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Stakeholders' Perception of Bioenergy Projects in Marginal and Underutilized Lands in Italy

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ABSTRACT

Large land areas in European countries can be considered marginal, underutilized, and contaminated (MUC). Many recent studies have shown that bioenergy crop cultivation can make this land profitable, creating new income opportunities for local citizens without interfering with food production. However, farmers, landowners, and local communities must become more familiar with bioenergy systems, potential value chains, and markets. This paper aims to present the results of stakeholder consultations implemented in two case study areas in Italy, i.e., Basilicata and Sardinia, about the possible establishment of bioenergy systems in the MUC land available at the local level. Stakeholders' perceptions were collected through interviews conducted on a one-to-one basis and through multi-stakeholder working group meetings organized in the context of BIOPLAT-EU, an H2020 project aimed at promoting the efficacy and profitability of using MUC land for sustainable bioenergy production. By and large, the findings of the consultations indicate that local stakeholders are prone to accept the establishment of innovative bioenergy value chains based on the cultivation of MUC lands in their regions. The majority of them recognized that bioenergy could bring a wide range of benefits at the local level, not only in terms of environmental externalities but also of economic and social development, such as through the creation of new business and job opportunities, therefore serving to alleviate or prevent the land abandonment and population decline currently on-going in these areas.

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1. Introduction

The European Union (EU) Member States, within the following decade, have to increase their production of renewable energy to achieve the ambitious targets set in the Recasted Renewable Energy Directive (henceforth REDII) [1] and to meet their Paris Agreement pledges. By replacing fossil fuels, bioenergy can play a crucial role in accelerating the energy transition, acting as an effective mitigation option and contributing to decarbonizing the EU country's economy. In particular, sustainable bioenergy is vital in reducing greenhouse gas (GHG) emissions from hard-to-abate sectors (e.g., heavy-duty transport and industry) in an integrated EU clean energy system. Bioenergy is an essential component of the EU energy system, accounting for 12% of total energy consumption and 60% of renewable energy use [2], while 34% of electricity comes from renewable sources. Regarding sectors of the economy, in 2020, the EU industry sector consumed 32% of final energy, followed by the transport sector with 26% of consumption, households at 25%, services at 12%, and finally, agriculture & forestry at 3% [3].

Following the mandates of REDII regarding environmental impacts and sustainability issues associated with land use and Indirect Land Use Change (ILUC) from cropland expansion, bioenergy actors have focused their attention on the possibility of cultivating dedicated crops in underutilized areas such as marginal, degraded, and contaminated land. Underutilized and marginal lands are those that, starting with poor geomorphological characteristics (e.g., stoniness, agronomic potential, degraded land, a poor combination of physical and chemical characteristics), are unable to provide sustainable biomass production and profitability for landowners and farmers, and, as a result, the local community's well-being [4].

In this sense, the EU Commission defined the certification criteria for ILUC-risk biofuels, bioliquids, and biomass fuels from abandoned or severely degraded land [5]. Appropriate integration of bioenergy crops into underutilized landscapes to produce advanced biofuels can further decrease bioenergy's environmental, economic, and social impacts, ultimately improving bioenergy systems' long-term sustainability.

However, these projects' success depends on stakeholders' support and participation. Stakeholders' perceptions of bioenergy projects can vary and significantly impact the project's success. Research has shown that various factors can influence stakeholders' perceptions of bioenergy projects on underutilized and marginal lands. These include the perceived benefits and risks of the project, the level of community engagement and consultation, and the level of trust in the project developers [6-8].

Studies have also shown that stakeholders and farmers may have different perceptions of the same bioenergy project, with some viewing it as an opportunity for economic development and others as a threat to the environment or traditional land use practices [9]. In addition, research has found that stakeholders' perceptions of bioenergy projects can be affected by their knowledge and understanding of the technology and the project's potential impacts. Interestingly, [10] highlighted that all stakeholder categories perceive the cultivation of annual crops on MUC lands as promising opportunities linked to technological pathways with high technology readiness levels (TLR), such as biogas/biomethane from sorghum and ethanol from switchgrass. On the contrary, perennial grasses, poplar, and willow, associated with highly innovative technological pathways with low TRL at the early market development stage, are ranked by stakeholders as medium opportunities and are less attractive due to long-term commitment. In summary, there is a need for effective communication and education to ensure that stakeholders have accurate information and can make informed decisions about the project.

