China.

Humans created the first significant urban centers and human agglomerations around 2000 years ago in the same river catchments. From the open irrigation channels archeologists have discovered in Mesopotamia to water supply and sanitation networks found in Knossos, Crete Island [26], we know that ancient civilizations like the Minoan, Egyptian, and Persian developed essential hydraulic equipment during the late 2nd Millennium. It includes the Norias hydraulic machinery in ancient Syria to transport water for irrigation at higher altitudes and the Qanats [27] subterranean tunnels to collect and transport groundwater over long distances for irrigation and water supply.

In the classical era from 600 BCE to 500 CE, the Greeks and Romans further improved different hydraulic infrastructure, like the Roman Aqueducts for water transportation in cities [28] and the Archimedes pump-screw that is used even today for elevating more than water in higher altitudes, such as wastewater with solid material in sewage treatment plants. Progress in hydraulics and water management was notable during the ancient empires like the Byzantine, Indian, and Chinese. Well-known is the water storage in huge reservoirs of drinking water for big cities, like the Basilica Cistern in Constantinople, the Chant Bahori in India, and the complex scheme of irrigation channels in the Yellow River, China. However, during that period and also in the Middle Ages and the Early Modern Era (500–1750) CE, the WRM paradigm has remained primarily empirical. Spiritual and religious concepts dominated water policy at the beginning of Greek and Roman customary law [29].

Signs of change in the human-nature interplay started with the 1st Industrial Revolution (1750-1870) and accelerated since 1870, after the 2nd Industrial Revolution. As shown in Fig. 2, since that date, the atmosphere has been exponentially filled with CO₂ emissions from massive industrial use for energy production of fossil materials like gas, oil, and coal [30]. During the same period, the consumption of water resources has impressively increased, especially for food production in agriculture [31] (Fig. 3).

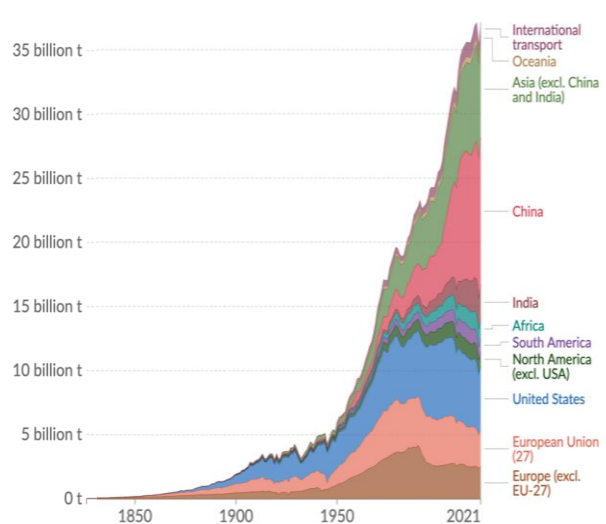


Figure 2. CO₂ emissions by countries, modified from [30].

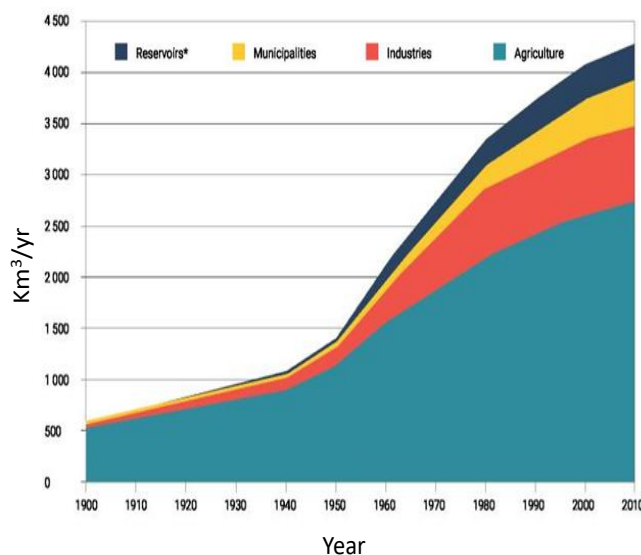


Figure 3. Global freshwater consumption by sectors, modified from [31].

