Panel 2.6. Consumption of wood, energy transitions and woodland management from a historical perspective. Part II

“Fuel supply to Madrid and forest transformations in an organic economy”

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INTRODUCTION

The methodological and thematic revision of agrarian history as a discipline has relied upon the exchange of ideas with related disciplines such as environmental history. One of its most important contributions is the concept of social metabolism, which, applied to urban areas in particular, allows us to undertake innovative studies on interactions between rural and urban areas (HOFFMANN, 2006). Of the different methodological approaches, we believe that the urban environmental imprint recently proposed is of particular interest in order to analyse the relationship between a city and the hinterland from which it obtains materials and energy in exchange for certain services (BILLEN, GARNIER, BARLES, 2012). The study of energy imprint, on the other hand, is centred around the supply of energy and its imprint on the land (KIM, BARLES, 2012).

The aim of the present paper is to analyse the energy imprint of eighteenth-century Madrid within an exclusively organic economy. Our aim, therefore, is to identify how energy was sourced and the impact that this had on forest landscapes. This will give us a greater understanding of the role of the different factors that have shaped forest areas.

To this end, we have structured our paper in two parts. Firstly, we will characterise the energy system in force in the eighteenth century, analysing the composition and consumption of energy, supply management and means of transportation. Secondly, we will focus on the energy imprint of this system, beginning with its regulation, followed by calculations of its supply and its impact on forest landscapes.

CONSUMPTION LEVELS AND PATTERNS

Fuel in Madrid in the Modern Age came exclusively from biomass, since charcoal was not available for urban consumption. The transition to fossil fuels had to wait until the arrival of railways.

The consumption patterns for the city are determined, firstly, by the climatological circumstances since the inland areas of the peninsula suffer from cold and long-lasting winters. We must also bear in mind that in Modern Age Madrid almost all fuel was destined for domestic consumption (above 90%), as opposed to industrial demand. Finally, we should also take note of the extreme social inequality that existed in terms of energy consumption, with distribution systems and prices that were more
favourable to the privileged classes (BERNARDOS, HERNANDO, MADRAZO, NIETO, 2011).

The fuel consumed in Madrid was predominantly made up of firewood and, in particular, charcoal, providing more than 80-85% of heat energy. A wide range of organic materials were also used, such as straw (more than 20,000 t a year) and dry dung (sometimes mixed with straw), as well as olive stones and animal waste. Although difficult to quantify and providing little heat energy, the latter two resources were key for the survival of large sections of the population that had little or no access to more valuable fuels.

Focusing our attention exclusively on charcoal and firewood, we have traced the development of its consumption from the second half of the eighteenth century in Table 1. Firewood (around 15,000 t a year) came from the immediate surroundings of the city, within a 20km radius. Half of the firewood used came from shrubs and bushes which generally speaking had little energy value: although the amount used was half that of charcoal, its energy contribution did not even reach 15%. Suffice to say that charcoal was the key to Madrid’s energy system in the Early Modern Age, the amount consumed growing from 30,000 a 35,000 t, almost in parallel evolution with the population. If we convert this quantity of charcoal into the amount of firewood needed for its production (at a proportion of 5 to 1), the annual consumption of firewood that supplied Madrid between the years 1760 and 1800 went from 165,000 t. to around 190,000 t.

The per capita consumption represents relatively high figures of almost 3kg of firewood/person/year, or 1 tonne per person per year (without taking into account other fuels). These figures stand out when compared with the fuel consumption in pre-industrial Europe (Table 2), since they are close to the levels of Paris (BOISSÈRE, 1990; KIM, BARLES, 2012) or the south of Germany and are triple the estimates for the Mediterranean. They are, however, similar to the figures obtained for Piedmont, which has a relatively similar climate (MALANIMA, 1996; WARDE, 2006).

The elevated levels of consumption are mainly due to the great relative weight of charcoal, since its production entails a considerable loss of thermic efficiency of around 54%. The availability of firewood in terms of the volumes required for Madrid’s consumption is thus greatly reduced when we take into consideration its real energy value. In 1760, a total of 1,173,612 GJ was made available as fuel (19.5 MJ/inhabitant/day), meaning that the real availability of fuel to Madrid residents was 50% above the minimum values established (MALANIMA, 2006).
Another way of evaluating Madrid’s consumption is to carry out an approximate calculation using the MEFA (Material and Energy Flow Analysis) method, as seen in Table 3. We see here that the Total Final Energy Consumption (TFEC) rose up to 7 GJ per capita/year. However, in order to obtain the TFEC, the total energy requirement (TER) was 14 GJ per inhabitant per year, which was almost double. This difference was generated in the process of converting firewood to charcoal. Compared to Paris, there was little difference in the consumption of firewood per inhabitant, but the Total Final Energy Consumption in Paris was double that of Madrid (KIM, BARLES, 2012). All in all, the total amount of fuel that was processed to supply Madrid was considerably high, since the TER is the most important concept to bear in mind when analysing Madrid’s energy imprint on the land.