The main aim of this paper is to explore stakeholders' perceptions collected during consultations and public meetings on the future implementation of bioenergy projects in underutilized lands.

The activities were carried out in 2020 and 2021 in the framework of the project "BIOPLAT-EU," financed under the EU H2020 program [11]. The project's overall objective was to promote the market uptake of sustainable bioenergy in Europe using marginal, underutilized, and contaminated lands (MUC) for non-food biomass production through the provision of a web-based platform that serves as a decision support tool. The project aimed to i) realize a database of maps of MUC land in Europe; ii) develop a public web-based platform with a user-friendly web-GIS tool for assessing the environmental, social, and techno-economic sustainability aspects of

different scenarios and value chains concerning specific conditions for bioenergy production on MUC land; iii) mobilize, involve and provide technical support to stakeholders on aspects linked to biomass production and processing, market access, management and access to finance. The platform was intended to be a core source of information with a help desk section for stakeholders. This work describes the results that emerged from the consultations of relevant bioenergy stakeholders identified at the local level, interviewed on a one-to-one basis or through the implementation of multi-stakeholder working groups conducted in two case study areas of the project in Italy, namely Basento valley in Basilicata region, and the area of Sulcis, in Sardinia region.

2. Materials and Methods

This study focuses on two areas located in Southern Italy: the area of Sulcis in the region of Sardinia (39°09' North latitude, 8°29' West longitude) and the Basento valley in the region of Basilicata (40°46' North latitude, 16°46' West longitude) (Fig. **1**). Both of the selected case study areas are among the "Sites of National Interest" (SIN as per their acronym in Italian) [12], which include polluted industrial and mining areas across the Italian territory. The two case study areas were selected among SIN areas as they exhibit marginality, disadvantages, and physical limitations such as poor soil capacity for crop productivity, degraded and contaminated soils, underutilized soils, barren and idle lands, and distance to markets [4]. The selection of the Basilicata Region follows a survey of potential study areas that identified in the Basento Valley the presence of an industrial area and an established biorefinery in the Ferrandina (Matera province). The Sulcis study area has been selected as a follow-up from the H2020 FORBIO project [13].

Figure 1: Study areas in Sardinia and Basilicata region, Italy.

A Mediterranean semi-arid climate with a bimodal rainfall distribution pattern characterizes the Sulcis area. The mean annual rainfall is 600 mm, and the mean annual temperature is about 16° C. As reported in the FORBIO

project [14], in Sulcis, the land suitable for bioenergy feedstock cultivation covers about 60 km^2. The Basento valley is characterized by a Mediterranean semi-arid climate and falls among the Italian regions most prone to landslides and floods and is located in a seismotectonic background responsible for strong earthquakes. Val Basento industrial area is included among the SIN due to the presence of pollutants derived from local chemical industrial plants. The chemical analyses show soil and groundwater contamination by heavy metals, polycyclic aromatic hydrocarbon, chlorinated solvents, and aromatic compounds [15].

The idea is to promote the use of marginal areas in the context of the bioeconomy sector, integrating them into energy systems and biorefining chains [16, 17], by cultivating crops that can be used as raw materials for the production of bioenergy or other types of bio-products. This should fulfill, on the one hand, the need to avoid any competition for resources that could be dedicated to food production and, on the other hand, the willingness to enhance the value of underutilized lands [18].

2.1. Stakeholder Consultation Process

Four Multi-Stakeholders Working Group (MSWG) meetings, two in each case study area, were conducted in 2020 and 2021, and several virtual interviews were performed on a one-to-one basis. The specific objectives of the consultations were to bring together local stakeholders representing a different group of categories (e.g., public and private landowners; bioenergy producers; civil society) to inform them about the efficacy and profitability of using MUC land for bioenergy production and to present them the functionalities of the web-based platform. The overarching goal of the meetings was to mobilize and encourage regional stakeholders to start their bioenergy projects. The selection of the candidate members of the MSWG was performed in a joint effort with regional offices of the Council for Agricultural Research and Economics (CREA). This approach allowed the organizers to ensure that involved stakeholders had a deep knowledge of the local context and significantly represented various categories of actors along the bioenergy value chains, such as farmers' associations, bioenergy producers, market players, end-users, research centers, policy, and decision-makers. Candidate members of each regional MSWG were contacted in advance on a one-to-one basis, both via email or virtual meetings (e.g., Skype; Teams; Zoom), to raise their awareness of the objectives and the activities foreseen in the BIOPLAT-EU project and to explore their interest in being involved in the activities, as representative of their specific stakeholder category. The CREA staff explored, with each candidate, the type of expected contribution to bringing in the MSWG. Each candidate was invited to share knowledge, best practices, and data relevant to the project's scope. During the MSWG meetings, members were invited to discuss the various bioenergy value chain options suitable or already available in the region, the main challenges and opportunities potentially characterizing these value chains, or the barriers hampering the development of new bioenergy projects. Project partners facilitated the dialogue among stakeholders in the MSWG meetings.

