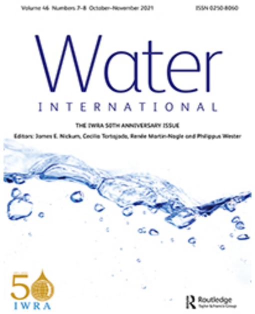

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ESSAY

The water–man eristic dialectics for sustainable hydro-governance

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ABSTRACT

Eristic and dialectics are used in their original meaning in Greek to describe conflicting relations between man and water (eristic) and their logical reconciliation (dialectics). A historic peregrination shows a dysfunctional relationship between humans and water. It became human-dominated, creating huge externalities in the state-of-the-art integrated water resources management (IWRM) model as well. The eristic–dialectical symbiosis of humans with water unifies harmoniously their contradictory relationship of conflict and cooperation. It has been used to develop a new policy model of water resources management that is illustrated here with two real case studies and can lead to a sustainable hydro-governance.

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Water–man conflicts; eristic–dialectical model; case studies

Introduction

Water is intimately related to man. It is the essential natural resource for upholding life and ecosystems. Water is the main constituent of human organisms, babies having the most, being born at about 80% of it. It is also the most important element for the functioning of human organs such as the brain and heart, muscles and kidneys. Even the bones contain 30% water. An adult human organism needs 2–3 litres of water per day to survive, not all of this being taken in liquid form, but also through food.

Man, as an intelligent being, has created his language and communication skills. He was then able to develop his way of thinking that over millions of years distinguished him from other animals. By setting up original technological tools, he developed special social environments, enabling him to make progress and separating him from nature.Burke (1963, p. 507) explains and justifies his definition of man as ‘the symbol-using animal, inventor of the negative, separated from his natural condition by instruments of his own making, goaded by the spirit of hierarchy and rotten with perfection’.

Throughout history, man has faced the natural/water environment as hostile and antagonistic. Hunting animals for food, cutting down trees to extend agricultural land and diverting streams were necessary for man’s survival and comfort of living. Even in our times, especially in the Greater South, humans fight against poverty by cutting down trees for trade, setting fires in the Amazonian forest for additional land and surviving devastating floods. Also in technologically advanced societies, man entertains

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antagonistic relations with nature and water. He builds dams to retain water from flooding that may put his property and life at risk and he struggles to mitigate losses from natural disasters, such as hurricanes, tsunamis, earthquakes and volcanic eruptions.

At the same time, in opposition to his adversarial attitude to nature/water, he benefits from rivers producing hydro-energy and promotes the green economy as a priority for sustainable socio-economic development. He also enjoys the beauty of natural landscapes partaking in water entertainments and sports, such as kayaking in rivers, swimming in the sea, and skiing and surfing.

The strong relationship between nature and man is in constant and dynamic evolution. The lifestyles and production patterns of human societies have adapted to climate changes subject to ecological variability of the biosphere as well. Since the Earth's formation and the appearance of life on it, changes in the natural environment, ecological species and human societies have been continuous and dynamic. Periods of slower evolution have been followed by those of rapid change due to stronger natural and anthropogenic pressures.

To realize the time scale of the nature–man evolutionary relationship, we should go back billions of years to the beginning of the universe and the timeline of the Earth and life formation. According to the latest estimation given by the Hubble Space Telescope, the age of the universe is 13.7 billion years (Hubble Space Telescope, 2021). The Earth's age is estimated by rock radiometry to be 4.5 billion years (USGS, n.d.) and the first appearance of life on our planet goes back to about 3.7 billion years (Smithsonian Institution, n.d.). Climate variability is continuous with periods of low temperature that have formed glaciers now covering Antarctica and many parts of Europe and North America, followed by variations in water streams, flora and fauna as well. The appearance of dinosaurs and flying reptiles, the extension of large mammals such as giant bison, mammoths and mastodons with impacts on human activities took place in different geological periods. These events have left their signature in vertical rock geological formations that geologists and other specialists have used for developing the Geologic Time Chart of our planet.

Geologists refer to the present period that started about 10,000 years ago as the 'Holocene', which means the 'wholly new' time in Greek. In the Holocene, recent human activities of modern man prevail over nature so strongly that a group of scientists recently claimed that since 1950, a new period has started. They call this period the 'Anthropocene' epoch, which means the new age of man. Although there is no scientific consensus about the beginning of the Anthropocene, there is strong evidence that recent human activities have profoundly altered the atmosphere (high concentration of greenhouse gases), the soil (nitrification from agricultural and other activities) and the oceans (marine pollution, dumping of plastics), leading to so-called climate change.

In the 2021 report of the World Economic Forum in Davos, the top five challenges humanity faces today, next to the Coronavirus pandemic, are related to environmental risks, as far as their likelihood is concerned (World Economic Forum, 2021). Climate change, natural disasters, extreme weather, loss of biodiversity and water crises are listed as top priorities for risk management and mitigation. Water is at the centre of these challenges because modification of precipitation patterns has provided less water in ever-humid regions. Extreme temperatures and more frequent floods and periods of drought result from atmospheric instabilities due to greenhouse gases. Water-related crises for drinking and agricultural irrigation have increased in many parts of the planet, especially in areas facing socio-economic problems. Pollution of rivers, lakes, humid areas and aquifers from industrial and agricultural activities has accelerated the loss of biodiversity and created threats to public health.

In this paper, we claim that this unprecedented environmental crisis is related to post-industrial environmental/water management policies. Separating man from nature, today's dominant water management paradigm is anthropocentric. The integrated water resources management (IWRM) framework is unable to generate water-resilient policies. As an alternative, we suggest considering the eristic–dialectical water resources management (EDWRM) as a new approach towards sustainable hydro-governance. Eristic and dialectics are used according to their first meaning in Greek to describe conflicting relations between water and man (eristic) and their logical reconciliation (dialectics). We explain below the steps to follow in the eristic–dialectical methodology and provide two illustrative case studies from practice.

The nature–man relationship in ancient societies

From the time of the Earth's formation and the first appearance of life, the relationship between nature and (later) man has been in constant evolution. Heraclitus of Ephesus, one of the Pre-Socratic Greek philosophers at the beginning of the fifth century BCE, summarized this idea of constant change with the phrase 'Panta Rei', which means 'all flows'. In fragments that survived of his written work in the form of aphorisms, Heraclitus claims that nothing is constant, because 'change is the essence of life that proceeds by conflicts'. This diachronic modification of the relationship between nature and man has been historically documented.

Indigenous people in the Amazon, Central America, Asia and the Pacific have a tradition of respecting forests, mountains and ecological species. Tribes in Africa and Asia designated sacred forest areas where animals and plants are not disturbed (Alcorn, 1993). In ancient India and China, the Buddhist religion was environmentally friendly, protecting forests and wildlife, and maintaining a harmonious relationship between man and nature (Bithin, 2019).

In ancient civilizations, a unified view of nature and man prevailed in people's minds. For example, in ancient Egypt at the time of the pharaohs, annual floods of the River Nile depositing fertile sediments were considered a gift from Nile God Hapi. In the first century BCE, the Roman writer Vitruvius reported that at the deepest place of a pyramid, the pharaohs prostrated before an urn full of water, the origin of everything (Vitruvius, n. d.). Rivers in ancient Greece were personified as man-gods. For example, the Ilissos stream in Athens is depicted in the Parthenon's west pediment as a reclining God. The statue was made by Pheidias from one piece of marble (Figure 1).