The importance of charcoal to Madrid’s energy consumption was mainly down to the reduction of transport costs, which was parallel to its reduction in volume. Another of its advantages was its easy adaptation to urban living conditions, since it could be used inside homes. In addition to this, we can add the growing number of the population living in homes without chimneys, where they would cook and heat their dwellings using charcoal. Finally, the fact that firewood burned in fireplaces meant a noticeable loss of heat due to dispersion and this is not the case for charcoal.

MANAGING THE CHARCOAL SUPPLY

The aim of the state intervention was to guarantee the supply of fuel to the city, which was also where the court was. To this end, it sought to control the offer conditions of fuel in three main ways:

- a forestry policy to protect and guarantee forestry production in forest and woodland areas,
- supply management to ensure that fuel reached the urban consumer
- promoting the commodification of the forest amongst rural communities

In this section we will focus on supply management, which included the full production process, transportation and commercialisation of fuel. The charcoal supply systems in place in Early Modern Age Madrid were managed both privately by fuel suppliers and by the government, although both worked together in practice (BERNARDOS, 2004; BERNARDOS, HERNANDO, MADRAZO, NIETO, 2011).

A means of private management was developed from 1561 onwards: obligation. The supply of charcoal was regulated by a contract between a company of private
businessmen ("los obligados" or fuel suppliers) and the Madrid local government. The fuel suppliers were committed to guaranteeing the supply of charcoal according to the quantities, prices and deadlines established by the authorities. In exchange for this, they would enjoy important privileges that would allow them access to wood, fuel and transportation with favourable conditions.

The fuel-supplier system was replaced by direct government administration from 1753 onwards as part of a policy that was increasingly interventionist in nature in terms of the supply to Madrid. On the other hand, private management came across increased difficulties due to a rise in demand linked to the city’s demographic growth during the decade of 1740. In addition, competition for forest resources increased due to the rush for urban construction.

The state management of the charcoal supply to Madrid lasted until 1806. The main improvement that it introduced was the close relationship between charcoal supply and forestry policy, upon the application of the Royal Ordinance of 1748.

The state intervention was also aimed at promoting the commercialisation of forest and woodland areas. Urban demand for firewood and charcoal demanded a parallel offer from owners and the owners of large estates and members of nobility had no problem in adapting to this situation. In the commons, however, it was possible that the commercialisation of charcoal would disturb the tradition organisation of forest land, based on the integration of livestock. In order to overcome such resistance, the government applied pressure in the form of taxes and obliged towns to sell produce from their forests for the manufacture of charcoal.

TRANSPORTATION OF FUEL

Madrid depended solely on the transportation of fuel via land due to the lack of navigable routes, except for those built between the great preindustrial cities of Europe. Despite these structural limitations, the demand for fuel was met thanks to a continual stream of carts and horsemen. This mode of transport had an important economic impact, including the drawn-out process of pulling together the peninsula’s domestic market and encouraging multiple activities in rural communities.

The transport of firewood and charcoal was carried out in two ways, depending on the degree of professionalization:
- On the one hand, fuel was brought to Madrid by professional transport providers, who would bring half of the fuel to the city, especially charcoal, in carts drawn by oxen.
Between 30,000 and 35,000 carts would arrive in the city each year, each with an average load of 700 kg. The majority of cart drivers came from different inland regions within the peninsular and were part of the Real Cabaña de Carreteros or “Royal Cart Drivers Collective”. This association enjoyed important privileges including access to communal pastures on their journeys, in exchange for guaranteeing the government the availability of modes of transport for basic merchandise.

- The rest of the fuel was brought to Madrid by non-specialised transport providers. These providers were usually peasants from areas of production, who would transport firewood and some charcoal to Madrid in wagons or with mules and donkeys.

