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Resilient Mediterranean Agriculture in the context of Water Scarcity under Climate Change

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1. Summary

Water resources are essential for sustaining human life and preserving the ecosystem's biodiversity. They also constitute the main "raw material" for economic activities like agriculture, tourism, energy production and industry. Particularly in the Mediterranean area, many different factors have greatly reduced the resilience of surface and groundwater resources, defining water resilience as the capacity of the hydrosphere to absorb and reduce external pressures. Some of these factors include the demographic increase in coastal zones, human concentration in urban areas, intensification of economic sectors like agriculture, tourism, transportation, oil and gas extraction and the effect of climate change. More recently, the shock of the COVID-19 pandemic has greatly impacted many economic activities in the Middle East and North Africa (MENA) region, including the South Med countries and created social problems by the disruption of the supply and demand chains.

Agriculture is one of the main water consumers in the Mediterranean, abstracting in the MENA region countries on the average 86% of total water withdrawals [2]. Agricultural over-pumping has depleted many aquifers, groundwater is polluted from agricultural nitrates and pesticides and sea-intrusion in coastal areas and small islands has increased groundwater salinization.

This policy brief summarizes the current situation of Mediterranean agriculture based on available data in the literature and research programs at the UNESCO Chair/INWEB, Aristotle University of Thessaloniki, Greece [7]. After reviewing sustainable water management methodologies, practical recommendations are suggested to policymakers especially in the MENA countries for resilient agriculture in the context of water scarcity under climate change.

2. Introduction

Agriculture has been historically one of the main economic activities in the Mediterranean countries which is producing food for the population needs and also contributing to the GDP as an important source of revenue. Agriculture has an intimate connexion with environmental issues and can have both negative and positive effects. The negative impacts can be serious, as agriculture is considered the main sector responsible for polluting water and soil with nitrates, pesticides and fertilizers. The positive impact can include trapping greenhouse gases within crops and soils or mitigating flood risks through the adoption of certain farming practices.

More recently, the shock of the COVID-19 pandemic has greatly impacted many economic activities in the Middle East and North Africa (MENA) region, including the South Med countries and created social problems by the disruption of the supply and demand chains. More specific impacts in food supply and how to alleviate negative impacts in agriculture in times of COVID-19 [1].

Agriculture in South and East Med countries is also accused of being the main consumer of irrigation water from rivers, lakes, and aquifers. Although irrigation water quantities are subject to yearly fluctuations and are subject to huge seasonal and spatial variability due to climatic and local soil conditions, *the agricultural sector remains globally the main pressure to water resources* and to global water scarcity that is one of the main challenges humanity faces today [3].

Agriculture uses up to 59% of total water consumption in Europe, 65% in the entire Mediterranean area (Euro-Med, South and East Med countries), and about 86% during the irrigation period between April and August in the MENA countries [4]. Statistical data are misleading when local variability is hidden by regional aggregation and when mean regional values don't show the severity of local conditions. As an example, statistical data over the last 15 years indicate that over-abstraction of water in Europe affects only 10% of rivers and 20% of aquifers [4]. However, in North and East Mediterranean countries and regions, like the Middle East (Syria, Jordan and Gaza), Guadiana (Spain and Portugal), Segura (Spain), and Thessaly region in central-eastern Greece, water scarcity during summer has taken dramatic dimensions. For example, Thessaly is a fertile sedimentary plain in Greece, drained by the river Pinios and having extensive groundwater resources. However, multi-year over-drafting of groundwater for irrigation has depleted regional aquifers and over-pumping of surface water in summer for several days makes disappear the Pinios River [10].

Water scarcity is predicted to further increase in the years to come because of climate change. Over-heating of the atmosphere from a constant increase of anthropogenic green-house gaseous emissions, mainly of CO_2, has already produced around the globe an increase of the mean atmospheric temperature by $1^{O}C$ above that of pre-industrial time. *In the Mediterranean region, the actual temperature rise is 0.4 ^{O}C higher, which means 1.4 ^{O}C above the pre-industrial time* [5]. Higher atmospheric temperature produces more evaporation and modification of precipitation patterns over the Mediterranean. *Climate models predict at least 15-20% less rainfall in the Mediterranean* by the year 2080 and also atmospheric instabilities that produce more frequently catastrophic floods and extensive droughts [5].