At that time, although rivers were friendly gods used to purify humans, they also were represented in the form of a dangerous bull or serpent with a human head. River-gods became angry from time to time, overflowing their banks to produce raging floods. This is the case of the Achelous River, the biggest river in central–western Greece that Hercules was able to fight and win (Figure 2).

Figure 1. Ilissos River-God on the West Pediment of the Parthenon. British Museum, London. https://www.britishmuseum.org/collection/object/G_1816-0610-99.

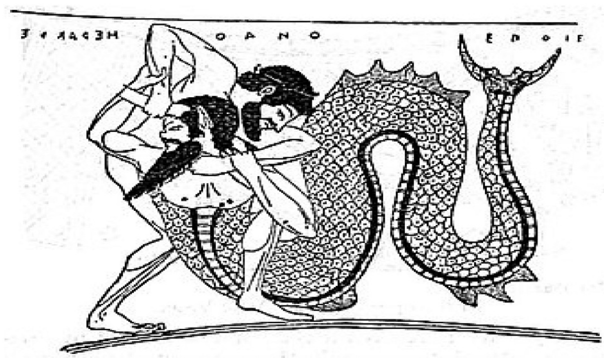


Figure 2. Heracles wrestling with Achelous River. British Museum, London. https://www.wikiwand.com/en/Achelous and https://www.britishmuseum.org/collection/object/G_1839-0214-70

In the fifth century BCE, the Athenian statesman and poet Solon, who is cited as one of the founders of Athenian democracy, promoted legislation regulating the use of groundwater. In ancient Athens, the construction and operation of private wells had to follow specific rules to protect public wells that covered the needs of water for all citizens (Solon, n.d.). Greeks and Romans had included and respected natural divinities in their religion. Apart from the main Olympian gods, Greeks had goddesses of nature, like the naiads for water, the dryads for trees and the oreads for mountains.

However, goaded by the spirit of rational organization and competition, Greeks and Romans have used nature to satisfy their needs. Many of their activities were the origin of environmental damage around the Mediterranean. Farming for food procurement, agricultural expansion, fires, hunting, cutting trees for timber construction, mining, urban expansions and destruction of nature in war were at the heart of negative environmental impacts. Well known is the destruction of forests in Attica during the invasion of the Spartans, the environmental damage by the Carthaginian Hannibal in

Italy, the consequences to humans and nature from the eruption of Vesuvius, and the terrible plague in Athens during the Peloponnese war (Hughes, 2014). However, we may notice that due to the limited technological and industrial developments of the Greco-Roman civilization, environmental threats were far less important than the global environmental damage we experience in post-industrial times.

Anthropocentric models of water resources management (WRM)

Traditional WRM models aim to satisfy human needs for sufficient water of good quality. The anthropocentric approach is based on the feeling that to serve human needs, freshwater natural resources are available in unlimited quantities. By the end of the first Industrial Revolution (1750–1870), man was able to control the natural environment. Disposing of advanced scientific and technical tools, he turned out to be stronger than nature. He placed himself at the centre of the universe with the sense of being surrounded by natural resources available to satisfy his needs and improve his living standards.

In industrial society, the separation of man from nature by the appropriation of natural resources, both renewable and fossil, was considered an achievement (Leiss, 1972). The domination of nature was a logical extension of the progress made in science and technology. Nature was excluded from the narrative of social progress and negative environmental impacts from industrial and other human activities, such as agriculture, were not considered of primary concern. Economists usually call these impacts external to human activities, that is, as *externalities* to the economic management model.

In the 19th century, only the socio-political discourse of Karl Marx on *historical materialism* mentioned environmental issues as an exception to the dominant ideology. Marx stated correctly that nature, together with evolving social conditions, is in continuous change. However, he was wrong by claiming that environmental problems were only due to *capitalism*, that is, the institution of private property and workers' exploitation by the owners of production (Grundmann, 1991).

Following the second Industrial Revolution (1870–1970), social and ecological environmental sensitivities have been constantly growing. During the last three decades of the 20th century, ecologists, environmentalists, United Nations international organizations, civil societies and non-governmental organizations (NGOs) have greatly influenced the contents of the WRM paradigm (Bhaduri et al., 2014; Gain et al., 2021). The technical hydraulic/hydrological model has been evolved by a systems approach to the so-called IWRM model.

In this paper, we argue that IWRM remains an anthropocentric paradigm. Two decades after its implementation in Europe in 2000, it has produced mixed results. To reverse this situation and face the strong environmental challenges of our planet under climate change, there is a need for its radical transformation. We show analytically and by specific case studies that the *water–man dialectical paradigm* is an improved framework of IWRM which could pave the way to sustainable hydro-governance.

Main social stakeholders

Before describing briefly the diachronic evolution of the anthropocentric WRM model, let us distinguish the main social players who influence this change, as shown in Figure 3.

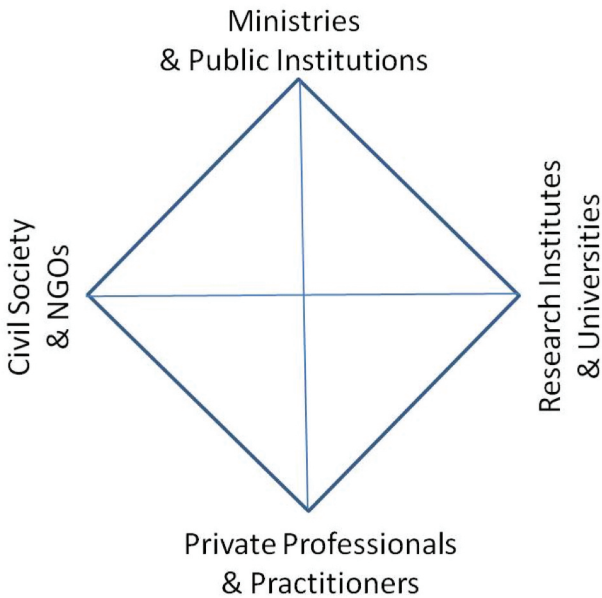


Figure 3. Social actors in water resources management (WRM) policy.

- *Public institutions*. Water policies are developed and implemented in the form of water laws, guidelines and regulations by governmental bodies. They act at different levels: at the central or national level, these are water-competent ministries and regulatory agencies that apply existing legislation, and compose and submit to parliament proposals for new laws subject to political sensitivities of the elected government and political parties. At regional and local levels, depending on the country's federal or centralized structure, the political power is exercised by local and regional water authorities that issue water licences, and supervise and control the application of national regulations. Public institutions at central and local levels take a political risk for their decisions and economic implications. In return, they distribute economic risks to private companies and water professionals.
- *Research institutes and universities*. These are public and private institutions for education and research, generating new scientific knowledge, publishing research papers, and suggesting new models for water and environmental management policy. They avoid economic risks related to public works and water-related infrastructure development (e.g., irrigation networks).
- *Private professionals and practitioners*. Water professionals are engineers, hydrologists, water-related scientists, technicians and private companies responsible for the design and implementation of public waterworks. Contrary to the two previous groups, they invest privately and take the economic risk of these investments.
- *Civil society*. Also called the 'Third Sector', it complements the public and private sectors. Civil society is composed of different professional and scientific organizations, labour unions, caritative foundations and NGOs. They play an increasingly important role in environmental protection and ecological remediation.

