Addressing Climate Change Impacts on Agriculture: Adaptation Measures For Six Crops in Cyprus

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Abstract: The agricultural sector of Cyprus is seriously affected by climate change impacts. In the framework of the ADAPT2CLIMA project, the available techniques and methods implemented worldwide for the adaptation of six crops (wheat, barley, potatoes, tomatoes, grapes, and olives) to climate change impacts were thoroughly assessed. The identified adaptation options were categorized according to the climate change impact they address as follows: measures against drought stress, heat stress, decreasing plant health, extreme weather events and reduced crop productivity. Another category that refers to measures that address more than one category of climate change was also added. The evaluation of the identified adaptation options was based on a self-administered semi-structured questionnaire. The identified adaptation measures were graded according to the following criteria: efficiency of the measure, urgency of implementing the measure, usefulness of implementation irrespective of climate change, technical difficulty, contribution to climate change adaptation, economic viability and social acceptance. Fifty-six respondents (experts and stakeholders) filled the questionnaire, suggesting twelve recommended adaptation measures (with high score ≥ 60%), which mainly refer to irrigation adaptation measures, cultural practices, and methods for upgrading external services to farmers. The recommended adaptation measures for Cyprus are thoroughly presented and discussed.

Keywords: climate resilience; crops; Mediterranean agriculture; irrigation measures

1. Introduction

The Mediterranean region has been identified as one of the most vulnerable areas to climate change [1]. Climate changes are expected to affect many economic sectors, and agriculture is one of the most exposed, as it is highly dependent on both climatic conditions (precipitation, temperature, relative humidity) and the availability of surface and groundwater resources for irrigation purposes. The climate change impacts refer to reduced crop yields due to high temperatures, increased water demand for irrigation and reduced water availability, driven by the prolonged periods of drought and water scarcity. Negative effects on agriculture will also be exacerbated by damages to crops caused by extreme weather events. In this context, the LIFE ADAPT2CLIMA (Adaptation to Climate change Impacts on the Mediterranean islands' Agriculture) project aimed to build a solid knowledge base on the future climate changes and their impacts on the agricultural sector of three European islands in the Mediterranean basin, namely Crete (Greece), Sicily (Italy) and Cyprus. The project focused on reducing vulnerability and increasing resilience to climate change risks by assessing the effectiveness of the available adaptation measures, developing a decision support tool (ADAPT2CLIMA tool) for enabling

well-informed decision-making for adaptation planning in agriculture and, ultimately, suggesting strategies for the adaptation of the agricultural sectors of the three islands to climate change.

In the framework of the ADAPT2CLIMA project, climate change projections for Cyprus were derived by state-of-the-art Regional Climate Models (RCMs) based on the intermediate mitigation scenario (RCP4.5) and the high emission scenario (RCP8.5). For the future period 2031–2060, the climate change impacts refer to a continual, gradual and relatively strong warming, combined by prolonged drought periods and reduction of annual precipitation under both climatic scenarios (reference period: 1971–2000) [2]. Specifically, the seasonal average temperature is expected to increase for all seasons, which will be up to 2 °C for winter, 3 °C for summer and 2.4 °C for the transient seasons under the RCP4.5 scenario, and even greater under the extreme RCP8.5 scenario. Increases in seasonal average temperatures will be accompanied by increases in average winter minimum and summer maximum temperatures. Regarding mean annual total precipitation, decreases between 5% and 15% are projected under both scenarios, while mountainous regions seem to be the least affected. During the winter period, a decrease of up to 10% is expected under both climatic scenarios. For the spring period, when the current precipitation ranges from 100 mm to 300mm, a decrease of about 20–24% throughout the island is projected only under the RCP8.5 scenario. In contrast, a reduction of about 20–30% throughout the island is anticipated for summer precipitation, whereas the decrease is projected to be higher in the western coastal areas (approximately 60%). Under RCP8.5, the decrease is projected to be about 20–30% in all areas, except for the southern–southeastern coastal regions where a decrease of 50% is expected [2].

