BRUSHWOOD BIOMASS FUEL-ENERGY DEVELOPMENT CHARACTERISTICS IN MONTADO (REGION ALENTEJO, PORTUGAL)

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Abstract

This article contains information on research which has mapped the development of spontaneous growth of biomass in "montado" in the Alentejo region of Portugal. The energy potential for commercial use was researched, as well. The research started 12 years ago. It was necessary, in this very beginning, to protect the monitored area with fencing from animals, humans and other influences which could distort the research results. Thanks to this we can consider the research conditions in these locations as being well under control. The main research objective focused on establishing a model of biomass growth and assessing the overall phytomass energy which could be gained in an abiotic reactor. The phytomass samples were collected from three zones of the monitored area which were divided on the basis of the age of the vegetation. The absolute amount of the biomass was found to be considerably different in each zone. During the first two time periods the quantity of biomass was increasing; however on the other hand the quantity of the elder part was decreasing. The maximum amount of shoot biomass was found in the zone which was nine years old – its average value (dry matter) was 960.74 g/m^2. The zone of 12 year-old- biomass produced on average 909.84 g/m^2 while the zone of 1.5 year produced 387.63 g/m^2. The phytomass samples were tested for energy content too. The average values of BE (burning energy) were calculated as follows: 18.117; 18.183; 17.921 kJ/g (for 1.5; 9 and 12 year old biomass, respectively). The rough energy content was measured and compared to the comparative fuel unit.

Key words: biomass; *Quercus suber L*., *Cistus spp.*, heating value, energy, mitra

INTRODUCTION

Global environmental change represents the most urgent present problem which should be resolved in the context of future sustainability. Portugal's ecosystem montado represents about one million hectares of agro-forest area (Alfonso, Roxo, 2001). Potes and Babo (2003) characterized montado as an ecosystem which was extremely well adapted to the Mediterranean climate. Montado, being a production system created by man, is also an option for the balanced use of nature based upon biodiversity (Babo, Potes, 2004). The basic historical utilization of this unique agro-silvo-pastoral area is for grazing ruminants and planting cork, pinus and eucalyptus trees (Fernando, Oliveira, 2006). The traditional management of the ecosystem typically consists of the control of shrubs, using biological (animals) or mechanical (machinery) means, and the integration of this operation into a crop rotation system (Carneiro et al., 2004). The shrubs have higher expansion ability to the non-range management limiting the agricultural utilization of this area (Olea, San Migueal-Ayanz, 2006). In 1993 twelve species of *Cistus spp*. in Iberia peninsula were described by Demoly and Montserrat. Impenetrable masses of *Cistus* plants are formed at early succession stages following woodland disturbances such as fire and soil overturning (Babo, Potes, 2004). Annually bushfires destroy thousands of hectares in montado. Our research focused on measuring the shooting biomass in order to propose its harvesting for energy production in the case when the phytomass could not be used for pastoral purposes. In fact it is a bushfire elimination measure in this area. This work focuses on the evolution and natural cycles of this shrub (Cistus) under the natural conditions of montado. The research area was provided by University in Evora which financed the fence to protect the research plots against grazing animals. The samples were gathered from three old biotopes (their vegetation was different in age) – in sequence one and half, nine and twelve years old. The results were used within the framework of EU AGRO 768.

MATERIALS AND METHODS

Area identification

The research area is an ecosystem called montado which is found in Portugal around Evora. In this area a mixed culture of oaks and pine trees (ratio 3:1) has been created during a couple of decades (Surový, 2007). For decades subsoil ploughing (and loosening) up to 40 cm deep was carried out in the area (Surový, 2007). All natural vegetation bindings were destroyed so that the new plants could become dominant in the area. The ploughing has a liquidating effect on the weed population and also limits the danger of bushfire spreading during the summer season.

The above described research area was fenced against grazing animals. Three different zones were identified in the area and the zoning was based upon the following: 1) original biotope – 12 years old; 2) biotope – 9 years old; 3) biotope – 1. 5 years old. There is a different level of plant growth in each of the zones. At first sight, the vegetation composes of herbs and small shrubs in the third zone (1.5 years) up to shrubs and trees in the first zone (12 years). In the oldest biotope (12 years) the tree vegetation is represented by the pinus sp. which dominates because it grows faster than the oak sp.