In the social arena of water-related activities, the four major social actors compete continuously to protect their interests, share political power, and influence environmental and water management policies. As an example of conflict, a strong debate is persisting on the dilemma of choosing between water as a public good or as a commodity. In fact, given that water is necessary for human existence, it should be considered a public good and even a human right. When water supply and sanitation are managed by private companies, they take the risk of investing in research and new developments, but in many recent cases, to maximize their profit, they tend to raise water prices.

Under the influence of the prevailing free-market economy, man's mastery over nature has become dominant (Hand & Van Liere, 1984). As a consequence, we could notice a tendency to separate man from nature. In primary and secondary education as well in universities, textbooks and educational material on water and nature follow a disciplinary approach. At the graduate level, although many university curricula adopt a multidisciplinary approach, they are far from integrating social issues to nature. For example, socio-ecology and eco-hydrology are still far from adopting a transdisciplinary approach between nature and man.

From a technocratic WRM to the systemic IWRM

The time evolution of the water–man relationship can be analysed during the last few decades as three distinct areas: (1) the type of global socio-economic development; (2) the structure of the WRM scientific paradigm; and (3) the WRM policy rules. These are summarized in Table 1.

During the first and second Industrial Revolutions, technical/engineering/industrial developments dominated the WRM paradigm. In these two periods, milestones were James Watt's first steam engine (1760) and the construction of the pharaonic Hoover Dam in Nevada/Arizona in the United States (1935). This gravity-concrete arch dam in

Table 1. Timeline for the milestones, global development and models of water resources management (WRM) policy.

Period	Milestone	Global development	WRM scientific paradigm	WRM policy model
1750–1870: first Industrial Revolution	1760: James Watt's steam engine	Industrial/ technological	Traditional/ empirical	Customary/local/ domestic law
1870–1970: second Industrial Revolution	1935: Hoover Dam, USA	Industrial/ technological	Hydraulic/ hydrological engineering	Management of technical infrastructure
1970–90	1972: Stockholm Declaration	Environmental/ ecological	Eco-technical	Environmental impact assessment (EIA)
1990–2000	1992: Dublin/Rio Statements	Economically sustainable	Economically efficient	Water cost recovery
2000–present	2000: World Water Forum, The Hague	Sustainable	Holistic-integrated, IWRM	European Union's (EU) Water Framework Directive (WFD)–World Economic Forum (WEF) nexus

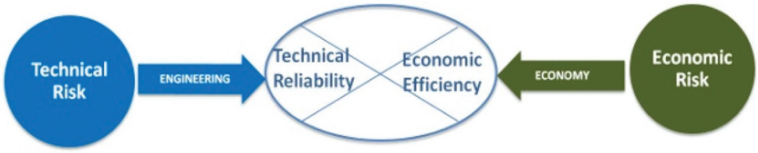
the Black Canyon of the Colorado River had used enough concrete to pave a two-lane highway from San Francisco to New York. It can be considered the symbol of the achievements of hydraulic engineering and the domination of nature by technology.

The dam has created Lake Mead, the biggest water reservoir in the United States and a vital source of development for the Southwestern States, such as California, Arizona and Nevada. In the past, based on the euphoria of technical success and some years of high flow in the Colorado River, the lake's water was over-allocated to boost various socio-economic activities in arid areas. The city of Las Vegas was grown in the desert of Nevada and agricultural and industrial activities have been developed in Arizona with abundant water supply from Lake Mead. The Hoover Dam has been designed to last more than a millennium. Today, less than a century after its construction, the Colorado River Basin faces an unprecedented crisis. The persisting drought was initiated in the year 2000, and by August 2021 Lake Mead has been reduced to 35% of its capacity. The water retention in large reservoirs inside the basin has facilitated its overuse in agriculture and other social activities provoking ecological devastation of the river's delta in Mexico and negative impacts on indigenous communities (Rivera-Torres et al., 2021). Adaptation and mitigation solutions are possible, but the lesson learned is that big-scale technical infrastructure creates a feeling of abundance, water being allocated beyond the quantity a river can deliver, creating severe ecological damage.

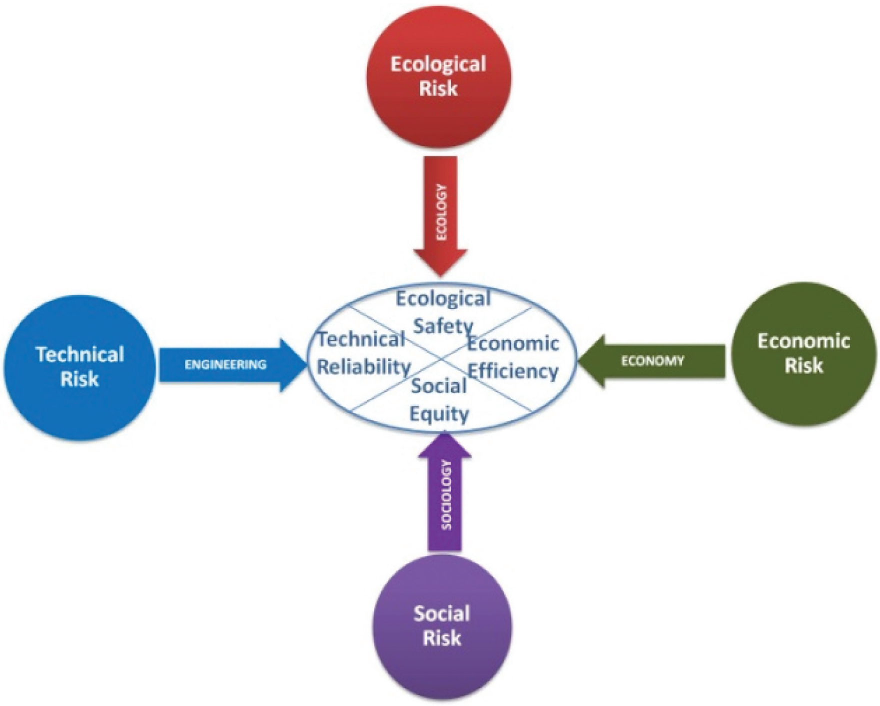
As shown in Table 1, environmental and ecological sensitivities started evolving with the 1972 United Nations (UN) Stockholm Declaration on Human and Natural Environment. Furthermore, the 1992 UN Dublin Declaration and in the same year the UN Rio Statement underlined the need for an economically efficient WRM and the obligation to recover the water management costs. The Rio statement, in combination with that of the 2000 World Water Forum, has confirmed the need for a sustainable WRM model (Ganoulis, 2001; Loucks, 2000). This model became the integrated WRM (IWRM) paradigm that follows a systems approach (GWP, 2000, 2004). IWRM has been adopted in the year 2000 by the European Union (EU) as a regulatory framework and has served as an efficient model of water policy in many countries around the world (EU WFD, 2000).