In Cyprus, the main crops of the island, which are suggested to be vulnerable to climate change impacts are: a) barley and (durum) wheat (cereals), b) tomatoes and potatoes (vegetables), and c) grapes and olives (perennial crops). For annual crops, during the last decade (2008–2018), the average areas harvested with barley and wheat were 20,902 hectares and 8028 hectares, respectively [3]. Being mainly rainfed crops, their yields remained low (<2 tons/hectare), while wheat yields were higher than those of barley (average yields: 1.92 tons/hectare vs. 1.28 tons/hectare). However, a sharp decrease in both barley and wheat yields (<0.5 tons/hectare) were recorded in 2008 due to drought stress. Moreover, potatoes are cultivated throughout most of the year in Cyprus (particularly in Larnaca and Famagusta Districts), where there are usually three crops per year (winter crop, intermediate crop, spring crop). The most popular potato variety is "Spunta", followed by the baked potato variety "Cara" and the salad type variety "Nicola". For the period of 2008-2018, the average areas harvested with potatoes and tomatoes were 4,702 hectares and 237 hectares, respectively. The average potatoes yield for all plantations (winter, intermediate, spring) was 22.5 tons/hectare but a decrease in 2010 yield (19.3 tons/hectare) was recorded, as a result of only one heavy frost event lasting for five hours [4]. The average tomato yield was significantly higher (72.1 tons/hectare) than that of other study crops, being mainly attributed to the fact that it is the only crop cultivated under greenhouse conditions [3].

Regarding perennial crops, grapes and olives are among the traditional cultivations of Cyprus. Black (Mavro) (red variety) and Xinisteri (white variety) are the main indigenous wine grape varieties, both used to produce the Cypriot wine "Coummandaria" (Protected Geographical Indication, PGI wine). Apart from the above varieties, the introduced wine type varieties of Carignan Noir, Cabernet Sauvignon and Shiraz as well as the table grape variety Sultana are the foremost important commercially cultivated varieties in Cyprus. Additionally, the landrace "Ntopia Ladoelia", which is a highly variable mixture of genetically distinct landraces, is the main olive variety (double purpose) cultivated in the island [5]. It is worth noting that "Ntopia Ladoelia" is characterized by erratic yields owing both to biennial bearing of trees and to rainfed conditions of cultivation. The second most popular grown variety is the Greek variety "Koroneiki" for oil production. During the last decade (2008–2018), the average areas with grapes and olives were 6915 hectares and 10,826 hectares, respectively [3]. The average yield for grapes and olives were 3.4 tons/hectare and 1.3 tons/hectare.

In the framework of ADAPT2CLIMA project, three crop simulation models (CropSyst, Olive model and UNIFI.GrapeML) [6–8] were used to simulate the performance of the six crops under

the projected climate changes for Cyprus [9]. For cereals and vegetables, a general advance in the phenological stages (both flowering and maturity) is expected. However, the flowering of early autumn sowing potatoes is expected to delay. The crop yield of potatoes seems to be independent from the sowing season. While the average yield loss is expected to be up to 9%, an increase was found for the early winter sowing season, ranging from 14% to 18%. Tomatoes, in all sowing seasons except the early winter, show a yield decrease by more 20–30% (based on the climatic scenarios). In addition, both early and late olive cultivars are expected to advance their flowering period for about 20 days. However, olive yield seems to be almost stable under climate changes, being probably attributed to water-resistant nature of olive trees, even though prolonged drought can adversely affect their yields. In contrast, yield losses are expected to be higher for late-matured grape varieties (24–38%) [9].

Taking into account both the projections for climate changes and their impacts on the performance of the six crops in Cyprus, it is an urgent need to develop a strategy of crops' adaptation to climate changes. To this end, the available techniques and methods implemented worldwide for the adaptation of the agricultural sector, with a focus on the six study crops, to climate changes were assessed. Furthermore, the adaptation measures were categorized according to the climate change impacts they address and evaluated based on seven criteria. Considering only the high score measures, the recommended adaptation measures for Cyprus are presented and discussed.

2. Methodology

2.1. Identification of Adaptation Measures

In 2016, an extensive literature review, including the reports of European and international organizations providing guidance on the adaptation of the six crops (barley/wheat, tomato, potato, grapes and olives) to climate changes, was performed [10–47]. An attempt has been made to avoid country-scale adaptation measures (such as using recycling or desalination water for irrigation), which were already reported in the National Adaptation Strategy to climate changes of Cyprus (incl. the agricultural sector) and are not tailored to the specific six crops. In particular, for recycled water there is a relevant action in the National Adaptation Action Plan, that aims to provide incentives to farmers for using recycled water to irrigate selected crops. However, some general measures, that can be applied to all six study crops, and/or current measures that are not so far fully adopted by farmers, were included. The identified adaptation measures were categorized according to the climate change impact they address as follows: drought stress, heat stress, decreasing plant health, extreme weather events and reduced crop productivity. Another category was suggested to be added, namely "total impact", which refers to the measures that address more than one category of climate change (e.g., drought stress, heat stress and reduced crop productivity) [48]. It is noted that heat stress is defined as the rise in temperature beyond a threshold level for a period sufficient to cause permanent damage to plant growth and development [49]. Conversely, drought stress occurs when both the humidity of the soil and the relative air humidity are low and the ambient temperature is high [50].

