Analysis of renewable energy and agro-food by-products in a rural landscape: the *Energyscapes*

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Abstract

Renewable energy sources currently play an increasingly crucial role that, owing to their spatial and high temporal variability, need a careful planning approach to develop a flexible spatio-temporal analysis framework.

From an energy point of view, thanks to its morphological, agricultural and environmental structure, a regional territory, such as the Basilicata Region (Southern Italy), can be considered as an interesting case study, since it is characterized by significant sources of renewable energy (biomass, wind, solar, hydro, *etc.*). This paper presents an analysis of the spatial supply and relationships between renewable energy potentials and rural land through the use of a Geographical Information System, implemented with the aim to analyze the energy usability, and to investigate the influence of unutilized biomass resources for bioenergy production, such as agro-food by-products, that are often spread on the territory and need to be collected and transported to conversion plants.

The study is carried out to bridge the gap between energy modelling and spatial planning, by integrating research and techniques in energy systems within a more general environmental and landscape framework. The concept of "Energyscape" may be considered as a spatial and temporal combination of the supply, demand and infrastructure for energy.

The temporal and spatial aspects, linking the biomass resource, the biomass by-product, the conversion plant size and the environmental impacts, are the starting point to simulate an interdisciplinary analysis able to define the importance of the spatial arrangement for decisions on energy plant localization, enabling to figure out optimal solutions in decision-making processes and in spatial planning.

Keywords: Agro-food by-products, Geographical Information System, Landscape, Energyscapes, Spatial planning.

1. Introduction

Renewable energy sources are a priority in the modern European society, they need to be carefully planned, since they are characterized by high temporal and spatial variability that would pose challenges to maintaining a well-balanced supply in the energy system.

A sustainable landscape refers to the conservation of certain landscape types or values and implicitly, the continuation of practices that maintain and organize these landscapes (Blaschke et al., 2013). The idea of sustainability is not restricted to particular types of landscapes, which can be natural or cultural, traditional or contemporary, spectacular or ordinary. The concept can be applied to practices that maintain traditional techniques in rural or pastoral landscapes, but it can also refer to the land qualities of natural landscape remnants, or of new contemporary landscapes (Antrop, 2006).

As well as the word "landscape" itself expresses role of shaping the lands by natural forces, an "*Energyscape*" may be considered as the effect deriving by the role played by energies as a force in shaping the visible features of the Earth's surface in delimited areas. Therefore, similarly as for cultural landscapes (Boyce, 2006), an energyscape is fashioned from a natural landscape by an energy exploitation. Energy is the agent, the natural area is the medium, the energyscape is the result.

The energy production needs to be planned, the location of conversion plants need to take into account infrastructure, neighbor distances and other environmental and social aspects. In the recent years the attention has been focused on the energy from *biomass by-product* and the enhancement of agro-industrial residues, although being products with a limited energy potential, will fit into the goals of the general energy efficient conservation and sustainable protection of the natural resources (Statuto et al., 2013).

Waste biomasses are however often diffuse sources, spread over large geographic areas, and need to be collected and transported to a conversion plant. The temporal and spatial aspects linking the biomass resource, the waste biomass, the conversion plant size, the transport system and the environmental impacts need to combine energy system planning and spatial planning (Blaschke et al., 2013).

This paper focuses on the identification and quantification of energy potential distribution, arising from the reuse of *agro-food by-products* exploited for energy purposes in Basilicata Region, considering the Municipality as a reference unit. The analysis has been carried out the most popular food crop, *grapes and olives*, in terms of pruning residues and by-product arising from processes of transformation of the agro-food industries, olive mills and wineries.

The results of the analysis aim to consider a spatially oriented information system to support efficient energy system planning, by identifying spatially explicit biomass resources that can be used for renewable energy production.

The characteristics of the case study area have been elaborated and the Geographic Information System (GIS) has been used to calculate the potential of agricultural residues. Results of the assessment and analysis are presented, in form of maps, in order to identify the resources distribution.

2. Materials and Methods

2.1. Case study

The *study area* consists of the total land in Basilicata region (Figure 1) and has a geographical area of 999,224 ha. It is a mostly rural territory; the population is 578,036 inhabitants (ISTAT, 2011/a), with a low regional population density (57.8 inhabitants per km^2).