The BIOPLAT-EU web-based tool with all its features and functions was presented during the meetings. The web tool combines a database on MUC lands in the EU and Ukraine with the Sustainability Tool for Europe and Neighboring countries (STEN). The maps are developed based on high-resolution data such as Copernicus high-resolution layers, time series data from Sentinels, and other satellites and their related attributes. The STEN tool can assess the social, environmental, and techno-economic sustainability aspects of defined bioenergy value chains on MUC lands. For more details regarding the web-based and web-GIS platform and the STEN tool readers are referred to deliverables available on the website of the BIOPLAT-EU project (Fig. **2**).

3. Results and Discussion

As previously stated, working group members were asked to attend these sessions to examine the bioenergy value chain possible in their areas, the key difficulties and potential of these value chains, and the project's evolution and participation in it. An overview of the study areas, including available MUC areas with identified bioenergy pathways, is reported in Table **1**.

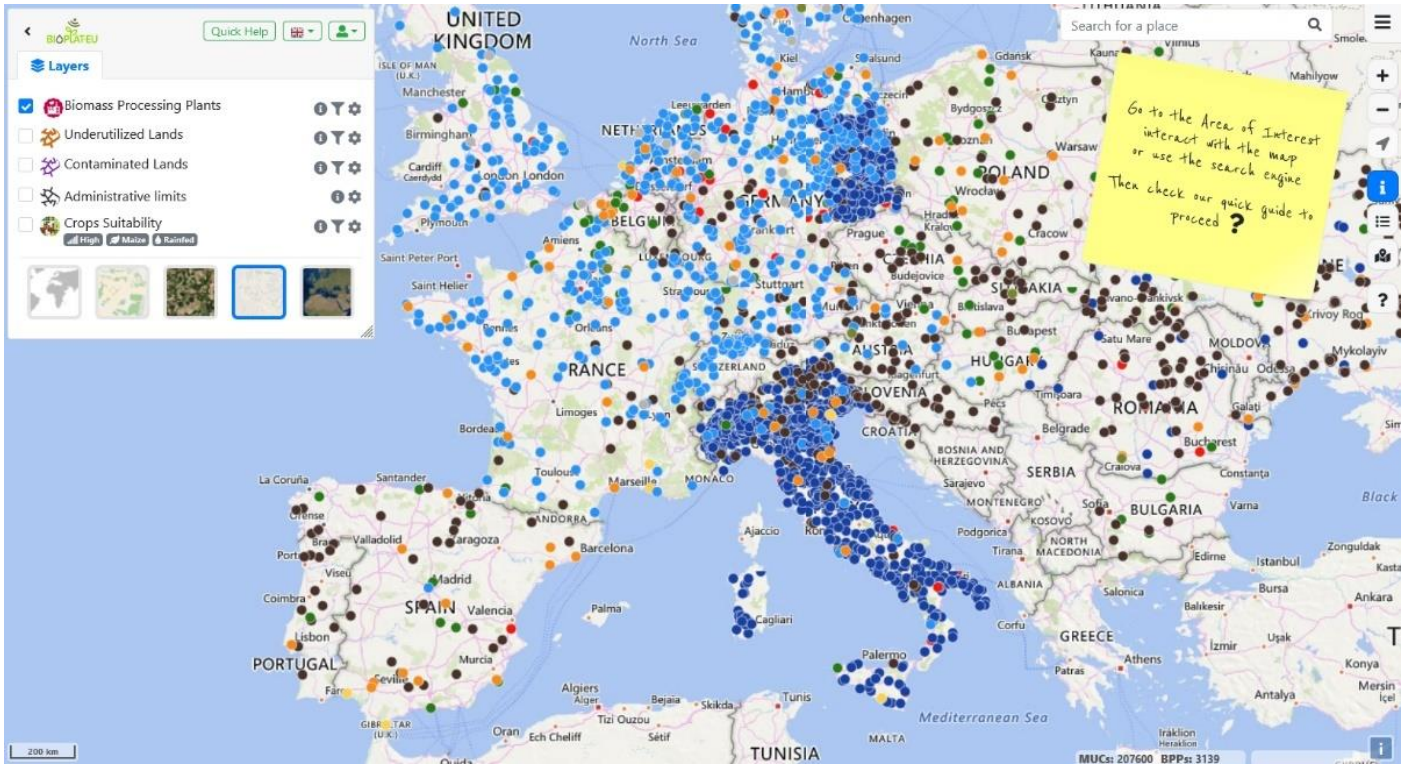

Figure 2: Screenshot of the BIOPLAT-EU web-GIS platform interface. Points in the image show the layer related to the bioenergy production plants.

Table 1: Overview of the main characteristics of the study areas and working group meetings.

	Sulcis Area	**Basento Valley**
MUC Area	~ 2000 ha	~ 6000 ha
Bioenergy pathway	biogas	biodiesel
Suitable crops	*Arundo donax* L.; energy crops and residues	*Camelina sativa* L; oilseeds
Stakeholders	Landowners, researchers, regional authorities, local authorities, and farm producers' association (34 people)	Landowners, researchers, regional authorities, local authorities, politicians, farm producers' association, bio-industry, industrial producers consortium, environmentalist association (44 people)
Stakeholder suggestions	Improving web-GIS functionalities; support schemes and incentives	Constant updating of financial data; support schemes and incentives

3.1. Working Groups in the Sulcis Area

The first MSWG meeting of the project in the Sardinia region was held in Cagliari on September 15, 2020, and involved 12 participants. The agenda of the event included two key sessions. The first session was dedicated to the exchange of knowledge: the meeting started with the introduction of the BIOPLAT-EU project, then participants were informed about the opportunity and benefits of using MUC lands for bioenergy production in their region, and ultimately, they were invited to share data and information on the current status of the bioenergy sector at the regional level. The second session of the meetings took place in the form of a round table discussion to stimulate the dialogue and foster networking and collaborations among the various stakeholders to overcome existing barriers that currently prevent the development of short, locally based bioenergy value chains. The round table was also helpful in identifying the most promising bioenergy value chains in the region based on the existing local situation.

