Terrace Landscapes as Green Infrastructures for a Climate-smart Agriculture to Mitigate Climate Change Impacts

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Abstract. Climate change is anticipated to impact adversely diverse levels of organized life. Mediterranean countries, counting Greece encounter the problem of increased desertification, with its islands being listed as areas of high risk. The Aegean islands are faced with major confrontations as areas of abandoned terraces with low vegetation cover. Nowadays, terrace fields are crucial as green infrastructures to mitigate climate change impacts, as they improve rainfall absorbency, reduce soil erosion, smooth extreme summer temperatures, moderate the risk of floods and forest fires while preserve the biodiversity and ecosystems services. LIFE–TERRASCAPE project aims to revitalize island terrace farming, through the implementation of Land Stewardship (LS) enterprise for the first time in Greece, in association to Information and Communication Technologies (ICT) applications. The study aims to measures of innovative agricultural establishment and production as an integrated adaptation strategy that elaborates new technologies and methods to mitigate climate change to terrace landscapes in island ecosystems. The cultivation plan and the technologies implemented to terracing restoration to protect land resources are presented and discussed.

Keywords: Climate change; agriculture; local landraces; ecosystem sustainability; innovation.

1 Introduction

Terrace cultivation is the method of growing crops on sides of hills or mountains by building graduated terraces into the slope. This method has been employed effectively for centuries to maximize arable land area and to avoid soil erosion and water loss. Terrace farming is the principal method for cultivation in the dry and poor soils of Aegean islands in Greece, supporting the agrarian communities, providing ecosystem services and preserving the biodiversity. On the other hand, the demographic changes in rural populations along with the urbanization have led to terrace abandonment and land-use alterations. Climate change and land-use alteration

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including abandonment threaten environment and rural communities sustainability (Pereira et al. 2012). Sustainable land management and policy intervention can contribute to reducing the negative impacts of climate change, support restoration of ecosystems and safeguard their sustainable use and rural development (Schadler et al. 2019).

Climate change and food security remain the main challenges of the 21st century. Climate change describes the long-term shift in global or regional weather patterns, and it is highly associated with the rise in global average temperatures. Terrace abandonment has a key role in amplifying the impacts of climate change with tremendous adversities to both the landscape and the communities (Giordan et al. 2017). The LIFE-TERRACESCAPE project centers on the restoration and re-cultivation of abandoned terraces at a multifunctional approach. The cultivation of terrace lands aims to a climate smart agriculture system to benefit both the society and the economy and lessen the climate change effects. The study presents the cultivation of terraced lands as functional green infrastructures using new technological applications to foster rural development.

2 Research Area

Most islands of the Aegean Sea are confronted with strong desertification issues. The impacts of climate change are being already noticed in the weather conditions of each area. Aegean islands are characterised by intense relief and low vegetation cover and thus, are listed as high-risk areas. Changes in the climate conditions are expected to influence negatively local biodiversity, ecosystem services, soil structure and composition, water reserves, and finally the primary production and economic activities on the islands (Karamanos and Voloudakis, 2011). Terrace cultivation has been for years the main cultivating system of perennial and arable crops on the islands of the Aegean Sea. However, during the last decades a significant drop in cultivation rate is noticed in these rural areas. The abandonment of terrace fields is often followed by massive soil movement due to stone walls collapse, surface water runoff, decline in soil depth and moisture, slope instability phenomena, and general alteration of the island landscape (Morreno de las Herras et al. 2019; Van Der Sluis et al. 2014). It becomes obvious thus, that terraces could be considered as 'climate-smart landscapes' that promote ecosystem resilience and adaptability to climatic change.

The study research area is located in the island of Andros. Nowadays terrace cultivation is indispensable to maintain sustainable development, food security and adequacy to control soil erosion and protect land resources. Fig. 1 presents the area of terrace cultivation in Andros island.

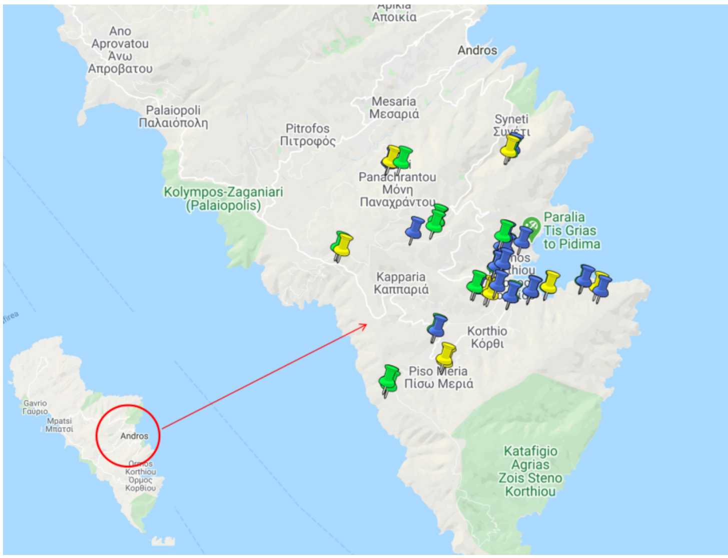

Fig. 1. The intervention area in Andros island. Terrace cultivation is shown with blue and green pins, meteorological station system is depicted by yellow.