In this policy brief existing methodologies for sustainable water management and food production are first reviewed. Then, combining with research findings at UNESCO Chair/INWEB, a founding member of FEMISE [7], practical recommendations are given for resilient agriculture under climate change, especially in South and East Med countries.

2. UN Policy Goals for Sustainability in Agriculture

The definition of *sustainability* goes back to 1992 with the UN Rio declaration that is based on the so-called 1987 Brundtland Report on "Our Common Future". In order to achieve the sustainability goal, *economic development should respect environmental preservation and social equity.*

In 2015 the UN General Assembly in the frame of the "2030 Agenda for Sustainable Development" adopted 17 "Sustainable Development Goals" (SDGs), 169 Targets and 230 Indicators. SDGs with particular emphasis on sustainable agriculture, water preservation and efficient energy use under climate change are the following: SDG2– "No hunger", SDG6– "Clean Water and Sanitation", SDG7– "Affordable and Clean Energy", SDG 13– "Climate Action", SDG 15– "Life on Land", and SDG 17– "Partnerships for the Goals" [6].

SDGs are not guidelines or methodologies on *how to achieve sustainability* in different economic sectors; they are rather sets of measurable indices *for indicating what is needed to be recorded for monitoring progress or regression* in achieving a given goal. Although countries may be assisted by UN institutions and other specialized agencies like UNEP, UNESCO, FAO, UNDP and GEF are active in monitoring the progress made by countries to achieve the goals, processing statistically the data and reporting [6]. However, they don't dispose of *specific methodologies on how to attain sustainability.* Countries should prepare and apply their policy plans for sustainable agriculture, environmental protection, and water management. National plans are not compulsory and most of the time, lack of financial support, poor infrastructure, and low stakeholders' involvement, make the sustainability progress slow and less effective. Instead of searching for sustainability, it is a question *on how to increase resilience in agriculture and environmental protection,* especially against water scarcity and climate change pressures.

In the fields of agriculture, water and rural development substantial efforts to address the current challenges have been recorded in the South-Med region. With technical and financial support from the EU-Med cooperation program, sufficient progress has been made in the region to improve technical infrastructure, save irrigation water and protect the environment [8].

Egypt has developed in 2009 a "Sustainable Agricultural Policy" with the main objectives to increase irrigation resilience, improve food security, decrease food pricing and create new jobs. Tunisia and Jordan are two prominent examples in the South-Med region to undertake structural changes in the agricultural sector. Tunisia, a major exporter of oil olive and Morocco as well have invested in water mobilization by creating numerous dams and water reservoirs for irrigation and flood retention. Lebanon established strategic partnerships with stakeholders based on a participatory approach. Progress made in South and East Med countries has been registered in the SDGs 2020 progress report [9], where Algeria, Tunisia, Morocco, Egypt, Jordan and Lebanon are in the top 100 countries with a score greater than 60% [9]. To maintain a long-term improvement in agriculture and environmental protection, the South-Med countries need an efficient methodology for agricultural water managing and implementing resilient policy measures.

3. Methodologies and Policy Measures

In the fields of agriculture, water management, and energy use, substantial progress has been recorded in the 1990s. Research activities in Universities, regional organizations and research institutions have formulated technical, social, political and economic frameworks and developed methodologies aiming at sustainable policy measures. The following two management paradigms have been implemented and evaluated during the last few decades in Europe and elsewhere:

I. the Integrated Water Resources Management (IWRM), and
II. the Water-Energy-Food Nexus (WEFN)

I. the Integrated Water Resources Management (IWRM) methodology

The IWRM methodology has emerged in Europe as a result of different contributions and conflicts from technical, economic and social points of view. From scientific/technical considerations the main idea was that water management cannot be effective if focuses only to water as a natural resource. Sustainable water management should *adopt an integrated approach* by associating different other natural resources, such as groundwater, soil, forests, vegetation and water-dependent ecosystems. It should also include economic and social issues, such as water tarification and pricing and encapsulate economic activities of different sectors, such as agriculture, tourism, energy, water supply, and industry.