Specification of botanic vegetation

The ecosystem montado is characterized by the *Quercus spp.* (*Q. suber* L. – cork tree, *Q. ilex* L. – Oak tree) which are used for cork and fruit production (Babo, Potes, 2004). The shrub population mainly consists of *Cistus spp*. (C. ladanifer, C. salvifolius, C. crispus) (Babo et al., 2000). Herbaceous annual plants are especially represented by *Trifolium spp., Medicago spp., Ornithopus spp., Lupinus spp., Vicia spp., Biserrula pelecinus* L. and other legumes and grasses (Carneiro et al., 2004). Natural regeneration of the plants is given by natural conditions, soil fertility, rainfalls and also by grazing animals (Babo et al. 2000, Alfonso, Roxo, 2001). The growth potential of individual plants is correlated with the fertility and rainfall as well.

In 1993 Demoly and Montserrat described 12 species of *Cistus spp*. in the Iberian peninsula. A long history of human activities has favored the distribution and abundance of *Cistus* species in the Mediterranean (2005). In our research, the biomass of main interest is especially based on this species.

The plant growth is uneven which carries a seasonal character and is narrowly coherent with the amount of the rainfall. The yearly distribution of the fresh fodder yield according to Olea and San Miguel-Ayanz (2006) is: *Spring: 60–70%, Summer: 0%, Autumn: 15–25%, Winter: 5–15%*. Olea and San Miguel-Ayanz (2006) say that the average yield of extensive grazing was measured arround 1 000–2 700 kg/ha per year.

The gathering samples

The sample collection was conducted in May 2007 because this period (Spring) enables the best quality work in the field; however sometimes it is very hot and dry. Priority of the selected research zones is that they are very well mapped. At first, selected points (1–14) were put into each 1 m^2 area. Their selection was randomly done according to statistics stratification. The selected research area was about 20 ha. Together all of the research area was 22 m^2. There were samples from tree clumps of more than 1 m^2 – later on they were recalculated to an area of 1 m^2. The gathered biomass was in fact a mix of fresh (green) and dry biomass – all the biomass was from the marked areas.

Immediately after having been collected the samples were immediately transported to laboratory at Evora University. They were first weighed on laboratory scales. Later on, they were put back into sacks and numbered 1–14. All measured data was recorded (presented in Table 1). The procedure continued by drying for 48 hours at 105°C (Samuelson et al., 2006). After drying, the samples were weighed again. All the data was recorded (see Table 1). In this phase the samples were divided into woody and leaf fractions in order to find out if their ratio was correlated to their weight prior to drying.

Field data collection

The collected data were statistically analyzed. The first row in Table 1 contains identification of the samples. In the second row there are symbols which describe the areas: **A**, **B** or **C**. They characterize the age of the vegetation. This means that area **A** was ploughed 1. 5 years ago but there are pines and oak which were planted 9 years ago. The weeds seem to be the dominant kind of vegetation and represent the major part of the biomass. This level of vegetation is ideal for pasture management (Olea, San Migueal-Ayanz, 2006). Area **B** was ploughed 9 years ago. We can recognize 3 groups of plants. The dominant vegetation is trees and shrubs. It is evident, at first sight, that pines grow faster than oaks. The herb diversity is presented by many families and species but weeds are not dominant in comparison with to zone **A**. At this level the shrubs do not enable any kind of grazing management. The ploughing of area **C** took place 12 years ago. The vegetation is mostly characterized by oaks and shrubs. The considerably high number of fully grown shrubs limited the weed population. A mixed culture of pine-trees, oaks and weed invasive plants is typical for these areas. A few sample areas had high level of subsoil moisture.

Notes on the size of area in m^2 of each sample are in the third row. The size differences between the samples depend on the location. For example if there was a shrub on the gathered area, it has been totally collected and then the size of the area was measured and noted.

The last row contains values of the weight of the harvested fresh biomass in grams which were weighted on laboratory scales in Evora's University.