In total, thirty-five adaptation measures for the six study crops and the six categories of climate change impact were identified (Table 1). The general measures, those that can be applied to all study crops, are fourteen, and mostly refer to decreasing plant health and total impact on crops. The remaining 21 measures are crop-specific and categorized as follows: (a) four measures for the cereals, (b) four measures for potatoes, (c) two measures for tomatoes, (d) nine measures for grapes, and (e) six measures for olives.

Table 1. The identified adaptation measures per crop. The climate change impact (drought stress, heat stress, decreasing plant health, extreme weather events, reducing crop productivity, total impact) that they address is recorded.

Adaptation Measures	General	Cereals	Vegetables	Perrenial Crops
Drought stress				
Use of green manure for vegetables			P, T	
Earlier planting of potatoes			P	
Breeding early maturing potato varieties for shorter rainy seasons			P	
Applying deficit irrigation strategies (e.g., regulated deficit irrigation) in olive groves				O
Applying conservation tillage combined with vegetation cover in row-middle floors during winter and mulching it at the beginning of spring in olive groves				O
Applying deficit irrigation strategies (e.g., regulated deficit irrigation, partial root drying or sustained deficit irrigation) in vineyards				G
Applying the principles of conservation agriculture in rainfed cereals		B, W		
Applying zero tillage and early sowing in wheat/barley crops		B, W		
Strengthen on-farm water harvesting	X			
Applying supplementary irrigation at critical periods of the cropping season in rainfed crops		B, W		O, G
Use of efficient irrigation systems and schedule	X			
Development of water markets and setting clear water use properties	X			
Heat stress				
Applying organic mulching for olive groves				O
Enhanced low skirts (crotches) in young olive trees				O
Applying straw mulch in the inter-row of vineyards				G
Artificial shading of vineyards				G
Use of kaolin clay as sunscreen for vineyards				G
Relocating vineyards to higher elevations or higher latitude that are presently cooler				G
Applying evaporative cooling of grapevines by overhead microsprinklers				G
Decreasing plant health				
Applying principles of Integrated Pest Management (IPM)	X			
Crop rotations in the row-middle floors of the irrigated olive groves				O
Strengthen increased diversity of cultivars or crops (diversification)	X			
Development of a data base with long-term monitoring data of population dynamics of main pest and disease of study crops at project areas	X			
Development of pest risk analysis model for the project areas	X			
Development of internet-based platforms for the main pathosystems in the project areas	X			
Enhanced global networking of researchers and stakeholders at all levels across plant protection spectrum	X			
Extreme weather events				
Tomato cultivation in greenhouse			T	
Development/improvement of early warning systems	X			
Reduced crop productivity				
Intercropping with legumes		B, W	P	
Total impact				
Use of local cereal landraces and/or local vegetable and tree varieties	X			
Breeding drought/heat resistant/tolerant crop varieties	X			
Improvement of agricultural advisory and external services for building resilience to climate change	X			
Strengthen local institutional support for promotion of adaptation measures	X			

B, W, P, T, O and G refer to barley, wheat, potatoes, tomatoes, olives and grapes.

2.2. Evaluation of the Identified Adaptation Measures

To evaluate the identified adaptation measures, a group of 56 experts was selected through nonprobability purposive sampling technique using their specialized knowledge on climate change on agriculture as the main selection criterion [51]. We followed a multidisciplinary approach to include, as far as possible, experts from various agricultural (or related) disciplines, such as agronomists, climate scientists, water specialists, and agricultural and ecological economists. A self-administered semi-structured questionnaire was designed by the research team and used as the basic research tool (Table S1: The questionnaire of adaptation measures for agriculture to climate change impacts.). The questionnaire was sent to the experts via email, including a cover letter explaining the objective of the research, while their participation was confirmed by telephone. The experts were asked to assign a score to each measure on a scale between 0 and 100 on the basis of seven criteria as follows: (a) efficiency of the measure, where 0 = least efficient and 100 = most efficient, (b) urgency of implementing the measure, where 0 = least urgent and 100 = most urgent, (c) usefulness of implementation irrespective of climate change, where 0 = least useful and 100 = most useful, (d) technical difficulty, where 0 = least difficult and 100 = most difficult, (e) contribution to climate change adaptation, where 0 = least significant and 100 = most significant, (f) economic viability, where 0 = least expensive and 100 = most expensive, and (g) social acceptance, where 0=least accepted and 100 = most accepted.