In the late 20th century, the concept of technical risk has been initiated with the development of nuclear power plants in Europe, USSR and USA. At that period, the Chernobyl disaster was served as a demonstration of catastrophic risk. The scientific methodology of 'risk analysis' emerged, aiming to evaluate risk in terms of probabilities and fuzzy numbers (Dubois & Prade, 1980; Ganoulis, 1991, 1994). As shown in Figure 4, a risk-based multicriteria analysis has been developed by Ganoulis (2001) and Ganoulis and Levner (2008) for the case of IWRM in national river basins and internationally shared river catchments. Technical, economic, ecological and social reliability has been taken into account (Figure 4a, b).

Twenty years later, the implementation of the IWRM policy in practice has given mixed results. As shown in this paper, to obtain effective water governance under climate change and to combat severe environmental impacts in the Anthropocene, there is a need for its radical revision.



(a): Technico-Economic Risk (1870-1970)



(b): Integrated Technical, Economic, Social and Ecological Risk (1970-2000)

Figure 4. Timeline evolution of risk-based water resources management (WRM) policy models.

The water–energy–food nexus (WEFN) paradigm

Nexus means a strong connection and its use to water–energy–food designates the strong relationship between these three resources. The WEFN was first coined in the 1990s as a topic of many UN-founded programmes. During the 2011 Berlin Conference, WEFN was recognized as an important issue of integrated WRM and sustainable development (Hoff, 2011). The WEFN can be considered an alternative to IWRM by designating water, energy and food as the most important resources to be managed systemically. This scientific paradigm was criticized by the Food and Agriculture Organization (FAO), arguing that to obtain sustainability next to three nexus elements one should add many others equally important, such as environment protection, land use, economic issues and climate change (FAO, 2014).

As shown by Ganoulis (2020, 2021), the WEFN model has three main shortcomings: (1) no definition is given on how to link the three elements of water, energy and food; (2) from a scientific point of view, we do not know how to model and predict the nexus; and (3) no guidance is provided for building multidisciplinary institutions for a nexus-based WRM and governance.

IWRM implementation: a need for a radical revision

The main idea of IWRM originated in the 1960s in France and it has influenced the EU's Water Framework Directive (WFD) (EU WFD, 2000). The French Water Law published on 16 December 1964 included a decentralized institution called a hydrographic basin committee responsible for developing water management plans at the river basin scale.

In 2000, the EU WFD was published in the *Official Journal* of the European Communities and became compulsory for all EU member states. The EU WFD is based on the IWRM scientific paradigm and is considered today as the most advanced water policy tool. The IWRM has been promoted by the World Bank and associated global institutions, such as the World Water Council (WWC) and the Global Water Partnership (GWP). Twenty years later, its application by the EU member states and some countries in Africa and Asia has failed to produce the expected results. The main ambitious goal of the EU WFD was to achieve by 2015 the *good status* (chemical, ecological and quantitative) of all surface and groundwater bodies in Europe, 'good' being defined as the state of the water body in the absence of anthropogenic pressures.

In 2019, the European Commission initiated the so-called Fitness Check of the EU WFD, aiming to assess whether the Directive is fit for purpose. Based on the results of river basin management plans (RBMPs) prepared by EU member states, the evaluation report was published in December 2019 (EU WFD Fitness Check, 2019). The main conclusion of this assessment was that the Directive, 20 years after its implementation, has produced mixed results and failed to achieve its main objective. In Europe today, only 40% of surface waters are in a good ecological state, mainly due to industrial and agricultural pressures. In Greece, where agricultural activities are dominant, 80% of its lakes and 30% of its rivers are below a good ecological state. Different reasons for this unfortunate situation are cited in the report, such as lack of sufficient financing, delays of the Directive's implementation by member states and non-integration of other sectoral policies, such as agriculture. In our opinion, the failure to achieve the Directive's objectives is principally due to its anthropocentric formulation and less to implementation problems that are described in the assessment report.

The core element of the EU WFD is the assessment of the environmental status of surface and groundwater bodies. The methodology is known as DPSIR, which means the evaluation of drivers, pressures, state, impacts and responses (WFD CIS, 2003a). *Driving forces* are mainly anthropogenic economic activities. They produce environmental *pressures*, such as nitrates, pesticides, heavy metals and wastewater. By monitoring pollutant concentrations, the next step is to assess the *state* (chemical and ecological) of water bodies and evaluate the *impacts* on ecosystems and public health. Finally, *responses* are formulated in a *programme of measures* (PMs) aiming to remediate the environmental state. The DPSIR process is repeated every six years until the 'good state' of water bodies is achieved.

Next to the technical DPSIR methodology generating the RBMPs, the EU WFD incorporates issues of environmental economics (WFD CIS, 2003b) and public participation (WFD CIS, 2003c). Ultimately, it results in a policy framework with the following critical characteristics:

- The basic problem formulation is *anthropocentric* and *technical*. The planning process is similar to a medical approach consisting first of the diagnosis of a health problem and then of a prescriptive therapy. In this process, man is positioned as an external observer of environmental water bodies. After analysing different human economic activities (driving forces), he first assesses the possible environmental impacts (diagnostic analysis). Then, based on scientific knowledge and technological tools, he *assumes being able to control and command the environment by applying the PMs* (therapeutic regime).
- The modification of water bodies by anthropogenic drivers (e.g., agriculture, industry, mining, transportation, energy production and tourism) may be quantitative (e.g., groundwater over-pumping), qualitative (e.g., eutrophication and chemical pollution) and ecological (loss of biodiversity). The main assumption is that these *modifications are reversible*: if driving forces produce negative impacts, in the opposite sense, a set of measures (PMs) can reverse the process and improve the state of water bodies (mechanistic approach).
- *Environmental water reversibility* may be considered synonymous with *water resilience*, defining resilience as the capacity of the water body to return to safe conditions by controlling the external pressure (WFD CIS, 2003a, fig. 2.3). If environmental water resilience is sufficient to recover pressures on water quantity and the physical properties of the water bodies, it is questionable and limited regarding complex physicochemical processes and ecosystem interactions in the *biosphere*. This is a relatively thin atmospheric layer of about 20 km height around the Earth and 500 m below the ocean's surface. All forms of life and different human civilizations on Earth have been developed in this layer for approximately 3.5 billion years, with complex interactions between living organisms, human activities and the broader natural environment (water, air, soil). In the recent Anthropocene, human activities have globally dominated the biosphere, producing climate change, loss of biodiversity and reducing environmental water resilience (Folke et al., 2021; Nyström et al., 2019). As a result of these huge human pressures, signs are visible that the process of the '6th great extinction of species', so-called *Anthropocene massive biodiversity loss*, has already started (David, 2021).
- In the DPSIR scheme, *social activities are not included* inside the system but are considered either as boundary conditions (drivers) or as part of the PMs (social measures). As a result, environmental impacts are considered *externalities* to human society or, if we use the military terminology, as 'collateral damage'. Externalities are often underestimated because it is difficult to evaluate the real monetary value of the natural capital (Figure 5a).

