proceedings

Proceedings

Charcoal Production Infrastructure in the Portalegre District, Portugal: First Assessment from Satellite Imagery and Field Observations †

Felipe Thalles Moreira Silva *, José de Jesus Figueiredo da Silva, David Filipe Ramos Silva, Luís António da Cruz Tarelho, Manuel Arlindo Amador de Matos and Daniel dos Santos Félix das Neves

Department of Environment and Planning and Centre for Environmental and Marine Studies (CESAM), University of Aveiro, Campus Universitario of Santiago, 3810-193 Aveiro, Portugal; jfs@ua.pt (J.d. J.F.d. S.); dsilva@ua.pt (D.F.R.S.); ltarelho@ua.pt (L.A.d.C.T.); amatos@ua.pt (M.A.A.d.M.); dneves@ua.pt (D.d.S.F.d.N.)

* Correspondence: felipe.thalles@ua.pt; Tel.: +351-234-370-349

† Presented at the Bioenergy International Conference, Portalegre, Portugal, 11–13 September 2019.

Published: 27 January 2021

1. Introduction

Energy plays a key role for humanity, so the best way to absorb the huge increase in energy demand is perhaps through energy diversification and decentralization [1]. In this scenario, the use of plant biomass as an energy source results in a favorable balance concerning greenhouse gas (GHG) emissions in relation to fossil fuels [2].

Biomass is arguably not the final answer to address all the environmental and energetic challenges faced by society in the 21st century, but if used in a sustainable and environmentally friendly way, bioenergy can contribute to a significant reduction of GHGs. In addition, the use of bioenergy reduces forest fire risks and diversifies the energy supply, along with its positive social impacts in rural areas related to the creation of new jobs along the fuel-to-energy chain [3]. In Portugal, about 3.1 million hectares of land are covered by forests, which represents 35% of the national territory [4], making Portugal a country with great potential for the exploitation of forest biomass.

Alto Alentejo, to which the Portalegre district belongs, is a Portuguese region located in the south central part of Portugal's mainland, essentially of rural characteristics, with a predominant farming, agricultural, and forestry profile. The distinctive socio-economic, climatic features, and forest of this region make it well placed to take advantage of some opportunities within the biomass-to-energy sector, mainly associated with the management of holm oak and cork oak stands [3]. As an example, the district of Portalegre is well-known for its historical link with charcoal production activities, although the existing infrastructure, location, and role of this activity to the rural economy and forest biomass valorization are largely unknown.

Carbonization is a thermochemical process in which biomass is heated to relatively low temperatures (<500 °C), under a controlled oxygen atmosphere, giving rise to the formation of a carbon-rich solid residue (charcoal) and a volatile fraction composed of condensable organic vapors and permanent gases. The proportions of these products depend on the production method employed, the process parameters, and the characteristics of the material to be treated [5]. According to Boateng (2014) [6], slow pyrolysis is characterized by a mild heating rate in the kiln and a long residence time, which usually varies within a few days, depending on the speed of circulation and exhaustion of pyrolysis gases, kiln geometry and type, kiln biomass disposition, and other factors that influence the kinetics of pyrolysis reactions.

This study aimed to provide a first insight on the relevance of charcoal production in the Portalegre district by providing information about the distribution of the production sites across the territory, the types and number of carbonization kilns, ancillary infrastructure, and the widely used types of biomass.

2. Experimental

The survey work that was carried out to characterize the charcoal production activities in the Portalegre district was mainly based on the analysis of satellite data and a limited number of field observations. The satellite data was available from Google web map applications that provided metering and georeferencing tools that were accurate enough for the purposes of this study.

The results were structured as an inventory, constituting a database regarding the major characteristics of each charcoal production site, including the following: location (municipality, parish, coordinates), on-site activities (e.g., charcoal production, wood piling), type of wood, use of machinery, number, type and cross-sectional area of kilns, and other pertinent observations. The data obtained was analyzed by basic statistical methods aiming to provide an initial idea about the existing carbonization infrastructure and its plausible relevance to the biomass-to-energy sector in the Portalegre district.

