REVIEW AND ASSESSMENT OF THE ADAPTIVE CAPACITY OF THE WATER SECTOR IN CYPRUS AGAINST CLIMATE CHANGE IMPACTS

C. Papadaskalopoulou[1]*, K. Moustakas[1], E. Katsou[1], K. Valta[1], D. Malamis[1], M. Zachariou-Dodou[1]

[1]*Unit of Environmental Science & Technology, School of Chemical Engineering, National Technical University of Athens, Zographou Campus, 9 Heroon Polytechniou Street, 15773 Athens, Greece*

**Tel. +30 2107723108; Fax: +30 2107723285; email: chpapad@chemeng.ntua.gr*

Abstract

The present paper presents a detailed review on the existing adaptation measures implemented in Cyprus in the field of water resources, as well as all water related aspects in the field of agriculture. The scope is not only to present these measures, but at the same to assess and evaluate them based on their effectiveness, viability and contribution to climate change adaptation. Given that there is no integrated adaptation policy on water related issues established at European level as well as in Cyprus, sectoral or case specific policies that also address climate change impacts (e.g. Water Framework Directive (WFD), Floods Directive) were mainly used. The measures reviewed are in the form of policy plans, strategies, legislative actions, guidelines, economic incentives, knowledge dissemination activities or research. Potential barriers to implementing adaptation measures were identified, including legal and policy-level inadequacies or inconsistencies, institutional, social, economic and cultural barriers as well as lack of awareness of climate change issues. The water related measures are presented per climate change impact and sector. The sectors identified as having strong relationship with water were water resources and agriculture. Furthermore, additional measures or measures that are already applied and need further enhancement in order to reinforce the adaptive capacity of Cyprus against climate change are presented.

Keywords

Climate change; adaptation; water resources; availability; demand; drought; flood; agriculture; Cyprus

1. Introduction

Water management constitutes a major field for climate change adaptation. The sectors identified as having strong relationship with water were water resources [1], as well as agriculture, which has close aspects that are relevant to water [2, 3, 4]. Water scarcity and drought as well as the declining levels of water in reservoirs are among the most pronounced climate change impacts on the water resources in Cyprus. Other impacts, such as the salinization of coastal aquifers and the water quality have not yet been directly linked to climate change, since there are a number of human factors affecting their condition as well. Furthermore, there is not sufficient data yet in all cases in order to estimate the contribution of each factor to the generation of the problem. As a result of the limited water availability of the island, it is essential to protect the quantity and quality of water resources in order to be able to satisfy water demand in a sustainable way in the future, taking into consideration climate changes.

2. Review and assessment of existing adaptation measures in Cyprus

2.1 Adaptation measures related to Water Resources

The government water policy of Cyprus is inextricably linked with the measures required for adapting to climate change impacts on water resources. According to the Water Development Department (WDD) of the Ministry of Agriculture, Natural Resources and Environment of Cyprus, the water policy focuses on the maximum potential exploitation of non-conventional water resources, such as desalinated and recycled water. The exploitation of sea water was prioritized at first in order to face intense and urgent water scarcity problems, as it constitutes a rather short to medium term solution with direct results in comparison with the exploitation of recycled water. Full exploitation of recycled water, on the other hand, is a long-term costly process, the success of which will decrease or even eliminate the necessity to build more desalination plants.

The construction of additional water supply works foreseen in the Strategic Water Development Plan for the period up to 2015 is also in progress. In addition to the implementation and subsidization of water conservation measures and the enhancement of water consciousness regarding the proper use of this precious resource, a systematic approach is promoted so as to decrease water demand.

Furthermore, the enforcement of the WFD constitutes an integral part of the government policy. Within this framework, the River Basin Management Plan, the Drought Management Plan, the Strategic Environmental Assessment Report, as well as the Water Policy Plan have been finalized and are implemented since 2011. The implementation of the Programme of Measures is now being carried out and is expected to be finalised by 2015.

Next, the measures implemented in Cyprus and that are considered contributing - directly or indirectly - towards the adaptation to climate change impacts on the water resources of Cyprus are being presented and evaluated.

2.1.1 Measures to increase water availability

Increase storage capacity

The capacity of dams has significantly increased since 1960 from 6 Mm^3 to 332 Mm^3. As a result, the accumulated storage capacity in 2010 was able to cover 4 times the average annual dam inflow of the period 1987-2010 (78.5 Mm^3). Main aim of the construction of a plethora of dams is to capture as much as possible of the surface runoff and to eliminate water losses to sea. This practice has reached physical limits as all major rivers and streams with adequate flows have already been dammed and even more, because there is no increasing trend in precipitation and natural run-off expected.

