ASSESSMENT OF CYPRUS' VULNERABILITY TO CLIMATE CHANGE AND DEVELOPMENT OF A NATIONAL ADAPTATION STRATEGY

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Abstract

Aim of this study is to make an assessment of the vulnerability of Cyprus to climate change and to develop a national strategy for addressing the identified vulnerabilities and increasing the resilience of the country to them. The methodology followed is based on three phases. The first phase includes the study of the past and current climatic data of Cyprus and the projection of future climatic conditions for the country with the use of regional climate models. The second phase refers to the assessment of the current and future climate change impacts as well as the adaptive capacity of Cyprus in order to assess the overall climate change vulnerability of Cyprus. The final phase refers to the identification of the relative adaptation measures for reducing the vulnerability of the country and to their evaluation with the development and use of a Multi-Criteria Analysis (MCA) software tool. The adaptation measures with the highest performance against the evaluation criteria are identified and integrated to the National Adaptation Plan of Cyprus to climate change, while suggestions are provided for their integration and mainstreaming into national and sectoral policies, strategies, plans and legislative documents. Overall, 52 vulnerabilities of the different policy areas of Cyprus to climate change were identified while over 270 relative adaptation measures were evaluated with the MCA method.

Keywords

Climate change, impacts, vulnerability, adaptation, projection, multi-criteria analysis, national adaptation strategy, Cyprus

1. Introduction

Climate change is now considered undisputable and it is strongly believed that this is attributed to a great extent to anthropogenic greenhouse gas (GHG) emissions from the mid-20th century. Global average air and ocean temperatures are increasing, precipitation patterns are shifting, snow and glaciers are melting, global average sea level is rising and extreme weather events, such as floods, droughts and heat waves are becoming more frequent and intense. Independently of the future climate change scenarios and of the efforts for mitigating GHG emissions, it is believed that climate will continue changing in the coming decades due to the previous and current GHG emissions.

Climate change impacts are becoming more obvious throughout the globe, with certain areas, natural systems, populations and sectors of the economy being more or less vulnerable to these impacts. It is clear that adaptation to the adverse impacts of climate change is necessary in order to reduce vulnerability of natural and human systems, to enhance viability of social and economic activities and to eliminate, to the highest degree possible, impacts from extreme weather events.

Recognizing the need for timely addressing climate change impacts in Cyprus and strengthening the country's adaptive capacity, the LIFE+ project CYPADAPT (LIFE10 ENV/CY/000723) on the development of a National Adaptation Strategy was undertaken. The project initiated on September 2011 and now it is reaching its completion. The work that will be presented in the following sections of this paper constitutes part of the work that took place in the framework of the CYPADAPT project.

2. Methods

The methodology followed is based on three phases. The first phase includes the study of the past and current climatic data of Cyprus and the projection of future climatic conditions for the country with the use of regional climate models. The second phase refers to the assessment of the current and future climate change impacts as well as the adaptive capacity of Cyprus in order to assess the overall climate change vulnerability of Cyprus. The final phase refers to the identification of the relative adaptation measures for reducing the vulnerability of the country and to their evaluation with the development and use of a Multi-Criteria Analysis (MCA) software tool.

It must be noted that the active engagement of stakeholders and experts (relative ministerial departments, associations, non-governmental organizations, universities, research institutes, etc.) was recognized from the very beginning of the project as a key element for the assessment of vulnerability, the identification and the evaluation of the adaptation measures and most importantly, for the development of the national adaptation strategy of Cyprus.

2.1. Climate change projection

First, an update of the observed changes in the climate of Cyprus due to the increase in greenhouse gas concentration in the atmosphere was made. For the projection of climate change in Cyprus in the future, the main regional climate model (RCM) used was the PRECIS regional model since its domain is the greater Eastern Mediterranean region with Cyprus lying in the centre of the domain. Besides PRECIS, six RCMs of the ENSEMBLES project have also been used namely KNMI, METNO, CNRM, METO, C4I and MPI. The results of the six RCMs were used as an ensemble mean for testing and comparing the respective results of PRECIS. All simulations concerning future predictions of climate change in Cyprus are driven by the A1B emission scenario of the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2000) which provides a good mid-line scenario for carbon dioxide emissions and economic growth. Two time periods, namely the control period (1961-1990) and the future period (2021-2050), were examined. The future period has been chosen specifically for the needs of stakeholders and policy makers to assist their planning in the near future, instead of the end of the twenty-first century as frequently used in other climate impact studies.

2.2. Assessment of vulnerability to climate change

The methodology followed for the assessment of impacts, vulnerability and adaptation (IVA) is structured upon 4 basic steps:

Step 1: Recording of the baseline situation. During this step, several data that are considered relevant for the IVA assessment were recorded, such as the natural resources available, demand, environmental condition, pressures, strategy plans, management measures etc.

Step 2: Identification of observed and expected impacts. In this step, literature review has been conducted on the observed and expected impacts of climate change worldwide and especially at the wider area where Cyprus is located. The impacts for the case of Cyprus were identified and relevant data were presented where available. Following, the trends of the observed impacts and the likelihood of the expected impacts were evaluated.

Step 3: Current vulnerability assessment. In this step, the overall vulnerability of Cyprus to climate change was assessed and the key vulnerabilities were identified. Vulnerability was assessed with the use of quantitative and qualitative indicators of sensitivity, exposure and adaptive capacity, based on the available data.