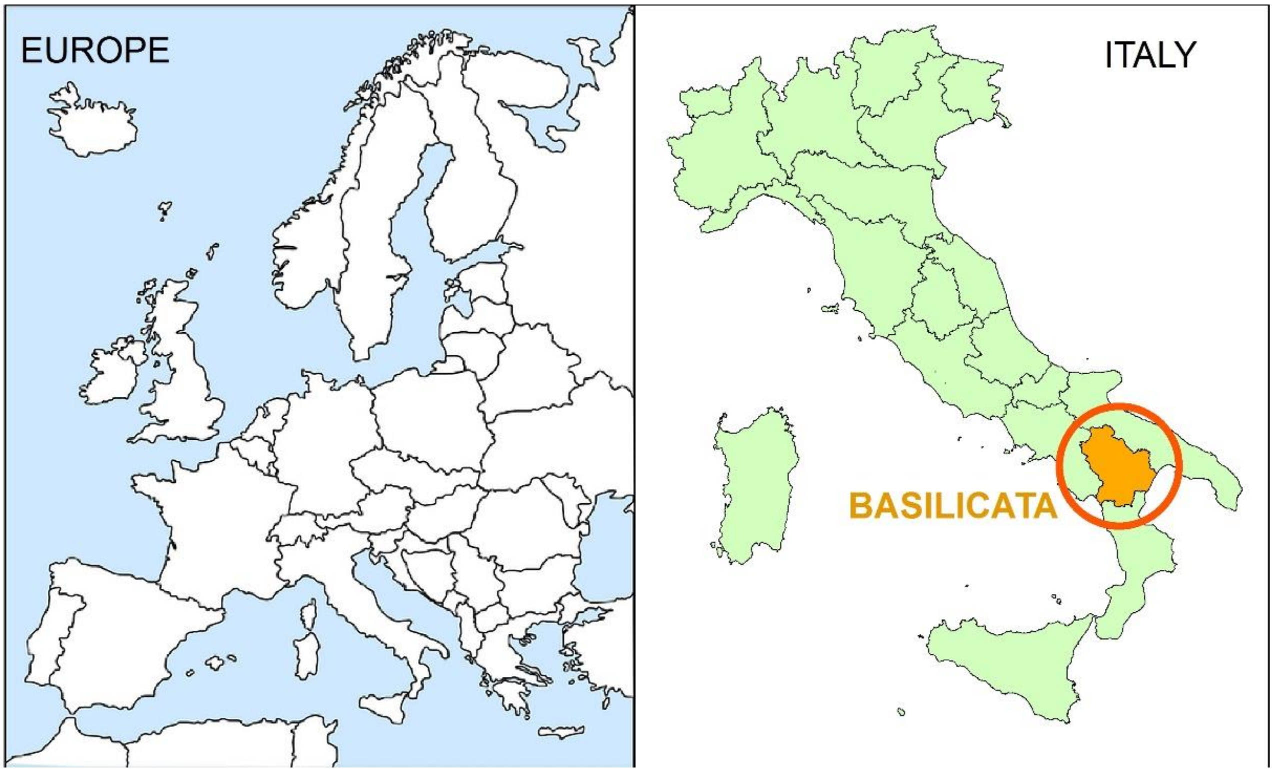

Figure 1. Study area – Basilicata Region

The territory of Basilicata shows wide morphological differences, mainly in elevation, ranging from sea level to over 2,200 m a.s.l. It is characterized by extremes of temperature and climate; on the upper hilly slopes, woody crops - such as grapevines, olive trees and other tree crops - cover the territory. In the east part of the region, mainly in the *"Collina Materana",* the landscape is in fact strongly characterized by olive tree cultivation alternated by orchards and woods (Figure 2). In the zone of *"Monte Vulture"* – an ancient, but now extinct, volcano - the territory is characterized by the grape cultivation (Figure 3), the volcanic soil giving the wine its rare and greatly appreciated characteristic flavor.