Apart from the scientific component, IWRM has been also influenced in Europe by new emerging stakeholders and private actors, such as big international companies of water supply and sanitation, water environmentalists, institutions, and NGOs very active in protecting water quality from different sources of pollution. A major component of the IWRM methodology refers to the important role of civil society, the inclusion of public and private institutions, and citizens in public participation, consultation and decision-making processes.

In 2000 the IWRM methodology has been adopted by the EU as a policy regulation framework called *the EU-Water Framework Directive (EU-WFD) 2000/60/EC*. According to the European Treaty, European Directives are compulsory and should be included in the national legislation of all EU Member-States. The main components of this Directive are: (1) adopting the river basin as a spatial unit for water management, (2) establishing national monitoring networks of water quantity, quality and ecosystems, (3) developing the River Basin Management Plans (RBMPs) and (4) implementing adequate remedial and regulatory measures.

Twenty years after the first implementation of the EU-WFD, the EU Environmental Commission has launched in 2019 an evaluation process. It is called the "*Fitness Check for purpose of the* Water Framework Directive (*WFD)*" and the Directive's assessment should be done in terms of its effectiveness, coherence, efficiency, relevance and transboundary cooperation. The evaluation results are mixed and some detected drawbacks are (1) *failure to effectively integrate sectoral economic policies, like agriculture*. This is because in the Directive *the notions of "what-to" and "how-to" integrate remain fuzzy* *and not well-defined*, and (2) it focuses mainly on water quality than on water quantity; the issue of water scarcity under climate change that is important for the Mediterranean countries is not a priority. South and East Med countries are aware of the IWRM methodology and its counterpart for planning and regulation that is the EU-WFD framework. However, unless a radical revision of its contents, the IWRM methodology is very difficult to be implemented in practice [11].

II. The Water-Energy-Food Nexus (WEFN)

The WEF Nexus has been presented in the 2011 World Economic Forum in Davos, Switzerland as *one of the most important issues for sustainable development*. The main idea behind this statement is the fact that the three sectors “Water”, “Energy” and “Food” are intimately related and should be taken into account in coordination. These three sectors are very important for sustainable agriculture and we can then consider WEFN as progress for a better definition of the IWRM methodology, i.e. *to know “what” to integrate during the process*. However, a closer analysis of the WEFN can show that it is not exactly the case, for the following reasons [7]:

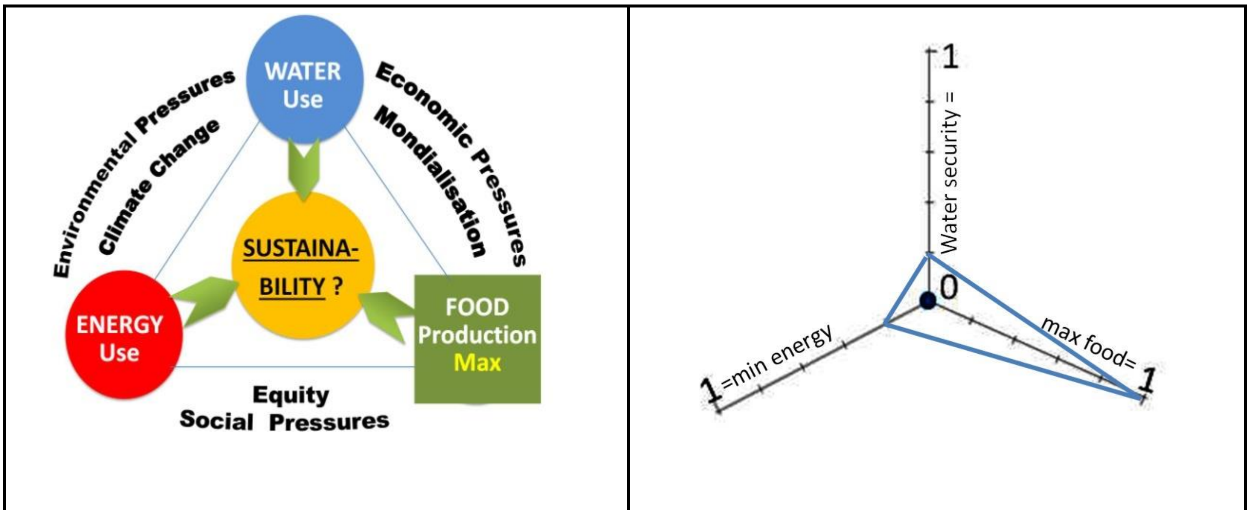
(1) The “nexus” Latin name of WEF indicates a strong relationship between the three sectors in form of a “Gordian knot”, but not provides any explanation of its structure.