Step 4: *Future vulnerability assessment*. In this step, the vulnerabilities identified in Step 3 were re-assessed in view of the projected future climate changes as well as in view of other relative socio-economic projections for the period 2021-2050. Regional climate models (RCM) were also used for the assessment of future vulnerability. In specific, the RCMs were used in order to calculate and plot certain vulnerability indicators which are associated with various climatic parameters. Thus, by taking into consideration (i) the current vulnerability assessment, (ii) the magnitude of the projected future changes in the climatic parameters considered to affect each impact and (iii) other socio-economic projections relative to the impact, the future vulnerability of Cyprus to climate changes was assessed.

The potential impact of climate change on a system may be described by its sensitivity and exposure to climate change. Sensitivity is defined as the degree to which a system is affected by, or responsive to changes in climate. In addition, the degree that the system is affected by other pressures (e.g. pollution) also contributes to its sensitivity to climate change. Exposure is defined by the degree to which a system is exposed to climate change as well as by the degree of expansion of the system at the study area. When either of these terms is zero, there is no impact at all and hence, there is no vulnerability. Furthermore, the greater the impact, the greater is the vulnerability. Adaptive capacity is defined by the ability of a system to adapt to changing climatic conditions and by its resilience to these conditions (autonomous adaptation) as well as by the effectiveness of the relative applied and planned adaptation measures to address climate change impacts. Vulnerability is defined as the degree to which a system is vulnerable or unable to cope with adverse climate change impacts. The greater the impact, the greater is vulnerability while the greater the adaptive capacity, the lesser is the vulnerability. The relationship between these terms is considered to be better reflected by the following qualitative equation (1) which was presented in (Harley et al. 2009) and was applied for the prioritization of vulnerabilities of Cyprus in the framework of this study.

$$Vulnerability = Impact - Adaptive\ capacity$$
$$where\ Impact = Sensitivity * Exposure \qquad (1)$$

For the prioritization of vulnerabilities of Cyprus to climate change, it was attempted to quantify the degree of impacts and adaptive capacity with the use of a qualitative 7-degree scale ranging from “None” to “Very high” (Table 1). The key vulnerabilities have been identified as those impacts gathering an overall vulnerability score ranging from “Moderate” to “Very high”.

Table 1: Impact, adaptive capacity and vulnerability scales

Degree of impact & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

The selection of the policy areas that have been taken into consideration in the IVA assessment where based on the categorization of policy areas for integrating adaptation, as these were identified in the European

Commission's White Paper entitled "Adapting to climate change: Towards a European framework for action". These policy areas where further categorized according to the specific characteristics of Cyprus, as follows: Water resources, Soil Resources, Coastal zones, Biodiversity, Agriculture, Forests, Fisheries & aquaculture, Public health, Energy, Tourism, Infrastructure.

The general concept of the methodology followed was adopted by the "Impacts, Adaptation and Vulnerability" Assessment Reports (AR) of the IPCC (IPCC 2001), while the assessment was further elaborated by the CYPADAPT project team. The basic idea of this concept has been applied with small variations in other regions as well such as in the Nordic countries for the assessment of vulnerability and adaptive capacity, in the framework of the Caravan project (CARAVAN).

The main sources of information used at international and European level were technical reports of the IPCC (Bates et al. 2008; Kundzewicz et al. 2007), the European Commission (EC 2008), the European Environment Agency (EEA) and the Joint Research Centre (JRC) (EEA 2010; EEA/JRC/WHO 2008) as well as other scientific publications on the subject. For the case of Cyprus, extensive literature review as well as contacts with numerous national authorities and organizations in Cyprus have been realized (visits, telephone, email). The main sources of information used were various departments of the Ministry of Agriculture, Natural Resources and Environment, the Ministry of Commerce, Industry and Tourism, the Ministry of Communications and Works, the Ministry of Health, the Ministry of Interior and the Ministry of Labour and Social Insurance of Cyprus as well as several academic and research institutions and private companies in Cyprus.

2.3. Identification and assessment of adaptation options

A database has been developed with the aim to provide information on the adaptation measures applied worldwide. The adaptation measures are categorized based on the sector they are applied, the specific characteristics of each country (population, GDP), while countries are also grouped based on their common geographical characteristics and other features (region, UN category, Annex I and non Annex I countries). In addition, adaptation measures may be searched with the use of keywords. Overall 790 adaptation measures applied in 195 countries have been inserted to the database. The adaptation options included in the database have been assessed from the United Nations Framework Convention on Climate Change (UNFCCC), the European CLIMATE-ADAPT Platform, several sector-specific guideline documents issued by international and European organizations, as well as from the 5th National Communications of various UNFCCC Parties.

For the assessment of the identified adaptation options, a review on the available decision making methods was made with special emphasis on those applied for the assessment of adaptation options. Considering that the development of a sound and commonly accepted National Adaptation Strategy is a complex process, requiring the integration of the opinions and the involvement of multiple decision makers from different sectors and experts from diverse disciplines, as well as the evaluation of various adaptation options based on multiple and potentially conflicting criteria, Multi Criteria Analysis (MCA) was considered as the most appropriate method for the evaluation of the adaptation options for the case of Cyprus.

Following, an MCA tool was developed where all the identified adaptation measures were incorporated to its database. The criteria selected for the evaluation of the adaptation measures were: I. Efficiency of the measure, II. Environmental friendliness, III. Supporting the prevention of climate change impacts, IV. Urgency for implementing the measure, V. Usefulness of implementation irrespective of climate change, VI. Technical viability, VII. Economic viability and, VIII. Public acceptance.