2.2. Spatial data and Geographical Information System

Energy modelling and the theoretical potentials are based on topography, climate, land use, and many other factors. Geographic Information Systems (GIS) can help decision and policy makers to make sound decisions based on information derived from properly designed geospatial databases.

Figure 2. Landscape characterized by typical olive tree.

In order to visualize the spatial distribution of biomass sources and their associated potential, all spatial task were performed using ArcGis version 10 software and its associated extensions Spatial Analyst. Through the use of GIS areal data, for example, values for whole municipalities and spatially explicit data in the form of vector or raster can be integrated. Some other statistical data for households within the area of interest are also used in the estimation of energy production; combining these data, the spatial distribution of the theoretical energy production can be mapped. In particular pruning residuals and agro-food by-products were estimated by statistic information at municipality level (ISTAT, 2011/a, ISTAT, 2011/b).

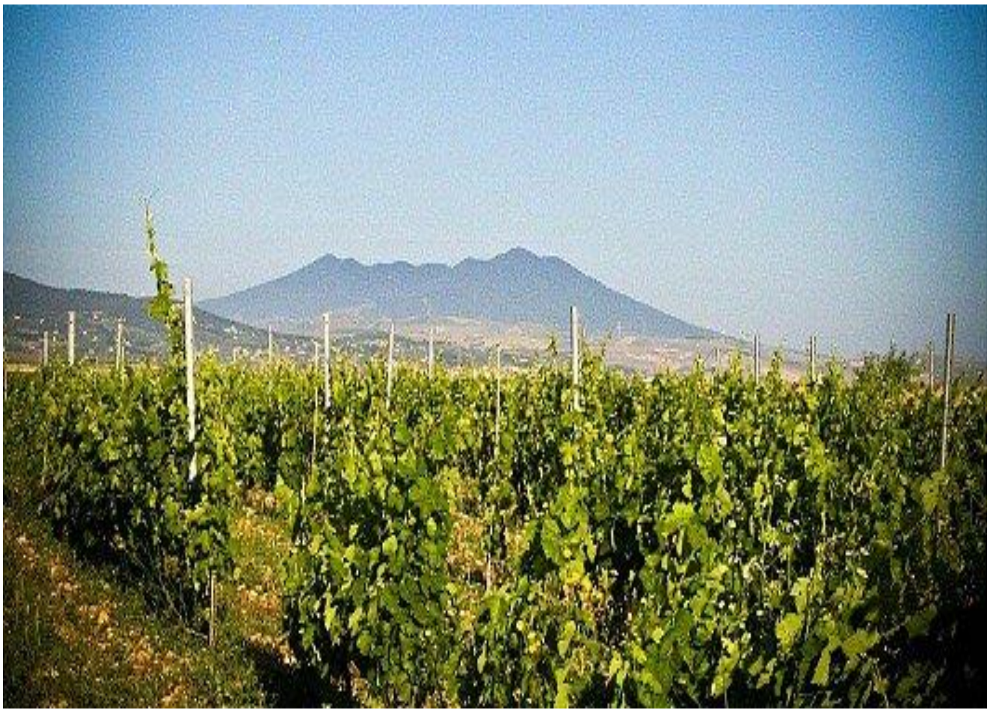

Figure 3. Landscape characterized by grape cultivation in Vulture area.

2.3. Calculations

2.3.1 Pruning residues

Large quantities of ligneous biomass can be obtained from the pruning operations (Table 1) carried out in Mediterranean fruit plantations (McKendry, 2002). At present these residues are usually destroyed by in-field burning or incorporated into the soil after their crushing, so there is no direct economic benefit, the biomass produced in fruit plantations not being employed to produce bio-energy, due to unsolved technical problems in harvesting and logistic operations, to which the most expensive costs of the chain biomass utilization are connected.

Depending on the technical criteria, olive trees can be pruned annually or biennially. The frequency of pruning has a strong influence on the quantity of biomass produced, and therefore on the quantity of pruning material. The average values obtained for dry matter and matter after cutting in Mediterranean areas are (Velázquez-Martí et al., 2011/a): 1.31 t/ha in annual and 3.02 tons/ha in biennial pruning. Since it is not possible to know when pruning takes place, we are here using an average value equal to 2.16 tons/ha.