The meetings enormously contributed to raising the awareness of local authorities on the various socio-economic and environmental benefits and drawbacks that a sustainable bioenergy sector could bring at the local level. As an example, growing bioenergy crops in MUC lands has some challenges (e.g., costs and production uncertainties) and opportunities (e.g., job opportunities, ecosystem services provision). Furthermore, stakeholder meetings allowed for the exchange of experiences, data, and information on current research activities on topics strictly related to the ones considered in the BIOPLAT-EU project.

The biogas value chain was recognized as having a high potential in the current regional bioenergy framework. Its broader adoption could serve as a strategy to foster the energy transition favoring, at the same time, the energy self-sufficiency and independence of the island. The traditional anaerobic digestion systems, which are already valuable in their current form, could further strengthen their role in the energy transition by being upgraded to produce biomethane and adopting the most recent technologies to produce hydrogen. Within this context, the Biogas Done Right model [19] for biomethane production in decentralized farms represents a win-win model for increasing the circularity of agricultural systems by producing digestate that is returned to the soil, to replenish soil nutrients and increasing organic carbon storage.

Future bioenergy policies shall, therefore, support the use of by-products and residues of agricultural systems as raw material for a successive step in the value chain, according to a cascading use principle. Nevertheless, due to the still very high costs of these innovative technologies, they currently have a limited presence on the island. The vast potential of MUC land in Sardinia shall be unlocked by promoting the cultivation of dedicated bioenergy species or by introducing the latest in well-balanced crop rotations and intercropping system, providing farmers with an additional opportunity to increase their income [20]. The MSWG agreed on the need to join forces among different stakeholders to promote coordinated action among the various realms involved in the bioenergy value chain: agriculture, forestry, energy, socio-economic development, and environmental management.