Control groundwater exploitation

In the past, the control exercised over illegal borehole drilling and over-pumping was inadequate. As a result, only 2 from the 19 groundwater bodies in Cyprus are not over-pumped (non sustainable abstraction) revealing the intense pressure posed on them. According to the provisions of the WFD, which takes into consideration the trends in groundwater bodies level, as well as the amount of unsustainable groundwater abstraction, 11 out of 19 groundwater bodies on which the Government of Cyprus exercises effective control, have been characterized as in bad quantitative condition. The Law on the Integrated Water Management 79(I)/2010 sets new requirements for granting permissions regarding borehole drilling and pumping. Furthermore, the Law foresees the installation and monitoring of water meters in boreholes, in order for the quantities of water pumped not to exceed the limits set. It is expected that with the new Law, a considerable number of violations that have been made in the past, will be eliminated.

Inter-basin water transfer

The interconnection of reservoirs and conveyor systems allows distribution of water across the island and offer some flexibility in operation. Existing water infrastructure involves large inter-basin transfers in the South-South-Eastern (South Conveyor Project - SCP) and in the South West-Western (Pafos Irrigation Project) parts of the island. This allows for considerable flexibility in water management and allocation in most areas. However, especially during the drought periods conflicts and demonstrations arise against inter-basin transfers of water. Local farmers demand full coverage of their water needs before any transfer is made.

2.1.2 Measures for the diversification of water resources utilisation

The use of non-conventional water resources, such as desalinated water, treated water from wastewater treatment plants, grey water and stormwater in water supply for various uses can substantially alleviate the pressures on the freshwater resources which are already high in Cyprus. Following, the progress made so far in Cyprus regarding the use of non conventional water resources is presented.

Construction of desalination plants

Desalination constitutes a secure source for safe drinking water supply, once demand management measures are fully implemented. After the failure of the Government of Cyprus to meet drinking water demand during the intense drought in year of 2008, when severe water cuts were imposed to many households, the Government decided to completely decouple water supply of the urban and tourist areas from rainfall and the satisfaction of the maximum demand during the summer period, with the construction of additional desalination plants. Within this framework, the WDD has prepared a Desalination Plan which foresees the operation of 5 Permanent Desalination Plants by 2012, with a total production of 252,000 m^3/day. The contribution of desalination plants to domestic water supply for 2010 amounted to 65%, which equals 55.5 Mm^3, while it is expected to reach 100% after the operation of the additional desalination plants.

The desalination capacity has increased from 40,000 m^3/d in 1997, when the first desalination plant in Cyprus operated, to 182,000 m^3/d in 2011 and about 252,000 m^3/d in 2012.

However, desalination is an energy intensive process producing a residue (brine) that must be carefully treated and disposed in order to prevent environmental degradation. Hence, desalination could be considered a mal-adaptation measure unless certain requirements are taken into account, such as the use of renewable energy and the proper treatment and disposal of brine generated. In Cyprus, programmes of systematic monitoring have shown local increase in salinity near to the bottom, without particular problems on the marine flora and fauna in most cases.

Reuse of municipal wastewater

Water reuse provides additional drought-proof water supply, favours a more local sourcing of water and avoids the use of high quality water sources where this is not necessary. The potential for water reuse depends on the availability and accessibility of wastewater, i.e. the wastewater infrastructure, and the acceptability by potential end-users and consumers.

There is an immense potential for growth of water reuse practices driven by both the demand for water and the increasing volumes of treated effluent. Aiming at compliance with the Urban Wastewater Treatment Directive (91/271/EEC) requirements, the wastewater collection and treatment infrastructure is being significanlty expanded and upgraded. Providing recycled water for irrigation began in 1998, with a small amount of around 1.3 Mm^3 and reached 12 Mm^3 in 2010, from which 9 Mm^3 were supplied for irrigation and about 3 Mm^3 for artificial recharge of aquifers. The capacity of the new Waste Water Treatment Plants in 2012 amounted to 59 Mm^3 per year and will reach up to 65 Mm^3 per year over the medium term (2015) and 85 Mm^3 for long-term (2025). The annual water recycling is expected to reach 28.5% of today's agricultural water demand [5].