Tab. 1: Identification of samples

1	2	3	4	5	6	7	8	9	10a	10b	10	11	12	13	14
B	B	A	B	A	B	A	B	A	B	B	B	C	C	C	C
1	1	2	1	2	1	2	1	2			1.96	1	3.2	3.12	1
3 922	2 142	2 086	5 386	4 177	3 564.7	6 906	4 117	3 511.8	6 387	6 060	12 447	5 496	7 722	6 149	4 044

Setting up the heating value

The last part of the experimental work was consisting of measuring the heating value of individual samples. One pellet from each of 14 samples which were gathered in the research area was produced. The pellets were produced from homogenized (shredded) biomass (particles up to 0.5 mm) (Fuksa, 2007). A laboratory shredder was used to chop up the biomass. The next step was the preparation of pellets from each sample. A press machine was used for this purpose. In total 14 pellets were prepared. The total number of pellets was: from zone **A** – 4 pellets, from zone **B** – 7 pellets and from zone C – 3 pellets (diameter of pellets 8 mm). The pellets were packed in cigarette paper and marked. Then the heat values of all the samples were measured in the calorimeter. The samples were burnt in calorimetric reactor LAGET MS; the released energy heated up water. The temperature change of the warmed water was noted and the gross energy calculated for each sample. The used calorimetric formula (Table 5) was used for calculating the results (Table 3).

RESULTS AND DISCUSSION

Amount of biomass

In total 14 different samples were collected from an area of 23 square meters; however the whole research area was 20 ha**.** The final dried weight of collected samples was 38 kg (see Table 3).

Statistical analysis

The four samples from the zone **A** had an average yield of 2 085.1 g/m^2 (see formulas in Picture 1) and the standard deviation was 1 172.768 g. The six samples from the zone **B** was 4 246.95 g/m^2 with standard deviation 1 465.538 g. The four samples from the zone **C** had 3 480.975 g/m^2 with standard deviation of 1 612.277 g. The yield variability according to zone was 56%; 34%; 46%, respectively. The differences within the groups (expressed by the variability of yield) are typical for this ecosystem. Other authors (Olea, San Miguel-Ayanz, 2006) published the yield as 1 000–2 700 kg/ha per year, which is concordant with our research.

Tab. 2: Characterization of formulas

Formula	Glossary
$Q_1 = c_1 \times m_1 \times (t_2 - t_1)$	c_1 – specific heat constant (J/(kg,°K) m_1 – mass of the sample (kg) t_1 – temperature before the calorimetric measurements (°K) t_2 – temperature after the calorimetric measurements (°K)
$BE = [c \times (t_2 - t_1)/m_1)] - BE_p \times 1000$	c – LAGET Calorimeter constant (J/(°K) BE_p –energy released after combustion of the pellet (J/g)

Tab. 3: Date for analyses

Samples	Vegetative age of biomass	Area size	Undried weight/m^2	Undried weight/m^2	Dry mass	Dry mass/m^2	Jutabag	Watter content	Moisture content
	year/group	(m^2)	(g)	(g/m^2)	(g)	(g/m^2)	(g)	(g)	(%)
1	9/B	1	3 922	3 922	1 984.8	1 984.8	108.3	1 828.9	46.63
2	9/B	1	2 142	2 142	1 700.5	1 700.5	111.2	330.3	15.42
3	1.5/A	2	2 086	1 043	817.7	408.85	112.2	522	50.04
4	9/B	1	5 386	5 386	2 768.3	2 768.3	109.7	2 508	46.57
5	1.5/A	2	4 177	2 088.5	1 895.1	947.55	107.6	1 033.4	49.48
6	9/B	1	3 564.7	3 564.7	1 477.8	1 477.8	110.1	1 976.8	55.45
7	1.5/A	2	6 906	3 453	2 701.9	1 350.9	109	1 993.1	57.72
8	9/B	1	4 117	4 117	2 421.2	2 421.2	108.4	1 587.4	38.56
9	1.5/A	2	3 511.8	1 755.9	1 659.5	829.75	107.5	818.7	46.62
10	9/B	1.96	12 447	6 350	8 080.6	4 122.7	217.6	2 010.2	31.65
10a	9/B		6 387		4 257		107.9		
10b	9/B		6 060		3 823.6		109.7		
11	12/C	1	5 496	5 496	3 044.7	3 044.7	108.1	2 343.2	42.63
12	12/C	3.2	7 722	2 413.1	4 484	1 401.2	108.5	903.4	37.44
13	12/C	3.12	6 149	1 970.8	2 925.1	937.53	109.3	924	46.88
14	12/C	1	4 044	4 044	1 999.2	1 999.2	107.8	1 937	47.90

The statistical tests on confidence (see Formula 2) for α = 0.05 the yield interval A, B, C was calculated It was the following: 2085 plus-minus 990; 4 246 ± 1 172; 3 480 ± 1 580, respectively. Confidential interval for the mean was 95%.