3. Results and Discussion

3.1. Types of Wood

Apart from cork oak and holm oak, there are considerable areas in the northern part of the Portalegre district where eucalyptus, olive, and other oaks are abundant. Of these, mainly cork oaks, eucalyptus and olives are cultivated. Nevertheless, the first two species are perhaps those having the historically highest contribution to the economy of rural areas in Portalegre, being traditionally used for the production of firewood, cork, charcoal, and feedstock for farming activities. According to the prospective work that was carried out based on the analysis of satellite images, one perceives a clear dominance of small wood logs (<1 m length) in relation to industrial round wood (≈2.5 m length) in the woodpiles of the charcoal production sites, which suggests that charcoal production is mainly based on wood from oaks and/or olive trees; the following fieldwork confirmed that the wood is mainly coming from the management of the cork oak and holm oak forests. However, it is worth noting that charcoal production in adjacent municipalities belonging to the Santarem district also uses large quantities of industrial round wood from eucalyptus stands, which shows that the production of charcoal in Portugal is not based only on cork/holm oak wood.

3.2. Types of Kilns

Carbonization kilns can be classified according to its external shape, as rectangular (Type I), cylindrical (Type II), semi-spherical or "igloo" (Type III), and square with a semi-spherical top (Type IV). According to the available information, most of the charcoal produced in the Portalegre district comes from type II, III and IV kilns, where their construction is mainly based on bricks, sometimes with metal covers and doors. Regardless of the type of kiln being used, the charcoal-making systems used are, in most cases, quite rudimentary, without the ability to control the operating conditions (mainly the temperature) or the volatile byproducts that are likely released into the atmosphere and soils. The operation of these kilns is based on existing know-how that was developed from trial and error strategies, without a scientific basis. Thus, there is a difficulty in standardizing the carbonization routine and obtaining higher charcoal yields.

3.3. Carbonization Infrastructure

On the basis of the information obtained to date, almost 50 charcoal production sites were found in the Portalegre district, equivalent to more than 450 kilns, of which about 80% seems to be active, or, at least, can be put into operation with little effort

Of the locations examined, see Figure 1, the municipality of Ponte de Sor stands out as the major focus of charcoal production, accounting for more than half of the total number of charcoal kilns that were found in the Portalegre district. Figure 2 further shows the approximate locations of the charcoal production sites across the territory.

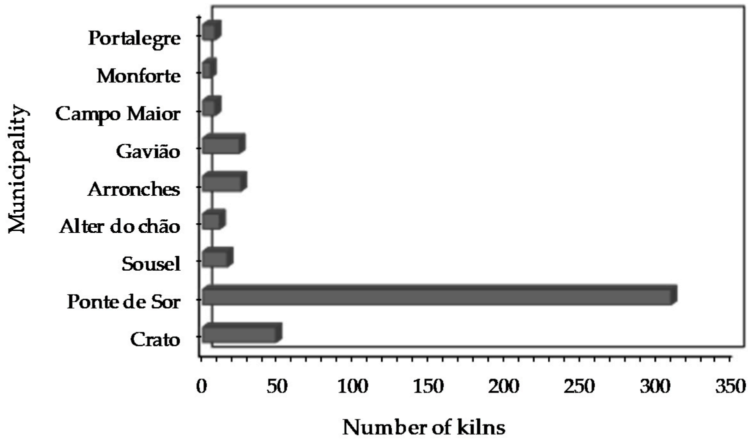

Figure 1. Number of charcoal kilns by municipality.

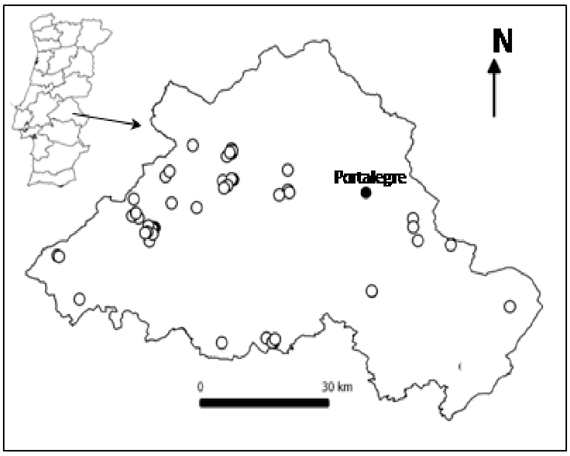

Figure 2. Spatial distribution of the charcoal production sites in the Portalegre district.