Regarding the use of recycled water in agriculture, specific quality standards have been established as well as measures for the protection of public health. The compliance with both quality standards and protection measures is obligatory.

In general, the treatment of wastewater in Cyprus includes tertiary processes followed by filtration. Treated wastewater is used for the irrigation of green spaces, athletic fields and crops (excluding edible raw vegetables) as well as for aquifer recharge.

Further treatment of certain quantities of the effluent with the Reverse Osmosis (RO) process is under consideration in order to reduce water salinity and the final effluent to be used for the irrigation of sensitive soils and crops. At the same time, the RO process is expected to enable the integrated management of all irrigation water resources. However, the application of RO presents some disadvantages, such as the high costs for the construction and operation of RO plants, and more significantly, the difficulty in selecting a management option for the brine produced which will be both techno-economically feasible and socially accepted. For example, the suggestion for thermal treatment of the brine from the RO plant, which is going to be constructed in the area of Aradippou, is socially acceptable, but it is quite expensive, while the conventional disposal of the untreated brine is not considered [5].

General aim is to use the increasing quantities of treated effluents produced for the irrigation of the agricultural crops, thus substantially alleviating the pressures posed to the agricultural sector due to water scarcity.

The acceptance of the use of treated wastewater from farmers was, at first, slow and reluctant. However, the water cuts imposed on agriculture during the recent drought periods in conjunction with the lower water tariffs set for recycled water in comparison with those of freshwater, led the farmers to turn to the use of recycled water, thus increasing the exploitation of this source. In the beginning, the recycled water was applied in fodder crops, while after the experience gained from its application, its use was expanded to other crops, such as flowers, olives, citrus, grapes, potatoes and dry onions [5].

Furthermore, treated wastewater is also used in Cyprus for aquifer recharge. So far treated wastewater from Paphos is used for the recharge of Ezousa's aquifer. The expansion of this measure to the aquifer of Kiti and Kokkinochoria is under investigation as well [5].

Artificial aquifer recharge

Artificial aquifer recharge offers an opportunity to store water in order to use it in periods of decreased availability and/or increased demand. This measure has begun to be applied during the recent years in Cyprus, by using treated effluent produced from the municipal wastewater treatment plants for recharging the aquifers. It must be noted that no industrial wastewater discharge is allowed in the municipal sewers and, thus, the water used for artificial aquifer recharge comes from the treatment of pure domestic wastewater. However, there is stakeholder opposition to groundwater recharge due to water quality concerns related to the risk of drinking water resources pollution. The quality of reclaimed water has always been an issue, but to date, the problem of micro-pollutants has not been considered yet. Though reclaimed water has to be analysed for bulk parameters and selected metals, no organic micropollutants are being monitored so far [6].

Stormwater use

The collection and use of storm water can result in further savings in fresh water consumption. In Cyprus, until recently there were no drainage systems and stormwater was collected in the sewage system. However, the last two decades, a separate drainage system is being developed in Cyprus in order to separately collect stormwater. So far, the drainage network in the majority of the big urban centres of Cyprus has been completed.

Furthermore, the Sewerage Board of Limassol-Amathus in cooperation with the five municipalities of the Greater Limassol area as well as the wider area of Paphos began the implementation of Sustainable Urban Drainage Systems (SUDS). SUDS are actually a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water. Up to now, no suitable measures have been identified for the case of Larnaca due to its topography (low-lying area).

2.1.3 Measures to decrease water demand

Replacement of water distribution networks

Water losses in domestic water distribution networks, mainly in rural areas, are quite high. The "unaccounted for" water in the main urban domestic supply distribution networks is estimated in the range of 15 to 20% and about 20 to 30% in the rural areas. Therefore, an additional effort should be made for the timely identification and replacement of defective pipes and for developing a more conscious attitude towards water conservation.

Water saving from the replacement of networks is expected to be substantially important compared to other possible water saving measures. From research conducted during the period 2009 – 2010 on the Water Supply Networks of the municipalities that do not belong to Water Supply Boards, more than 80% of the networks have been replaced for the 63.4% of the municipalities [7].

Water allocation

Water allocation mechanisms under drought conditions (water rationing) have been established to provide priority to maintaining domestic and municipal water supplies. The second priority is to maintain supplies to perennial crops at 80% of the recommended application levels. Seasonal vegetable crops constitute the third priority. The water cuts in irrigation from the South Conveyor System during the period 2000-2010 ranged from 10% to 90% with the exception of 2004 where the water cuts were equal to zero. The cuts in the drinking water supply ranged from 13% to 23% for the same period [7].

