



# Sustainability aspects of energy crops in arid isolated island states: the case of Cyprus



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## ABSTRACT

The promotion of policies aiming to the establishment of sustainable energy crops cultivation is currently one of the major efforts in the field of biomass. Stakeholders and experts are struggling to define and adopt those measures which will enable the promotion of appropriate energy crops. This study examines sustainability aspects of energy crops promotion in Cyprus, an island state in the Mediterranean, with arid climate, limited water resources, yet with strict biomass penetration targets arising from the European 2020 policy. The main input in this study is the detailed characterization of the performance of six energy crops in Cyprus. Through a multicriteria analysis, this work prioritizes the suitability of these crops in Cyprus, based on specific quantitative criteria. The sustainability of the most promising energy crops that result from this process are assessed both in terms of the production costs as well as of the potential production yield using Geographical Information System (GIS). According to the outcome of this analysis, it is shown that the possibility of promotion of energy crops in Cyprus is extremely limited and in any case insufficient to satisfy the expected contribution of biofuels in the energy mix of the island. Also the results prove that the production costs result to a non-competitive price compared to the commodities prices of the examined grains in the national market. Based on the findings of this study, strategic guidelines for the development of a framework for the sustainable promotion of energy crops in Cyprus are provided as food for thought.

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## 1. Introduction

The environmental and climate change awareness has significantly enhanced the driving force for innovation in the fields of science, technology and policy the past few years. Following the international commitment for a reduction of the Greenhouse Gases (GHGs) to at least 80% below the benchmark 1990 levels by 2050, signed under the Kyoto Protocol, the European Union (EU) has decided on several challenging targets addressed to its Member States. More specifically the Member States are asked to fulfil the obligation for a 20% contribution of the renewable energy sources (RES) to their national overall energy consumption by 2020 and a 10% contribution of RES to the transport sector, under the Directive 2009/28/EC (European Parliament and Council, 2009, 2012) on renewable energy. According to the 2009/28/EC directive

(European Parliament and Council, 2009, 2012), biomass is defined as the biodegradable fraction of products, waste and residues from biological origin from agriculture, forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste. Furthermore the European Parliament and Council aim to the transition to biofuels that deliver substantial greenhouse gas savings when also estimating the indirect land-use change emissions (European Parliament and Council, 2009, 2012). Energy crops, plants grown especially to make biofuels such as biodiesel and bioethanol, are considered as a main biomass source. Cyprus, being a EU member state since 2004, is faced with the challenge of utilizing biomass derived from all possible sources, including energy crops.

The scope of this study is to examine the potential contribution of energy crops to the production of biofuels in an isolated island state with limited water resources and arid climate, namely Cyprus. Considering that currently Cyprus has no policies for the promotion of energy crops, the objective is to answer whether encouraging energy crops production through legislation and incentives would be beneficiary towards fulfilling the European target for biomass

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## Nomenclature

### Abbreviations

AHP	Analytic Hierarchy Process
ARI	Agricultural Research Institute
DEM	Digital Elevation Model
DTM	Digital Terrain Model
ELECTRE	ELimination Et Choix Traduisant la REalité
EPIC	Erosion productivity impact calculator
EU	European union
GAIA	Graph Alignment, Identification and Analysis
GIS	Geographical Information System
IE	Inference engine
MAUT	Multi-attribute utility theory
MCA	Multicriteria analysis
PROMETHEE	Preference Ranking Organization Method
RES	Renewable Energy Sources
TOPSIS	Technique for order preference by similarity to ideal solution

utilisation. In this study cultivation data from a pilot energy crops study conducted by the Agricultural Research Institute (ARI) of Cyprus will be obtained and further evaluated using a multicriteria analysis (MCA). The findings of this analysis will be further exploited to perform cost and quantification assessments, namely feasibility and GIS analyses. Lastly recommendations related to the energy crops potential and utilisation will be provided.