The available residual biomass obtained from pruning operations in vineyards depends on the type of vineyard (for table grape or for wine production) and on the supporting structure or cropping system. The shape of the structure of plantation has a strong influence on the quantity of biomass produced, then on the quantity of pruning material, as well as in the residual material that is produced. From the estimation conducted by Velázquez-Martí (2011/b) in a Mediterranean area, the standard vineyards produce an average of 2.15 tons/ha of dry biomass. The presence of irrigation increases the biomass in the vineyards by 42%.

Table 1. : Estimation of dry matter (tons/year) from pruning trees

Pruning residues	ha	tons/(ha year)	tons/year
Olive grove	27,721.68	2.16	59,878.82
Vineyards	5,567.11	2.15	11,969.28

2.3.2 Agro-food industry

Significant residues for energy purposes are those deriving from the olive oil industry, the exhausted pomace, and those arising by the alcoholic grapevine/wine industry, exhausted marcs (Statuto et al, 2013). The main by-products of the oil industry are made from pomace and vegetation water. In the absence of homogenous data about the regional production capacities of the olive oil mills and the real amount of pressed olives, an estimation of process residues was carried out starting from olive groves surface and data concerning the average production of olive. Considering the spatial data deriving from the Agriculture Census (ISTAT, 2011/b), the average annual quantity of by-product (40%), the amount of virgin pomace was calculated to about 14,720 tons, 55% of them being considered as exhausted pomace, usable for energy purposes.

Similarly, the amount of exhausted marcs usable for energy purposes were determined (Mancini et al., 2008). Assuming an annual production of about 8 tons/ha of grape, the part of the territory dedicated to the cultivation of vine grape equal to14,000 ha, and the amount of extractable exhausted marcs equal to 4.6% of the production of wine grape, it derives for the entire regional territory a production of about 6,440 tons/year.

2.4. Bioenergy calculation

The assessment of the biomass energy potential is based on the total biomass potential and the respective Lower Heating Value (LHV) of each biomass type available for energy purposes. The LHV is different for each type of biomass, and its value depends on the chemical structure of biomass, on the content of moisture in the biomass and on the content of hydrogen in the biomass (Cosic et al., 2011). The energy potential [GWh/year] for different types of biomass available over the regional territory is calculated using the Eq (1):

$$B_{ep(n)} = E_{p(n)} x \, LHV_{(n)} \qquad (1)$$

where:

$B_{ep(n)}$= energy potential for different categories [MWh]

$E_{p(n)}$ = technically available potential of biomass type n [tons];

$LHV_{(n)}$ = the lower heating value of biomass [MWh/ton].

3. Results and Discussion

Table 2 shows the energy potential [GWh/year] for different types of agro-food by-product deriving from the exploitation of pruning residues and from the transformation of olive and grape, available in the regional territory, divided according with its municipalities.

Considering the spatial distribution of data and the calculations, it is possible to identify the energy distribution in

Basilicata Region (Figure 4 and 5) potentially arising from the olive and grape chains. From the superimposition of the different base maps it is possible to identify the total amount of energy (Figure 6) deriving from the valorization of the considered olive and grape agro-food by-products and wastes. In figure 6, that represents the distribution of the theoretically energy potential, it is possible to identify two areas, (in the north-eastern area, and near the coastline of the Ionian Sea), where energy availability is the greatest,and where it would be possible to suppose the localization of some biogas plants installations. According to Höhn et al. (2014), the maximum transportation distances for raw materials vary from 10 to 40 km, mostly depending on the orographic characteristics of the territory.