The MCA tool processes stakeholders evaluations on the proposed adaptation measures and produces alternative adaptation scenarios, based on the degree of vulnerability of the system to climate change, the weights assigned to the evaluation criteria and the weights assigned to the different stakeholder groups (competent national authorities, relevant national authorities, research institutes, NGOs, sectoral unions and

associations and, civil society organizations). The adaptation measures with the highest performance against the evaluation criteria are identified in order to be integrated to the National Adaptation Plan of Cyprus to climate change.

3. Results and discussion

3.1. Vulnerability

In this section, a summary of the main vulnerabilities of the eleven policy areas of Cyprus that were identified through the impact, vulnerability and adaptation assessment is presented. The results in detail are provided in the report on the future climate change impact, vulnerability and adaptation assessment for the case of Cyprus (CYPADAPT 2012).

It must be emphasized at this point that an attempt has been made to prioritize the identified vulnerabilities in order to set the priorities for action for reducing vulnerability and enhancing the adaptive capacity of Cyprus to climate change, although several times not all the necessary information was available for the assessment, or, a more comprehensive scientific analysis was required. For that reason, a series of measures aimed at enhancing knowledge through the promotion of research on the effects of climate change in Cyprus, is suggested. The results of the research will be used for a re-evaluation and a detailed assessment of Cyprus' vulnerability to climate change to take place while the adaptation measures will be adjusted accordingly.

3.1.1. Water resources

The first priority of the water resources sector in Cyprus with respect to its vulnerability to climate change is related to the water availability for domestic water supply and irrigation in mountain areas. In Cyprus, the low levels of effective rainfall and the consecutive years of drought in conjunction with the intense agricultural development that took place during the second half of the previous century led to the depletion of surface water stored in reservoirs and the exploitation of aquifers. Furthermore, cuts in water supply by Government imposed in periods of drought or high water pricing have often led private water consumers to illegally abstract water from boreholes (indirect climate change effect), which resulted in further deterioration of groundwater quantitative status. According to the Water Development Department (WDD) of the Ministry of Agriculture, Natural resources and Environment of the Republic of Cyprus (MANRE)(WDD 2008), only 2 of the 19 groundwater bodies in Cyprus are in good quantitative status. Water availability is considered very sensitive to climate change and especially to the decrease in precipitation. In particular, it was estimated that for a projected reduction of 5% in average precipitation in Cyprus for the period 2021-2050, a reduction of 23% in dam inflow compared to the period 1970-2000 is expected (CYPADAPT 2012). Mountain areas are characterized by low adaptive capacity for coping with this impact mainly due to the insufficiency of government water supply works in these areas which is mainly attributed to techno-economical reasons.

The second priorities of the sector to climate change are related to the (i) water availability for irrigation in coastal and plain areas, (ii) groundwater quality and (iii) droughts. Concerning water availability in plain and coastal areas, although this is enhanced by government water works thus reducing competition for water between the domestic and the agricultural sector, it does not always meet actual water demand for irrigation (especially during drought periods), while climate change is expected to intensify this problem.

According to the Fourth Assessment Report (AR4) of the IPCC, it is believed with high confidence that higher water temperatures, increased precipitation intensity and longer periods of low flows exacerbate many forms of water pollution. However, there is no evidence for climate related trend in water quality (Parry et al. 2007). In Cyprus, a trend in groundwater quality deterioration is observed which is however attributed to the rapid urbanization of the last 30 years that had as a result the inappropriate wastewater disposal, the intensive cultivation which resulted in the excessive use of fertilizers and in the over-pumping of groundwaters which

led to the salinization of coastal aquifers (WDD 2008). Groundwater quality is considered a crucial issue for Cyprus in view of climate change since a potential sea level rise would exacerbate seawater intrusion to the coastal aquifers, while lower recharge rates, may increase concentration of pollutants.

Droughts affect water availability and water quality. Southern and south-eastern regions in Europe present significant increases in drought frequencies (Kundzewicz et al. 2007). Drought phenomena in Cyprus are very frequent, persistent and severe and have lasted up to 8 consecutive years. In particular, Cyprus registered among the highest frequencies of droughts in Europe in the period 1976 to 2006, with a large part of its territory being affected whenever droughts occurred (EC 2008). As for the future climate changes associated with droughts, the PRECIS results show that the length of the drought periods is projected to increase up to 12 days/year on average, and thus the vulnerability to droughts is expected to increase as well.

The third priority of the water resources sector in Cyprus concerning climate change vulnerability is related to the water availability for domestic water supply in urban areas. As also previously mentioned, the island's freshwater resources are not sufficient most of the times for satisfying drinking water demand, while climate change is expected to intensify this problem. However, the implementation of a plethora of Government Water Works has alleviated the problem of water scarcity in the urban areas for now, as continuous water supply to the domestic sector has been secured, mainly by desalination plants.

The fourth priority of the sector concerning climate change vulnerability refers to the quality of surface water bodies. Surface water bodies in Cyprus are mainly comprised of the storage reservoirs with no inflows during summer months, thus resulting in low pollutant dilution capacity. Climate change and in particular increasing temperatures will result to increased eutrophication rates, stratification and low levels of dissolved oxygen which will further deteriorate their quality.

The fifth priority of the sector with respect to climate change vulnerability is associated with floods. Despite the considerable rise in the number of reported major flood events in Europe over recent decades, there is yet no proof that the extreme flood events of recent years are a direct consequence of climate change (Christensen and Christensen 2007; Kundzewicz et al. 2006). In Cyprus, an increase of 37-49% has been observed in the intensity and quantity of precipitation for a duration of precipitation between 5 minutes and 6 hours for the period 1970-2007 in comparison with the period 1930-1970 (Pashiardis 2009). For the same period, records on flooding events (WDD 2011 – Annex III) present also an increase.