The Industrial Revolution is also a landmark of the so-called greenhouse effect of climate change on Earth. As shown in Fig. 4, this phenomenon causes a continuous rise in global temperature, known as global warming (WG) [32]. In terms of the mean temperature variation over a certain period, Global Warming (GW) happens at different scales, such as Early, Medium, and Advanced GW (Fig. 4). For these time scales, as for the previous Pleistocene and Holocene epochs, a correlation exists between natural climate conditions and the human behavior against nature. We may deduce three main clusters of such interaction and different types of WRM models.

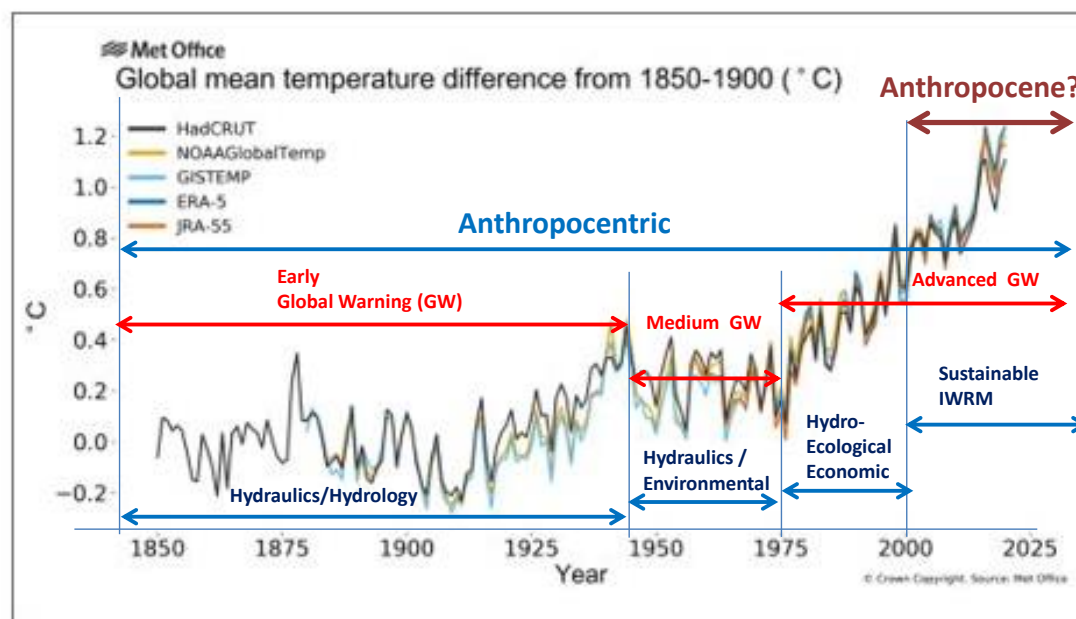


Figure 4. Changes of the WRM model (1850-2025) in relation to climate, modified from [32].

Three Clusters of Nature-Human Interaction

The Pleistocene is a period we may call *naturalistic* because nature was the dominant force in the balance of power between nature and humans (Fig. 1).

The Holocene Epoch, also called the Human Age, is a preminent period of stable climate conditions enhancing significant socio-economic and cultural progress. For scientific and geological reasons, the Holocene is still in place. Due to significant technical progress, humans gradually moved their relationship with nature from a *naturalistic* to a *dualistic* type until the beginning of the 2nd industrial revolution in 1850 (Fig. 1). This means a coexistence of human respect for nature with resistance against natural forces. A typical example of this dual behavior from ancient Greece is the Acheloos River, considered to be semi-God and, at the same time, a giant snake, defeated by Hercules for producing catastrophic floods [33].

Referring to the rise in global temperature shown in Fig. 4, our aim is not to analyze the GW phenomenon from a scientific point of view. We want to investigate how humans behaved against nature during that time and the consequences of this behavior to WRM models and global water security. Observing how changes in the WRM model narratives correlate with global climate change and particular temperature variations is interesting.