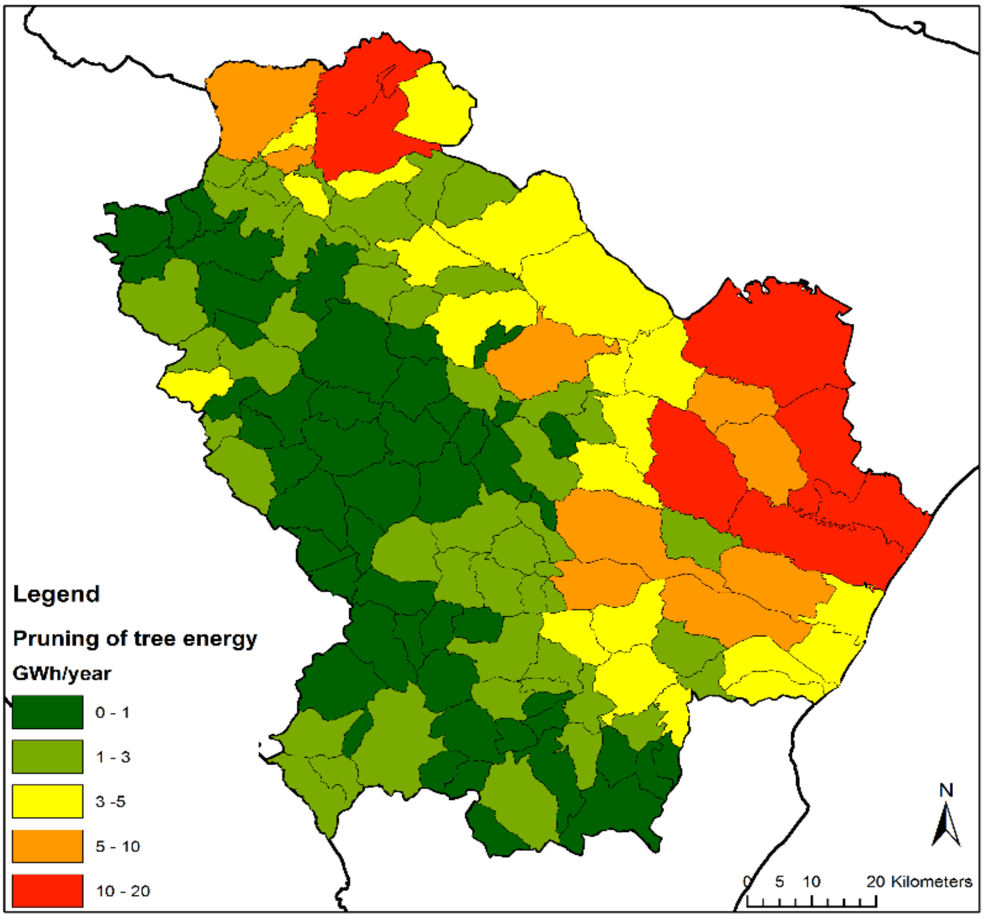

Figure 4. Potential energy from pruning residues of olive and grape over the regional territory divided according with its municipalities

The Energyscape definition considers “the complex spatial and temporal combination of the supply, demand and infrastructure for energy within a landscape”. The landscape should be understood as a dynamic and open system where biophysical, social and economic factors interact to define the current structure (Tortora et al., 2015)., while the energy system interacts with the local environment, and the use of renewable energy sources means to promote the creation of new energy landscapes. These landscapes will be made up of new visible elements (new power plants) and invisible ones (new relational, production and distribution nets), linking new cultural images to the use of renewable energy.

The implementation of a Geographical Information System allows to figure out optimal solutions in decision-making processes and in spatial planning according to some pre-defined criteria. The pre-defined criteria for an “energy landscape” should require a location where optimal site parameters, such as the cost of biomass or agricultural field, transportation cost, distance between biomass location and plant location and on the size of the energy plant, services offer the best solution. Through GIS-functionality, planners are able to evaluate a range of reasonably optimal solutions, within the general context including economic or political expediency as well.