Finally, when the public management of the supply began in 1753, an enforced mode of transport was established for charcoal to be applied at times of agrarian crisis. The neighbouring villages of charcoal-producing areas were obliged to make trips to Madrid transport fuel at prices fixed by the government.

Through these measures, the availability of the modes of transport necessary was guaranteed, but with elevated costs, impacting on the real prices of fuel in Madrid. In the case of charcoal, transport costs made up half the final selling price, and in years of agrarian crisis this rose to 60%. When it came to the primary material (firewood), on the other hand, transport costs accounted for around 16% of the selling price and the production costs a quarter. The sale price was a political one that was fixed and subsidised by the government. As a result, at times it failed to cover actual transport costs.

**LAND AND FORESTRY REGULATION**

Before it was established as the capital in 1561, Madrid was a modest urban centre of around 15,000 inhabitants. It obtained its fuel from a hinterland that was relatively nearby: firewood came from the “dehesas” and groves on the banks of the Jarama and Manzanares rivers, and firewood and charcoal came from the nearby Sierra de Guadarrama.

In the second half of the sixteenth century, the sudden increase in the city’s population disrupted the traditional supply mechanisms in place. State intervention aimed to bring in a forestry policy that aimed to guarantee the supply of firewood and charcoal to Madrid. Its main components were the regulation of the exploitation of woodland and the demarcation of an area of land allocated for urban consumption requirements (HERNANDO ORTEGO, 2010, 2013).
The *Instrucción de 1574* (or “Order of 1574”) was the first step towards defining this forestry policy. The duties of Guarda Mayor (“Main Keeper”) and Juez Conservador (“Conservation Judge”) of the forest and woodland areas surrounding Madrid were created, covering an area of over 15,000km² in size. From this moment, the land that provided fuel became regulated and controlled by the State instead of by the municipality. Another key aspect of this rule was the technical regulation of forest exploitation, which was applied to the two forest structures that were responsible for the supply of charcoal to Madrid: high forests of holm oaks and coppice forests. It was decided that the oaks in coppice forests would be cut down every 12 years and holm oaks, every 17 years. This measure was clearly designed to promote silviculture, resulting in forest areas specialising in producing the charcoal that was so necessary for urban supply throughout Europe.

Despite the limited application of the *Instrucción de 1574*, the institutional mechanisms that it had established for the supply of fuel to Madrid remained. In 1620, however, the area set aside for Madrid’s charcoal supply was extended to a radius of 111.5 km in size, more than doubling the area allocated in 1574 (39,057km²). This significant increase in land allocation responded to the sudden increase in the population of Madrid at the time (140,000 inhabitants at the beginning of the seventeenth century).

The introduction of new legal restrictions continued with the regulation of forest exploitation, such as the *Ordenanza forestal de 1670* (or the “1670 Forestry Ordinance”) and the better-known *Ordenanza de Montes y Plantíos de 1748* (or “1748 Woodland and Plantation Ordinance”). Of the content of these ordinances, of particular interest to us are the logging periods of coppice forests, which were set aside for the manufacture of charcoal. In 1670, the periods established for coppicing were reduced: oaks were cut down every 10 years and holm oaks every 15, whilst in 1748, it was decided that the latter would be cut down every 10 years. The aim to increase the productivity of forest areas stood in direct contrast with other protection measures set in these ordinances. Although the sustainability of forest areas may have been placed in risk, the continuity of the traditional logging periods limited its possible negative impact.

The implementation of the 1748 Ordinance coincided with the state management of the charcoal supply from 1753 onwards. Both measures responded to the growing difficulties that were arising in the fuel supply. In short, in the second half of the
eighteenth century the process of implementing forestry policy culminated with the management of fuel supply to Madrid.

The initial area to which the 1748 Ordinance was applied was initially 111 Km, but again the growth of the urban population and the demand for fuel led the authorities to continue extending the area, widening the woodland allocated for supplying fuel firstly to 140 km and then to 167 km. This area, as we shall see, was increased again several times at the end of the eighteenth century.

**ENERGY IMPRINT**

Now that we have established how fuel supply was organised and the quantities and kinds of fuel that were consumed in Madrid in the eighteenth century, in what follows we will focus on the city’s energy imprint. How many hectares of woodland and forests were needed to meet the city’s energy requirements? How far was it necessary to go to obtain charcoal?

In order to understand the impact that Madrid’s energy consumption had on the land, we will also look at the forest landscapes affected. From which areas of woodland was this energy taken? What species of tree were used? And what forest formations were employed? Who owned these woodland areas and forests?