The score of each criterion for each measure was calculated as the mean value of all respondents. Similarly, the score of each measure was calculated as the arithmetic mean of all seven criteria. To put it differently, a weighted average (using equal weights) of the score of each criterion was applied for calculating the total score of each measure. The assignment of equal weights to the criteria was decided by the research team of the project ADAPT2CLIMA in Cyprus after several discussions, as it was considered that all seven criteria are of equal importance. For instance, the research team unanimously agreed that social acceptance of a measure is equally important with economic viability and vice versa. In essence, equal weighting is the method most commonly used when no explicit evidence to prefer a criterion over another is available, as is the case with this study. It is noted that regarding criteria (d) and (f), the scores assigned by experts were reversed (viz. 100–actual score) since they are having a negative impact on the total score for each measure. In addition, the questionnaire included an open-ended question, where experts could propose and grade on the same scale any additional measures other than those identified by the research team. All calculations were executed using EXCEL 2016.

3. Results

Fifty-six respondents filled the questionnaire. All the respondents came from the project areas (Cyprus, Italy and Greece) except for two persons from Spain. Most of them were either researchers in relevant fields (39%) or government employees (50%).

3.1. Score of the Identified Measures

Based on the overall ranking for the separate criteria used, the average score for the identified measures ranged from 69% ("the use of efficient irrigation systems and schedules") to 34% ("Applying evaporative cooling of grapevines by overhead microsprinklers") (Table S2: Average score (mean ± SD) of each criterion and score for the general adaptation measures. Number of respondents is given in parenthesis, Table S3: Average score (mean ± SD) of each criterion and score for the crop-specific adaptation measures. Number of respondents is given in parenthesis.). In terms of efficiency, the general measure of "the use of efficient irrigation systems and schedules" was considered by far the most efficient measure (87% average score), while "applying supplementary irrigation at critical periods of the cropping season in rainfed crops" came second (82%). In contrast, the crop-specific measures of "enhanced low skirts (crotches) in young olive trees" (heat stress group) is characterized as the less efficient measure (50%). As far as urgency of implementation is concerned, "the use

of efficient irrigation systems and schedules" was ranked first (80%), while "applying evaporative cooling of grapevines by overhead microsprinklers" ranked last (31%). Regarding their usefulness of implementation irrespective of climate change "the use of efficient irrigation systems and schedules" was ranked first (85%) and "improvement of agricultural advisory and external services for building resilience to climate change" and "applying principles of Integrated Pest Management-IPM" came second (77%). Based on their technical difficulty the crop-specific measures of "earlier planting of potatoes" and "use of green manure for vegetables" are considered the easiest to implement (43%). The general measures of "use of efficient irrigation systems and schedules" (77%), "strengthen on-farm water harvesting" (72%) (drought stress group) and "improvement of agricultural advisory and external services for building resilience to climate change" (72% average score) are considered as the most significant contributors to climate change adaptation. "Artificial shading of vineyards" (79% average score), "relocating vineyards to higher elevations or higher latitude that are presently cooler" (72%) and "applying evaporative cooling of grapevines by overhead microsprinklers" (72%) were ranked as the most expensive to implement. Conversely, the crop-specific measures of the "earlier planting of potatoes" (38%) and the "use of green manure for vegetables" (38%) were ranked as the less expensive to implement. In addition, "improvement of agricultural advisory and external services for building resilience to climate change" (81%) and "development/improvement of early warning systems" (79%) are considered as the most socially accepted measures, while "applying evaporative cooling of grapevines by overhead microsprinklers" (27%) and "relocating vineyards to higher elevations or higher latitude that are presently cooler" (35%) were ranked as the less socially accepted measures.

Apart from the identified adaptation measures, four adaptation measures have been proposed as follows: a) Education of farmers in matters of irrigation, fertilization, plant protection, cultivation techniques, b) Promotion of precision agriculture and adaptation of agricultural robotics and Information Communication Technologies (ICT-Robotics), (c) Agricultural education in climate change issues, and (d) Pricing of irrigation water (application of the revised price of water).