As shown in Fig. 4, three types of temperature variation and subsequent models of WRM are distinguished:

- 1) Early Global Warming (GW), from 1850 to 1945

During that period, an increase of less than 0.5 °C in the global mean temperature was observed (Fig. 4). It is the period where the 2nd Industrial Revolution started with a massive emission of CO₂ in the atmosphere (Fig. 2). During these years, science and technology have grown exponentially, especially in the hydraulic/hydrological engineering domain. In 1935, designing and constructing the giant Hoover Dam in the Colorado River, USA, was the period's milestone [34]. Since then, humans have become strong and self-confident and have thought of dominating nature by using big rivers and water resources as human assets. We may call this period *anthropocentric*, i.e., human-dominated [14] (Fig. 4).

- 2) *Medium GW*, from 1945 to 1975

The global mean temperature during that time seems stable but still exceeds the average 1850-1900 reference temperature. During these 30 years of implementation of anthropocentric WRM

models, signs of adverse environmental impacts started to be visible. Point and diffuse pollution in rivers, lakes, and groundwater have mobilized environmentalists and NGOs. A milestone of this period is the 1972 UN Stockholm declaration, stating that economic development cannot be effective without environmental protection [35] and the necessity of an Environmental Impact Assessment (EIA).

3) *Advanced GW*, from 1975 to 2025

As shown in Figs. 4 and 2, the exponential increase of CO₂ continues with the global mean temperature increasing by more than 1.2 °C. In terms of change in the WRM model, this anthropocentric period is divided into two sub-periods

3.1) 1975-2000, a period of *ecological concern*

The 1992 UN Rio Summit, in Ch.18 of Agenda 21, reflects the need for environmental protection. This text [36] defines the necessity to establish the IWRM model, considering the ecological dimension of water and its economic value. Agenda 21 was the base for formulating in NY, during the 2000 UN Summit, the Millennium Development Goals (MDGs).

3.2) *After 2000*, a period some scientists call the *Anthropocene*

The UN World Summit on Sustainable Development in Johannesburg in 2002 marked a political engagement for adopting multilateral partnerships to promote sustainable economic development [37]. The Johannesburg declaration promoted later on in the 2015 NY World Summit the 17 Sustainable Development Goals (SDGs). However, after almost 50 years from the 1972 Stockholm Declaration, the integrated management of natural resources produced severe externalities. The IWRM remained anthropocentric, and a third more CO₂ was accumulated in the atmosphere. At the same time, the global temperature exceeded 1.5 °C, substantial topsoil degradation, and rising seas from glaciers melting. The footprint on geological strata of recent human activities after 2000 is so drastic that many experts suggest the initiation of a new Geological Epoch called the Anthropocene [38].

As shown in Fig. 5, the stability of the dialectic relationship between humans and nature depends on the ratio of two opposite forces: (i) A: the human pressures on nature (externalities), and (ii) B: the natural forces on humans (natural constraints). The power ratio B/A is a function of the climate and human societies' scientific and technical development. We can distinguish three clusters: (i) B>A: naturalistic during the Pleistocene epoch; (ii) B≈A: dualistic during the Holocene; and (iii) B<A: anthropocentric, after the industrial revolutions.