## 2. Literature review

Although the accepted perception for biomass utilisation and biofuels is that they significantly aid to the atmospheric GHG budget reduction efforts and raise the national energy security, some question whether they are genuinely sustainable processes. [Koh and Ghazoul \(2008\)](#) argued that the land use change, for instance clearing lands for energy crops cultivation, causes the release of the stored carbon in the above- and below-ground biomass, thus contributing to the atmospheric GHG emissions. [Fargione et al. \(2008\)](#) claimed that clearing lands to produce biofuel feedstock create a carbon deficit, which applies to both direct and indirect land use changes. They defined carbon debt as the amount of CO<sub>2</sub> released during the first 50 years of the land conversion process. For the two most common ethanol feedstocks, the study found that sugarcane ethanol produced on natural cerrado lands would take about 17 years to repay its carbon debt, while corn ethanol produced on U.S. central grasslands would result in a repayment time of about 93 years. Accordingly, [Gawel and Ludwig \(2011\)](#) highlighted the significance of putting forward appropriate national and international climate change, energy and agrarian policies that are based on full information regarding adverse effects caused by land use change. Due to the limited availability of land for cultivation purposes, sustainability issues and land use management practices are crucial aspects that must be taken into consideration towards defining a strategy for the promotion of energy crops in Cyprus, as also discussed in [Stürmer et al. \(2013\)](#) for the case of Austria. Furthermore, biofuel policies have significant impacts on food and energy prices, and on land-use. [Martinet \(2013\)](#) has stated that the magnitude of these effects depends on the market response to price, and consequently on the agricultural supply curve that in turn depends on the land availability and relative prices. In the global effort to tackle with both increasing demand for food and energy, biofuels have been blamed for the observed rising in the prices of major food commodities. ([Harrison, 2009](#))

The degree of sustainability of biomass utilisation is determined by the economic, environmental and social growth derived by the whole process. Ultimately, the final product— bioenergy— should be cost- competitive to both fossil fuels and food, less energy- intensive and environmentally- harmful than the current practises, and contribute to the improvement of the quality of life of the society through its consumption. However, the controversy of the degree of sustainability of biomass utilisation for biofuel production has been widely presented in literature. [Asal et al. \(2006\)](#) analysed the extent to which the adoption of a specific development scenario would contribute to the sustainable development of Argentina. [Faaij and Domac \(2006\)](#) also discussed the methods by which sustainable bioenergy production could be realised, additionally to the assessment of the potential of the international bioenergy market. The case study of sustainable biomass utilisation for energy purposes in India was presented in [Kumar et al. \(2009\)](#), whereas the debate for the sustainability of biofuels production has also been put under the test for the case of Brazil. [Finco and Doppler \(2010\)](#) have evaluated the relationship between small-scale oil seed activity and food production and the deforestation of the native forests by developing different scenarios using a model that took into consideration a range of environmental and socio-economic indicators. In their works [Kochaphum et al. \(2013\)](#) and [Ajanovic \(2011\)](#) also concluded that food prices were not significantly affected by biofuels production. Also in [Sliz-Szkliniarz \(2012\)](#), it was concluded that the cultivation of energy crops was not likely to affect the food supply independence over the medium-term in Kujawsko–Pomorskie in Poland.

A scenario analysis for worldwide energy crop potentials up to 2050 was performed in [Thrän et al. \(2010\)](#). Out of the three scenarios developed, amongst which the ‘sustainable land use’ scenario indicated the lowest potentials with 18 EJ in 2010 and 16 EJ in 2050. [La Rovere et al. \(2011\)](#) identified the benefits of ethanol production in Brazil including increased energy security, foreign exchange savings, and employment, and reduced urban air pollution and carbon dioxide emissions. In [Terrapon-Pfaff et al. \(2012\)](#) the potential of second generation energy crops, namely sisal residues in Tanzania was assessed. Also having in mind the use of global forests to meet the renewable energy targets, an approach to account for sustainable levels of timber flows was proposed by [Bringezu et al. \(2012\)](#). The key points of the efficient biomass utilisation have been defined in the literature as follows: ([Jones 2011](#))

- The maximisation of the total annual energy crop yield produced per hectare.
- The maintenance of sustainability and the minimising inputs.
- The biofuel maximisation produced per unit of biomass.

[Mitchell \(2000\)](#) discussed the development of bioenergy systems models, including a production information system and a decision making system, as well as the challenges that are met when a number of models are integrated into a single model. The employment of a multiscale modelling approach to investigate the spatial distribution of first and second generation energy crops for the period 2000–2030 was investigated in [Hellmann and Verburg \(2011\)](#), whereas a spatially explicit land use model was employed to allocate the energy crops within the European countries. [Fischer et al. \(2010a\)](#) also presented a study involving the allocation of energy crops in Europe in 1 km grid cells. [Fischer et al. \(2010b\)](#) continued to the implementation of their findings about the European energy crops potential by developing three land conversion scenarios in Ukraine.

Extensive documented literature is proving the employment of GIS technology for the definition of the energy crops’ potentials. [Dimakis et al. \(2011\)](#) assembled a review of the available methodologies and tools utilised to define the potential of the

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