3.2. The Recommended Adaptation Measures

The adaptation measures that scored the highest average rating (≥60%) were considered appropriate to be included in the adaptation strategy of climate changes impact on agricultural sector in Cyprus. In total, 12 adaptation measures have been selected, which refer to (a) irrigation adaptation to climate changes (drought stress group, 4 measures), (b) decreasing plant health group (2 measures), (c) cultural practices, namely intercropping with legumes and the use/breeding of local/stress resistant varieties (a combination of reduced crop productivity and total impact groups, 3 measures), (d) methods for upgrading external support of farmers (total impact group, 2 measures), and (e) efficient early warning systems (extreme weather events group, 1 measure) (Table 2).

Regarding the measures of drought stress group, the general measure of "the use of efficient irrigation systems and schedules" is suggested to be more efficient, urgent and with higher contribution to adaptation to climate change impacts compared to the crop specific measure of "applying deficit irrigation strategies (e.g., regulated deficit irrigation) in olive groves" (Figure 1). However, the latter measure found to be the easiest to implement. Conversely, all the recommended irrigation adaptation measures proved to be highly socially accepted (≥65%), apart from "strengthen on-farm water harvesting" (58%).

Table 2. The average total score (mean ± SD) of the recommended adaptation measures. The category of the measure and the number of respondents for each measure (N) are given.

Recommended Adaptation Measure	General	Crop-specific	N	Total Score (%) (Mean ± SD)
Drought stress				
Use of efficient irrigation systems and schedules	X		54	69 ± 10.5
Strengthen on-farm water harvesting	X		55	60 ± 14.4
Applying supplementary irrigation at critical periods of the cropping season in rainfed crops		X	55	62 ± 10.7
Applying deficit irrigation strategies (e.g., regulated deficit irrigation) in olive groves		X	52	64 ± 13
Decreasing plant health				
Applying principles of Integrated Pest Management (IPM)	X		56	65 ± 12.9
Strengthen increased diversity of cultivars or crops (diversification)	X		54	60 ± 14.6
Extreme weather events				
Development/improvement of early warning systems	X		55	64 ± 12.2
Reduced crop productivity				
Intercropping with legumes		X	53	64 ± 13.8
Total impact				
Improvement of agricultural advisory and external services for building resilience to climate change	X		55	68 ± 8.8
Strengthen local institutional support for promotion of adaptation measures	X		54	66 ± 10.1
Breeding drought/heat resistant/tolerant varieties	X		55	61 ± 15.5
Use of local cereal landraces and/or local vegetable and tree varieties	X		54	63 ± 16.3
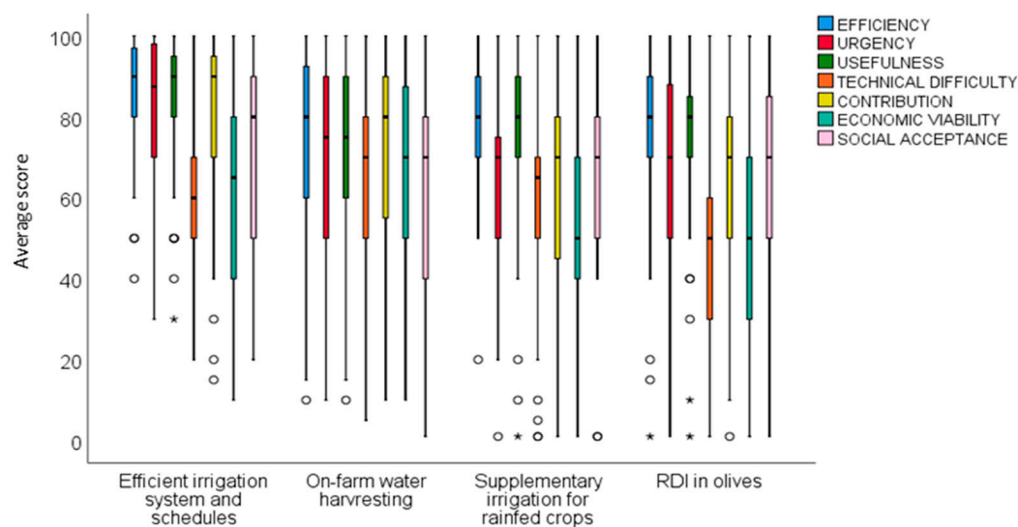
Figure 1. Box plots of the average score of each of the seven criteria for the recommended measures of drought stress group that address irrigation adaptation options to climate change impacts on agricultural sector in Cyprus.