2.1 Land use cultivation and study design

The re-cultivation plan of the study is based on the selection of appropriate crops and varieties, which will contribute to the mitigation of climate change, as well as to the production of high-added value products. Therefore, emphasis is given in the use of local landraces, which are considered valuable genetic resources due to their high adaptability to the indigenous climate and landscape conditions (microclimate, soil composition, soil slope, geological and architectural peculiarities), preserving and promoting biodiversity. Cultivation operation plan integrates a selection of local varieties of cereals, legumes and vegetables for terraces restoration as green infrastructures. Barley landraces are included due to their high tolerance to drought conditions, compared to wheat and other cereals. Legumes are considered a rich protein source in human and animal diet, but more importantly, legumes can be used for the enrichment of poor soils (typical of the island landscape) due to their ability to fixate nitrogen. The selected crops are finally used in cropping schemes of low-input and organic farming as "climate-smart" and friendly cultivars. Native biodiversity is enhanced by the reinstatement of local landraces, the use of cropping mixtures and low input-farming.

2.2 Implementation of Land Stewardship (LS) and ICT applications

The Land Stewardship (LS) enterprise is utilized for the first time in Greece as a strategic method to encourage active participation of local bodies and land users, in terrace re-cultivation through a land consolidation scheme. The LS enterprise aims to transcend land fragmentation and cost-input resources to enhance sustainable terrace cultivation and benefits. Taken into account the geomorphological difficulties of terrace cultivation an operational cultivation plan in association to appropriate machinery and cutting edge technological applications, are engaged. Adequate terrace machinery and man-power are both key drivers of terrace cultivation and productivity sought by the LS enterprise. Thus terrace-machinery is used in rotation by LS members to enable all agricultural practices such as soil preparation, sowing, weed management, and crop harvest.

Moreover, the Information and Communication Technology (ICT) applications used contribute significantly to the efficient utilization of natural resources, to support a climate-smart agriculture. Thus a widespread meteorological system was established in several sites across the cultivated terraces. This meteorological system provides a thorough monitoring of local climate conditions and a crucial record of climate change impact on the surrounding area. Data collected from the meteorological stations are further used for the development of local weather forecast and models that are indispensable to climate smart agriculture. In this study, projections derived from a state-of-the-art Regional Climate Model (RCM) -within the framework of EURO-CORDEX- were used to examine the potential future climate changes in the Aegean region. The RCA4 regional climate model SMHI (Collins et al., 2011; Martin et al., 2010) with boundary conditions from the global HadGEM- ES model of the Met Office Hadley Centre (MOHC) was found to give the best results for the Aegean region following evaluation. In order to depict future climate changes, maps for the Aegean area were constructed along with the analysis in climatic indices relevant to extreme phenomena and agriculture, based on models' temperature and precipitation simulations at a horizontal resolution of approximately 12km. The selected climatic indices which directly or indirectly affect agriculture in the examined area were: mean maximum (T_{max}) temperature; Number of days with: T_{max}>30°C (hot days), T_{max}> 35°C (heatwave days); Total Precipitation (PR); Maximum length of dry spell (consecutive days with PR<1mm). Changes in climate indices between control period (1971-2000) and two future periods, the near- and distant future period (2031-2060 and 2071-2100, respectively) were examined under two new IPCC emissions scenarios, namely the RCP4.5 and the RCP8.5, representing the medium mitigation scenario and the high emission scenario, respectively (Table 1).

Table 1. Changes of climate indices for Aegean region between the near future period 2031-2060 or the distant future period 2071-2100 and control period 1971-2000, under the future scenarios RCP4.5 (weak climate change mitigation scenario) and RCP8.5 (non-mitigation scenario with high emissions), based on the projections of the selected Regional Climate model.