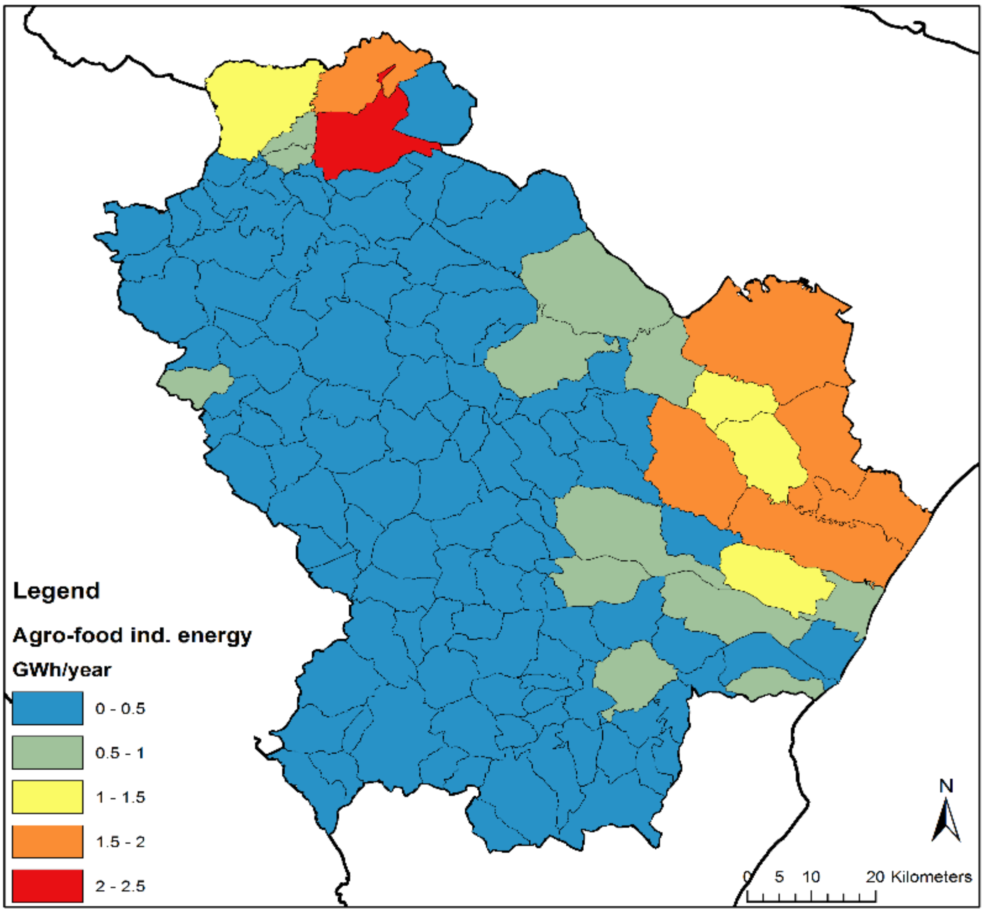

Figure 5. Potential energy from olive and grape agro-food by-products over the regional territory divided according with its municipalities

Table 2. : Estimation of potential energy

BY- PRODUCTS	Dry Matter	LHV	Potential energy
	tons/year	MWh/ton	GWh/year
Pruning of trees			
Olive grove	59,878.82	4.99	298.80
Vineyard	11,969.28	4.85	58.02
Sub-Total Pruning of trees			**356.82**
Agro-food Industries			
Exhausted pomace	8,096.00	4.1	33.19
Exhausted marcs	6,440	3.5	22.54
Sub-Total Agro-food Industries			**55.73**
TOTAL			**412.55**

The decision to install an energy plant needs a preliminary management plan to analyze the energy supply system that demonstrates the compatibility of the intervention with the renewability of the resources located in the surrounding area for the duration of its useful life. In this case, territorial studies, conducted in this work, are essential to identify the territorial framework, and to define the correct planning strategies. Using biomass and renewable energies can significantly contribute to the job creation and economic development of rural economies, preserving and protecting the landscape and its main characteristics.

The valorization of agro-industrial residues, although being products with a limited energy potential, will fit into the goals of the general energy efficient conservation and sustainable protection of the natural resources. Taking into account that pruning and agro-food industries residue poses serious problems for its disposal, since it is concentrated in well-defined areas, it would be possible to get a valuable new energy source through a correct spatial localization of energy plants.

Finally, a more wide analysis should be performed, in order to include in the general evaluation about the recovery of these by-products and wastes coming from the olive and grape chains, also suitable considerations on how the current practice of crushing organic material, leaving it to slowly degrade within the rural land, may contribute to the improvement of the physical and chemical characteristics of the agricultural soil, as well as about a more global economic approach, able to define the most suitable options in an holistic way.

