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SETTING M.Sc. THESIS

Monitoring of brushwood biomass form *Quercus suber* L. plantations in Alentejo region, Portugal.

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Abstract Title: Monitoring of brushwood biomass form Quercus suber L. plantations in Alentejo region, Portugal.

Abstract: The growth and phytomass evolution is specific process depending on concrete condition. In the montado are surroundings limits like soil, rundown of rains and temperature. The evolution of brush phytomass under *Quercus suber* L. is continual process which proceeds in specific cycles. In this thesis were under investigation the datas from the vegetative ages 1 and half, 9 and 12 years. The process of evolution phytomass is growthing in certain period than quantity of phytomass is decreasing. The maximum growth among phytomass could be expected in the ninth year. In the first measure (18month vegetative ages of phytomass) was found out in the average 51% of water content. In the next measures (9 and 12 years old phytomass) were content of water lower and was observed ration of water capacity 40% and 44% respectively. Average brute energy of the samples was 18.11 KJ/g, 18.18 KJ/g and 17.92 KJ/g, respectively.

Keywords: Phytomass; *Quercus suber L.*; evolution of phytomass quantity; *Cistus latundifolia* sp.; caloricity, energy, Mitra.

Abstrakt titul: Sledování kvantitativních změn fytomasy v podrostu *Quercus suber* L. korkové plantáže v Mitře v regionu Alentejo v Portugalsku.

Abstrakt: Růst a vývoj fytomasy je výraznou měrou ovlivněn podmínkami, které jsou v dané oblasti specifické. V ekosystému montado patří k limitním faktorům: půda, roční úhrn srážek a teplota. Vývoj křovinné fytomasy v podrostu *Quercus suber* L. je specifický svými vývojovými cykly. Pro tuto práci byla nasbírána data, která mapují vývoj podrostové biomasy v 1 a půl roce, v 9ti letech a ve 12 ti letech stáří. Zjistili jsme, že rostlinná biomasa nejdříve roste, potom množství biomasy klesá. Maximální množství biomasy můžeme očekávat v devítii letech. V roce a půl obsahovala fytomasa 51% vody, v devíti letech 40% vody a v dvanácti letech obsahovala fytomasa průměrně 44% vody. Výhřevnost vzorků byla 18,11KJ/g pro jeden a půl roku starou biomasu, 18.18 KJ/g pro devět let starou biomasu a 17.92 KJ/g pro dvanáct let starou biomasu.

Klíčová slova: Fytomasa, *Quercus suber L.*; kvantitativní vývoj fytomasy; *Cistus latundifolia* sp.; výhřevnost, energie, Mitra.

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Declaration

The following Master thesis was prepared in my own words without any additional help. All used sources of literature are listed at the end of the thesis. I agree with lending this thesis.

Prague, 24.4.08 Ondřej Vacek

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PREFACE

At the present time developed world focuses on alternative source of energy. The research, business and other activities are joined with renewable resources. The press on this behavior is adequate to the knowledge about global worming processes, constantly developing modern technologies, present political situation, waning source of fossil fuels and with them still increase price for oil. Depending on the natural condition of country what course will take? We can found countries which use the energy of wind, sun, tides, waves, river, biomass or geothermal source. But we take interest in farmers so we are looking for sources in agricultural system.

The evaluation of natural potential of ecosystems its exploitation and sustainable development should be the common goal for scientists, country-side and current society.

1 INTRODUCTION

1.1 Overview of study area

The global environmental change represents the most contemporary problem urgent to resolve for the surviving of future generations. It threats all environments and living forms in the earth, changing cropping patterns, biodiversity and economic structures. The question of natural resource consumption, environmental protection and sustainable development, takes an essential importance through the use of bio-energy carriers in worldwide implementation, which could serve like a catalyze in the measures to resolve principally the question of greenhouse effect in widely form (Munoz, et al., 2005) .