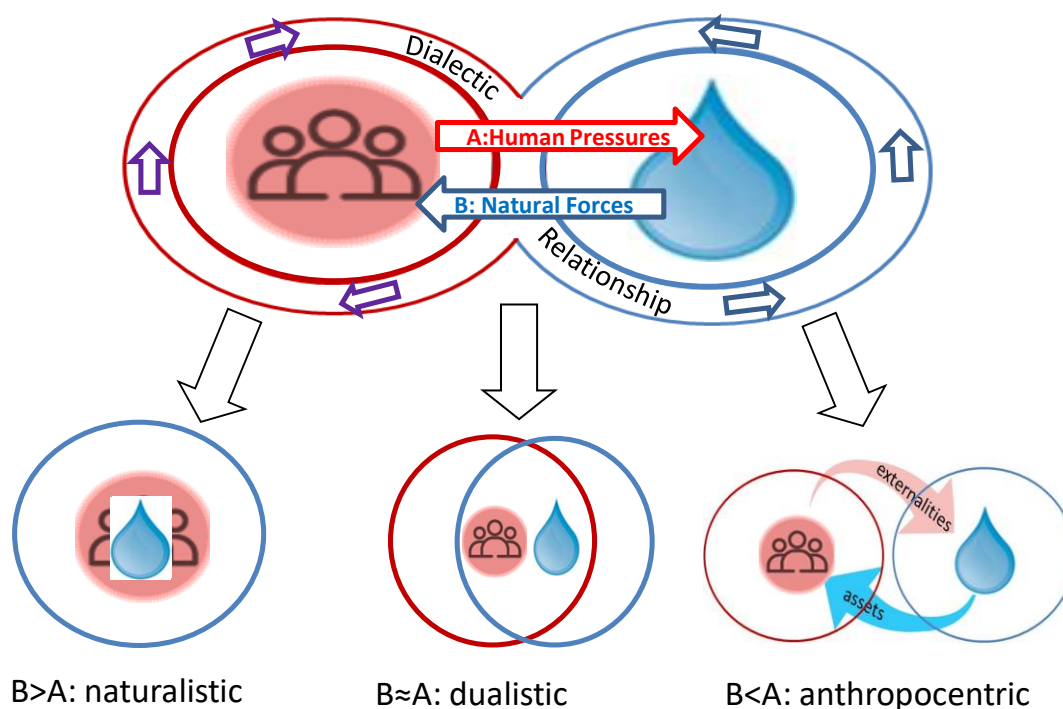


Figure 5. Three clusters of the dialectic human-water relationship.

We should notice here that the dialectical nature-human relationship shown in Fig. 5 as the union of two opposite forces differs from the recently promoted Nature-Based Solutions (NBs) [39]. Using natural materials and the bio-engineering approach of NBs are very useful for small-scale restoration of water infrastructure works and ecosystem preservation. However, NBs don't include the conflictual character of nature-human dialectics, and they don't define how human prosperity is preserved by implementing NBs. The dialectical conflict resolution model we suggest brings a harmonic symbiosis with nature when the opposite dialectical forces come to an equilibrium (tuning the two opposite pressures).

The WRM Timeline Metabolism

In pre-historic times, humans' water use was elementary, mainly as a necessity for survival. In historical times and, more recently, with the exponential growth of science and technology, water management has taken the form of scientific and technical WRM models. The evolution of these models reflects the timeline of water-human interaction following the climate variability of our planet.

During the last few decades, IWRM models have recorded significant externalities such as surface, groundwater, and soil diffuse pollution, ocean acidification [40], and changes in precipitation patterns producing extreme floods and droughts. The loss of biodiversity has accelerated, together with the increase in freshwater consumption. Although a reduction in global freshwater consumption was recently recorded, as shown in Fig. 3, global water consumption has increased since 1900 by more than eight times, with agricultural activities consuming more than 70% of the total. It follows a rapid increase in the global population on Earth. Tab. 1 summarizes the WRM timeline and the change in water policy since the pre-historic period.

Table 1. Timeline evolution of WRM and Water Policy models.

Period/ Temperature	Time Interval	Water- Human Interplay	Milestone of a WRM Model	WRM Model	Water Policy Model
Pleistocene +1 to -6 °C	up to 11 kyr	Naturalistic	Homo Sapiens	Empirical	Spiritual
Holocene Optimum	11 kyr-600 BCE	Dualistic	Agriculture	Irrigation	Religious Customary
Holocene Optimum	600 BCE-1700 CE	Dualistic	Roman Aque- ducts	Early Hydraulics	Religious Customary
Holocene Optimum	1750-1850	Dualistic	1 st Industrial Revolution Watt's Steam Engine	Hydraulic Engineering	Early Hydro- Technical Infrastructur e Management
Early Global Warming 0 - +0.5°C	1870-1945	Anthropo- centric	2 nd Industrial Revolution 1935 Hoover Dam, USA	Scientific/ Engineering Hydraulics Hydrology	Hydro- Industrial Management