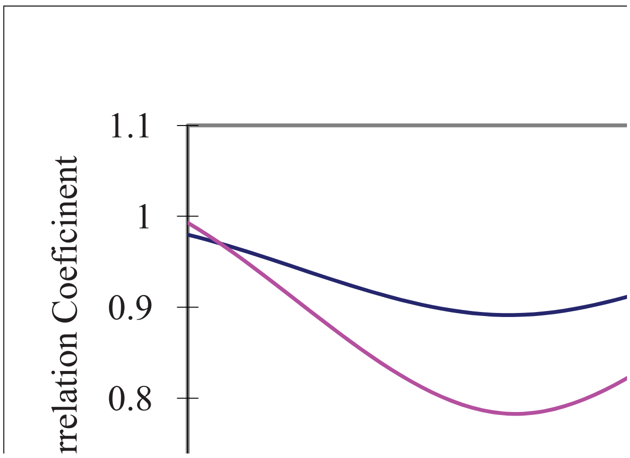
$$SD = \sqrt{(x_i - \bar{x})^2} \qquad \text{Formula 1}$$

$$\bar{x} - t_{\alpha/2;v}\frac{SD}{\sqrt{n}} \le \mu \le \bar{x} + t_{\alpha/2;v}\frac{SD}{\sqrt{n}} \qquad \text{Formula 2}$$

Legende for formulas 1, 2, 3:
SD = Standard Deviation
x_1 = value of parameter
$\bar{x}$ = average value of parameter
$t_{\alpha/2;v}$ = criterion of Student distribution
n = frequency of measurements
μ = mean value of the distribution
y = dependent variable

Except for the yield, moisture of samples and dry mass content dependence on the vegetative age were analyzed. Figure 1 shows the above relationship processed by the Excel statistical program Correl (see Formula 3). In Figure 1 there are curves which express the correlation of water and dry mass content depending on the age of the vegetation. It is evident that the variability of dry mass as related to the fresh mass and water content in the fresh mass harvested in the zones of different age was not excessive. Its values express a close relationship with a correlation coefficient near to 1. In the zones **A**, **B**, **C** (the case of the dry mass yield) are 0.98; 0.89; 0.99 respectively. In the case of water content in zones **A**, **B**, **C** the values of the correlation coefficient are 0.99; 0.78; 0.98 respectively. Samples from zone **B** demonstrated a higher variability of both characteristics. This could be due to the higher content of woody matter in the samples. Woody matter represents 84% of the whole sample matter from **B** zone.

Fig. 1: The relationship of dry mass and water capacity by age



$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2\,(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2\,\sum_{i=1}^{n}(y_i - \bar{y})^2}} \qquad \text{Formula 3}$$

The relationship of dry mass and water capacity by age

According to the correlation program results the level of correlation between the yield of fresh mass and amount of dry mass was very close, as was the water content of the fresh mass (about 98%).
The following Table 4 shows the water content according to zones **A**, **B**, **C**. The samples from zones **A** and **C** had deviation (of water content) of under the 5%. On the other hand in the case of sample **9/B** non-uniform growth was found; this was the place where shrubs and herbs were evidently unevenly distributed. But also despite this sample **9/B** seemed to be more perspective than **1. 5/A** and **12/B** (from an energy and an economic point of view).

Tab. 4: Humidity of samples

Vegetative ages/group	Average water content (%)	Standard deviation
1.5/A	50.97	4.74
9/B	40.53	15.25
12/C	43.71	4.77

The harvested biomass parameters were compared with forage and energy crops. We found out that in comparison with the forage and some energy crops the researched biomass includes higher ratio of dry matter. For example, the forage crops are harvested when they have about 20–40% of dry mass and some energy crops with 50% of dry mass in the same time period (Hutla, Strasil, 2004). This advantage achieved under the montado conditions should be a motivating element for the future research of the solid bio-fuels production. In principle, the biomass from montado as to the dry matter content can directly be transformed to fuel. For example, these results can be compared with the energy crop *Phalaris arundinaceae sp.*, which was widely investigated in the last period. Yield potential of *Phalaris sp.* depended on the harvesting time and ranged from 5.212 t/ha (spring) to 7.214 t/ha in the autumn. In the case of the moisture content, it was about 19% in the spring while in the autumn some 50% of the moisture was found (Hutla, Strasil, 2004).