In our analysis of energy imprint we will focus on the forest areas (forests and woodlands) that were the main providers of energy. We cannot forget, however, that a small percentage of the fuel used in Madrid came from non-forest areas. Javier has already noted that fuel was taken from shrub lands, groves and cultivated areas: olive groves, vineyards, and the straw left over from herbaceous crops, etc. In short, fuel resources were exploited to the maximum, wherever they came from. Despite their diversity, however, in Madrid it was charcoal in particular was consumed, followed by firewood.

It seems clear and logical that the journeys to bring charcoal to Madrid should increase in distance as the years went by and the city increased in population and consumption needs. The average and maximum distances covered from the forest and woodland areas from which charcoal was brought to Madrid allow us to trace this increase.
On the one hand, the average distance from the forest and woodland areas that supplied Madrid did not increase in the eighteenth century, but varied between 88.6 km and 107.6 km, with those furthest away almost always more than 200km from the capital. This demonstrates that the boundaries of the land allocated for charcoal supply to Madrid seemed to have been well-known and stable throughout the eighteenth century, although years later forests and woodland areas that were particularly far away were included.

On the other hand, if we consider the distance of the forest and woodland areas from Madrid in terms of the charcoal produced, we discover that this clearly exceeds the average distance: 110km as opposed to 95km. In addition, this average distance does indeed increase throughout the century: from 109 km in 1725 to 122 km in 1794.

Another important piece of data is that the average distance of the ten woodland areas furthest away from the court grows as the century progresses, going from 160km in 1725 to 181km in 1803. And these ten areas also provide the city with a significant amount of charcoal (27.6% of the fuel consumed in 1794, for example).

The increased participation and importance of the areas furthest away is thus essential in order to ensure fuel for the city. At the same time, these long distances demonstrate that the reduction in weight that was caused by converting firewood into charcoal was essential to reduce transport costs.

Madrid’s energy-imprint was conditioned by the kind of energy consumed in the city. It has already been noted that converting firewood into charcoal reduced transport costs, but this also led to the consumption of a greater area of forest. By making the necessary calculations, we can affirm that at the end of the eighteenth century, the total consumption of firewood in the city was around 190,000 t, that is, 3kg of firewood per person per day.

In order to establish the surface area needed to satisfy this increased consumption, we must understand the forest productivity of the woodland areas that supplied Madrid. Identifying figures on the productivity of forest and woodland areas is difficult because of the great variations in growth depending on the type of woodland in question, its location and its management. We have used information from the eighteenth and nineteenth centuries alongside present-day calculations on the production of firewood in the woodlands and forests of the central peninsular.
In this way, a distinction should be made between the productivity of the coppice forests, whose firewood productivity has been estimated at around 2,000kg/ha/year (GONZÁLEZ DE LA PEÑA, 1873, 84; MADARIAGA, 1917, 277; SERRADA HIERRO, 2008, 27), as opposed to that of “dehesas”, which is only 1,000 kg/ha/year (SERRADA & SAN MIGUEL-AYANZ, 2008, 872). Obviously, this forest productivity is significantly lower than the estimations of 4m³/ha/year in Germany or England, or 2.8-3.8m³ in France or 2-4m³ in the south of Germany (WARDE, 2006).

Lastly, we know that the 55% of the charcoal that arrived in Madrid at the end of the eighteenth century came from coppice forests, and 45% from “dehesas”.

Taking into consideration all of these estimations, we can affirm that Madrid’s energy imprint increased in the second half of the eighteenth century from 117,000 ha to 138,000 ha, which is around 0.77 ha per inhabitant per year. This data is significantly above the European average calculated by P. Malanima to be at 0.5 ha per inhabitant per year. The explanations for this are to be found in other causes, such as the fact that charcoal was the main fuel supplied to Madrid.

**EFFECT ON FOREST LANDSCAPE**

So far we have managed to offer estimates of Madrid’s energy imprint at the end of the eighteenth century that are relatively accurate. However, we must now ask ourselves about the forest areas that were affected by this imprint. What species of tree, what kind of forest formation and what kinds of property were affected? Without a doubt, the supply of charcoal to Madrid had a significant impact on various types of forest landscape.