The second MSWG meeting of the project in Sardinia was held in September 2021 and involved 22 participants. The objectives of this second MSWG meeting were to demonstrate and test the web-GIS tool together with the local stakeholders in a way to gather their feedback which could help fine-tune the web-GIS. Thereafter MSWG members were informed about the outcomes of the feasibility study developed on a potential biogas short value chain in Sardinia. According to the feasibility study developed in the project, the biogas short value chain hypothesized after the first MSWG meeting, which included an electricity production facility from feedstock produced across 6,000 hectares of MUC land in the study area, is not financially feasible. The main weaknesses were the vast amount of raw material needed, the high price of the feedstock material, and the logistical (including pre-treatment) and transportation expenses. For more details regarding opportunities and constraints for implementing biogas energy plants in this study area, see the project report [21]. On the other hand, as suggested in a recent study in Italy [22], farmers are willing to sell straw for bioenergy, but the authors underline that fluctuation in the price of the raw material can compromise the economic sustainability of the value chain.

Regarding the web-GIS tool, a recent literature review suggests that integrating GIS in Life Cycle Assessment improves spatially explicit decision-making and the efficiency of resource management [23]. In this regard, MSWG members suggested to further improving the STEN tool with data from direct observation. Then, they asked to revise the positions of the biogas plants in the web-GIS tool, as these not always correspond to the actual position of the plant on the ground rather to the legal premises of the bioenergy firm. Solving this issue would allow to come out with more valuable sustainability assessment data (e.g., regarding transport distance). Stakeholders suggestions have been implemented and are currently available for registered users. A further objective of improvement is related to the need to include existing rural infrastructures, mainly local streets, to transfer biomass from production fields to the processing plant in the STEN tool. This adjustment can contribute to further refining the outcomes of the sustainability tool. This stakeholder suggestion has not yet been implemented in the system as it requires the acquisition of a very high-resolution geospatial dataset. Another stakeholder suggestion was to further improving the web-GIS tool in order to include potential competitive uses for the biomass produced in MUC lands (e.g., other types of bio-based value chains, such as for the production of bioplastic), therefore allowing for a more consistent and comprehensive feasibility study or sustainability assessment of bioenergy systems. Also, this stakeholder suggestion has not yet been implemented in the system as it requires

elaborations not initially foreseen in the project, which is oriented to bioenergy. In conclusion, stakeholders highlighted that the BIOPLAT-EU web-based tool gives valuable insights into input-resource interactions, addressing the complexity of the competing uses of resources by allowing comparison of multiple scenarios considering a range of combinations.

3.2. Working Groups in the Basento Valley

The first MSWG meeting of the project in the Basilicata region was held in Matera in October 2020 and saw the participation of 20 participants. (Fig. **3**).

Figure 3: Working Group Meeting held in Matera on October 14, 2020.

The agenda of the event included two key sessions. As reported above for the Sardinia region, the first session was dedicated to the exchange of knowledge introducing the project, and informing about the opportunity of using MUC lands for bioenergy production. The second session, built upon the outcomes of the first one, was organized as a round table discussion to stimulate the dialogue and to foster networking and collaboration among the various stakeholders participating in the meeting in a way to overcome existing barriers that currently prevent the development of short, locally based, bioenergy value chains. The round table was also helpful in identifying the most relevant bioenergy value chains currently present in the Basilicata region to explore opportunities for their further scaling up or replication.

The MSWG meeting has offered a concrete opportunity to exchange knowledge among the various stakeholders in the bioenergy sector in the Basilicata region and to set the basis for future collaborations and coordinated actions given the forthcoming definitions of regional plans and strategies, both in the rural and industrial realms, for the period 2021-2027. The Basilicata area is an excellent example of the energy transition road, with 86% of electric power produced from renewable energy sources in 2016. Here, dedicated producers' associations and hubs have been established to facilitate interaction among private entrepreneurs, scientists, farmers, and local and regional authorities to ensure a coordinated effort toward sustainable local development based on circular and low-carbon economy principles. The region provides several prospects for the bioenergy sector to thrive. For example, there is significant development potential for biogas and biomethane, and the region may already count on the availability of critical infrastructures, such as Greens witch biorefinery facilities.