	Climatic changes / Differences - Near future (2031-2060)							
Climatic Index	**Cyclades**		**Dodecanese**		**Central Crete**		**N Aegean**	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Hot days (d/y)	+27	+27	+25	+25	+25	+30	+20	+25
T_{max} (°C)	+3	+5	+4	+5	+2	+3	+3	+4
Heatwaves	+2	+6	+10	+20	+2	+5	+10	+30
PR (%)	-7	-7	-5	-5	-5	-5	-5	-5
Maximum length of Dry spell (d/y)	+40	+50	+40	+45	+25	+34	+34	+40
Climatic changes / Differences - Distant future (2071-2100)								
Hot days (d/y)	+30	+35	+25	+30	+35	+60	+25	+30
T_{max} (°C)	+4	+6	+5	+6	+4	+6	+6	+6
Heatwaves	+25	+30	+40	+50	+12	20	+35	+48
PR (%)	-15	-25	-15	-25	-15	-25	-15	-25
Maximum length of Dry spell (d/y)	+40	+50	+40	+50	+50	+60	+55	+60

Implemented ICT and applications are closely linked to the cultivation operation plan for better utilization of natural resources. More precisely, rainfall frequency and distribution throughout the growing season play a major role and actually determine the kind of crops to be cultivated in the area. The cumulative precipitation (mm) for two growing seasons (2018-2020) in Andros island (Fig.2) shows that there is significant rainfall during the period February to June, which coincides with the critical growing stages of the winter crops. Crops like barley and legumes have increased need for water supply during the seed filling stage (April to early May), and thus take full advantage of the available "green water" (rainfall water that is stored as soil humidity).

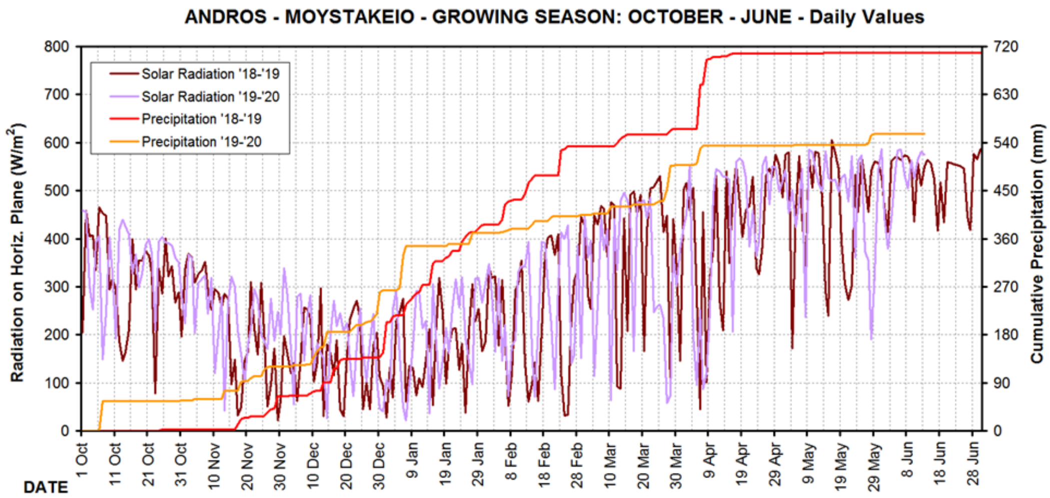

Fig. 2. Cumulative Precipitation and Solar radiation in Andros island during two growing seasons (2018-2020).

All meteorological data is available and accessible to every farmer through a user-friendly mobile application. The latter enables them to organize efficiently terrace cultivation and management, according to local weather conditions. Furthermore a Geographic Information System (GIS) application depicts the selected cultivated terraces in association to soil chemical analyses in order to develop a spatial map of terrace cultivation impacts on soil composition and properties. Knowledge of soil composition counting nutrient status, soil-type, and soil organic matter is a powerful tool in decision-making process of crop cultivation, and management of integrated farming systems and natural resources.

3 Conclusions

According to primary results from the re-cultivated terraces in Andros island, the selected local varieties show a good adaptability to the island landscape and microclimate conditions. Grain and legume cultivations were characterised by high "green" water use efficiency (WUE), taking full advantage of the rainfall period on the island during the growing season. Terrace cultivation enhances soil organic matter and increased soil's water holding capacity, thus lessening the impact of run-off water and soil erosion. Moreover, legumes crops are widely known for their impact on soil fertility and structure due to the symbiotic nitrogen fixation ability. Crop yield and quality were also assessed. Physicochemical analysis of the produced crops showed high content of micro and macro nutrition elements, which can be further exploited by local industries for the production of added value products of origin, in support of the local economy.

The cultivation system of terrace fields is expanding and the influences on climate change mitigation are encouraging. It becomes obvious that modernization of the agricultural land management and primary production can be achieved by introducing innovative technologies and applications to traditional practices, paving thus, the transformation path towards a climate smart agriculture. Therefore, implementation of geospatial technological innovations, including GIS, remote sensing and precision agriculture are crucial to substantially support natural resources management and effective crop forecasting, to reduce crop uncertainty and chemical footprint towards a sustainable agriculture development.

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Conflicts of Interest: The authors declare no conflict of interest.

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