Use of water supply meters

Metered supply allows users to observe their consumption and to follow up effects of water saving measures. The installation of individual water supply meters from the drinking water consumers in Cyprus is almost catholic, while for irrigation purposes it is restricted mainly in areas supplied with water from Government Water Works or from boreholes in certain groundwater bodies that are under Special Water Savings Measures. It has been observed that the introduction of water meters could achieve water savings of 10 – 25% of the total consumption [7].

Redistribution of irrigated land

Land redistribution constitutes another measure which is directly linked with the decrease in water demand, through the reduction in the fragmentation of agricultural holdings, the opportunity for scale economies in irrigation works and the achievement of significant water savings. Since 1969, 62 out of 73 submitted redistribution plans referred to irrigated land and 3 to mixed, irrigated and rainfed land. In addition, another 12 plans are in progress and 27 under examination, both referring to irrigated land.

It is difficult to estimate the efficiency of the redistribution of small holdings of irrigated land and its contribution as a water saving measure. However, irrigated areas that have been redistributed have shown increased irrigating efficiency mainly because the application of improved irrigation systems is more feasible in that case, thus resulting in savings in irrigation water [7].

Water pricing

The existing water pricing system is not considered to be an effective tool for achieving water savings. It was found that there is no elasticity in water demand in relation to its current price, both in drinking and irrigation water, as the variations in water prices have not affected so far average water demand. Actually, reductions in water demand were observed during periods of intense water scarcity, which is attributed mainly to the raising awareness campaigns. It must also be mentioned that with the introduction of the new desalination plants, the costs of water production and supply will change significantly and the pricing system will move to a new balance. For these reasons, the WDD, in compliance with the WFD, has assigned a study for the implementation of appropriate pricing policies of water services as well as for the implementation of penalty charges for overconsumption (quota system). It is expected that with the implementation of the new pricing policy additional water savings will be achieved.

Subsidies for drinking water savings

The WDD has been offering subsidies in order to reduce drinking water consumption mainly in households with the use of untreated groundwater or greywater in certain uses, as well as the recycling of hot water. The water-saving subsidies are for (i) the drilling of boreholes for watering gardens, car wash, etc, (ii) the installation of a grey water treatment system for watering gardens, (iii) the installation of a hot water recirculator and (iv) the connection of boreholes with toilet cisterns. In 2009, 1,331 applications were approved, from which approximately 45% referred to drilling boreholes [7].

Awareness campaigns

Awareness campaigns are essential in order to achieve water savings. During the last decade the awareness campaigns have been intensified by the WDD, with lectures in schools, advertisements, distribution of informative leaflets and other initiatives. It is difficult to estimate their efficiency in actual water savings; however, a downward trend in water consumption was observed after 2004 when the campaigns were intensified [7].

Table 1 summarizes the demand management measures along with the estimated savings (Mm^3/yr) and the time period (years) used for the estimations. It was estimated that these measures could save a total of 91.4 Mm^3/yr.

Table 1: Water demand management measures and estimated savings [7]

Measure	Water savings (Mm^3/yr)	Data coverage (years)
Replacement of water supply networks	3.3	2000-2010
Use of non-conventional water resources		
Recycled water	12.5	2005-2008
Desalinated water	55.5[1]	
Stormwater	0	
Subsidies for reducing domestic water demand		
Borehole drilling	1.3	1997-2010
Borehole connections with toilets	0.3	
Grey water recycling	0.03	
Hot water circulators	0.05	
Water allocation and cuts	41.5	2000-2010
Use of water meters	8	1986-2009
Redistribution of irrigated land	4.4	1991-2009
Irrigation systems	20	1960-2000
Total	**91.4**	

[1] *Desalinated water supply was not included in the demand savings total.*

Many of the measures adopted have already alleviated the problem of water scarcity, as continuous water supply has been secured by desalination plants and significant savings have been achieved in water consumption. However, there is still potential for further improvement on increasing water availability in order to satisfy human, environmental and social demands.