(2) From a scientific point of view, we don’t know how to model WEF and make future projections.

(3) For policy and governance, we don’t have adequate institutions and guidelines for managing it.

If WEFN is used for maximizing food, that is most of the time the goal, it is done by over-using water resources and energy. This is usually the situation in the field, as shown schematically in figure 1.

Figure 1. Unsustainable WEFN Policy with Low Water Resilience.



A Non-Sustainable WEF Nexus	A Low Water-Resilient Solution

4. The unique role of water

Experts and professionals from each of the three WEF sectors argue the predominance of their own discipline. For example, agronomists think that because of the needs for food of a growing population, food production comes first. Energy production and distribution are also often considered as the most important between the three economic sectors because of their high price and difficulties to be produced. Water scientists and water professionals replicate that water resources are finite and water is the most important resource to be preserved, as it is the origin of life and cannot be substituted by any other natural resource. Seawater desalination in remote agricultural areas is of high cost and wastewater reuse although very helpful in many cases, cannot produce the needs of huge quantities of irrigation water.

In reality, if there is no prioritisation between the three WEF components, in any particular application there are winners and losers. Maximising the food production, as in the case of Thessaly [10], food becomes the winner, and surface and groundwater resources, as well as energy consumption, are the losers (see Figure 1).

Mediterranean countries have the same priority for food production, which makes the process WEFN unsustainable. As a consequence, extended water scarcity under climate change continues to retrograde the environmental quality and jeopardise the subsistence of humans and terrestrial ecosystems.

5. Towards a Hydro-Centric-Food-Energy Nexus Management (HFENM)

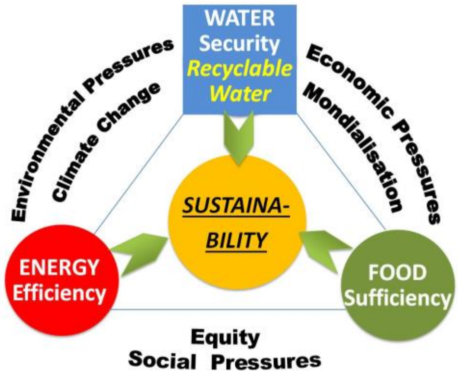
If we formulate the "nexus management problem" in mathematical terms, the "nexus" equation is complex and almost unsolvable, because it has many objectives and no one optimum solution [7]. Mathematically, only one objective can be optimized in terms of a dependent variable, e.g. maximizing food production as a function of energy costs.

The WEF nexus is a multi-objective, multidimensional and, non-stationary problem consisting of three objectives, namely water, energy, and food that are linked together. Every objective is a function of many variables, such as space, time, hydrological conditions, cost, environmental impacts, and the kind of energy (fossil, nuclear, renewable). For any particular case, the aim is to maximize food (agricultural production) and at the same time minimize the amount of water and energy costs. *This is a multi-objective optimization problem that mathematically has no unique optimum solution*. It has a space of multiple possible solutions and the solution we can choose depends on our preference for one of the three WEFN components [7].