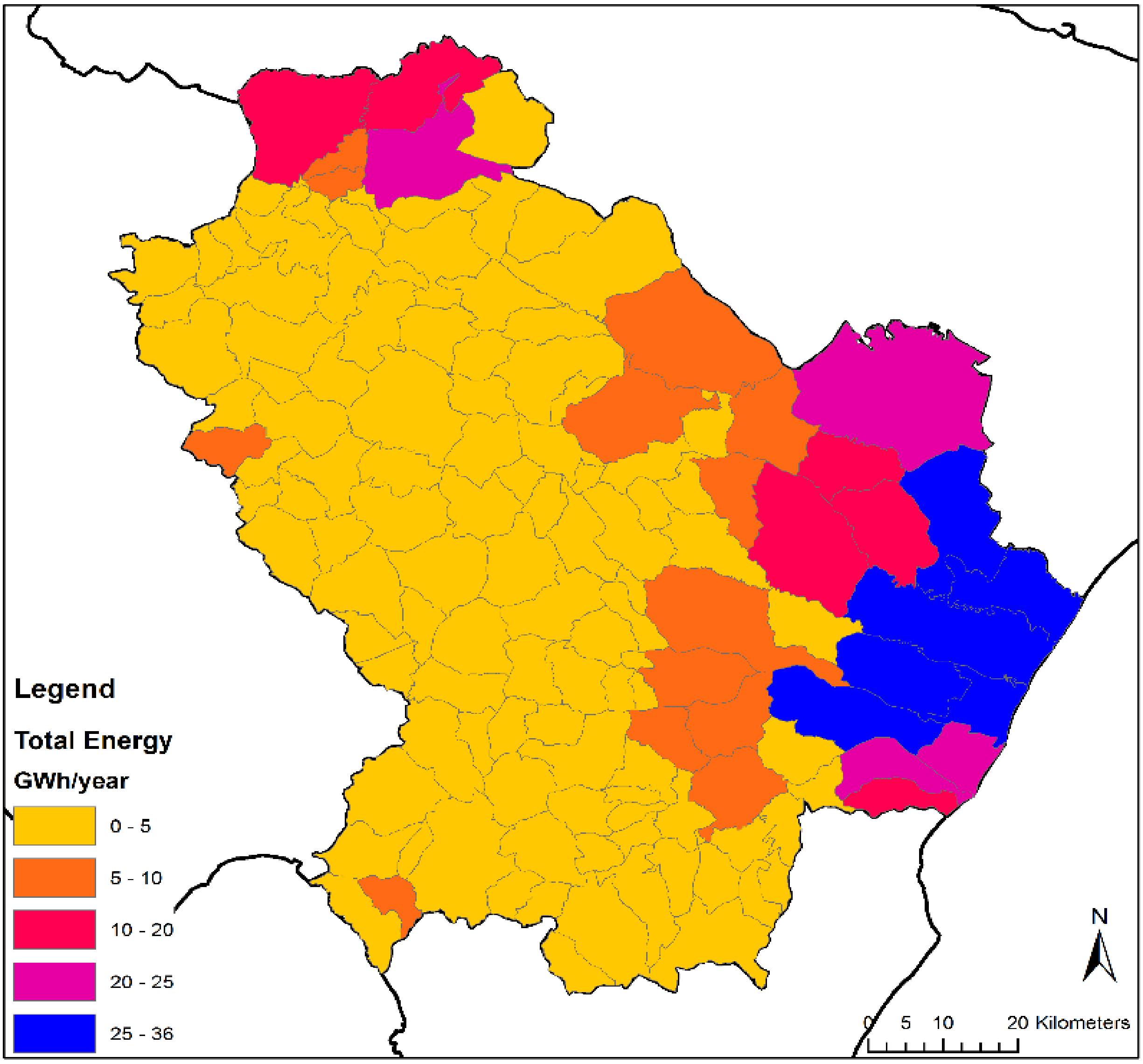

Figure 6. Total potential energy deriving from olive and grape chains in Basilicata Region

4. Conclusions

In this paper, the attention was focused on the availability of energy deriving from the exploitation of renewable energy sources and especially from agro-food by products, in terms of pruning residues and agro-food industry residues obtained by olive and grape, in relation to a spatial distribution. In particular, in the current situation considered with reference to the Basilicata Region, the availability of energy from the valorization of agro-food by-products and wastes allows understanding the total amount of energy in a framework containing geographic and spatial characteristics.