Figure 3 plots the charcoal production sites by the respective number of kilns. Approximately 50% of the analyzed sites have up to five charcoal kilns. This means that although there are many kilns in the district, there is considerable dispersion of the infrastructure across the territory. Yet, it is worth mentioning that there is a relevant number of production sites with more than 20 kilns, and even over 30 kilns in a limited number of sites. It is therefore clear that the larger production sites involve significant manpower and machinery to be able to handle the large amounts of biomass and charcoal involved in those activities.

Using the Google Earth web application (www.google.com/earth), it was possible to evaluate the diameter/side of the kilns, thus allowing us to estimate the respective cross-sectional areas. Figure 4 illustrates the number of kilns per cross-sectional area; the main conclusion is that the majority of the kilns have a cross-sectional area between 8 to 22 m^2. To the limits of the distribution, it can be seen that there are very small kilns with less than 7 m^2, as well as very large kilns with more than 40 m^2 of cross-sectional area.

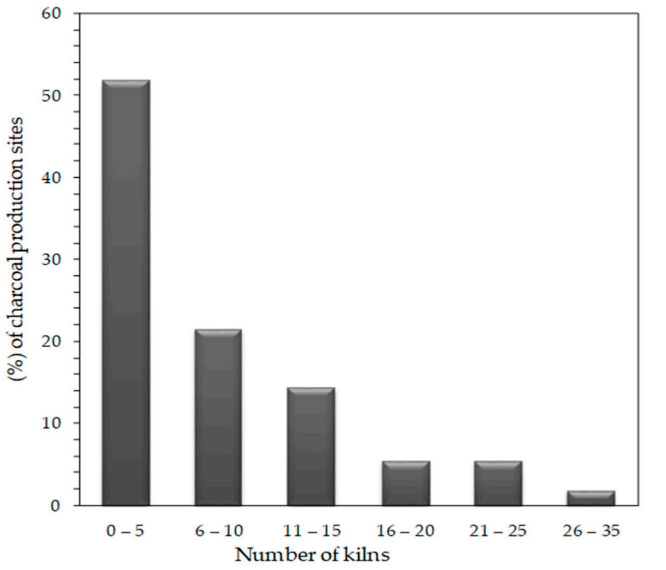

Figure 3. Percentage of charcoal production sites by the number of kilns.

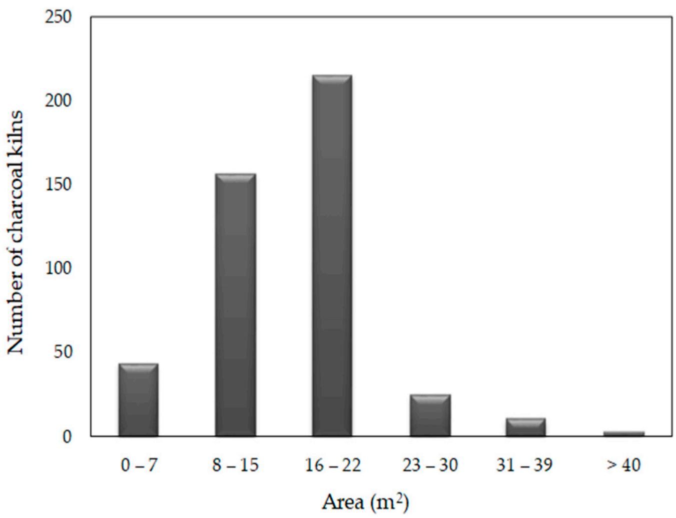

Figure 4. Number of kilns by cross-sectional area.

3.4. Ancillary Infrastructure and Machinery

Approximately half of the analyzed sites use machinery (e.g., trucks, tractors, loaders), thus suggesting that considerable amounts of biomass and charcoal are involved in the activities. With reference to Figure 3, this means that machinery is generally needed in production sites with more than 5 kilns. Ancillary infrastructure related to, for example, wood sawing, weighting, sieving, debarking and warehouses could also be seen in some places, thus pointing to some level of industrial organization.