According to the respondents, the three recommended cultural practices are highly efficient (≥72%) and useful for implementation regardless of climate change impacts (≥68%). In addition, the implementation of "intercropping with legumes" (48%) for cereals and potatoes is easier than that of "breeding drought/heat resistant/tolerant varieties" (61%). Nonetheless, the cost for "breeding drought/heat resistant/tolerant varieties" (60%) proved to be higher than that for "use of local cereal landraces and/or local vegetable and tee varieties" (48%) or "intercropping with legumes" (48%). Accordingly, the respondents suggested that the cultural practice of "use of local cereal landraces and/or local vegetable and tree varieties" (70%) could be more socially accepted than ""breeding drought/heat resistant/tolerant varieties" (62%). Both the recommended measures of decreasing plant health group were considered as easy to implement (≤53%) and cost effective (≤52%). However, the implementation of the measure "applying principles of Integrated Pest Management (IPM)" found to be more efficient, urgent, and useful and socially accepted than the measure "strengthen increased diversity of cultivars or crops (diversification)".

As far as the measures for upgrading external support to farmers are concerned, both of the identified measures were ranked high in the list with recommended measures (Table 2). The measures were evaluated as highly efficient, urgent, socially accepted, useful and with high contribution to adaptation to climate change impacts (≥69%), while they are characterized as low cost and easy to be implemented (≤56%). In addition, the measure "Development/improvement of early/warning systems" suggested to be high socially accepted (79%), despite its technical difficulty (65%) and cost of implementation (63%). Nonetheless, the efficiency of the measure is suggested to be high (78%), while its implementation is considered as useful (75%) and urgent (77%) for coping with extreme weather events.

4. Discussion

4.1. Irrigation Adaptation To Climate Change Impacts

Climate change impacts on precipitation patterns and their distribution through the year increase the demand for water, due to increased crop evapotranspiration, and increase water shortages, particularly in the spring and summer months [52]. Even though the agricultural sector in Cyprus is already facing water shortages, climate changes are expected to cause greater problems on groundwater quality and quantity in the future due to increased water demand for irrigation, resulting in decreased

water availability and deterioration of water quality. In this sense, it is not surprising that the highest scored measures aim to improve water use efficiency in irrigation. Specifically, the general measure of "the use of efficient irrigation systems and schedules" ranked first in the list with the recommended measures. The appropriate irrigation infrastructure is expected to reduce water losses and increases irrigation efficiencies [11]. To this end, public policies systematically provide subsidies (e.g., through the Rural Development Programme) for investment in efficient irrigation systems (drip and microsprinklers systems), especially for high-valued crops [53]. Besides the efficient irrigation systems, following an irrigation schedule based on monitoring of specific parameters (climate, soil, weather, trees respond, and system efficiency) is also required for successfully alleviating drought stress. However, farmers should be aware of adjusting their farm-specific irrigation schedule throughout each season and from year to year. The implementation of the measure "strengthen on-farm water harvesting" (67%), which allow for the building of on-farm storage reservoirs (either individually or shared with neighboring farms) as well as the installation of rainwater harvest equipment, which is suggested to be more costly than "the use of efficient irrigation systems and schedules" (62%). However, the efficiency of the measure remains high (75%), and its implementation is useful (72%) and urgent (71%) for coping with the great uncertainty in seasonal precipitation patterns.

Conversely, the general measure of "development of water markets and setting clear water use properties" with a score of 49% was excluded from the recommended measures. Water markets refer to water resources reallocation both between and within sectors. In the agricultural sector, water is usually reallocated from crops with a low to high marginal value of water. For example, high-value crops, such as fruits and vegetables, remain a priority for water markets compared to low-value crops, such as cereals or rice. In areas with abundant water availability, farmers can purchase water in the market as contingency in dry years, instead of investing in efficient irrigation systems with high capital investment that may be needed only in dry years [53,54]. Nevertheless, the respondents pointed out the limited social acceptance of the measure (40%), which is a common concern about water markets, along with the conflict among different stakeholders [55]. Despite of the water allocation problems that may arise, a comparative study between water market and irrigation subsidy policies has evidently dedicated the advantages of water markets over irrigation subsidies for the countries in Southern Europe [53].

