Planning the energy valorization of agricultural co-products, by-products and waste in a landscape context

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Summary
Within the current global trend aimed to increase energy saving and exploit renewable energies, agriculture may play a significant role, mainly when the energy valorization of agricultural by-products, co-products and waste is concerned. Agricultural biomass is a diffuse source of energy, having one of the highest potential to cover renewable energy needs for the future, but the previous restoration of organic matter in the soil should be anyway properly considered. Litter decomposition governs the soil nutrient levels and the carbon cycle, consequently influencing the physical and chemical properties of the soil, which are the key components to maintain the productivity of agro-ecosystems and the entirety of rural landscapes. In the present paper, the spatial relationships between renewable energy potentials, coming from agricultural co-products, by-products and waste, and the rural landscape, were analyzed through the implementation of a GIS over the whole territory of the Basilicata Region. This internal Southern Italian Region can be considered as a *benchmarking* case study, since it is characterized by big sources of renewable energy connected to its morphological and environmental structure, as well as to its traditional agricultural and food productions. Basing on the quantity of agricultural residues, the energy production in this study area after restoring the nutrient balance of the soil was estimated in the framework of a planning process able to preserve the rural landscape.

1. Introduction
The temporal and spatial aspects linking the biomass resource, the waste biomass, the energy conversion plant size, the transport system and the environmental impacts need to combine energy system design with spatial planning (Blaschke et al., 2013). In the recent years the attention has been focused on the energy from biomass by-products, while the exploitation 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). Agricultural co-products, by-products and waste, other than being considered as an important energy source, are indeed important factors for restoring the level of organic matter in the soil (fig. 1.1). Litter decomposition governs the soil nutrient levels and the carbon cycle, influencing the physical and chemical properties of the soil, which are the key components to maintain the productivity of agro-ecosystems and the entirety of rural landscapes (Endeshaw et al., 2015).
This paper focuses on the identification and quantification of biomass distribution, arising from agro-food productions in Basilicata Region. The analysis has been carried out considering main traditional cultivation - *i.e.*: cereal straw and pruning residues

(olive groves and vineyards) - implementing a Geographic Information System (GIS) for calculating the energy potential of agricultural biomass, after restoring soil fertility.

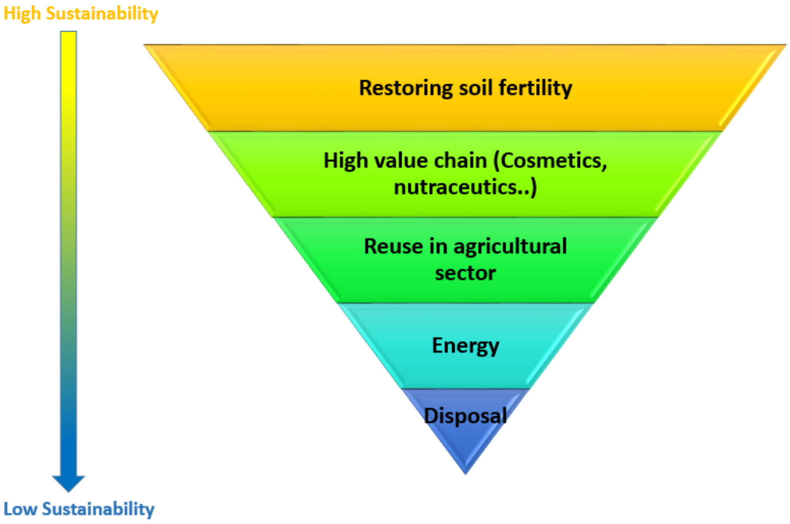

Figure 1.1: Agricultural by-product, co-product and waste management hierarchy.

2. Materials and Methods

2.1. Biomass production: Cereal crops

After harvesting cereal crops, a large quantity of straw, estimated to have a larger volume than the crop itself, is available as a waste. Several studies assumed that about 50% of straw was actually used as bioenergy feedstock; the other part is used as litter for the animals, or left on the field to promote chemical, physical and biological soil fertility. In order to evaluate the spatial variability of different crops, the data derived from agricultural census (2010) of the *Italian National Institute of Statistics* (ISTAT, 2011) at an average humidity of 14% were used. For each cereal crops it is so possible to estimate the straw amount (Tab. 2.1) generated every year over the regional territory.

Table 2.3: Estimation of dry matter from cereal straw

	Land	**Straw per hectar**	**Total of straw**	**Dry matter**
Crops	***ha***	***t·ha^{-1}***	***t·year^{-1}***	***t d.m.·year^{-1}***
Common wheat	7,545.95	2.50	18,864.88	16,223.79
Durum wheat	136,333.69	2.30	313,567.49	269,668.04
Rye	296.20	3.00	888.60	764.20
Barley	17,909.90	3.02	54,087.90	46,515.59
Oats	18,285.19	1.00	18,285.19	15,725.26
Grain maize	887.18	14.60	12,952.83	11,139.43
Other cereals	1,743.57	3.00	5,230.71	4,498.41
TOTAL			**423,877.59**	**364,534.73**

2.2. Biomass production: olive trees & vineyards

Depending on the technical criteria of olive trees pruning system, the average values obtained for dry matter after cutting in Mediterranean areas is (Velázquez-Martí et al., 2011/a) equal to 2.16 tons/ha. The available residual biomass obtained from pruning operations in vineyards depends on the type of vineyard and on the supporting structure or cropping system. Adopting the estimation conducted by Velázquez-Martí (2011/b), a production of 2.15 tons/ha of dry biomass on average was here considered (Tab. 2.2).