Although we will not go into too much detail here, we should bear in mind, on the one hand, the various climatic conditions at large in the centre of the peninsular that condition the distribution of tree species and their productivity. One the other hand, we should also take into account the different kinds of land and its exploitation, which has led to the shaping of very different forest landscapes. Each area of woodland was developed in a different way depending on the kind of production that was given priority (firewood, wood, pastures, etc.), shaping the forest accordingly (LÓPEZ ESTÉBANEZ ET. AL., 2013). The supply of fuel to Madrid meant that the production of firewood took precedence at the cost of other uses of the forest.
When dealing the question about how the woodland areas were affected by this imprint, we are fortunate that the sources of information at hand provide us with data on the location of these woodland areas, the charcoal produced and the owners of the land, as well as the tree species there and, at times, even the kind of forest formation. All of this information provides us with a good idea of the forest areas from which Madrid obtained its charcoal at the end of the eighteenth century.

In total, we have managed to locate 692 woodland areas surrounding Madrid: their distribution can be seen on the slide.

The origins of the charcoal that came to Madrid shapes a ring around the city on the map which begins at around 30km and extends to 150km away. This distribution recalls von Thünen’s location model, which sketches this second ring for the woodlands that produced energy, beyond intensive agriculture.

As may be expected, this model does not comply fully with reality since we know that in the areas closest to Madrid there are indeed forests and woodland, such as the royally-owned “El Pardo” (ca. 30.000 ha), woodlands owned by nobility, the “dehesas” and woodland areas of towns or groves, and others belonging to Madrid region (HERNANDO ORTEGO, 2003). In fact, we know that some of the firewood that came to the city came from the closest areas because the fact that it only needed to be carted such a short distance meant that it was not worth converting it to charcoal.

On the other hand, it just so happens that the first slopes of the Sistema Central are just 30 km away from Madrid. Other smaller mountainous areas, such as the Sierras Ibéricas or Montes de Toledo are around 80-120 km away. The areas of charcoal production for Madrid therefore remained considerably loyal to these mountainous areas close to Madrid, although charcoal was also brought in from farmed areas.

An interesting piece of information on the origins of the charcoal that heated Madrid is the remarkable coincidence with the current forest area of the central peninsula. This allows us to deduce that these forest areas were considerably stable, as was the sustainability of the charcoal production that continued in many areas throughout the nineteenth century and the beginning of the twentieth century.

If to the above information we add the figures for the amount of charcoal produced per woodland area, we can get a clearer idea of the effect that the supply had on Madrid’s
hinterland. The area that provided Madrid with the most charcoal during the eighteenth century was that of La Alcarria, although the percentages of charcoal brought in from each area varied from year to year. This means that some years, most of the charcoal came from the Real de Manzanares area, whilst others the Toledo and Talavera areas were the main providers.

On the other hand, it is of particular interest that the Real de Manzanares woodland areas provided a very small average amount of charcoal (10,358 kg average per area), whilst the La Alcarria areas’ average is slightly higher (15,519 kg/area), as is that of Cuenca (21,405 kg/area). In Toledo, on the other hand, the average amount of charcoal provided by each area is much greater (49,226 kg/area).

Specific data highlight the differences in production for each town, which are clearly down to the size of the woodland areas there. In 1794, for example, 2,639 t of charcoal were brought to Madrid from Ossa de Montiel (Albacete), 210 km away, which is more than the amount transported to the capital from the entire Real de Manzanares (2,455t) and Cuenca (1,663t) areas that year.

The forest landscape of each of the areas is of little significance. Whilst the slopes of the Sierra of the Sistema Central and La Alcarria are predominantly woodland areas that are not particularly large in size, as is the case today, in the sierras and plains of the Meseta Sur and in the west, we find large forestry estates.

With regards to the ownership of these forest and woodland areas, the towns were ahead of the nobility: 68% of the charcoal produced was provided by towns whilst only 32% came from individual owners, who were mainly noblemen or churchmen. It is of particular interest that in the woodland areas of Talavera and Castilla la Vieja, to the west, most of the charcoal made came from private estates. The forest formations that produce the charcoal in these two areas are mainly “dehesas” made up of large estates that were usually owned privately.

If, in fact, the relationship between the ownership of the woodlands and the forest formation is taken into consideration, it turns out that of the “dehesas” that supplied Madrid with charcoal 58.8 % belonged to private owners, whilst only 35.2% of coppice forests were owned by individuals.