Crop-specific measures that improve water use efficiency in irrigation raised recommended adaptation options as well. The measure of "applying supplementary irrigation at critical periods of the cropping season in rainfed crops" ranked as highly efficient (82%) and not expensive enough for implementation (53%). Indeed, the rainfed cereals and vineyards are expected to respond favorably to supplementary irrigation while, for rainfed olive trees, the periods just before flowering and at stone hardening are critical for applying supplementary irrigation. On the other hand, the improvement of water use efficiency for irrigated olive groves allow mitigation of drought stress impact on olive trees by reducing losses from the system (evaporation and runoff) and increasing the effectiveness of stored soil moisture. Deficit irrigation strategies are purposed for regions under conditions with high water scarcity with aim of lowering water usage for irrigation purpose [20]. Applying regulated deficit irrigation (RDI) methods, along with the monitoring of climatic conditions, trees' status and soil moisture, will improve the water use efficiency of olive groves and allow accurate irrigation scheduling. For example, the night-time irrigation of olive groves can markedly improve water utilization efficiencies and conserve water, especially during the summer months. The respondents also suggested that the measure "applying deficit irrigation strategies (e.g., regulated deficit irrigation) in olive groves" is not expensive (48%) and the easiest (45%) to implement.

Conversely, the three deficit irrigation strategies being commonly applied in vineyards (Regulated deficit irrigation (RDI), partial root drying (PRD) and sustained deficit irrigation (SDI)) are marginally excluded from the recommended adaptation options. According to the respondents' perspective, the implementation of the relative measure ("applying deficit irrigation strategies (e.g., regulated deficit irrigation, partial root drying or sustained deficit irrigation) in vineyards") is expected to have a rather

low contribution in alleviating the impacts of climate change in vineyards (59%) and the urgency of implementing the measure is not high enough (57%). Even though the technical difficulty of the measure ranked low (50%), RDI in vineyards is a specific practice at a specific time. Factors, such as soil type, weather and stage of growth, should be considered for irrigation scheduling and avoiding regulated deficit irrigation shortcomings [49].

4.2. Measures Related To Cultural Practices

The measure "use of local cereal landraces and/or local vegetable and tree varieties" is the most socially accepted among the recommended cultural practices, and it can also be implemented without any serious technical difficulty (52%). Given that local varieties or landraces of the six crops are proposed to be better adapted to the hot and dry conditions, the measure is considered as highly efficient (72%) and useful for implementation irrespective of climate change impacts (72%). However, in absence of local varieties, the measure "breeding drought/heat resistant/tolerant varieties" is an urgent need. For grapevines, breeding programs should focus on the development of very late ripening genotypes or genotypes able to produce high quality wines under elevated temperatures since the phenological stages of vines are expected to advance under warmer conditions. For tomatoes and potatoes, wild relatives of *Solanum* species are of utmost importance for breeding abiotic stress tolerant varieties. Specifically, *Solanum* species have evolved under a wide range of geographical and climatic conditions, and thus offer a vast diversity of tolerance traits for breeding [56,57]. Several breeding programs have so far yielded potato cultivars or hybrid clones with increased tolerance to high temperatures [47]. Despite the high efficiency of the measure (76%), the respondents pointed out the technical difficulty in breeding for abiotic stress (61%) as it usually takes 12–20 years for breeding a new variety and plant abiotic stress tolerance is complex enough.

Another recommended cultural practice is the "intercropping with legumes" for cereals and potatoes. The measure aims at increasing crop productivity through enhancing the nutrient/supplying availability of the soil. Specifically, intercropping (growing multiple crops on one plot) or crop rotations with legumes support biological N-fixation and prolong slow-release of N from complex organic modules from soil organism, boosting soil health [46]. According to the respondents, the measure of "intercropping with legumes" is characterized as efficient (73%), useful for the implementation, irrespective of the climate change (74%), not expensive to be implemented (48%) and socially accepted (63%). It is noteworthy that its implementation is considered to be the easiest among the recommended cultural practices, because intercropping with legumes has so far been a common practice for cereal and potato growers in Cyprus.