3.1.2. Soil resources

The first priority of the soil resources of Cyprus with respect to their vulnerability to climate change is related to the phenomenon of desertification. Desertification is a phenomenon which threats one third of the planet's soil resources, especially in arid and semi-arid areas. The causes contributing to desertification are multiple and may be associated with climatic factors such as the prolonged drought periods and the intense precipitation events. Desertification constitutes a serious threat for Cyprus too since relative study (I.A.CO Ltd, 2007) showed that 57% of its soils are characterized as "Critical" to desertification, 42.3% as "Fragile" and only 0.7% as "Potential" to desertification. No area has been characterized as not threatened by desertification. Climate change is expected to deteriorate the degree of desertification in Cyprus.

The second priority of the soil resources sector of Cyprus concerning climate change vulnerability is related to soil erosion. Soil erosion is directly associated with climatic factors and especially climate change related factors, such as intense precipitation and prolonged periods of drought as well as with the increase in wind speed. The Mediterranean region is particularly susceptible to soil erosion, mainly due to intense precipitation events followed by prolonged periods of drought (EC/JRC, 2009). In Cyprus, the phenomenon of soil erosion is common mainly due to the type of its soils, the sparse vegetation, the topography of the island and the climatic conditions. Factors associated with the intense exploitation of natural resources and agricultural land, urbanization, deforestation as well as pollution, intensify the problem. In addition, extreme weather events

like storms and fires also deteriorate the situation. Climate change, and in particular the increase in the duration and intensity of droughts and the increase in intense precipitation is expected to further deteriorate the issue of soil erosion in Cyprus.

The third priority of the soil resources of Cyprus concerning climate change vulnerability is related to soil salinization. In Cyprus, salinization is mainly observed in soils where irrigation with high salinity water (either from salinized aquifers or from certain wastewater treatment plants) takes place (I.A.CO, 2007). Considering that climate change is expected to lead to further reduction of water availability and potentially to sea level rise, soil salinization will be exacerbated.

3.1.3. Coastal zones

The first priority of the coastal zones of Cyprus with respect to its vulnerability to climate change is related to the coastal erosion. Coastal erosion is caused by the physical removal of sediment by wave and current action (Sterr et al., 2003), as well as by sea level rise and by human interventions which cut off the sediment transport to coasts. Erosion constitutes a serious issue for the coasts of Cyprus, especially for the sandy and gravel beaches of the island such as the coastlines of Larnaca and Limassol which have been suffering from severe erosion during the last 30 years. According to Coccosis et al. (2008), 110km or 30% of the coastline which is under the control of the Republic of Cyprus is subject to erosion. However, the phenomenon of coastal erosion in Cyprus is mainly attributed to human interventions which in some cases are triggered by natural causes associated with climate change.

The second priority of the coastal zones of Cyprus concerning climate change vulnerability is related to coastal flooding, inundation and squeezing. Scientists project an increase in the frequency of large storms in the coming centuries which can cause storm surges that flood low-lying coastal areas and allow destructive wave action to penetrate inland (Nicholls & Hoozemans 1996). At the same time, a potential sea-level rise would increase the area likely to be inundated by these coastal storms. 'Coastal squeezing' is another major problem presented by sea flooding when physical or anthropogenic barriers obstruct the process of landwards retreating. Given the significant proportion of Cyprus coastline occupied by urban and tourist infrastructure (45%) (Coccossis et al., 2008), coastal squeezing may constitute a serious issue for certain areas in the future.

3.1.4. Biodiversity

The first priority of Cyprus' biodiversity with respect to its vulnerability to climate change is related to the impacts on (i) terrestrial ecosystems and (ii) wetland ecosystems.

Climate change and in specific the rise in average temperature, the reduction in precipitation, the sea level rise and the increase in the intensity and frequency of extreme weather events like floods and droughts, are expected to affect species abundance and populations, their distribution as well as the extent of their habitats. A northward and uphill movement of species has been observed which is, however, sometimes hindered by manmade barriers (e.g. urban development), landscape fragmentations and the physical characteristics of species which inevitably leads to their extinction. Cyprus, as an island presents substantial landscape fragmentations for terrestrial ecosystems. In the case of mountains, landscape fragmentations are associated with the inability of species for moving at higher altitudes due to physical limits of mountains. In addition, mountain ecosystems are threatened by fires which are further triggered by climate change factors. Changes in communities appear due to the intrusion of new competitors. In general, the keystone species expand their distribution over the less adaptable. The invasive species bring along new threats for the host populations such as diseases. The most typical example is the establishment of new pest species due to warmer winters.

Wetlands and the terrestrial areas surrounding them are autonomous ecosystems where a great number of animal and plants live, many of them facing extinction. For these reasons, wetlands are considered particularly sensitive to climate change and especially to temperature rise, precipitation reduction, increase of extreme

weather events and the sea level rise. In Cyprus, wetlands provide habitat for many endemic and migratory species. However, wetlands are limited due to water scarcity and are comprised mainly by artificial water bodies, such as dams. It is worth mentioning here that, the introduction of exotic fish species in Cyprus dams altered the species balance and caused the reduction of populations of endangered endemic species. In general, the wetlands of Cyprus are threatened by reduced water availability. Regarding the ecological status of surface water bodies of Cyprus, this was rated as good according to the criteria of the Framework Directive 2000/60/EC. However, other wetlands, such as salt marshes and marshes, have been severely degraded due to human activities (intensive agriculture, waste management, etc).