2.1.4 Measures for the protection of water quality

In order to protect freshwater from pollution, a wide range of legislation has been established in Europe. Most notably, the WFD aims to attain good ecological and chemical status of fresh and coastal waters by 2015. The Programme of Measures defined in the Cyprus River Basin Management Plan [5] includes the establishment of regulations or basic measures that should be implemented in order to achieve the objectives set out for 2015. Following, all measures applied in Cyprus that are considered to contribute to the protection of water quality are presented.

Designation of protected areas

In compliance with the Article 6 of the WFD, Cyprus has created a register of all areas lying within its river basin district, which were considered requiring special protection under specific Community legislation for the protection of surface water and groundwater or for the conservation of habitats and species directly depending on water. The register includes all water bodies identified under Article 7 of the WFD and all protected areas covered by Annex IV of the WFD. Indicatively, *Figure 1* depicts these Natura 2000 areas on the map of Cyprus.

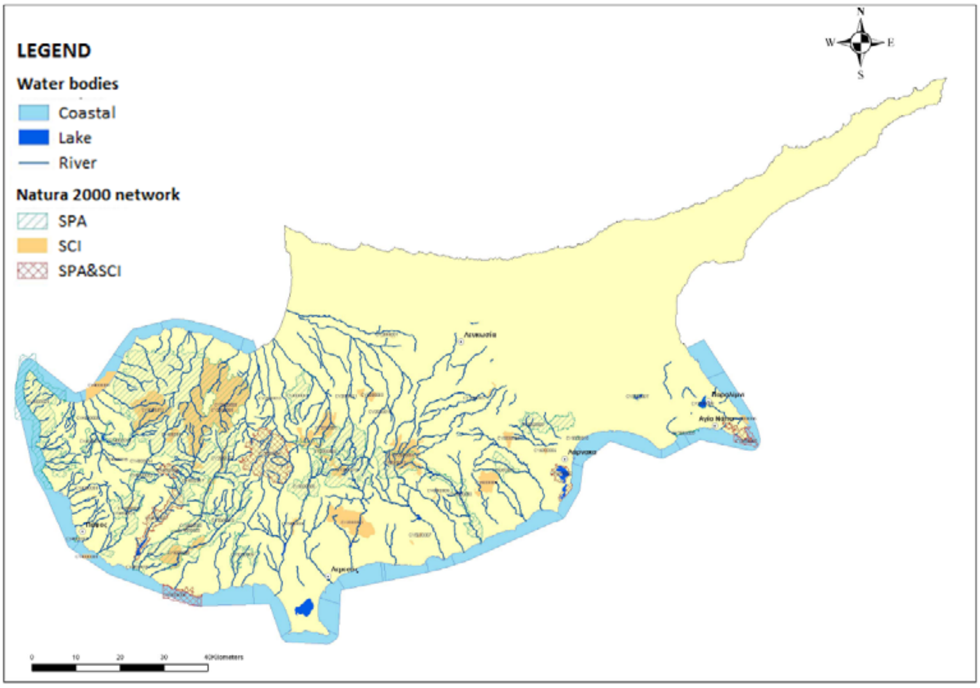

Figure Error! No text of specified style in document.**.** Map of Natura 2000 areas in Cyprus depending on water

As it can be seen, a considerable number of river, lake and coastal bodies in Cyprus are included in the Natura 2000 network.

Protection from point source discharges likely to cause pollution to water

The legislation of the Cypriot Government referred as “Water Pollution Control Laws 2002-2009” is the main tool with which all issues related to water pollution control from industrial and other activities are regulated. Article 6 of the Water Pollution Control Law (No. 106(I)/2002) prescribes that the discharge or disposal of any substances potential to cause pollution to water and soil is illegal without previous permission. Especially for installations included in the provisions of the Integrated Prevention and Pollution (IPPC) Directive (large units with significant pollution potential), the Law No. 56(I)/2003 for Integrated Prevention and Pollution Control is applied.

Furthermore, aiming at compliance with the Urban Wastewater Treatment Directive (91/271/EEC) requirements, the wastewater collection and treatment infrastructure is being significantly expanded and upgraded. The capacity of the new Wastewater Treatment Plans in 2012 amounts to 59 Mm^3 per year and will reach up to 65 Mm^3 per year over the medium term (2015) and 85 Mm^3 for long-term (2025) [5].