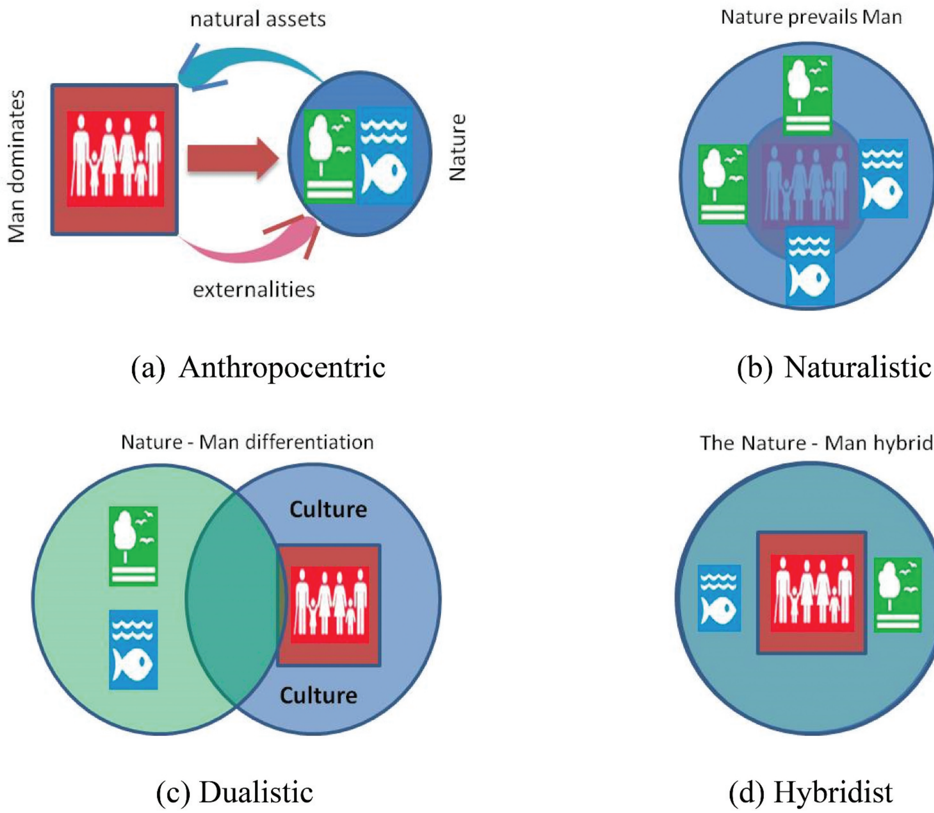


Figure 5. Alternative nrelational models for .

- The Directive is based on the IWRM framework that follows a water-centric approach for *integrating different water-connected sectors*, such as agriculture and industry. However, although the hydrocentric principle is correct, there is *no guidance on how to coordinate existing silos institutions for implementing a cross-sectoral water policy* or how to create new ones for ensuring an integrating task.
- *Joint planning of transboundary water resources* shared between different countries is not compulsory in the Directive. Between EU member states and also in river catchments shared with non-member states, common planning of transboundary resources is only encouraged and is effective only in basins with strong international river authorities (e.g., the Danube, the Rhine).
- The planning process starts by assessing the existing situation of driving forces, without a prior analysis for resolving existing social conflicts and reducing environmental pressures at the source. This *approach is more reactive than proactive.*
- Natural laws that may reduce anthropogenic pressures by self-absorption, that is, nature's self-assimilation carrying capacity to sustain external pressures are not taken directly into account.

From the reasons above, we may conclude that a radical change of the IWRM policy is urgently needed. This is supported by the mixed results obtained after 20 years of implementation of the EU WFD and the degradation around the globe of aquatic ecosystems in the Anthropocene.

The nature–man relational models of WRM

To develop a sustainable scientific paradigm of WRM and policy framework, the basic issue is in the definition of an efficient conceptual relationship between nature/water and man. Based on all possible combinations between the two, we can derive four alternative nature–man relational models (Figure 5): (1) man dominating nature (anthropocentric); (2) nature prevailing man (naturalistic); (3) nature–man differentiation (dualistic); and (4) nature–man coexistence (hybridist).

(1) *Man dominating nature or the anthropocentric* WRM model (Figure 5a). It has been historically formulated by the IWRM paradigm and, as described above, it has provided support to the EU WFD policy model. Although IWRM has produced many positive results in the Global North, it is still part of the water-related environmental crises humanity experiences today.

In the *anthropocentric model*, sometimes known as *productivism*, nature serves human society by providing *natural assets*, such as water, air, food and fossil energy. Hopefully, this *natural capital* is not only stocked on the planet but is also regenerated in the biosphere by complex natural and biochemical processes and ecosystem services. For example, freshwater resources are recycled through the hydrological cycle and forests are naturally regenerated. Man uses the *natural capital* to produce income from goods and services, such as water supply and sanitation, housing, transportation and infrastructure. This is the *produced capital* that man can develop through *human capital*, which consists of tools related to education, labour and technological innovation. By increasing his capital, man returns to nature, what economists call *externalities* (Figure 5a). These are different forms of water pollution, solid waste and land use (i.e., deforestation, agricultural activity, urbanization). In economic terms, the total economic progress made is monitored by global domestic product (GDP) per capita. In recent times, humanity has faced the so-called 'impact inequality', that is, the fact that human activities, linked to exponential population increase, have generated a demand for natural assets that exceeds the biosphere's regeneration potential. Data show that since 1992, although average GDP has increased by 200%, the natural capital per person has been reduced by 40% (Dasgupta, 2021). Our ecological footprint continues to exceed nature's regeneration potential: while in 1961 humanity needed 0.7 of our planet, in 2008, 1.5 planets were necessary to satisfy humanity (WWF, 2008). Concerning the overuse of natural water resources, the situation is locally visible, when groundwater overdraft exceeds not only the renewable groundwater resources but also drains part of surface water and groundwater stocks. As a result, groundwater levels are steadily declining, the flow of streams is reduced and aquifers are depleted.

(2) *Naturalistic model* (Figure 5b). This is based on the assumption that nature prevails to man and human policy should follow natural laws. Some philosophers claimed that man should learn from nature, and natural laws should guide the development of human civilization. For example, in the 1700s, the political philosopher Jean Jacques Rousseau,

born in Geneva, believed that man should enjoy living close to nature. He argued that society corrupts the inherent good of human behaviour and nature should be the master of informal education. Subordinating men's civilization to natural laws is a regression and a danger reducing the technological progress of human societies.

(3) *Dualistic model* (Figure 5c). This paradigm emphasizes the fact that man has different characteristics from nature. Nature anthropologists, such as Claude Lévi-Strauss, underlined the fact that humans are the same everywhere on Earth and that the role of culture, including technologies and production structures, differentiates man from nature. This dualistic model assumes that culture means human society and minimizes the profound relationship between man and nature.

(4) *Hybridist model* (Figure 5d). The terms 'hybrid' and 'hybridization' are well known from progress made in natural and zoological sciences producing new plants and animals by genetic manipulation. For example, the famous sheep 'Dolly' is reported as the first cloned mammal. Hybrids are also the genetically modified crops (GMO) commercially available in the United States.

Apart from specific animals and plants, hybridization can also produce hybrid conceptual entities without discrete boundaries. To describe man's relation to nature, some social scientists and human geographers have suggested *hydro-sociology* as a new hybrid entity. Intending to add the socio-political discourse to the technical/hydrological narrative of WRM, social scientists described the *hydro-social hybrid*. Although in the hydro-social model they recognize dialectical conflicts between social actors, the unification of hydrological and socio-political processes dissipates the original characteristics of nature and man.