Medium Global Warming	1945-1975	Anthropo- centric	UN 1972 Stockholm Water Declaration	Hydro- Environmenta l Protection	EIA Enviro- Impact Assessment
Advanced Global Warming 0 - +1.5°C	1975-2000	Anthropo- centric	UN 1992 Rio Declaration	Hydro- Ecological Economic	Ecological Water Cost Recovery
Anthopo cene Era?	2000-now	Anthropo centric	Johannesbur g 2002 World Summit	Sustainable Dev. Goals (SDGs)	Sustainabilit y EU WFD 60/2000/EC

Involving Stakeholders and Decision-Makers in IWRM

In the use of natural water resources, it is essential to clarify the structural connection between three different activities, which are

1) Science/Management, 2) Policy/Law, and 3) Governance/Decision-Making.

At every administrative level, we distinguish these activities as follows:

- *Science/management* is a set of decisions at the lowest level on planning, controlling, and operating specific projects. Formerly, it should be the domain of science and technology, the use of results of scientific analysis and research, data processing, and simulation of different scenarios;
- *Policy/Law* is a set of customary, national, and international laws and regulations aiming to generate decisions for controlling, correcting, and implementing managerial plans and activities;
- *Governance/Decision-Making* is the integration of policy and management into socio-political decision-making.

These three interacting domains form a complex socio-economic environment called the Science-Policy-Governance Nexus (SPGN) [12]. Apart from the usual socio-economic sectors within the SPGN, the main profiles of water stakeholders are classified as follows:

(1) *Knowledge Generators*. They actively develop the scientific and technical background of WRM at different scales. They are University Professors, researchers, teachers, and other persons involved in private and public research and education activities. They act as councilors to elected politicians, supporting and advising scientifically and technically the Parliament, Ministries, Regional and Local Administration.

(2) *Law and Policy Makers*. In democratic countries, the socio-economic and political system of governance relies on the rule of law. Lawyers and experts in public administration formulate the law nationally. Regional and local authorities also issue regulation texts and decrees.

(3) *Water Professionals*. These are engineers and qualified technicians responsible in the private and public sectors for designing, constructing, and maintaining water-related infrastructure. They play a significant role in developing public and private works and infrastructure for water services, such as water supply, public health, irrigation, and energy production. They should cooperate with scientists to update their technical skills and comply with legal rules and water regulations.

(4) *Public Society*. In the democratic world, public associations and all citizens are theoretically involved to play a significant role. It can be involved in public decision-making or electing people's representatives at different levels, such as local, regional, and national. Non-governmental organizations (NGOs), Non-Profit Associations, and Professional Lobbying groups are essential stakeholders in the water sector, primarily through modern social media and the Internet.

SPGN reflects how different countries behave economically, socially, and culturally in the international arena. Between the three main elements of SPGN, many feedback and several issues

interact, like socio-economic sectors and international relations, history, education level of the population, religion, and national economies. For example, science is the principal tool for developing water management models. It also benefits from empirical inputs from stakeholders who can be experts in policy and governance. Lawyers and social scientists make water regulations and laws to translate scientific knowledge into legal forms. To this aim, scientists could translate physical entities, like freshwater, groundwater, streams, and aquifers, into legal terms and develop legislative texts. Also, politicians need scientists and lawyers to exercise policies and governmental activities [12].

In this complicated SPGN structure, the main question is how a scientific narrative on the IWRM model could be redefined to enhance stakeholders' involvement as an essential part of the model.