The Geographic Information Systems that was implemented, that allows the opportunity to indicate the availability of energy deriving from the valorization of the different considered agricultural by-products, can be considered as a valuable tool, usable by policy makers, for proper planning and management of energy resources. The produced maps, that express the values of energy availability, on a regional scale divided at municipal level, show the areas that are most productive in terms of energy from the exploitation of olive and grape residues. The use of by-products and waste for energy purposes appears a proper way, since it enables to facilitate and/or solve environmental problems in the processes associated with their disposal within the same agricultural context, while valorizing the typical landscape as well.

References

Antrop, M., 2006 Sustainable landscapes: Contradiction, fiction or utopia?, Landsc. Urban Plan. 75, 187–197. doi:10.1016/j.landurbplan.2005.02.014.

Blaschke, T., M. Biberacher, S. Gadocha, I. Schardinger, 2013. “Energy landscapes”: Meeting energy demands andhuman aspirations, Biomass and Bioenergy. 55, 3–16. doi:10.1016/j.biombioe.2012.11.022.

Boyce, R.R., 2006. All Possible Worlds: A History of Geographical Ideas, 4th revised edition, Prof. Geogr. 58, 119–120. doi:10.1111/j.1467-9272.2006.00518_6.x.

Cosic, B., Z. Stanic, N. Duic, Geographic distribution of economic potential of agricultural and forest biomass residual for energy use: Case study Croatia, Energy. 36, 2017–2028. http://dx.doi.org/10.1016/j.energy.2010.10.009

Höhn, J., E. Lehtonen, S. Rasi, J. Rintala, 2014. A Geographical Information System (GIS) based methodology for determination of potential biomasses and sites for biogas plants in southern Finland, Appl. Energy. 113, 1–10. doi:10.1016/j.apenergy.2013.07.005.

ISTAT (Italian National Institute for Statistic) 2011/a, 6° Censimento Popolazione e Abitazioni. - Popolazione residente - livello comunale. ISTAT. Roma. Italy. https://censimentopopolazione.istat.it/.

ISTAT (Italian National Institute for Statistic) 2011/b, 6° Censimento Generale dell’Agricoltura. - Utilizzazione del terreno dell'Unità Agricola - livello comunale. ISTAT. Roma. Italy. http://censimentoagricoltura.istat.it/.

Mancini, A. M., C.M. Berton, C.L.D. Apote, C.L. Pari, E. Sandro, S.D. Andrea, 2008. Caratteristiche tecniche delle biomasse e dei biocombustibili. *Progetto Biomasse Enama (Mipaaf).*

McKendry, P., 2002. Energy production from biomass (part 1): Overview of biomass, Bioresour. Technol. 83, 37–46. doi:10.1016/S0960-8524(01)00118-3.

Statuto, D., A. Tortora, P. Picuno, 2013. A GIS approach for the quantification of forest and agricultural biomass in the Basilicata region, J. Agric. Eng. doi:10.4081/jae.2013.(s1):e125.

Tortora, A., D. Statuto, P. Picuno, 2015. Rural landscape planning through spatial modelling and image processing of historical maps, Land Use Policy. 42, 71–82. http://dx.doi.org/10.1016/j.landusepol.2014.06.027

Velázquez-Martí, B., E. Fernández-González, I. López-Cortés, D.M. Salazar-Hernández, 2011/a. Quantification of the residual biomass obtained from pruning of trees in Mediterranean olive groves, Biomass and Bioenergy. 35, 3208–3217. doi:10.1016/j.biombioe.2011.04.042

Velázquez-Martí, B., E. Fernández-González, I. López-Cortés, D.M. Salazar-Hernández, 2011/b. Quantification of the residual biomass obtained from pruning of vineyards in Mediterranean area, Biomass and Bioenergy. 35, 3453–3464. http://linkinghub.elsevier.com/retrieve/pii/S096195341100211X.