The pollution load to be treated is set to 675,000 population equivalent (p.e.) of which 80% are generated in urban agglomerations, which are the greater areas of Nicosia, Larnaca, Limassol and Paphos, and the municipalities of Ayia Napa and Paralimini. Existing sewage treatment plants have been extended recently. The Limassol-Amathus sewage treatment work has been enlarged from a treatment capacity of 70,000 p.e. to 272,000 p.e. and is now able to handle 40,000m^3 per day. Such upgrades correct the overload under which some plants have been working for years and eventually improve effluent quality [5].

Protection of groundwater bodies from salinization

The water policy of Cyprus on the salinization of groundwater bodies is based mainly on the prevention of seawater intrusion with the achievement of a positive balance between the abstractions and recharge, by setting proposed volumes of abstraction for each of its aquifers according to their quantitative condition. Furthermore, the measures foreseen for the achievement of a good chemical status of Cyprus groundwater bodies until 2015, in compliance with the WFD, also contribute to this direction.

However, it must be noted that the rehabilitation of a groundwater body heavily affected by sea intrusion is a very slow process and sometimes almost impossible [8] and prerequisites the moratorium of abstractions which is not always possible to be imposed especially in the case of private drillings.

Farm-level measures

The main threat to water quality is posed through pollution from intense agricultural activities. Farm-level measures need to be encouraged that reduce run-off from agricultural land, especially when fertilizers and livestock manures have been applied. Fertilizer efficiency and application methods need to be improved. Hence, farmers need to be made aware of the best practices both with respect to the application of manures and fertilizers and controlling soil erosion. The use of buffer strips (hedgerows, vegetative rows) beside water courses can be effective in reducing nutrient leaching. However, the adoption of such measures depends mainly on the farmers' awareness, willingness and economic ability to implement them. Following, the measures undertaken by the Cypriot Government through the Rural Development Programme 2007-2013 in compliance with the European Common Agricultural Policy (CAP), to encourage the implementation of such measures on farm-level, are being presented.

Cross compliance (Rural Development Programme 2007-2013)

Cross compliance constitutes the minimum requirements that farmers receiving direct payments from the Cyprus Rural Development Programme (RDP) must comply with. These requirements are divided in the (i) Statutory Management Requirements (SMRs) and the (ii) Good Agricultural and Environmental Conditions (GAECs).

In Cyprus, the compliance with SMR's and GAEC's are required from all beneficiaries of the Axis 2 measures of the Rural Development Programme 2007-2013, as well as from the beneficiaries of the Area Payment Schemes and other direct payment schemes. Hence, their enforcement is obligatory only for those farmers receiving financial assistance under the abovementioned schemes and do not have a catholic application to all farmers.

2.1.5 Measures for the protection from floods

The main adaptation measures towards the increasing frequency and intensity of flooding events require the separate collection of stormwater, the establishment of riverbed protection zones, as well as the construction of flood protection works. In Cyprus, until recently stormwater was collected in the sewage system, which was not designed to accept stormwater and, as result, when heavy rainfalls occurred, the capacity of the sewage systems was frequently exceeded causing flooding events. However, during the last two decades, a separate drainage system is being developed in Cyprus in order to collect stormwater. So far, the drainage network in the majority of the big urban centres has been completed. As for the riverbed protection zones, these have been established by law in several areas located next to rivers indicating that no building is allowed, but due to the lack of effective control these zones have been violated. Several flood protection works have been made in Cyprus, such as bridges and retaining walls, but they do not constitute an integrated approach to flood management.

It is worth mentioning that Sustainable Urban Drainage Systems (SUDS) have started to be implemented in some urban centres of Cyprus for the reduction of flood risks and the exploitation of stormwater for aquifer recharge. For example, in Limassol the construction of four stormwater retention ponds is promoted, with a total capacity of 200,000 m^3. The first pond has already been formed in part of the flood protection work west of the port. The second pond has been scheduled as part of the flood protection works in the area west of the 1st Industrial Zone of Limassol. In the Paralimni lake there is a channel system which controls the water outflow from the lake (flood protection work), recharges the aquifer and sends water to the dam. Moreover, the area of Paphos has been identified as a suitable area for the implementation of SUDS, while for the case of Larnaca due to its topography, no suitable measures have been identified. In Nicosia, no such initiatives have been implemented yet [9].

The Law 70(I)2010 on the Flood Risk Assessment, Management and Preparedness, which harmonizes the Cypriot legislative framework with the Floods Directive 2007/60/EC, states that Flood Hazard maps and Flood Risk maps must have been prepared by the end of 2013, while Flood Risk Management Plans must be prepared by the end of 2015. The WDD has already implemented preparatory steps in conformity with the EU Directive for the Preliminary Assessment of Flood Risks and has identified 19 areas in Cyprus, as areas for which

Potential Significant Flood Risks exist or might be considered likely to occur. It is expected that the identification of those areas will motivate the relevant authorities in order to implement all the necessary flood protection works.