According to the hybridist model, hybridization of nature and man may generate two new entities:

- *Hydro-social territories* are geographical areas where hydrological and social processes are combined (Cornut & Swyngedouw, 2000).
- *The hydro-social cycle* is a hybridist combination of the hydrological cycle and sociological processes. Because water and society are dialectically unified in this new entity, it is not clear how they can interact continuously in space and time (Linton & Budds, 2014).

The eristic–dialectical model of WRM

Dialectics comes from the Greek *dialogos*, *dia* meaning 'between' and *logos* being the 'argument'. Exchanging arguments in a dialogue is the first meaning of dialectics. *Eristic* from the Greek *eris* means 'to fight'. A WRM model we suggest to improve the IWRM is one based on a conflicting dialectical discourse. To clarify the new model, we may distinguish three main categories of dialectics: (1) a methodology for learning, (2) a logical structure and (3) a model of the nature–man relationship.

- *Socratic–Platonic dialectics a method for active thinking and learning*. It was initiated by Socrates, the father of Greek and Western philosophy, and reported by his pupil Plato in his famous 'dialogues' (Plato, n.d.). Socratic dialectics is also called 'maieutic', a term meaning 'giving birth' in Greek. In fact, in Socratic dialectics, the dialogue starts with a general question that is a false statement or forms a paradox. Socrates then poses questions as if ignorant, and by exchanging logical arguments the discussion ends by revealing the 'truth'. The maieutic method became popular in schools of law. In front of large audiences, two groups of students are asked by professors to provide arguments to support their case. The discussion starts with a controversial argument and reaches an agreeable logical conclusion by exchanging arguments.

- *Aristotelian dialectics*. Aristotle, who was a student in Plato's Academy of Athens in the mid-fourth century BCE, incorporated his formal logic in dialectic argumentation. He applied formal logic to explain paradoxes and resolve controversial statements. According to Aristotle, between two contradictory narratives, only one is logically correct. For example, nature cannot be united and simultaneously separated from man: if not, it is against the principle of the 'excluded third' or *principium of tertii exclusi-tertium no datur* in Latin. Aristotle wrote that the first to introduce dialectics was Zenon of Elea, a pre-Socratic Greek philosopher of the Eleatic School in Magna Grecia (Southern Italy), who became famous for his paradoxes. However, a few decades before Zenon, it was Heraclitus of Ephesus who wrote a book on the dialectics of nature.
- *Heraclitus dialectics*. Hegel, the German philosopher at the beginning of the 19th century, made Heraclitus known as the first to invent the *dialectics of nature*. Hegel said that 'there is no proposition of Heraclitus which I have not adopted in my logic'. From the unique book Heraclitus wrote, only some fragments have survived together with many references to his dialectic philosophy from other ancient writers (Diels, 1906). In Heraclitus' dialectics, nature and man are at the same time united and separated, cooperative and antagonistic.

In the EDWRM model, we follow the Heraclitan dialectics. It puts at the centre of human activities 'eris' that in Greek *έρις* is the *conflict*. Heraclitus wrote in fragment 8: 'πάντα κατ' ἔριν': all by conflict come out and '… ἐκ των διαφερόντων καλλίστην ἁρμονίαν …': from the opposites stems the best harmony. In the EDWRM model, water and man keep their identity and conflicting characteristics that vary in space and time (eristic). The symbiotic coexistence is achieved by a creative unification of the conflicting opposites (dialectics). This management process of starting with conflicts (being) to reach the harmony of the opposites (becoming) increases the human and natural water resilience towards sustainable hydro-governance.

The structure of the eristic–dialectical relationship between man and water is shown in Figure 6. Nature, through its fundamental laws of the hydrological cycle and renewable energy production, supplies man with recyclable water resources and renewable energy. She also offers ecosystem services through her biological renewable capacity and assimilates human wastewater and water pollution up to a certain amount. At the same time, nature remains adversarial to man as it is the origin of natural water-related disasters, such as floods, droughts, hurricanes and tsunamis.

From man's side, human activities impose on nature environmental pressures, including wastewater, water pollution and loss of biodiversity. At the same time, man by education and technical innovation uses science and technology as well as renewable

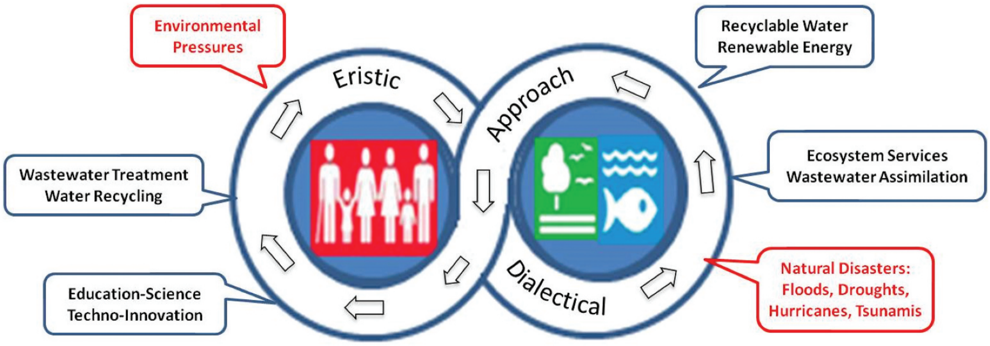


Figure 6. Eristic–dialectical water–man relationship.

natural resources of water and energy to conserve water, produce and stock new forms of energy (such as hydrogen, nuclear fission and fusion), and rehabilitate environmental damages. The use of different fossil energy sources that nature was created is not sustainable because of the release of greenhouse gases into the atmosphere.

The coexistence of man and water is achieved if humans *respect natural laws without giving up their needs*. When the attunement of contraries is achieved, it is not a compromise or a zero-sum competitive game, but the realization of man and water harmonious symbiosis.

Although the EDWRM model differs conceptually from the anthropocentric IWRM, it keeps steps from the IWRM and subsequently from the EU WFD that have been proven successful in real applications. To demonstrate the similarities and differences between the two approaches, a step-by-step comparison is given between the implementations of both the EU WFD and EDWRM model (Figure 7):

- Step 1: *River basin authorities* (RBAs). The EU WFD recommends WRM plans be established at the river basin scale. It starts by legally establishing the RBAs responsible for collecting data, assessing the existing natural end ecological status of the water bodies, and developing the RBMPs. In the EDWRM model, RBAs have different duties and priorities during the management process. Collected hydrological data remain important for understanding the physical problem. Furthermore, in the new approach, strong *consultation with stakeholders* is a priority for discovering social issues and their conflictual interaction with water resources.
- Step 2: *Joint action plan* (JAP). As shown in Figure 7, in the EDWRM approach the DPSIR pressure–response process that is the main component of the EU WFD is replaced by the *stakeholder consultation for setting up a JAP*. The aim of the JAP is to establish a participatory monitoring programme of hydrological and socio-economic data, analyse existing conflicts, implement dialectical solutions of conflict resolution, and register the progress made. In the JAP, not only are the anthropogenic pressures on water resources considered, but also, in the opposite direction,