The total agricultural area in CR is 4, 2 million of ha and forest area in CR is 2, 65 million of ha (ČÚZK, 2008). These areas are being transformed by the human activity. On the contrary Portugal has ecosystem montado with its natural character. Montado is rich in high species diversity and product potential which should be used in the authentic environment (Ferreira et al, 2005). The Portugal's ecosystem montado represents about million of hectare agro-forest area (Mosquiera, Losada, 2005). The basic utilization of this agrosilvopastoral area is for pasture, production of cork and pinus and eucalyptus planting (Ferreira et al, 2005). Nowadays, some farmers are not interested in setting up new cork plantations but in planting *eucalyptus* trees, which are not endemic for this area. This trend is supported by the worldwide market and short-term profits that cannot be compared with cork oak's profit. From ecological point of view this behavior is not acceptable it can be even devastating. This action can be without exaggeration compared with slashing and burning of forest areas in developing countries (Ferreira et al, 2005). The situation is not sustainable because *eucalyptus* makes profit at present time *pinus* make profit for the next generation but cork oak could remain profitable for more than 500 years (Ferreira et al, 2005). On the other hand from the cork plantation farmers have profit 45 Euro per ha while from the eucalyptus it is 3 times higher so farmers will earn 150 Euros per ha (Claire-Poole, 2005). This fact resulted in planting *eucalyptus* trees that in the case of bushfires get burned much quicker than cork oaks (Claire-Poole, 2005). In the montado are surroundings limits like soil, rundown of rains and temperature. The soils are shallow and poor of humus organic material (Correia, Mascarenhas, 1999), with over than 50% on classes E and D (bedrock or very thick soils, with no agricultural ability), mainly derived from schists (Alfonso et al, 2001). Cultivation is becoming less important in the system rotation, whereas livestock production is becoming more relevant and the ground cover is used only as pasture. The cork is still valuable and, in most cases, is the first priority in the exploitation (Pinto-Correia, 1999). Average annual rainfall decreases to less than 500 mm. (Joffre et al., 1999). Average temperature: 16.1°C, average minimum temperature during January: 5.3°C, average maximum temperature during August: 28.9°C (Reis-Zorro, 1999). This work is not only focused on cork oak trees, but also on shrub weed phytomass, which is being produced in this ecosystem. The most wide spread species of shrub land is *Cistus salviifolius* L. (Cruz, 2004). This shrub is fast growing plant in the specific montado conditions and its evolution is well observed in five years cycles. In hot summer months this phytomass represents real danger of bushfires (Menard, 2005). The correct approach and precaution in the right time could prevent in this ecosystem danger of bushfires (Ferreira, 2005) simultaneously increase the possibility of cork oak recruitment (Holmgren, 2002) and at least could bring the financial and the energy benefits.

Energetic sector in Portugal is currently about 90% depending upon foreign energy sources (note that inter-annual fluctuation) are significant due to a large component of hydroelectricity in the energy mix) (Hulme-Sheard, 1999). To join agrosilvopastoral ecosystem montado with renewable energetic profit is chance for current time (Kaltschmitt et al., 1996).

1.2 Ecosystem montado

Ecosystem montado we can found around Mediterranean area (A.1).The montado is the agro-silvo pastoral system specific to the region of Alentejo, Southern Portugal, comprising an open formation of Cork and Holm oaks in varying densities (Correia-Mascarenhas, 1999).

Montado is also characterized by thin soils and tree cover, dominated by Holm oak *Quercus rotundifolia* and cork oak *Q.suber* at up to 20 trees per ha (Herrera, 1995). Like the extensive category, there is no irrigation and the fallow area is high. A typical rotation is similar to that of the extensive category, although the fallow stage is often longer and forage lupines *Lupinus luteus* may be included.

This agro-silvopastoral system has three vegetation components (trees, shrubs and herbs) used for multiple species animal husbandry in extensive production systems (Potes-Babo, 2003). In the wild, the cork oak (A.1.) is but one element of the Mediterranean maquis, sharing space with other tree species, including *Quercus ilex, Q. faginea, Q. pyrenaica, Castanea sativa*, etc., as well as an immensity of shrubs such as *Arbutus unedo, Viburnum tinus, Erica* *arborea, Pistacia lentiscus, Rhamnus alaternus, Phillyrea latifolia, Calluna vulgaris, Smilax aspera, Juniperus sp., Ulex sp., Cistus sp*., aromatic essences (Acácio et al., 2007).