As opposed to this kind of open forest, 65% of the charcoal that came from the coppice forests surrounding Madrid was the common property of the towns. An extreme case is
that of the area of La Alcarria, where charcoal from common ground makes up 98% of the total produced and coincides with the predominance in coppice forests of *Quercus ilex* (holm oak) and *Quercus faginea* (Portuguese oak). In fact, the example of La Alcarria demonstrates how common areas were placed at the service of the Court for the supply of fuel and residents were particularly active in the transportation of charcoal to Court as non-specialised mule drivers.

The charcoal that came from the area of El Real de Manzanares has a special tale to tell. We have already seen that charcoal came from many small woodland areas. Especially common was the transportation in carts of charcoal from coppice forests, including a special type of forest formation: fields and meadows, which supplied 15% of the charcoal taken from this area. In these formations, which still exist today, we find ash trees (*Fraxinus angustifolia*) and Pyrenean oak (*Quercus pyrenaica*) spread out amongst the meadows or planted in lines. This reflects a particular kind of small business that was the result of several neighbouring landowners joining together, making charcoal and selling it directly in Madrid.

In addition to the charcoal produced in “dehesas” and coppice forests, “root” charcoal produced by uprooting holm oaks in some “dehesas” is also of interest. This kind of charcoal makes up 10.4% of the total amount that reached Madrid and came mainly from the large areas of Toledo and Talavera. Generally speaking, the production of “root” charcoal was related to areas that had been prepared for agriculture. For this reason, we believe that these holm oaks were not only uprooted to make charcoal, but also to increase the land area for farming through distribution amongst neighbours or ploughing private woodland areas.

Finally, the overwhelming predominance of holm-oak over other types of tree for charcoal-making purposes is clear. In fact, it was responsible for around 70% of the total charcoal consumed in Madrid, followed by oak or a mixture of both species. Charcoal made from other kinds of wood, such as *Quercus faginea* (Portuguese oak) or the ash only account for around 1.5% of the charcoal produced between them. We are also aware that other trees were also used, such as the wild olive tree (*Olea europaea var.silvestre*) or the pinetree.

Of course, the ecological conditions were favourable for the holm oak, but we can be sure that this proportion is an over-representation of the land area that was really covered by holm oak in the centre of the peninsula in the eighteenth century (MANUEL
It is without a doubt rather down to the preference for making charcoal from this species due to its hard wood and the fact that it reduces less when converted into charcoal.

CONCLUSIONS

To conclude our article, we will gather together some ideas on the energy model that Madrid relied upon in the eighteenth century and its consequences on the land:

At the end of the eighteenth century, the fuel consumed in Madrid came from biomass. Most of the fuel came in the form of charcoal, which accounted for around 85% of the heat energy consumed by Madrid residents. This supremacy of charcoal, as we have already seen, had surprising consequences:

- The Total-Final-Energy-Consumption (TFEC) was of 7.1 GJ per inhabitant per year. This is slightly higher than the estimates for the Mediterranean area, which is not surprising given Madrid’s climate.

- The Total-Energy-Requirement (TER) was of 14 GJ per inhabitant per year, which was double the TFEC.

The above can be explained by the energy loss caused during the process of converting firewood into charcoal, instead of consuming the former directly. This was without doubt due to the distance between the areas in which the charcoal was produced and the means of transportation which was necessarily land based (animals and carts). As a result, if we compare Madrid to other south-European cities, we see that the fuel supply had a greater impact on the surrounding forest areas.

The energy-imprint calculations for Madrid at the end of the eighteenth century, bearing in mind the firewood used and the productivity of the forests and woodlands, reached almost 140,000ha, that is 0,77ha per inhabitant per year, above the 0.5ha per inhabitant per year that was set as a reference for organic European economies.

The fuel supply was, therefore, one of the government’s main concerns. The institutional response to this problem was to develop a forestry policy to ensure the conservation and availability of areas for charcoal supply, as well as the regulation and even direct management of the supply system.
In any case, the production and marketing of the fuel consumed in Madrid was, generally speaking a **sustainable activity**. The strongest evidence for this affirmation is that for centuries charcoal came from the same areas and, as Madrid’s population increased, charcoal began to be produced in areas further away as an extensive solution. This continual expansion generated conflict amongst the rural communities, due to changes in the traditional means of exploiting woodland areas.

The fuel supply to Madrid encouraged woodland areas to specialise in the production of charcoal, a fact that explains the large areas of coppice forest due to its greater production of firewood. In a few cases, we have discovered that woodland areas were uprooted, but it seems that this was not down to the production of charcoal but rather for crop cultivation purposes.