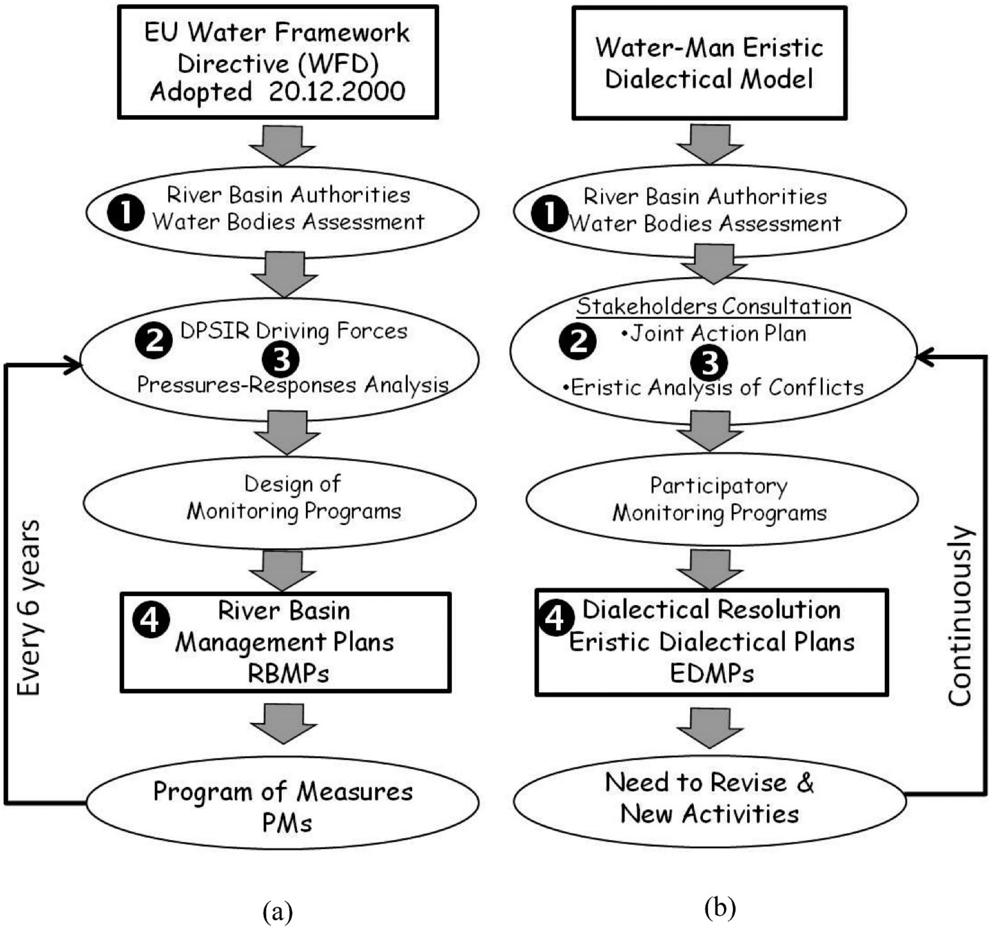


Figure 7. Steps for implementing the European Union's (EU) Water Framework Directive (WFD) (a) and the eristic–dialectical water resources management (EDWRM) model (b).

the natural assets as improved by technological tools for resolving the conflicts. The new man–water integrated approach eliminates the externalities by taking into account *nature's feedback* together with man's technological solutions.

- Step 3: *Conflict eristical analysis* (CEA). In the CEA process, conflicts are classified into two kinds: (1) conflicts between humans and nature (*anthropo-natural*); and (2) social, economic or political between stakeholders (*anthropo-socio-economic*). In the EDWRM model, anthropo-natural conflicts are recognized when man violates natural laws. For example, when human settlements are set up on a flood plain with a high risk of flooding or when water allocation exceeds the recyclable water resources. Different economic, social or political interests between groups of stakeholders or individual social actors are at the origin of anthropo-socio-economic conflicts. These can be also related to natural water/environmental and ecological issues. In the EDWRM approach, conflicts and social fights involving socio-economic competition and antagonism are not considered negative but as a source for achieving sustainable solutions.

- Step 4: *Dialectical conflict resolution* (DCA). This is the most crucial and more difficult part of the new model. It is based on a critical reflection and profound knowledge of natural laws for realizing the *unity of the opposites*. There is no general rule for achieving the harmonious coexistence of contradictory issues because, in every particular situation, conflicts are different and refer to various natural laws. To understand the process, Heraclitus had suggested two simple examples: (1) a bow is functional when the attunement between two opposite forces is obtained: the pressure on the bow and the tension on its resistant string; and (2) in a lyre, the ancient musical instrument Greeks used for the recitation of lyric poetry, the best performance is achieved when at every string opposite tensions are tuned.

To move from the conceptual EDWRM model to real applications, consider the simplified example of building a new dam on a river. The conflict between man and nature originates from the fact that for hydro-energy production man modifies the river flow and blocks the fish migration upstream and downstream from the dam. A sustainable solution could be achieved by harmonizing this conflict as follows: in the design of the dam, flow ladders are provided to allow fish migration. Passes for fisheries such as salmon have already been constructed in Europe and the United States. For the eristic–dialectical approach, this is not a compromise between different technical solutions, but a design based on two opposites (damming and not damming the river). The harmonious solution incorporates the river hydraulics to fish migration in a single technical structure.

The EDWRM model's structure can be summarized as follows:

- Man and water are separated (eristic conflicts) and united (dialectic cooperation).
- Stakeholder activities are embedded into the model and conflicts originate solutions.
- Nature offers to man assets of recyclable water, energy and ecosystem services.
- Man uses science and technical innovation to regenerate nature's assets.
- Externalities are included in the unified man–water system and can be compensated by nature's feedback and man's innovative technical solutions.
- Man–water harmonious coexistence is achieved by respecting natural laws (e.g., the hydrological cycle) and satisfying human needs for water security and quality of life.

Examples of application

To illustrate in practice the EDWRM approach, two case studies from our personal experience are reported.

A case study of flood control *(Ganoulis, 2003)*

This refers to flood protection of the city of Heraklion on the Greek island of Crete. The Giofyros River flows through Heraklion, Crete's capital city, and is one of the most important rivers on the island (Figure 8a).

The Giofyros River catchment is relatively small at about 200 km^2, with mean annual precipitation of 800 mm and an average flow rate of 30 m^3/s. The area is heavily cultivated and covered by vineyards and olive trees. The climate of the region is Mediterranean, and although extreme precipitation is of low frequency, it is at the origin

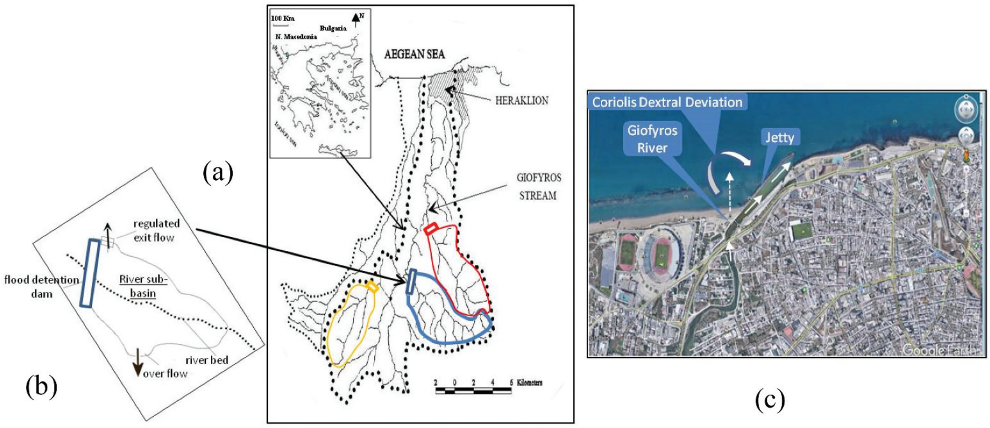


Figure 8. The Giofyros River Basin (a), a flood detention dam (b) and the Coriolis-based dextral diversion of the mouth of the Giofyros River (c).