The second priority of Cyprus' biodiversity concerning climate change vulnerability is related to the impacts on marine ecosystems. The anticipated changes in temperature may cause fluctuations in sea water temperatures. Changes in sea water temperatures are responsible for changes in physiology and sex ratios of marine species, alteration in timing of spawning, migrations, and/or peak abundance and also, for the increasing of invasive species, diseases and algal blooms. These impacts are leading to reduced production of target species in marine systems. Changes in ocean currents, in the temperature of the upper sea layers, in salinity and in the global thermoline are responsible for the changes in the distribution of plant species (UNEP, MAP, RAC/SPA 2010). Changes in the marine food-webs cause alterations to the food availability of fish, birds and marine mammals. The marine flora and fauna of Cyprus are characterized by great diversity and low biomass, making them vulnerable to climate change. Anticipated changes in temperature, salinity and nutrient levels may further affect marine biodiversity. Marine habitats of neuralgic importance -such as *Posidonia oceanica* meadows- are very sensitive to salinity, temperature and sedimentation alterations. A potential loss of these meadows would bring catastrophic consequences for the marine biodiversity of Cyprus and its commercial fisheries (Parari 2009). Furthermore, as the Red Sea temperature increases, migration of species from the Red Sea to the Mediterranean Sea is observed, causing the displacement of other endemic species. Invasive species enter into the Mediterranean Sea through the Gibraltar straits, the Suez Canal and by being carried in ballast water of ships. Indicatively it is mentioned that, the number of invasive species introduced in the coastal and offshore waters of Cyprus has grown over the last 50 years, with the rate of new biological invasions in the Mediterranean Sea being as high as 1 new species every 9 days (Zenetos et al. 2008).

3.1.5. Agriculture

The first priority of the agricultural sector of Cyprus with respect to its vulnerability to climate change is related to the crop yields. Climate change is expected to benefit agricultural productivity in some areas due to the increase of temperature. In addition, the growing season of the plants is expected to be elongated as a result of the reduction in the number of frost nights (EEA, 2008a). In Cyprus, the increase in average temperature is expected to have positive effects in some agricultural areas and especially in mountain areas. In addition, the growing season is expected to elongate as the days without frost in Cyprus are estimated to be reduced by about eight days/year for the period 2021-2050. However in southern and warmer latitudes of Europe like Cyprus, the potential positive impacts on crop yields are not of such a significant magnitude as are the potential negative impacts, which include reduced crop yields due to high temperatures, increased water demand for irrigation and reduced water availability due to periods of prolonged droughts, water scarcity, rainfall decrease and increased competition for water between sectors, which will in turn be much more intense (Behrens et al. 2010). In Cyprus, severe drought events directly affect the agricultural sector, as due to its limited available water resources cuts in the irrigation water supply are often imposed by the government. Climate change in the future is expected to further exacerbate current adverse conditions in the agricultural sector, as the maximum mean temperature and the periods of prolonged droughts are projected to increase. In addition, the projected decrease of 5% in the precipitation at the areas where the main dams of Cyprus are located, could lead to a 23% decrease in the future total dam inflow, thus further increasing competition for water between sectors. Last but not least, pest outbreaks, emergence of new pests and pathogens and an

increase in the frequency of diseases, as secondary effects induced by higher temperatures and prolonged growing season will pose extra risk for crop production.

The second priority of the agricultural sector of Cyprus with respect to its vulnerability to climate change is related to the crop production losses due to extreme weather events. There is evidence that from the beginning of the 21st century, damages to crops due to the occurrence of extreme weather phenomena show an increasing trend. These extreme events are likely to increase in frequency and magnitude, thus leading to a greater exposure of crop yields (EEA 2008a; GCRIO 1995; Bruggeman et al. 2011). In Cyprus, the most common factor causing damages to crops is hail with a frequency of occurrence 100%, followed by frosts with a frequency of occurrence 83%, droughts with 70%, heatwaves and windstorms with 53% each, and floods with 47% (AIO, 2008b). According to the projections of the regional climate model PRECIS for the period 2021-2050, the periods of drought (rainfall <0.5mm) will increase up to 12 days/year on average, the average number of heatwave days (maximum temperature> 35^{o}C) will increase from 2 to 34 days/year, while the average number of frost nights (minimum night temperature <0^{o}C) is expected to fall up to 8 days/year on average.

3.1.6. Forests

The vulnerability of Cyprus' forests to the dieback of tree species, insect attacks and diseases as well as the vulnerability to forest fires are both considered of equal importance in view of climate change. The prolonged periods of drought, the reduction in rainfall and the increase in average maximum temperatures in summer are affecting trees resulting in distress and in the final stage, necrosis. The typical Mediterranean climate with mild winters and hot, dry summers favors the development of harmful organisms in large populations. Climate change and in particular rising temperatures and droughts are expected to further promote growth and spread of these organisms. Cyprus' forests have already been extensively affected by dieback of tree species, insect attacks and diseases with the most important incident recorded during the prolonged drought period of 2005-2008, which had a significant effect on a large number of forest species, including Pinus brutia, Pinus halepensis, Pinus pinea, Acacia, Cypress, Arbutus andrachne, Quercus alnifolia, Crataecus azarolus, and Olea europaea (Ioannou 2010; Cyprus Institute 2011), while thousands trees of Brutia Pine species (Pinus brutia) and Stone Pine (Pinus pinea) were attacked by insects (Department of Forests 2011a; Department of Forests 2011b). The impact of droughts and of the increase in temperature may result in a significant reduction of pine forests with the forests of black pine at the top of Troodos mountains being faced with extinction. The cedar and riparian forests are also considered particularly vulnerable. Species with slow regeneration ability are most at risk. The effect of pine caterpillar (pest) will expand due to the increase in temperature. Other harmful organisms from warmer regions are also expected to affect the forests of Cyprus. Generally, the quality of forests in terms of density, growth and vitality is expected to deteriorate, with shrinkage of high forests and prevalence of maquis and garrigue vegetation (MANRE).