The fact that areas of forest still exist in the areas from which charcoal was transported to Madrid is evidence of the fact that the city managed to successfully preserve the forestry of many areas. This does not mean that we should ignore the loss of tree cover that occurred in the 150 years that followed. However, we believe that the deforestation that has often been blamed on the production of charcoal to supply Madrid is in fact the result of other key causes.

The consequences of this deforestation on the forest landscape of the areas surrounding Madrid can be noted today. The coppice forests that were so abundant in the areas surrounding the capital have not been functional for decades and are barely even exploited for their firewood. However, these forest formations are evidence of the exploitation of woodland to guarantee the essential resource of fuel for centuries.
TABLE 1 - CHARCOAL AND FIREWOOD CONSUMPTION IN MADRID, 1761-1800

<table>
<thead>
<tr>
<th>YEAR</th>
<th>INHABITANTS</th>
<th>CHARCOAL (TONNES)</th>
<th>FIREWOOD EQUIV. (TONNES)</th>
<th>TOTAL FIREWOOD (TONNES)</th>
<th>VOLUME (TONNES)</th>
<th>KG/CAP/DAY</th>
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<td></td>
<td></td>
<td>TONNES/YEAR</td>
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<td></td>
<td></td>
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<tr>
<td>1761</td>
<td>150,000</td>
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<td>158.588.625</td>
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<td>161.826.335</td>
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<td>187.676.840</td>
<td>187.692.840</td>
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TABLE 2 – ESTIMATES OF FUEL CONSUMPTION IN EUROPE, 18th CENTURY

<table>
<thead>
<tr>
<th>AREA</th>
<th>KIND OF CONSUMPTION</th>
<th>KG/PERSON/DAY</th>
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<td>Northern Europe</td>
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<td>South of Germany</td>
<td>Urban + Rural</td>
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<td>Urban (domestic)</td>
<td>2,6 – 2,7</td>
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<td>Dijon</td>
<td>Urban (domestic)</td>
<td>2</td>
</tr>
<tr>
<td>Piedmont</td>
<td>Urban (domestic)</td>
<td>2,3</td>
</tr>
<tr>
<td>Piedmont</td>
<td>Urban (domestic + industrial)</td>
<td>2,8</td>
</tr>
<tr>
<td>Italy</td>
<td>Urban + Rural</td>
<td>1</td>
</tr>
<tr>
<td>Madrid</td>
<td>Urban (domestic + industrial)</td>
<td>2,8 – 2,9</td>
</tr>
</tbody>
</table>


TABLE 3 – ENERGY CONSUMPTION IN MADRID AND PARIS, 18th CENTURY.

<table>
<thead>
<tr>
<th></th>
<th>PARIS, c. 1730</th>
<th>MADRID, c. 1760</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFEC (GJ/cap/year)</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>TER (GJ/cap/year)</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>FIREWOOD CONSUMPTION (kg/person/day)</td>
<td>2,74 *</td>
<td>2,9</td>
</tr>
</tbody>
</table>

### TABLE 4 - AVERAGE DISTANCES AND MORE DISTANT FORESTS FOR THE CHARCOAL SUPPLY OF MADRID 18TH CENTURY.

<table>
<thead>
<tr>
<th></th>
<th>1725</th>
<th>1762-1764</th>
<th>1767</th>
<th>1794-1795</th>
<th>1803-1804</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average distance</td>
<td>93.3</td>
<td>103</td>
<td>88.6</td>
<td>107.6</td>
<td></td>
</tr>
<tr>
<td>Weighted average distance (km)</td>
<td>109.5</td>
<td>104.4</td>
<td>122.5</td>
<td>101.6</td>
<td></td>
</tr>
<tr>
<td>More distant forest</td>
<td>200</td>
<td>225</td>
<td>183</td>
<td>210</td>
<td>210</td>
</tr>
<tr>
<td>Ten more distant forest – average (km)</td>
<td>160</td>
<td>182.3</td>
<td>173</td>
<td>174</td>
<td>181.2</td>
</tr>
<tr>
<td>Ten more distant forest – prod (kg)</td>
<td>3,244,714</td>
<td>5,543,964</td>
<td>3,289,572</td>
<td>6,209,528</td>
<td>946,399</td>
</tr>
<tr>
<td>Ten more distant forest - prod. (%)</td>
<td>16.2</td>
<td>9.3</td>
<td>16.3</td>
<td>27.6</td>
<td>10.0</td>
</tr>
</tbody>
</table>