A New Dialectical IWRM Model for Conflict Resolution

Economic and environmental data in support of recent econometric studies indicate that the global financial conditions of humanity during the last decades have improved substantially. According to the World Bank [41], although economic disparities are substantial between advanced economies and developing countries, from 1995 to 2018 i.e., in 23 years, the global economic growth of human wealth on our planet increased by 80%. However, this economic development is non-sustainable as it has been developed at the expense of natural assets from which humanity has benefited. According to [41], between 1992 and 2021, i.e., for almost ten years, the global domestic product (GDP) per capita doubled. However, the available natural capital per person decreased by 40% during the same period. As natural capital, we count the total monetary value of environmental renewable and non-renewable resources, such as water, soil, forests, food energy, and ecosystem services. In other words, there is a *Capital Inequality* between human wealth and the availability of natural resources, and this disparity is growing. We may conclude that the adverse environmental situation is due to excessive anthropic pressure on nature, including the anthropocentric character of the IWRM model. This global human-nature conflict is analyzed historically and analytically to find and suggest sustainable WRM solutions.

To reduce global negative environmental impacts from human activities, two possible alternative solutions that are very difficult to implement could be the following.

(1) reduce the level of current global GDP, which means slowing down human activities, producing additional economic growth, and

(2) alleviate negative externalities by undertaking global remediation measures, such as planting more trees and restoring the ecological status of water bodies like rivers, lakes, and aquifers.

The first solution is unfair because it could penalize developing countries to have access to a better quality of life. The second one can produce only limited visible results as it is operational only in the long term. For example, planting the necessary number of trees needs extensive areas, and possible results can be visible after a few decades. Also, de-nitrification of soils is likely, but it can take many years and cost an unaffordable amount.

We could develop a nature-human conflict resolution model to avoid environmental externalities by analyzing the water-human interplay's dialectic character. The terms *dialectic* and *dialectical approach* derive from the Greek "dialogos," a conversation between two persons exchanging contradictory arguments. Instead of two persons, we have humans and nature, as described by nature's laws. By nature, we mean all the non-human entities, i.e., the natural environment, the soil, the atmosphere, the hydrosphere and biosphere, the flora and fauna, and all ecosystems on our planet. In our approach, humans are not a homogeneous group of people but human societies consisting of different categories of stakeholders with particular socio-economic water-related interests. These social groups are farmers, industrials, water professionals, environmentalists, and other social entities developing economic activities interacting with water use. They are also categorized into the four groups of stakeholders we have defined previously. The dialectical conflict resolution model we propose consists of two main steps

1) Defining the human-human and the nature-human conflicts

We call this step *eristic* from the Greek "eris," which means strife. Two kinds of conflicts are distinguished:

- a) conflicts between different social groups (human-human), and
 - b) conflicts between social groups and the corresponding natural laws (human-nature).
- 2) Dialectical resolution

Logical arguments and alternative measures are formulated to attenuate the nature-human conflicts. The best solution is the unification of the opposites, which means respecting the natural laws. The harmonic symbiosis between humans and nature also reduces human-human conflicts.

The main idea for developing the *Eristic-Dialectical Model* (EDM) was first coined by Heraclitus [43, 44], the Greek Pre-Socratic Philosopher, formulated by Socrates, the father of Greek philosophy, and ultimately adopted in the 19th Century by the German Philosopher Hegel [44]. It served later on as the primary argument in the materialistic dialectical theory developed by Karl Marx and Friedrich Engels [45].

The steps to follow in any EDM/IWRM model are shown in Fig. 6, where a comparison is illustrated with the state-of-the-art IWRM model.

Step 1: the conflict resolution is undertaken by a River Basin Authority (RBO), responsible for monitoring at the river catchment scale

Step 2: the RBO develop a consultation with all stakeholders to define a Joint Action Plan (JAP)

Step 3: different human-human and water-human conflicts are identified corresponding to each socio-economic activity (Eristic Analysis)

Step 4: The Dialectical River Basin Management Plans (D-RBMPs) are formulated dialectically by unifying human interests and the natural laws

Step 5: Monitoring of D-RBMPs can initiate a new JAP followed by a revision of steps 3 and 4.