Forest fires are considered as a major and permanent threat for the forests of Cyprus. Every year, forest fires cause enormous and irreparable damage to forest ecosystems. Cyprus' forests are vulnerable to climate change mainly due to the high temperatures and prolonged drought periods that prevail in the island during summer, but also because of the accumulation of flammable vegetation (Department of Forests, 2012). Cyprus Fire Weather Index (FWI) values for the period 2008-2010 are among the highest in comparison with the other European countries located in the Mediterranean. The overall findings of the future Fire Weather Index calculation for Cyprus based on the climate change projections suggest that the number of days with fire risk will be increased by 5 to 15 days and the number of days with extreme fire risk will present an increase of 1 to 5 days per year.

3.1.7. Fisheries& aquaculture

The most important vulnerability of the fisheries and aquaculture sector is considered to be the reduction in the quantity and diversity of fish stocks. Changes in the distribution of the marine fish stocks caused by the

increase in Sea Surface Temperature (SST) are expected to alter the balance between competitors, predators and invasive species. Furthermore, the increase is SST may result in an increase in the diseases and parasites in fish stock. The above mentioned changes definitely have an effect on the abundance and species composition of the fish stock (World Fish Centre 2007). It must be mentioned that even a small reduction in the amount of fish stocks of Cyprus, will considerably affect the sector and especially marine pelagic fishery since the amount of available fish stock is already limited due to the spatially confined marine fishing areas (small shelf extention) (Lamans 2006) and to the low bioproductivity potential of the eastern Mediterranean. In addition, Cyprus is highly exposed to the invasion of alien species because it is located near the nautical channel of Suez which favours the migration and relocation of the Lessepsian species (Mitov 2009). Although several adaptation measures have been undertaken, the adaptation potential especially for the pelagic fishery is limited.

The main changes in climate that are considered to affect the quantity and diversity of freshwater and marine aquaculture are the changes in SST and in the inland water temperature, the changes in precipitation and water availability as well as, the changes in the frequency and intensity of extreme weather events. Higher inland water temperatures lead to more stable vertical stratification of deep lakes, increased oxygen depletion in lake bottoms and more frequent harmful algal blooms, which may in turn worsen dry season mortality, bring new predators and temperature-dependent diseases and change the abundance of food available to fishery species thus reducing the overall availability of fish stocks (EEA/JRC/ WHO 2008; World Fish Centre 2007).

The most important vulnerability of the fisheries and aquaculture sector is considered to be related to the cost implications for fishermen. The main cost implications of climate induced impacts for fishermen are mainly attributed to extreme weather events and the sea level rise. In particular, increased intensity and frequency of storms may lead to decreased frequency of inshore and offshore pelagic fishing due to increased risk to fishers. Furthermore, storms may result in loss of aquaculture stock and damage to or loss of aquaculture facilities and fishing gear with the aquaculture installations (coastal ponds, sea cages) being at greater risk of damage. The intrusion of some Invasive Alien Species (IAS) may cause significant damages to the fishing gear and catches. Last but not least, important cost implications are related with the loss of wild and cultured stock, the increased production costs and the loss of opportunity as production is limited (World Fish Centre 2007).

3.1.8. Public health

The first most important vulnerability of the public health sector of Cyprus to climate change refers to the deaths and health problems related to heat waves and high temperatures. According to the IPCC (2007), hot days, hot nights and heatwaves have become more frequent. Additionally, IPCC ascribes by 50 per cent the increase of heat wave related deaths to climate change, and expresses an 80 per cent level of certainty that increasing temperatures will have a negative impact on health. For Europe, it was estimated that mortality increases 1-4% for each 1°C rise in temperature above a specified ceiling (Menne et al. 2008). This prediction is also in accordance with observations in cities of Mediterranean Basin (GSK/Accenture/SSEE, 2011). The results of the estimation of future heat-related mortality for the case of Cyprus showed that there will be an increase of up to 10 excess deaths per day under very hot weather conditions. To investigate the potential negative impacts of climate warming on human comfort, the humidity index or “Humidex” (Masterton and Richardson, 1979) - a parameter employed to express the temperature perceived by people - has been examined. The average summer humidex for the control period as calculated by PRECIS for inland (Nicosia) and southeastern (Larnaca) regions, varies from 40 to 42°C revealing “great discomfort” conditions for people. As far as future changes are concerned, a significant increase in humidex of about 3.5 – 4°C is projected for all the domain of study. This means that “significant danger” conditions are anticipated mainly for inland regions where humidex is projected to reach approximately 47°C. On the other hand, the adaptive capacity of public health

towards this impact is not satisfactory enough given that the protection of the population from heat waves is not always possible.

The second priority of the sector with regard to its vulnerability to climate change is considered to be associated with the vector-borne and rodent-borne diseases. Vector-borne diseases (VBD) are among the most well-studied diseases associated with climate change, due to their widespread occurrence and sensitivity to climatic factors. Climate change is expected to lead to changes in infectious disease transmission by vectors such as mosquitoes and ticks, as a result of changes in their geographic range, seasons of activity and population size (Confalonieri et al. 2007).