2.1.6 Measures for the protection from droughts

Drought management is an essential element of water resources policy and strategies in the EU and especially in drought prone areas, like Cyprus. Following the recent drought management of 2008 in Cyprus, it was found that adaptive strategies were limited. Dealing with the shortfall of water resources consisted of corrective and emergency measures with the implementation of drought mitigation plans. Decision makers have reacted to drought episodes mainly through a crisis-management approach by declaring a national or regional drought emergency programme to alleviate drought impacts. Nevertheless, nothing can be done to reduce the recurrence of drought events in a region. Therefore, drought management should not be regarded as managing a temporary crisis. Rather, focus must be given on developing comprehensive, long-term drought preparedness policies and action plans that place emphasis on monitoring and managing emerging stress conditions and other hazards associated with climate variability in order to significantly reduce the risks and vulnerabilities to extreme weather events.

A Drought Management Plan [10] should provide a dynamic framework for an ongoing set of actions to prepare for, and effectively respond to drought, including periodic reviews of the achievements and priorities, readjustment of goals, means and resources, as well as strengthening institutional arrangements, planning, and policy-making mechanisms for drought mitigation. Effective information, early warning systems and drought risk maps are the foundation for effective drought policies and plans, as well as effective networking and coordination between competent authorities in water management at different levels. In addition to an effective early warning system, the drought management strategy should include sufficient capacity for contingency planning before the onset of drought, and appropriate policies to reduce vulnerability and increase resilience to drought. When working towards a long-term drought management strategy, it is necessary to establish the institutional capacity to assess the frequency, severity and localisation of droughts and their various effects and impacts on crops, livestock, the environment and specific drought impacts on populations. This is rather a complex process that requires increased capacity, strong institutional structure as well as active administrative and public involvement.

The WDD of Cyprus in conformity with the EU guidelines has elaborated a Drought Management Plan in 2010 [5] in order to address these issues. The DMP of Cyprus structures upon the EU policy on drought management and is closely linked with the Government Water Policy which is based on the WFD criteria and objectives. The main elements of the Cyprus DMP are:

- An early warning system based on hydrological indicators
- A correlation of indicators with thresholds for different drought stages and alert levels to trigger action
- A set of phase-specific measures to achieve objectives.

The actions against drought according to the level of alert may include the notification of responsible operators, raising awareness for sustainable water use, notification of users for consumption reduction, increase in desalinated water production, intensive controls of abstractions and leakages, limits to the abstractions from dams, releases from dams only for river ecosystem protection. Cyprus has considerably increased its adaptive capacity in coping with drought by adopting the EU guidelines on water and drought management. However, the Cyprus DMP and its Water Policy have been recently implemented and have yet to be tested to prove their efficiency in achieving the abovementioned goals.

2.2 Adaptation measures for Agriculture

The climate changes observed during the recent years in Cyprus related to the increased temperature and evapotranspiration as well as the decreased precipitation have created numerous adverse impacts for the agricultural sector, such as increased water requirements for irrigation, decreased water availability for irrigation, increase in run-off, deterioration of water and soil quality, increase in pests, diseases and weeds and decreased crop and feedstock productivity. Hence, the development and enforcement of measures and incentives that enhance crop adaptation to global warming, water shortages and other biotic and abiotic stress factors.

The measures undertaken in Cyprus that have contributed to the adaptation of the Cypriot agriculture sector to climate changes are identified. As the adaptation measures for the agricultural sector depend mainly at farm level action, incentives are provided through the Rural Development Programme of Cyprus, which is structured upon the Common Agricultural Policy of the EU, in order to make the implementation of these measures more attractive to farmers. Furthermore, research activities on adaptation are on-going in order to promote those adaptation measures that best fit to the specific characteristics of agriculture in Cyprus.

Following, the existing adaptation measures are categorized and presented per climate change impact on the agricultural sector.

2.2.1 Measures to reduce risk of drought and water scarcity

The measures to adapt to the expected decrease in water availability and drought risk in the agricultural sector may be categorized in three groups: (i) increase water supply, (ii) reduce water demand and (iii) improve the efficiency of irrigation.