### TABLE 5 - OWNERSHIP, FOREST SPECIES AND FOREST STRUCTURE OF THE FORESTS AND WOODLANDS THAT PRODUCE CHARCOAL FOR MADRID, 18TH CENTURY

<table>
<thead>
<tr>
<th>PARTIDOS</th>
<th>Alcarria</th>
<th>Castilla La Vieja</th>
<th>Cuenca</th>
<th>Real de Manzanares</th>
<th>Talavera</th>
<th>Toledo</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public (commons)</td>
<td>97.9</td>
<td>42.9</td>
<td>59.6</td>
<td>64.0*</td>
<td>46.8</td>
<td>69.9</td>
<td>68.0</td>
</tr>
<tr>
<td>Private</td>
<td>2.1</td>
<td>57.1</td>
<td>40.4</td>
<td>26.0</td>
<td>53.2</td>
<td>30.1</td>
<td>32.0</td>
</tr>
<tr>
<td>Forest species</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holm oak (Q. ilex)</td>
<td>45.9</td>
<td>94.8</td>
<td>65.5</td>
<td>35.7</td>
<td>68.8**</td>
<td>89.6</td>
<td>69.2</td>
</tr>
<tr>
<td>Holm oak &amp; oak (mixed)</td>
<td>31.0</td>
<td>5.2</td>
<td>25.4</td>
<td>19.8</td>
<td></td>
<td></td>
<td>16.3</td>
</tr>
<tr>
<td>Oak (Q. pyrenaica)</td>
<td>22.4</td>
<td></td>
<td>27.6</td>
<td>7.3</td>
<td>7.0</td>
<td>13.0</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>Other mixed</td>
<td>0.4</td>
<td>Qi,Qf</td>
<td>Qi,Qp,Fa</td>
<td>8.6</td>
<td>Qi,Qp,Fa</td>
<td>Qi,Qp,Qf</td>
<td>1.3</td>
</tr>
<tr>
<td>Forest structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>monte bajo</td>
<td>89.9</td>
<td>3.8</td>
<td>70.2</td>
<td>68.3</td>
<td>20.5</td>
<td>34.7</td>
<td>51.9</td>
</tr>
<tr>
<td>monte hueco</td>
<td>3.2</td>
<td>96.2</td>
<td>29.8</td>
<td>2.3</td>
<td>74.2</td>
<td>57.3</td>
<td>41.7</td>
</tr>
<tr>
<td>monte alto</td>
<td>4.5</td>
<td></td>
<td></td>
<td>5.2</td>
<td></td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>monte bajo y alto/hueco</td>
<td>2.4</td>
<td>14.2</td>
<td></td>
<td>8.0</td>
<td>3.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cercas y prados</td>
<td>15.2</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

Qi (Quercus ilex) = Holm oak; Qp (Quercus pyrenaica) = Oak; Qf (Quercus faginea) = Portuguese oak; Fa (Fraxinus angustifolia) = Ash

* 24.4% belongs to the Crown (Forest of Viñuelas y El Pardo), that reach 1.4% of the total.

** From Aldea del Fresno (Madrid) arrives pine charcoal and from Villarejo de Montalbán (Toledo) arrives wild olive (Olea europeans). Both mixed with holm oak charcoal.
MAP 1 - ADMINISTRATIVE EVOLUTION OF THE CHARCOAL SUPPLY AREA OF MADRID

MAP 2 – CHARCOAL ORIGINS FOR THE CHARCOAL SUPPLY OF MADRID, 18TH CENTURY

MAP 3 – QUANTITY OF CHARCOAL FROM EACH PLACE FOR THE SUPPLY OF MADRID, 18TH CENTURY

MAP 4 – OWNERSHIP OF THE FOREST USED FOR MAKING CHARCOAL FOR THE SUPPLY OF MADRID, 18TH CENTURY
MAP 5 – FOREST STRUCTURE OF THE FOREST USED FOR MAKING CHARCOAL FOR THE SUPPLY OF MADRID, 18TH CENTURY

MAP 6 – FOREST SPECIES USED FOR MAKING CHARCOAL FOR THE SUPPLY OF MADRID, 18TH CENTURY
BIBLIOGRAPHY


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