Leishmaniasis is a sandfly-borne disease endemic to Cyprus, with a high prevalence of human visceral Leishmaniasis. As climate changes, new species, such as L. tropica may colonize Cyprus, as well as the drug-resistant L. Infantum (Alker 2009; Dujardin et al 2009). In addition, West Nile Virus (WNV) which is a Flavivirus transmitted through bird-feeding mosquitoes, has had reported cases in Cyprus. The epidemic potential of this virus begins from 20^{o}C while it reaches its peak at 40^{o}C (Alker 2009). The geographical position of Cyprus also favors the transmission of vector-borne diseases from regions where many vector-borne diseases are endemic. Finally, the vector of Chikungunya that is transmitted by the Asian tiger mosquito, Aedes albopictus, is a highly invasive species that is rapidly spreading across Europe, while Cyprus constitutes a high-risk area for Ae. Albopictus establishment.

The third priority of the public health sector of Cyprus with regard to climate change is associated with the water-borne and food-borne diseases. Heavy precipitation has been linked with water contamination by pathogens or other pollutants while water scarcity creates opportunities for transmission of theses pathogens, due to inadequate hand-washing and personal hygiene. Increased faecal bacteria contamination is also likely to affect drinking water intakes and bathing waters (Symeou 2009). Higher water temperatures may result in increased occurrence of harmful algal blooms, thus deteriorating the quality of water. Water-borne diseases are likely to increase with climate changes in Cyprus such as decreased rainfall, increased temperature, increase in the frequency of extreme weather events (droughts, heavy rainfall, floods). However, in Cyprus there is a number of measures in place such as sanitation and drainage systems, thus being less vulnerable to the transmission of these diseases. Contamination of food may be induced by higher temperatures which enhance the survival and proliferation of viruses, bacteria and fungi in foodstuffs (McMichael et al., 1996). Temperature-sensitive food-borne diseases, such as Salmonella sp., and others are likely to grow in Europe (Kovats et al. 2003) as a result of climate change.

The last priorities of the public health sector of Cyprus with regard to climate change are the flood-related deaths and injuries and the air pollution-related diseases**.** The frequency and intensity of extreme weather events such as heavy rainfall, storms and floods are anticipated to increase, having immediate effects such as deaths and injuries. The air pollution health risks related to climate change are caused primarily from the increased concentrations in the atmosphere of particulate matter and ozone. Tropospheric ozone O_3 is the major pollutant being related to climate change while ground-level ozone (smog), though less concentrated than ozone aloft, is more of a problem because of its health effects. During heat-waves, the atmospheric conditions contribute to increases of tropospheric ozone and particulates leading to mortality incidents. Studies have shown that climate change has contributed to an increase in ozone concentration in central and south-western Europe (EEA/JRC/WHO 2008, EEA 2012).The ground-level ozone in Cyprus constitutes a general problem. However, in the cities the ozone concentrations are lower than in the background because of the depletion by the primary emitted pollutants there. The particulate matter (PM10) in Cyprus primarily originates from Sahara dust events and anthropogenic activities such as traffic and secondarily industrial activities. The higher values of PM10 have been recorded in the main urban centers (reaching the EU limit values) (Ministry of Labour and Social Insurance 2007). Climate change might also impact the severity and

timing of air allergens, such as pollen or mould. Another indirect impact of climate change on health comes from potentially changing ultraviolet radiation (EC 2013a).

3.1.9. Energy

The main vulnerability of the energy sector of Cyprus with respect to climate change refers to the energy demand for cooling and heating. Climate change has a significant impact on the sector of energy, as power consumption is linked to several weather variables (mainly air temperature). Consumption of energy is particularly sensitive to weather, since large amounts of energy cannot be stored and thus energy that is generated must be instantly consumed. In addition, the fact that Cyprus is an energy isolated (non-interconnected) and energy dependent (oil imports) island, makes the sector more vulnerable to climate change. Countries at low latitudes like Cyprus will be significantly affected in terms of cooling demand due to the temperature increase, resulting in an increase of cooling degree days and a decrease of heating degree days. Projections of energy demand in Cyprus for the period 2021-2050 compared to the period 1960-1990, show that there will be a reduction in energy demand for heating in the winter months of the order of 5%, while the energy demand for cooling is expected to increase in the summer months approximately 10%. Therefore, it is estimated that the annual energy demand for heating will increase by 5%. However, given that there is potential for increasing energy supply in Cyprus in order to meet the increasing energy demand.

3.1.10. Tourism

The first priority of the tourism sector of Cyprus with regard to its vulnerability to climate change is the water availability for meeting water demand for irrigation and other uses. According to the report on the Water Policy of Cyprus (WDD 2011), the water demand from the tourism sector is estimated to be 15% of the domestic water supply or 4% of the total water demand. In addition, in 2000 daily water use per tourist in Cyprus was more than double in comparison with the water consumption of local residents (Rossel 2002). Consumption varies of course depending on the type of lodging and facilities offered such as swimming pools and golf courses. Indicatively it is mentioned that in 2010, 64% of the tourist accommodations in Cyprus provided swimming pools (CARBONTOUR 2010). In addition, the current Tourism Strategy of Cyprus promotes the development of golf tourism, which however will substantially increase the sector's water demand for the irrigation of golf courses. Considering that the available water resources of the island are already under pressure and that climate change is expected to exacerbate the problem of water availability for irrigation in the tourism sector.