Table 2.2. : 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. Biomass for soil fertility restoration

An increase in quality and quantity of soil organic carbon (SOC) could improve the soil productivity. Lehtinen *et al.* (2014) reviewed 50 long-term experiments in Europe and found that Soil Organic Carbon concentration increased with 7% due to straw incorporation. The sequestration potential for straw incorporation reported by several studies is 0.7 Mg C ha^{-1} $year^{-1}$ (Reiter, 2015). The situation of organic matter content of soil in Basilicata is reported in figure 2.1 arising from information concerning the *"Carta Pedologica dei Suoli"* (Basilicata Region, 2006). Ligneous pruning residues need specific treatment and water to ensure activation of the composting process, and the consequent estimation of organic matter is therefore quite difficult to be calculated.

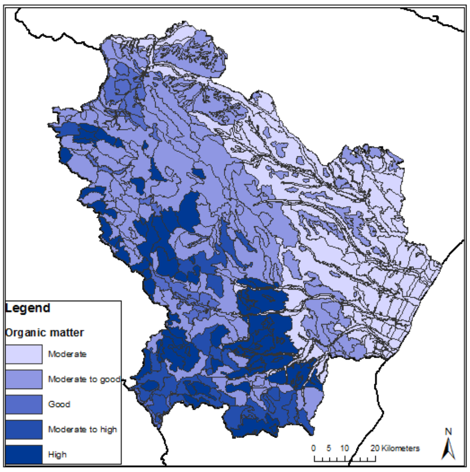

Figure 2.1: Organic matter content of different soils in Basilicata region.

3. Results and Discussion

Starting from the quantification of agricultural biomass it was so possible to evaluate the spatial distribution (fig. 3.1), in terms of tons of dry matter per year.

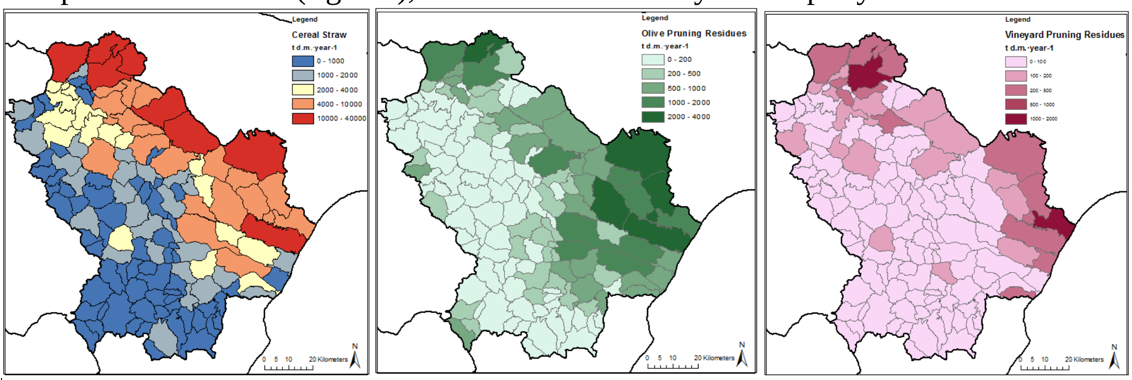

Figure 3.1: Estimation of dry matter $year^{-1}$ of cereal straw, olive and vineyard pruning residues

The biomass energy potential was therefore calculated on the total biomass potential production and the respective *Lower Heating Value (LHV)* of each biomass type. A value of 218,191 tons/year of biomass could be indeed considered all over Basilicata region for energy production, after having previously assured a proper restoration of the fertility of the same soils in which that biomass is originated, leading to an estimated amount of 1,051 GWh/year. More added-value options could be anyway investigated for possible valorization in different production chains (cosmetic, nutraceutical, etc.). Considering the spatial distribution of organic matter and the by-product distribution, it is possible to notice that in the east part of the Region, where the organic content is smaller, there is an higher availability of biomass. More analysis is therefore needed for optimizing its valorization within a more general holistic approach, able to properly consider the safeguard of the rural landscape, which is the general framework system in which all different ecosystems may evolve in a sustainable way.

4. Conclusion

The results coming from the implementation of a GIS at regional level have shown that a sound planning of co-products, by-products and waste biomass flows coming from agro-food production could reveal a very powerful tool, having an hidden economic value, when this resource is valorized according to a hierarchy. Within this specially focused approach, suitable collection station, aimed to receive agro-food biomass so as to identify it and direct towards the most convenient solution, should be realized, so as to contribute to the socio-economic growth of a region having a so high natural potential connected to its traditional agricultural and food productions.

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