Nevertheless, the absence of specific production stages in the value chain, such as the local cultivation of oil seed crops and the facilities for the pre-treatment of harvested material (i.e., specialist oil extraction mills), prevents the establishment of a complete local short oil-based bio-economy pathway (e.g., biodiesel). Noteworthy, the last regional rural development plan (2014-2020) gave incentives to the landowner of marginal lands to keep them as set aside. To overcome identified barriers to the development of local bioenergy value chains, dedicated incentives, and supporting measures shall be introduced for the benefit of the farmers, through the EU Common Agriculture Policy, and for the industries, through the program for the use of EU structural funds or other regional development plans which were, at the time of the meeting, in the process of being developed for the period 2021-2027. Stakeholders acknowledged the critical role that MUC lands might play in developing oil seed crops or biomass to be utilized as fuel for biorefineries. As suggested by [24], tailored support schemes and incentives are key tools for promoting market uptake and competitiveness of advanced biofuels.

The second MSWG meeting of the project in the Basilicata region was held in September 2021 and saw the participation of 24 participants. The aim is to present and test the web-GIS tool with local stakeholders to collect their feedback on it, allowing for its fine-tuning. Last but not least, the MSWG meeting presented and validated the significant results of the feasibility study conducted within the project. In this context the MSWG members proposed that the tool shall be further improved by adding an online function for it to retrieve actual and updated financial data from publicly available databases relevant to market pricing of both biomass and biofuels [25]. There are datasets reporting market prices for biomass and biofuels every six months. In light of the positive results achieved during the project implementation the members of the MSWG proposed continuing to explore opportunities to support the development of a short-biodiesel value chain in Basilicata, taking advantage of the biorefinery already in place in the municipality of Ferrandina [26], to bring social and economic benefits at the local level. The findings of the stakeholder consultations performed in Basilicata have been recently confirmed by a recently published study [25], according to which the region of Basilicata has extensive areas suitable for the cultivation of energy crops, but ensuring the sustainability of potential bioenergy pathways, the nexus among water, energy, food, and land use should be carefully assessed. Overall, the findings from the MSWG meetings show that local stakeholders and investors recognized attractive opportunities on MUC lands in terms of job opportunities, economic growth, and market development for high-value-added products and bioenergy. However, implementing such projects can be challenging due to several factors, including a lack of infrastructure and technical expertise and resistance from local communities.

One key lesson learned is the importance of involving local communities in the planning and implementation of bioenergy projects. Engaging with local stakeholders helps build support for the project and ensures that it is tailored to meet the community's needs. Additionally, providing training and resources to local individuals can help build capacity and ensure that the project is sustainable in the long-term.

Another important lesson is the need for robust technical and financial planning. Bioenergy projects in MUC lands can be technically complex, and it is essential to have a clear understanding of the technical requirements and potential challenges. Additionally, securing funding and financing for such projects can be challenging, and it is important to have a comprehensive understanding of the costs and potential revenue streams.

Finally, bioenergy projects in MUC lands may be subject to various regulations and laws, and it is important to understand the requirements and potential obstacles clearly. In conclusion, implementing bioenergy projects in MUC lands can be challenging. However, with proper planning and using tools such as the STEN tool, these projects can provide a sustainable energy source while preserving valuable agricultural land.

3. Conclusion

This study presents the primary outcomes of public consultations carried out in the "BIOPLAT-EU" H2020 project to collect stakeholder perceptions on the possible establishment of short bioenergy value chains based on the cultivation of dedicated bioenergy crops in locally available marginal, underutilized, and contaminated land. The consultations, implemented both as Multi-Stakeholders Working Group meetings and one-to-one-based interviews, brought to light a general positive stakeholders' view regarding the establishment of bioenergy

pathways in MUC land. The showcase of live examples of the web-GIS and STEN tools developed during the project informed the stakeholders regarding the possibility of assessing, with an ex-ante approach, the sustainability and profitability of short bioenergy value chains to be implemented at the local level. Results indicate an overall acceptance of bioenergy systems in these areas and ample opportunities to develop or scale up sustainable bioenergy supply chains based on the cultivation of MUC lands if dedicated supporting policies and strategies are developed in the short-term. Consulted stakeholders have recognized bioenergy as an opportunity to foster local development, thanks to the fact that it can bring environmental, social, and economic benefits, such as adding value to MUC land and creating new job and business opportunities. The availability of innovative tools, such as those exposed during the meetings, has been recognized as having a great potential to support bioenergy-related decision-making processes, therefore serving as a flywheel to attract new investments for the establishment of new bioenergy pathways in these areas. Starting from these positive premises, future coordinate efforts among stakeholders should be given to removing obstacles to implementing such projects in the study areas. The results of this study suggest that significant efforts need to be directed toward tailored technical and financial guidance by experts for overcoming technical, economic, and legal obstacles to market adoption.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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