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Conclusive Results of the European Project OPTIMA: Optimization of Perennial Grasses for Biomass Production in the Mediterranean Area

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The European Project OPTIMA–Optimization of Perennial Grasses for Biomass Production in the Mediterranean Area (GA 289642, coordinated by the University of Catania)–was conceived with the ambitious aim of identifying and optimizing new strategies for the sustainable use of land in marginal Mediterranean areas particularly exposed to climate change. Curiously, although today the term "marginal land" is on everyone's lips, there is no clear definition for it [1]. Generally speaking, marginal land is considered as a land of low-opportunity cost where it is not worth cultivating food crops; however, the degree of marginality remains vague and complex to estimate as it strongly depends on context and domain. Rabbinge [2], for example, provided an agronomic definition of marginal lands basing on crop growth, Van Orshoven [3] defined marginal land in terms of biophysical constrains, and the FAO [4] proposed an economic perspective of marginal land. An enlightening review article on the definition of marginal land has been submitted during the OPTIMA project by Soldatos and collaborators (under review).

Four perennial species, miscanthus (*Miscanthus x giganteus* Greef & Deuter ex Hodkinson & Renvoize), giant reed (*Arundo donax* L.), switchgrass (*Panicum virgatum* L.), and cardoon (*Cynara cardunculus* L.), formed our reference basis. Other lesser-known endemic species were analyzed and evaluated in a less detailed way, but in sufficient depth to understand their production potential in biomass terms.

The interdisciplinary setup of the project allowed, on one hand, a more in-depth approach as regards the individual aspects of physiology, biotechnology, genetics, agronomy, conversion processes, and socio-economic and environmental assessments of the aforementioned species, and on the other hand, a systematic analysis designed to identify the true development potential of the entire production chain. The nearly-completed 5-year project involved a considerable effort to harmonize the results in a general and all-inclusive context. This special issue is an attempt to provide an overall picture which summarizes the main results achieved, emphasizing the progress made, the uncertainties, the limits, and the possible development strategies of the above-mentioned species in the Mediterranean area. We thank the BioEnergy Research editorial board for agreeing to our request and for their considerable help in carrying it out. We would like to also thank all the anonymous reviewers for their important contributions in improving the articles of this special issue of BioEnergy Research.

The special issue covers various aspects of the production chain. Elena Sanchez and collaborators addressed physiological studies on salinity and water stress effects on biomass production that revealed substantially different physiological responses of giant reed ecotypes, despite their probable common genetic origin, a fact that is certainly of interest in breeding this species for an increased biomass yield. Ana Luisa Fernando and collaborators stress the appropriateness of associating biomass production with plant purification ability. The authors show that growing giant reed or miscanthus on heavy metal contaminated soils could prevent the leaching of heavy metals and groundwater contamination. Another positive environmental effect concerns the reduction of soil erosion potential. Luciano Cosentino and collaborators quantified the

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ability to reduce erosion through cultivation of miscanthus and giant reed compared with traditional agricultural systems. The effect of the diffusion of perennial grasses on the accumulation of carbon in marginal areas or areas where cereal is grown in the Mediterranean region was analyzed by Andrea Nocentini and collaborators in a simulation study using the DayCent model. Nils Rettenmeier and collaborators and Ana Luisa Fernando and collaborators studied the environmental impacts of new potential agro-energy systems at the systemic level by means of life cycle assessment (LCA) and Environmental Impact Assessment (EIA) methodologies. The authors pointed out that the cultivation of perennial grasses on marginal land in the Mediterranean region provides potentials for climate change mitigation. Their use for stationary heat and power generation can achieve greenhouse gas and energy savings up to 13 Mg CO_2 eq. and 230 GJ per hectare per year.

Sustainability is not just about environmental issues; economic and social factors are also involved. Reducing the costs of giant reed and miscanthus propagation is an obligatory step in the development of these crops on a commercial scale. Peter Soldatos examined the economics of cultivation of the aforementioned perennial crops by using life cycle costing analysis (LCCA) and discounted cash flow (DCF). The author showed that under current economic and climatic conditions in south Europe, their production cost in marginal lands is significantly affected by the degree of "land marginality". Interestingly, assuming a biomass selling price of 65 €/Mg (dry biomass), only the giant reed was profitable; however, the space-time production of the crops still involves considerable uncertainty, making it difficult to provide categorical responses. The variability in long-term production and its associated uncertainties are described and discussed in an interesting study by Efthimia Alexopoulou and collaborators, which reports original production data collected over exceptionally long periods (up to 16 years). Luciano Cosentino and collaborators summarized some innovative systems of vegetative propagation, with interesting prospects for giant reed and miscanthus. The preliminary results on hydro-seeding of switchgrass seem equally interesting for the diffusion of the species in marginal lands and for more sustainable management of the crop.

We would like to conclude our editorial with a few observations on the project of a more general nature. OPTIMA has, for all of us, been a fantastic experience for its spirit of solidarity, sharing, willingness to compromise, and collaboration, all fundamental qualities in achieving the results obtained and a solid basis for future activities. But ambitious projects like OPTIMA produce not only positive results, but also regrets and unachieved aims. Acknowledging this does not mean a declaration of failure, but a necessary and important step in outlining new objectives. The production chain based on these species is still a largely unexplored field of research. While on one hand the marked interdisciplinary nature of OPTIMA was undoubtedly an added value, on the other hand it made the analysis of the production chain difficult. A longer study period would certainly have made the analysis of the production results in a wider and more general context. The concept of "marginal environment or land" and its various definitions was the topic of lengthy debate throughout the duration of the project, which failed to reach a conclusive definition. One of OPTIMA's main merits is that it allowed long-term experiments to become part of the project, generating unique production results of fundamental practical interest. The considerable spatial and temporal variability in production is difficult to interpret but necessary, more than ever, for industrial planning and parameterization of environmental (e.g., LCA), econometric, production, and logistic models. A greater ability to predict production would mean more reliable means of supporting decisions involving the territorial allocation of biomasses and biorefineries, a topic of considerable current interest for the European Commission (see for example the ongoing European project S2BIOM).

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