of catastrophic flash floods. The city has been rapidly expanded around the river without integrated urban planning and provision for mitigating flooding risks. In the past, losses of private property and even human life have been registered as a consequence of floods, such as the flood of January 1994. At that time, after several days of low precipitation and saturation of soils, an extreme storm produced a devastating flood. Many houses in the coastal area near the mouth of the river were flooded, and damage to private and public property, including the city's wastewater treatment plant, was evaluated at some millions of euros.

The expert team of Aristotle University of Thessaloniki was designated by the city's authorities to suggest measures of flood control. Many decades after the implementation of these measures, the area has remained safe from floods that have been recorded with negative impacts in other parts of the Island. The flood management process has followed the steps provided by the EDWRM model shown in Figure 7b.

- *Developing a JAP (step 1)*. This has been established in cooperation with the regional agency for Eastern Crete development (OANAK). In parallel, a close collaboration with local authorities and stakeholders has enabled us to define the flood problem and its origin.
- *Eristic analysis of conflicts (step 2)*. Possible conflicts between natural laws and human activities have been analysed. The main conflict comes from the city's expansion into the river's flood plain. The radical solution of removing the population from the Giofyros River basin was of course not satisfactory for the population. Two main natural laws have been identified to be violated during a flood: (1) the *hydraulic law*: the water overflows the riverbanks when the flood's flow rate (e.g., 300 m^3/s for $T = 20$ years) exceeds the flow capacity of the riverbed (Ganoulis, 2003); and (2) The *Coriolis phenomenon* in the Northern Hemisphere. Due to the Earth's rotation and negligible tidal forces, the outflow of Mediterranean rivers shows a

dextral deflexion (Li et al., 2011). As shown in Figure 8c, by a dextral diversion of the Giofyros mouth, Coriolis inertial forces can facilitate the transportation of sediments from the river's mouth and floodwaters are easily evacuated into the sea.

- *Dialectical resolution (step 3)*. (1) To resolve the hydraulic conflict, that is, a flood exceeding the river's flow capacity, alternative solutions are described by Ganoulis (2003). A dialectical solution in harmony with hydraulic law consists of building a few shallow flood *detention* dams across the Giofyros basin (Figure 8b). In contrast to flood *retention* reservoirs, a *flood detention reservoir* is complemented by an outlet pipe up to a certain altitude. During the flood, the peak of the floodwater is accumulated into the detention reservoir and the remaining floodwater is safely evacuated into the river. (2) To maintain the Coriolis effect for solid transportation, an earthen jetty has been constructed into the sea to protect the dextral deviation of the river's mouth (Figure 8c).

Towards a resilient Mediterranean agriculture *(Ganoulis, 2021)*

This second application refers to the hydrological cycle as the basic natural law for generating and preserving recyclable water resources on Earth. The case study aimed to formulate a policy document for promoting resilient Mediterranean agriculture under climate change.

Water scarcity in the region is related to the climatic crisis. Preserving food production and farmers' revenue is actually under threat. Over-pumping of groundwater for irrigation has resulted in the depletion of many aquifers and the salinization of coastal groundwater from seawater intrusion. After having reviewed the weakness of the IWRM model and the WFEN to ensure sustainable agriculture, the main conflict was identified in the farmers' practice of overusing water by violating the hydrological cycle.

Agriculture in arid and semi-arid areas such as the Mediterranean, California and many parts of Australia is the main consumer of water from rivers, lakes and mainly from aquifers. Irrigation uses up to 59% of total water consumption in Europe, 65% in the Mediterranean and about 86% during the irrigation period in the Middle East and North Africa (MENA) countries.

Food production depends not only on irrigation water but also on energy consumption. The three sectors 'water', 'energy' and 'food' are intimately related, and should be taken into account in coordination. In reality, if there is no prioritization between the three WEF components, in any particular application there are winners and losers between the components. If food production is maximized, food becomes the winner and surface and groundwater resources, as well as energy consumption, are the losers (Ganoulis, 2021). Farmers everywhere in the Mediterranean also prioritize food production, which makes the WEFN process unsustainable. As a consequence, extended water scarcity under climate change continues to retrograde environmental security and jeopardize the subsistence of humans and terrestrial ecosystems.

Following the EDWRM model of conflict resolution, a resilient strategy consists of establishing a multi-year water balance in the watershed and maximizing food production by using only sustainable surface and groundwater resources. A potential loss of farmers' revenue can be compensated for by using renewable energy at a lower cost (Ganoulis, 2021).

In conclusion, the new EDWRM paradigm asks for a radical change in our perception of how humans interact with nature. From the historical review, such a conceptual change of the IWRM model may take a few decades to be implemented in practice. This underlines the importance of the IWRA's contribution to research, education, and capacity-building of scientists and water professionals and to disseminate critical dialectical thinking.

Conclusions

Many global indicators and increasing natural disasters around the globe are warnings of our planet's unprecedented environmental threats of anthropogenic origin, such as climate change, deforestation, water scarcity and rapid loss of biodiversity. The environmental and ecological state of natural water resources is the common denominator of these threats. In this paper, its reflection aims to provide an answer to a fundamental question: To face these challenges, what kind of change should we apply to the current WRM paradigm?

This paper's historical revision of the relationship between nature and man shows that it is constantly changing between conflict and cooperation. From the appearance of modern man on Earth about 10 million years ago, the nature–man relationship has changed from friendly in indigenous people and old societies to antagonistic in ancient civilizations. After Industrial Revolution in the West in the 18th century, the domination of nature by man was considered an achievement of progress made in science and technology. Our historical review of global WRM models shows that although the global initiatives of UN institutions and NGOs called for sustainability, today's water resources models for IWRM and WFEN remain anthropocentric. They both have had difficulties producing sustainable results.

Analysing, apart from the anthropocentric, all alternative relational models between nature and man, such as the naturalistic, dualistic and hybridist, we show that the EDWRM paradigm can improve water resilience, leading to sustainable hydro-governance. The EDWRM model is based on the observation that man and nature are at the same time antagonistic (eristic approach) and cooperative (dialectical relation). Sustainable solutions are investigated by analysing water-related conflicts (eristic analysis) and can be implemented by unifying the opposites (dialectical synthesis), which means respecting natural laws and human needs as well.

The steps to be followed in the EDWRM model are described analytically in comparison with the IWRM approach (Figure 7) and two case studies illustrate its application in practice. As the new model needs a radical change of the human attitude to nature, the role of IWRA in education, technical training, and critical thinking of water professionals and other water stakeholders is of paramount importance.

Disclosure statement

No potential conflict of interest was reported by the author.

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