The second priority of the sector concerning climate change is related to heat waves. Heat waves are very likely to affect tourist decisions regarding the travel destination or the length of stay due to tourist discomfort, especially for those population groups that are sensitive to such events (e.g. elderly). Heat waves are a common phenomenon in Cyprus during summer when the majority of tourists visit Cyprus. However, the impact on tourism is not so intense considering that the most sensitive population groups to heat waves (i.e. the elderly people), prefer to take their holidays during the cooler seasons of the year. In addition, heat waves may affect the tourism sector through increased energy costs for cooling or due to failures in the energy supply network that may cause business interruptions. According to PRECIS climate model, in the future (2021-2050) the mean number of days per year in Cyprus with daily maximum temperature higher than 35°C (heat wave days) is expected to increase from 2 days to 34 days on average. The latter is anticipated to intensify the vulnerability of Cyprus' tourism to heat waves.

The third vulnerability of the tourism sector of Cyprus is related to the impact of coastal erosion. Reduced aesthetics of coasts due to erosion have a negative impact on tourism preferences. Considering that approximately 95% of the tourism infrastructure in Cyprus is located at the coast and that the phenomenon of erosion is already apparent in many of the coasts of Cyprus, the tourism sector of Cyprus is particularly

vulnerable to coastal erosion. However, coastal erosion is mainly attributed to harmful practices, such as sand and gravel mining and to a lesser extent to climatic factors. An increase of extreme weather events and sea level rise as a result of climate change are expected to cause or exacerbate coastal erosion phenomena (Nicholls & Hoozemans 1996; Gordon et al. 1992; Sterr et al. 2003).

The fourth vulnerability of the sector is related to the availability of drinking water. Water reserves especially during summer when the majority of tourists visit Cyprus are usually low. Climate change is expected to further reduce water availability. However, the vulnerability towards this impact is reduced due to the adaptive capacity of Cyprus for increasing drinking water supply mainly with the use of desalination plants.

Finally, the impact of climate change on biodiversity attractions constitutes the last vulnerability priority for the tourism of Cyprus. Climate change could affect natural ecosystems by worsening their state. Loss of natural attractions and species and reduced landscape aesthetics could result in significant reduction of the nature-based tourism. However, considering that the percentage of nature based tourism in Cyprus is very small compared to the share of beach tourism, which constitutes 90% of total tourism, the vulnerability towards this impact decreases.

3.1.11. Infrastructure

The first priority of the infrastructure sector of Cyprus with regard to its vulnerability to climate change is related to the risk for urban infrastructures. Urban infrastructures such as construction and urban infrastructures are sensitive to climate change and particular to extreme weather events (heavy precipitation and flooding, strong wing, high temperatures) (EC 2013b). The main recorded impacts on the urban infrastructures in Cyprus so far refer to the damages caused by floods. The urban centers of Larnaca, Limassol and Nicosia are sensitive to flood risks mainly due to their dense structuring and the restriction of green space, the elimination of natural waterways for the construction of roads, the deficient or even absent stormwater drainage system and the covering of waterways and drain entrances with garbage. Climate change is expected to exacerbate this problem.

The second priority of the infrastructure sector of Cyprus is related to the risk for coastal infrastructures. Coastal infrastructures are affected by climate change through sea floods, coastal erosion and sea level rise. In Cyprus, there is substantial concentration of infrastructures at the coastal areas since three out of four of its main urban centres as well as the majority of its tourism infrastructure are located at the coast. However, it must be mentioned that sea level rise does not constitute threat for Cyprus for the near future (EC, 2009).

3.2. National Adaptation Strategy of Cyprus

Following the vulnerability assessment and the evaluation of the proposed adaptation measures, a document on the National Adaptation Strategy (NAS) of Cyprus to climate change was prepared. The Strategy comprises of the adaptation measures which were proposed through the MCA evaluation process in which various stakeholders and experts participated. Furthermore, the Strategy provides suggestions for the integration and mainstreaming of the adaptation measures into national and sectoral policies, strategies, plans and legislative texts. Overall, over 200 measures for enabling adaptation to the climate change impacts on the eleven policy areas of Cyprus are included in the NAS. The adaptation measures included in the Adaptation Plan are actions that are already implemented or planned, actions that are implemented but their efficiency and effectiveness needs to be enhanced and actions that are not implemented but are considered necessary for enabling Cyprus to adapt to climate change.

In the Strategy, the Sustainable Adaptation Scenario is presented, according to which equal weight has been assigned to the technical, environmental and social criteria. Considering that the economic evaluation of measures is a more complicated process, it was decided not to take into account during this phase the economic criteria, but to conduct a separate cost-benefit analysis for the selected adaptation measures.

The document on the National Adaptation Strategy of Cyprus is based on the notion that climate change is a long-term process and that is yet unclear which will be the impacts of climate change and when they are going to happen. For that reason, it is important that in parallel to the implementation of the Adaptation Strategy, a periodic re-evaluation of the vulnerability and of the proposed adaptation measures must be carried out by a specifically assigned Monitoring Team followed by the necessary adjustment and updating of the Adaptation Plan.

4. Conclusions

The results of this study provide an enlightening overview of the vulnerabilities of the different policy areas of Cyprus to climate change and of the proposed adaptation measures which can constitute the basis for a more oriented research, raising public and stakeholder awareness and active stakeholder engagement in the implementation of the National Adaptation Strategy. The methodology followed is consistent and thorough thus providing a useful tool for the competent authorities of Cyprus as well as of other countries to develop, implement and update their National Adaptation Strategies.

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