Increase water supply

As also mentioned in the Section of Water Resources, the reduced water availability due to reduced rainfall and the increased evapotranspiration has led the Government of Cyprus to adopt a series of measures such as the increase of water reservoirs and the use of non conventional water resources, which have significantly alleviated water stress. However, as water demand for agriculture may not be always satisfied completely by government water works, farmers may explore other ways to supplement water supply and secure sufficient and continuous irrigation of crops. This may be achieved by on-farm rainwater harvesting and establishing small-scale water reservoirs on farmland while ensuring the sustainable use of water resources and avoiding groundwater overexploitation. The Rural Development Programme 2007-2013 of Cyprus is providing incentives to farmers for the implementation of these measures through the following measure:

- Submeasure 1.5 "Modernisation of agricultural holdings". Through this measure financial support is provided to farmers for the modernisation of their agricultural holdings, including the installation of stormwater collection tanks.

Reduce water demand

Water demand in agriculture may be reduced by adopting less water intensive crops, increasing water retention in soils, soil moisture and reducing run-off.

Use less water intensive crop patterns

The existing crop patterns in Cyprus have been developed many years ago, when water availability was substantially higher. The decrease of water availability during the last years highlights the need to turn to less water intensive crops. However, this is a rather time-consuming process as most farmers have been adjusted to certain crops in terms of experience, know-how and equipment.

Among the proposed measures in the Programme of Measures of the Cyprus River Basin Management Plan [5], the carrying of a study on the readjustment of crops towards a less water intensive crop mix in collaboration with the Department of Agriculture, the Agricultural Research Institute, the Ministry of Commerce, agricultural organizations, etc was proposed.

Increase soil moisture, water retention and reduce run-off

The measures applied in Cyprus for the improvement of soil moisture, water retention and the reduction of surface run-off also apply for the case of preventing soil erosion.

Improve water use efficiency in irrigation

Use of advanced irrigation systems

A Water Use Improvement Project has been implemented by the Department of Agriculture since 1965. According to this project the government provided farmers with technical and financial assistance to turn from traditional surface irrigation methods to modern irrigation methods. Due to the relatively high installation costs, the drip method was initially used for irrigation of high value crops, such as greenhouse vegetables and flowers. At a later stage, the installation cost was reduced, and the use of drippers, mini sprinklers and low capacity sprinklers was expanded for irrigating trees and field vegetables. As a result, during the last decades farmers have extensively adopted modern irrigation systems. The new technology introduced is continuously being tested by the Agricultural Research Institute in order to evaluate the different systems under local conditions and select the appropriate irrigation method for each cultivation. The progress in the irrigation efficiency from less than 45% in 1960, reached 71% in 1980, 80% in 1990, 84% in 2000 and 90–95% in 2010. The on-farm irrigation systems comprise 90% micro-irrigation, 5% sprinkler irrigation and 5% surface irrigation [7].

Irrigation scheduling

Decisions on when and how much to irrigate are critical both to water use efficiency and to crop health. Irrigation scheduling aims at determining the exact amount of water to irrigate and the exact timing for application. Irrigation scheduling offers an opportunity for improving water efficiency at farm level. The Rural Development Programme 2007-2013 of Cyprus is providing incentives to farmers for the implementation of this measure. One of the eligible actions for funding includes the application of integrated production management which inter alia foresees the sustainable use of water by following certain irrigation programmes and irrigation schedules [11, 12].

3. Conclusions

In Cyprus, there is no specific policy in place for adapting to climate change impacts. All measures presented in this paper refer to measures undertaken that have not been developed for addressing climate changes per sector, but are considered to contribute towards this direction as well.

The magnitude of contribution of those measures to addressing climate changes varies according to their effectiveness, their relation to climate change impacts (direct, indirect), their range of implementation (government level, private level), the obligation for implementation (legally binding, optional), while some climate change impacts may not be adequately addressed.

In addition, in some cases it is noticed that although some measures applied in one sector may act beneficially or negatively towards climate change adaptation in another sector, there is no coordinated action between sectors to promote or avoid, respectively, these measures.

Finally, it is highlighted that there is a need for the development of an integrated national adaptation strategy in Cyprus through which the coordination and intensification of existing good practices towards climate change adaptation will be achieved while bad practices will be rescinded, the identified weaknesses and inadequacies will be addressed and the additional suggested measures will be incorporated.

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