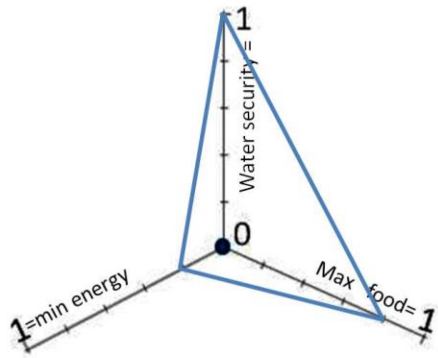
Choosing water preservation as the predominant issue we adopt a "nature-centered" approach, which is a prerequisite to sustainable agriculture. Apart from the unique property of water as being a source of life, water is not only a "*renewable" but also a "recyclable" resource,* through the process of precipitation and evaporation in the hydrological water cycle. Water resources can also be naturally stored in the form of groundwater resources, in contrast to solar power and wind energy that are good renewable resources but without natural storage capabilities [7].

Therefore, the "Hydro-Centric-Food-Energy Nexus Management" (HFENM) paradigm for sustainable agriculture we are proposing, consists of evaluating first the long term renewable and stored water resources potential and then, examine only alternative solutions of food production and energy use that respect water security (Figure 2). This is an added value on-line with the measures that have been already implemented in the South and East Med countries for recycling wastewater and saving irrigation water [2].

Figure 2. Sustainable WEFN Policy with High Water Resilience.



A Sustainable WEF Nexus



A High Water-Resilient Solution

6. Policy Recommendations

The main social actors for water and environmental policy in Med countries are: (1) Pubic governmental institutions at various levels, such as Ministries, Policy Institutions, Regional Administration and Local Water Agencies; (2) Private Water Professionals and Practitioners; (3) Knowledge generators, such as Universities and Research Institutes, and (4) The Civil Society, including Water and Ecological Associations, Environmentalists and NGOs. These social players are in constant evolution between conflicts for defending their interests and cooperation for achieving economic interests. In democratic countries, "good" water governance is the art of an elected government to coordinate these different social parties by distributing among them fair economic and political power. This is important for involving citizens, stakeholders and water users in an efficient water management plan. The EU cooperation can help mainly by providing economic and technical assistance. However, the EU-WFD model of IWRM is complex and very difficult to be exported to South and East Med countries.

From previous considerations, the following policy recommendations could facilitate the application of the HFENM model at the river basin scale and pave the way to sustainable agriculture in South and East Med countries. River basin authorities are responsible to:

(1) Consult and involve the participation of local water stakeholders, farmer unions and agricultural associations for developing a common *multi-year Action Plan for water monitoring and management.*

(2) Establish "*hydrological water balances*" at the river catchment scale to evaluate the multi-year quantity of *renewable water*. The sustainable *annual groundwater yield* is evaluated. Water balance is based on

data collected by river authorities in cooperation with local stakeholders, national hydrological institutions, and private consultants.

(3) Maximize food production by *use of only renewable surface water and sustainable groundwater yield.*

(4) *Adapt plant patterns,* if necessary to fit the renewable water availability.

(5) Maximise the *renewable energy sources* for irrigation, e.g use of solar pumping.

(6) Increase the *efficiency of irrigation systems* (reduce water losses, use pressure pipes reticulation and drip irrigation, when possible)

(7) Use "*Smart Agriculture*": sensors, hardware, computers, software, robotics, GPS, satellites and drones to reduce labor and increase agricultural production.

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FEMISE is a Euromed network established in June 2005 as a non-profit, non-governmental organisation (NGO) following 8 years of operation.

FEMISE is a Mediterranean Think-Tank that gathers more than 100 members of economic research institutes, representing the 37 partners of the Barcelona Process.

Its main objectives are:

- *to contribute to the reinforcement of dialogue on economic and financial issues in the Euro- Mediterranean partnership, within the framework of the European Neighbourhood Policy and the Union for the Mediterranean,*
- *to improve the understanding of priority stakes in the economic and social spheres, and their repercussions on Mediterranean partners in the framework of implementation of EU Association Agreements and Action Plans,*
- *to consolidate the partners of the network of research institutes capable of North-South and South-South interactions, while it sets into motion a transfer of know-how and knowledge between members.*

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