Fig. 2: Ratio of fresh and dry mass

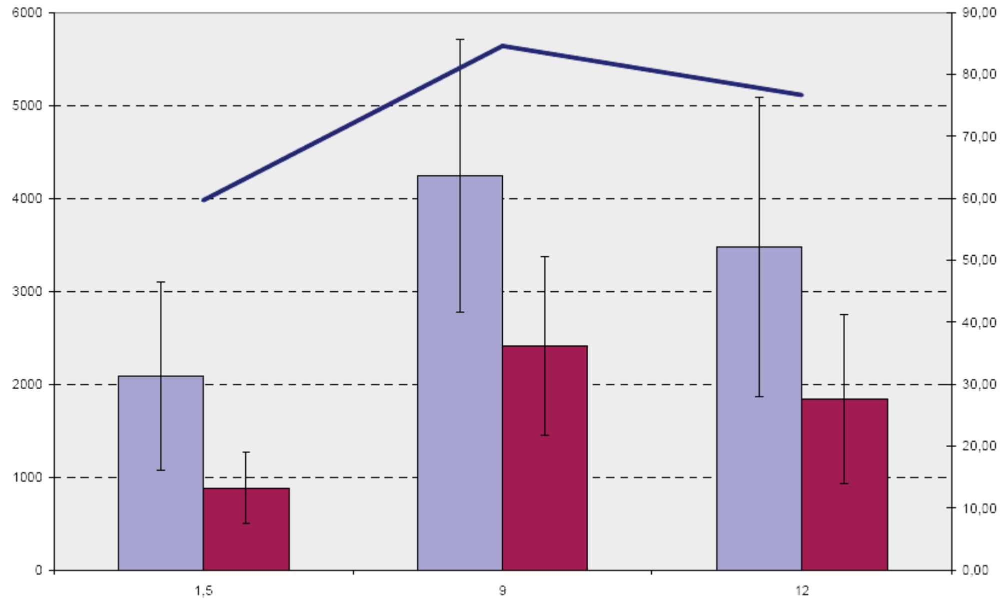


Figure 2 shows fresh and dry biomass values after gathering the samples. The blue columns represent fresh mass and the magenta columns dried biomass contents (from the zone **A** up to the zone **C** respectively. Their standard deviations don't manifest excessive variations. The dry matter contents are growing until 9 years. In the summer (hot) season the growing proportion of dry biomass in the brushwood contributes to a greater risk of bushfires (Fernando, Oliveira, 2006).

By use of the above gathered data, the yield per hectare was calculated. It was found 24 tones (recalculated) of fresh matter per ha for 9 years period (see Table 5). It can be supposed that though the expressively lower yields than the other energy crops normally have the agro-silvo-pastoral area can be used for energy production purposes, too. It is especially for the reason that the above areas cannot be more used for the animal grazing (Alfonso, Roxo, 2001).

Tab. 5: Accumulative yield in time

Sample (age of biomass)	Ø yield (g/m^2)	Corresponding yield (t/ha)
1.5A	884.275	8.84
9B	2 421.55916	24.22
12C	1 845.67051	18.46

The average energy value from all the gathered samples was 18 kJ/g which is compatible to other energy crops. In the following Table 6 heating values of all the gathered samples are reviewed. Their dispersion is characteristic by very low values (values of standard deviations). Basically we know the moisture content is the most important factor which influences the heat content. (Jevič, Šedivá, 2000). By this it becomes evident that the biomass from montado could be a competitive fuel to wood and fossil coal. The heating value (BE) of wood (water content higher than 20%) and brown coal is lower then biomass from Mitra area (Hutla, Sladký, 2000).

The statistical evaluation of the heat content values shows (see Table 6) that differences between the samples across the zones are insignificant. According to the coefficient of variability which is lower than 2.5% in all samples. The lower variability of the heat content values was found in zone **C** (0.9%). The confidential intervals for zones **A**, **B**, **C** were found 18.117 ± 0.37; 18.183 ± 0.35; 17.921 ± 0.16 kJ/g. Formulas 1–3 were used for these calculations.