Comparing the EDM model with the anthropocentric IWRM model, we can observe in Fig. 6 that step 1 is expected to be shared for the two models, followed in IWRM by the Driving Force-Pressure-State-Impact-Response (DPSIR) step, the establishment of River Basin Management Plans (RBMPs) and the Program of Measures (PMs).

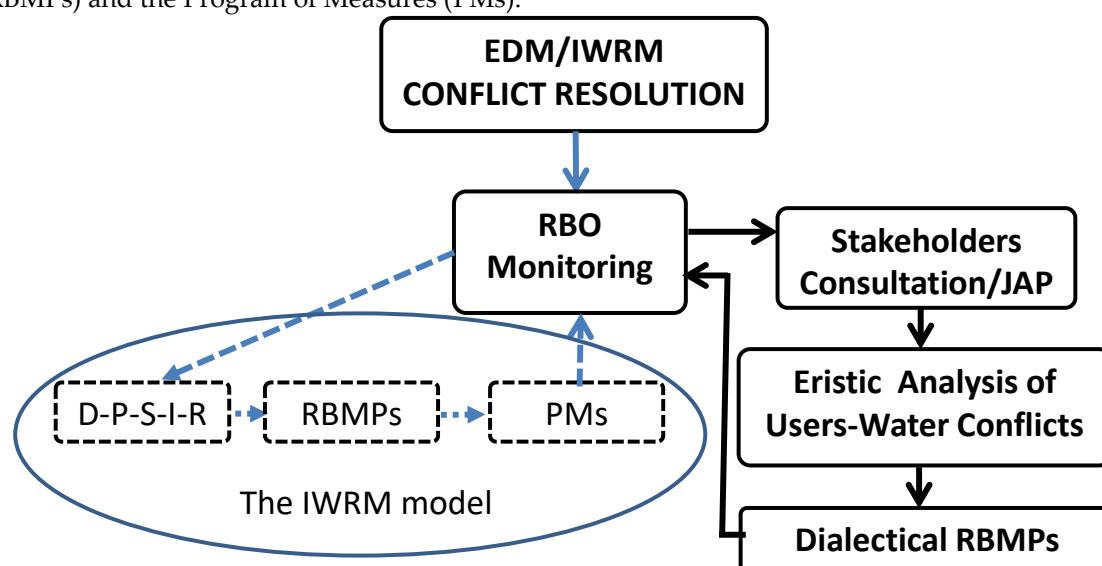


Figure 6. The EDM-IWRM model in comparison with the state-of-the-art IWRM model.

Case Studies

Dialectical Flood Management in Crete Island, Greece [46, 47]

This case study refers to applying the EDM model for flood mitigation and adaptation in the case of Giofyros River, Iraklion City, Crete Island. In the past, the urban part of the river Giofyros has experienced several flood damages to neighboring urban infrastructure and losses of private and public property. The severe flood of January 1994 produced significant impacts worth many million Euros, including critical damage to the city's wastewater treatment plant. Public and town authorities decided to establish a coalition of local stakeholders, University Professors, researchers, water

professionals, and consultants to design and implement an efficient flood risk management framework. Details on the steps followed for developing an Eristic-Dialectical Integrated Flood Management Plan are reported in [10, 47]. They are similar to those shown in Fig. 5 for the IWRM-EDIFM conflict resolution model. To find a dialectical solution, we identified the two human-water coexisting opposite behaviors: (i) friendly, as humans enjoy the river's water services, the green areas near the river, and the refreshing temperature during the hot summers, and (ii) adversarial to the river, because of the negative consequences the river's floods had created, such as loss of property and even human lives. However, humans underestimated or felt able to overcome the forces of nature, so they occupied and constructed their properties in a part of the river's 20-year floodplain (humans against nature). Due to this anthropocentric behavior, river floods inundated every 20 years in this part of the city (water against humans). The Dialectical Flood Risk Management solution [47] brings harmony between humans and nature by unifying the two opposites, i.e., keeping safe the inhabited area along the river by retaining upstream the 20-year flood peaks with a system of flood detention reservoirs, constructing a flood levee and opening the river bed (tuning human activities with the hydrological laws).