4.3. Measures for Enhancing Plant Health

Crop losses due to pests can account of up to more than 40% worldwide [58]. Under climate change scenarios, temporal interactions among weather, cropping systems and pests become more and more unpredictable [59]. Faced with uncertainty and decreased plant health, "no regrets" measures of crop protection that refer to potential worst cases scenarios are strongly recommended [41]. The measures of "applying principles of Integrated Pest Management (IPM)", "strengthen increased diversity of cultivars or crops (diversification)" and "development/improvement of early warning systems" were ranked high as useful for implementation irrespective of climate change impacts (No regrets measures) (≥61%). Regarding diversification, crop rotation enables cropping systems to become less vulnerable to a build-up of diseases, weeds and insect pests [14]. It has been found that the overall population of weeds in the cropping system can be reduced significantly when cereals and legumes are rotated and appropriate herbicides used in each phase [60]. Moreover, mixing varieties (e.g., potatoes) enhances biodiversity within a plot, thereby reducing the plot's vulnerability to different weather impacts and minimizing the risk of yield loss due to diseases and pests, as well. In addition, IPM systems integrate cultural, biological, and chemical control methods to reduce harmful insect populations below a threshold that otherwise will cause economic losses. IPM strategies are widely used because they are

dynamic and can be internally diversified to locally adapt cropping systems. However, in the face of climate change, the locally adaptive and diversified IPM systems have to be redesigned so that to become resilient enough to meet extreme weather fluctuations and the invasive pests in an area [41]. To this end, the recommended measure of "development/improvement of early warning systems" (64% overall score) is suggested to be an efficient measure (78%) for coping with extreme weather events, supporting farmers to apply efficient IPM systems. Indeed, early warning systems can alert farmers about imminent extreme weather events and enable them to take protection measures in time.

4.4. Measures for Upgrading External Support

As the climate changes, so does the role of agricultural advisory and extension services. Farmers need wide-ranging advice both on available options to help adapt farming systems and on the climate itself (e.g., weather forecasts, seasonal forecasts and longer-term climate trends). It seems that, after several years of declining investment, the urgent need for climate adaptation provides an opportunity to revivify extension services, and the respondents took the opportunity to stress it out. However, improved extension services ought not to provide "one-size-fits-all' solutions or static advice (e.g., fertilizer packages) [44]. Extension and advisory services are obligated to collaborate with public and private research centers for sharing indigenous and scientific knowledge to farmer. Local institutions can also support farmers by i) producing and sharing knowledge, and ii) providing financial services, credit, and access to markets. In this context, institutions can produce and share information and help resource-poor smallholder farmers translate information into knowledge and action. These institutions include: i) farmer field schools that train and enable farmers to adopt new techniques, ii) farm radio shows that provide easily accessible, useful and needs-driven agricultural and weather-related information to farmers, and iii) local agricultural demonstration plots and events. Regarding financial support, the benefits gained by adopting adaptation measures for farming systems against climate changes usually take time to materialize, and most farmers with limited access to credit and markets cannot afford it. It is therefore important to strengthen institutional support to farmers by providing credit, insurance, social safety nets, and payments or rewards for environmental services [44]. In line with the respondents, the two recommended measures for upgrading external support are not technically difficult (54–56%) or expensive (50–53%) to be implemented, while they are highly efficient (77–78%) and socially accepted (77–81%).

5. Conclusions

For coping with climate change impacts on agricultural sector in Cyprus, twelve adaptation measures are proposed for being included into adaptation strategy, based totally on the experts' prioritization. The recommended adaptation measures are mostly general measures that address irrigation and plant health issues. Measures related to cultural practices are also included, focused mainly on the selection of local or stress resistant crop varieties as well as intercropping with legumes in cereal and potatoes. Moreover, the adaptation measures underlined the need for upgrading agricultural advisory services and institutional support for promotion of adaptation measures.

Even though the selection of the above adaptation options was the result of an evaluation process based on the subjective judgement of experts, this approach, besides any limitations, remains a pragmatic and fast way of assessing complex phenomena [61,62], such as the one presented in this article (viz. climate change adaptation in a cross-sectional study). However, it can be considered as the first step in order to have the recommended adaptation measures selected, tailored and applied as appropriate for the context, including agroecological zones, farming systems as well as cultural and socioeconomic context due to the diversity within agricultural systems [44], because the recommended adaptation measures are context specific in both space and time [63]. In this sense, further research is needed to evaluate the response of the recommended measures to adaptation of Cypriot agriculture to climate change impacts using field experiments based on sound methodological processes.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-4433/11/5/483/s1, Table S1: The questionnaire of adaptation measures for agriculture to climate change impacts, Table S2: Average score (mean ± SD) of each criterion and score for the general adaptation measures. Number of respondents is given in parenthesis, Table S3: Average score (mean ± SD) of each criterion and score for the crop-specific adaptation measures. Number of respondents is given in parenthesis.

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