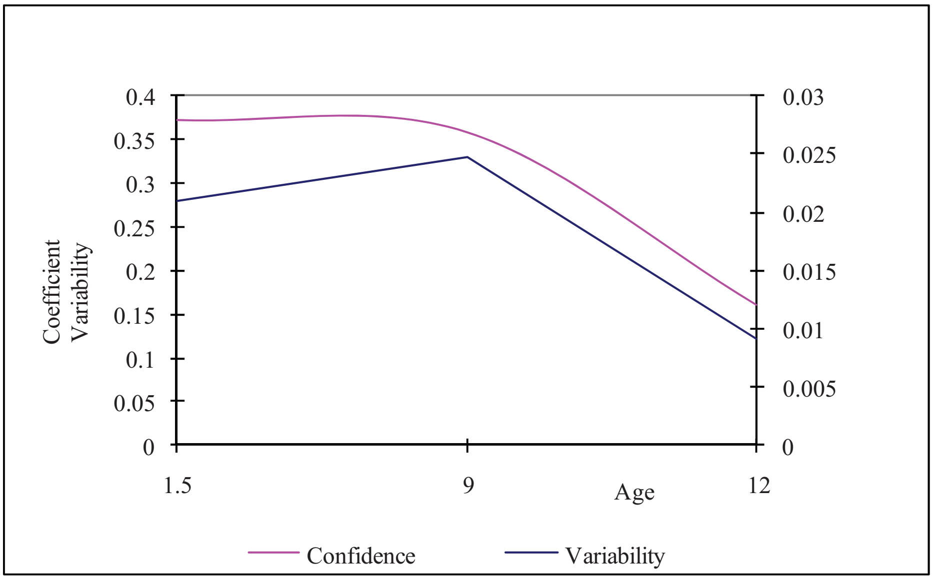
Tab. 6: Heating values of the gathered samples

Vegetative age	BE_1 (KJ/g)	BE_2 (KJ/g)	BE_3 (KJ/g)	BE_4 (KJ/g)	BE_5 (KJ/g)	BE_6 (KJ/g)	BE_7 (KJ/g)	Average BE (KJ/g)
1.5/A	17.582	18.344	18.428	18.115	–	–	–	18.117
9/B	17.814	18.843	18.233	18.631	18.3	17.789	17.668	18.183
12/C	18.211	17.9	17.961	–	–	–	–	17.921

Tab. 7: Heating value statistics

Age	St. deviation	Average	Variability	Confidence
1.5	0.38056	18.11725	0.021005	0.372942
9	0.448909	18.18257	0.024689	0.359195
12	0.164794	18.024	0.009143	0.161495

Fig. 3: Variability and confidence of heating characteristics



CONCLUSION

Our research shows the important potential of utilization of natural region montado for energy production. On the basis of research (not yet fully completed) it has been found that the vast area called montado (in Alentejo region, Portugal) could contribute a huge amount of biomass to the regional energy balance. Based upon the above results the following conclusions and recommendations can be formulated:

1. It has been found out that the investigated ecosystem produces a significant amount of biomass. During a 12-year research period the highest yield (t/ha) was found after nine years; after which the yield decreased a lot. The maximum yield amounted to 24.2 tones/ha of dry mass.
2. As stated above the harvesting cycle with regard to the maximum yield has been determined as about 9 years. The harvesting operation should be done by heavy duty machinery including shredders. The most optimum period of harvest is the spring.
3. The advantage of harvested biomass in montado is its high dry mass content (up to 59%) which eliminates the necessity of intensive post-harvest drying. It already appears in the spring time and this can be considered as an economy-enhancing factor. The harvested biomass can efficiently be used for solid bio-fuel production in a different form.
4. The pellets which ware produced during the tests with the use of the montado biomass had a heating value up to 18 MJ/kg – the highest heat content values were measured in the nine year old biomass (18.8 MJ/kg). This is nearly the same value of heat content as black coal – 25 MJ/kg produced in a bituminous coal mine.
5. The 2003 summer fires in Portugal destroyed 425 000 ha of grassland – most of them belonging to montado. From one hectare of montado 23 tons of invasive phytomass could be harvested each 9th year which would substitute energy of about 17 tons of black coal.
6. The harvest time (the spring is proposed) could profit not only from low biomass humidity but also from cork oak tree (sobreiro) pruning which would provide additional organic biomass.
7. It would be wise to continue in the research of montado biomass use for energy production and get information which could motivate local farmers to have a better environmental approach to the montado area as well as to preserve the natural character of the local landscape. Additional financial subsidies for the farmers could complement the advantages of montado biomass use and provide incentives for local farmers.

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