Sustainable Agricultural Irrigation in the Mediterranean

According to statistical data [48], farmers in the Mediterranean countries use more than 86% of water resources for irrigation in summer, compared to 59% for Europe and 69% worldwide. The Water-Energy-Food Nexus model (WEFN) was applied in this brief as an integrated system framework for reducing the overuse of irrigation water. The main idea was to use the synergies of the integrated approach to maximize food production while minimizing water and energy use. Because mathematically and physically, no unique solution can obtain the target, based on economic considerations, farmers tend to increase food production by overusing water and energy. The management brief [48] recommends a dialectical solution based on renewable surface and groundwater quantities and renewable energy sources, such as solar pumps for groundwater extraction. In this way, respecting the natural laws in agricultural activities can bring a sustainable harmonic nature-human coexistence.

Dialectical Urban Water Security: the Case of Attica Peninsula, Greece [11]

The urban water metabolism depends on how cities use their water resources, manage wastewater, and protect urban surface and groundwater bodies, like rivers, lakes, and aquifers. This case study refers to the Attica Region, where Athens, Greece's capital, is located. Athens has a long-lasting and well-documented history describing the water-city relationship from ancient times to the historic period of classical Greek civilization, and after that, from the Ottoman occupation to modern times after the Greek independence in 1830. According to the Greek myth describing the city's creation, Athenians opted for a town with scarce water resources but with the possibility of developing new knowledge and wisdom thanks to the goddess Athena. Athena, one of the 12 main ancient Olympian Gods, was chosen by the people of Athens as the city's protector. In a public competition, she offered the olive tree for cultivation and her wisdom for socio-economic development. Historical data can explain the ancient myth as follows: without major rivers, the Attica Peninsula could protect Athens from significant floods, although the two minor streams in the area, Ilissos and Kephissos, together with available groundwater resources, could offer enough water for drinking and entertain green areas in the city. Also, the fertile soil of the peninsula provided the successful plantation of olive trees for oil production and other agricultural uses. Following the proclamation of the Greek state, the city authorities recently decided to cover most of the urban streams, including the rivers of Ilissos and Kephissos. The related public works for "water reclamation" were initiated by the need to accommodate many people, create new avenues for traffic, and combat surface water pollution and mosquito contamination of urban neighbors along the streams. In the case study, we analyze a dialectical solution to uncover the two major streams to ensure their ecological flow in summer and harmonize dialectical urban activities with the natural hydrological laws.

Conclusions

From the previous historical analysis, we may draw some valuable lessons, such as

- 1) The nature-human relationship and the WRM models continuously change over time.
- 2) Human behavior towards nature is expressed by the coexistence of two contrary attitudes, i.e., conflict and cooperation. This relationship is an ontological principle called dialectical.
- 3) The coexistent two opposites are not always in balance. Humans usually conceive their interaction with nature as a competition between their abilities and the strength of natural forces. Depending on the prevailing power, three clusters have been identified here in different historical timescales: (1) the *Naturalistic* cluster, i.e., nature's domination over humans during the Pleistocene; (2) the *Dualistic* period during the Holocene, which is characterized by the balance of two opposites, and 3) the *Anthropocentric* period since the 2nd Industrial Revolution, when humans felt being able to dominate nature.
- 4) The IWRM paradigm is currently accepted to be the state-of-the-art WRM model. It is anthropocentric, and its implementation since 20 years ago in Europe and elsewhere has generated substantial adverse environmental impacts. Fossil observations and recorded physicochemical data show that humanity has entered a new geological period called the Anthropocene.
- 5) To reduce anthropogenic externalities, it is urgently needed to improve IWRM by involving stakeholders and decision-makers in the water governance process.
- 6) The new IWRM dialectical model we suggest here is based on analyzing conflicts between human activities, followed by a dialectical reconciliation between humans and the natural water laws. By unifying the water-human contradictory behaviors, we achieve sustainable water governance by avoiding negative environmental externalities.
- 7) Three selected case studies illustrate the practical implementation of the EDM-IWRM model.

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