Regarding the spatial organization of the kilns in each production site, it can be said that around 70% of the sites exhibit an in-line arrangement of the kilns or are arranged in a planned manner. The remaining sites are considered to be poorly organized or not organized at all, as the kilns are not placed according to a given geometry or are randomly distributed.

3.5. The Relevance of Charcoal Production for Biomass Valorization in the Portalegre District

An attempt was made to provide an estimate of the amounts of biomass and charcoal associated with the carbonization infrastructure in the Portalegre district. From the aforementioned cross-sectional area of the kilns and assuming an average height of 3 m, the total volume of existing kilns was estimated after discounting the wall thickness and unused volume, corresponding to about 10% of the total volume. Then, the total mass of wood that can be fed into the carbonization kilns was obtained based on a density of 600 kg/m^3 for stacked wood logs. The carbonization process is slow and the average duration of a batch cycle, including wood loading, drying and pyrolysis, and charcoal cooling and unloading, was considered to vary between 12 and 24 days. Thus, a kiln can accomplish between 12 to 25 annual carbonization cycles if a utilization factor of 80% is assumed. Under these conditions, our estimate was that the amount of wood being carbonized across the Portalegre district can easily approach or even exceed the amount of fuel used in a medium-size biomass power plant, like the one in Mortágua (≈10 MVA [7] taken here for comparison purposes as it is a well-known dedicated biomass boiler in Portugal. Such fuel consumption is equivalent to an overall charcoal production that can easily exceed 10 kton/year, depending on the cycle length and the exact geometry of the kilns, and considering an average charcoal yield of 20% by mass (wet basis).

4. Conclusions

This study deals with the relevance of charcoal production in the Portalegre district by compiling data on the production sites, types and number of kilns, ancillary infrastructure, and the widely used biomass types. The analysis of this data makes it clear that charcoal production is a widely exploited activity in this district, being closely related to the valorization of residues (mainly wood) from cork oak and holm oak forests. The size span of the individual carbonization sites, the dispersion of the infrastructure across the territory, and the estimated overall biomass carbonization capacity indicate that charcoal production cannot be ignored within the regional biomass management plans, namely in the present context of risk reduction of forest fires. Furthermore, it highlights the importance to further characterize the operation of existing carbonization kilns, including the overall mass-balance, charcoal quality, and major gaseous emissions, to be able to understand whether the traditional process can be improved regarding both the carbonization efficiency and environmental compatibility.

Acknowledgments: Thanks are due for the financial support to CESAM (UID/AMB/50017/2019), to FCT/MCTES through a national fund, including project reference PCIF/GVB/0179/2017.

References

1. García, R.; Pizarro, C.; Lavín, A.G.; Bueno, J.L. Characterization of Spanish biomass wastes for energy use. *Bioresour. Technol.* **2012**, *103*, 249.
2. Kern, S.; Halwachs, M.; Kampichler, G.; Pfeifer, C.; Proll, T.; Hofbauer, H. Rotary kiln pyrolysis of straw and fermentation residues in a 3 MW pilot plant: influence of pyrolysis temperature on pyrolysis product performance. *J. Anal. Appl. Pyrolysis* **2012**, *97*, 1.
3. Lourinho, G.; Brito, P. Assessment of biomass energy potential in a region of Portugal (Alto Alentejo). *Energy* **2014**, *81*, 189–201.
4. ICNF. *IFN6-Areas dos usos do solo e das Especies Florestais de Portugal Continental*; Resultados preliminares; Instituto de Conservação da Natureza e das Florestas: Lisbon, Portugal, 2013.
5. Cortez, L.A.B.; Lora, E.E.S.; Gómez, E.O. *Biomassa para Energia*, 1st ed.; Editora Unicamp: Campinas, Brazil, 2009.
6. Boateng, A.A. *Curso: Pyrolysis of Biomass for Fuel & Chemicals*; ARSUSDA: Porto Alegre, Brazil, 2014.
7. Pina, C.; Pereira, L.I.; Alvarenga, M.O. *Ordenamento do Território na Resposta às Alterações Climáticas: Contributo para os PDM*; Edição Digital; Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo: Lisboa, Portugal, 2019; 93p, ISBN 978-972-8872-38-0.