1.2.1 Recruitment in montado

Ecosystem montado have a long history of alteration by human disturbances such as grazing, clearing, and fire (Aschmann, 1973). Regeneration of original vegetation types after disturbance seems to be halted under certain circumstances, and some successional stages become notoriously persistent (Holmgren, 2002). In the Iberian Peninsula, original evergreen oak forests have been transformed by human management into a mosaic landscape of forest patches, oak savannas, shrublands, and grasslands. In the absence of human management, the usual pathway of natural succession in oak savannas is through the gradual colonization of the understorey by different shrub species (pioneer *Cistus* shrubs, followed by other shrub communities like *Arbutus* and *Erica*), mixed with oak natural regeneration, which leads to forest recovery in the medium-term (Goncalves, 1991). Although some natural forest regeneration has indeed occurred in some areas after agricultural land was abandoned during the 1960s, the transition from shrublands to oak savannas and forests is rare (Goncalves, 1991). Recent estimations for southern Portugal indicate that 60% of the shrublands patches remain as such after 45 years (1958– 2002) and less than 10% progress to oak savannas or forests (Acácio et al., 2007).

Tree recruitment limitation in Mediterranean oak systems has been attributed to a variety of causes, including low seed input due to scarcity of viable seeds and poor seed dispersal (Pulino-Dıaz, 2005), high levels of seed predation by wild and domestic animals (Herrera, 1995) and low seedling survival due to thermal and water stress (Pulino, 1999).

Natural seedling recruitment is more abundant in forests (3.6 seedlings per m2) than in savannas (1.1 seedlings per m2), and very low in shrublands (0.1 seedlings per m2). This difference is due to density of the three vegetation as well as types of shrubs level.

1.3 Cork oak versus other trees

An update to the national forest inventory has been concluded in 2006. It showed that forest area increased 2% between 1995 and 2006 to a total of 3.4 million hectares and eucalyptus plantations decreased 4% to a total of 647 thousand hectares. The forest inventory also revealed 300 thousand hectares of young forest stands (Menard, 2005). New studies on future wood availability are being prepared.

In the current time proceed the research which monitoring the present situation of cork oaks, counting them and observe its augmentation and damage after bushfires. Unfortunately this research requires time and modern cray computers which could scan the pictures from the satellites (Surový, 2007). From the National Forest Inventory are provided the following data on the main forest raw materials and respective area of forest occupation (Deslandes, 2007).

Table 1 - The most common trees species in Portugal (Deslandes, 2007)

Species	Area (thousand ha)	Volume (million m^3)
Maritime pine (*Pinus Pinaster)*	710,6	67,1
Cork oak (*Quercus suber*)	737,7	–
Eucalyptus (*Eucalyptus globulus*)	646,7	41,3
Other species	1 318,3	–
TOTAL	3 412,3	–

1.3.1 Performance of the paper and wood industry

In 2006 the incidence and gravity of forest fires were close to the average of the last twenty years. There were 21,681 fire events and a total burned area of 75,052 hectares, of which 36,521 ha corresponded to forest stands. The following chart shows the production, imports and exports of the main wood raw materials in 2005 and 2006 (estimates) (Bennett, 2007).

Table 2 – Timber needs in Portugal (Bennett, 2007)

		Production thousand m³	Imports thousand m³	Exports thousand m³
Coniferous logs	2005	2 111	3	22
	2006	2 100	7	51
Non - coniferous logs	2005	50	148	4
	2006	70	118	4
Eucalyptus pulpwood	2005	6 590	122	1179
	2006	6 590	100	1415

The sawmill industry has contracted sharply in recent years due to the reduction in the area and volume of maritime pine caused by forest fires. There are now an estimated 250 sawmills (versus 730 in 1998) employing around 5,000 people (10,700 in 1998) (Deslandes, 2007).

.Exports of sawn softwood – which once surpassed one million cubic meters, by the mid-eighties – has now fallen to some 340 thousand m3. The chart below shows the production, imports and exports of wood boards in 2005 and 2006 (estimates) (Bennett, 2007).

Table 3 – Table of wood balance (Bennett, 2007)

		Production	Imports	Exports
		thousand m³	thousand m³	thousand m³
Particle board	2005	850	60	502
	2006	800	72	473
Fiber board	2005	405	141	364
	2006	420	168	364

More than 95% of pulp and paper production in Portugal is currently concentrated in four companies (Bennett, 2007). The consolidation process that occurred is now being implemented throughout the various organizations. Increased pulp and paper capacities were announced and new developments are expected at any moment. In 2006 the pulp industry worked at full capacity (99.5%) (Bennett, 2007). In the paper industry, the capacity utilization rate was 97.5%. Pulp production increased by 3.67% in 2006, compared to 2005. 49% of pulp produced was exported, an increase of 38% from the previous year. Papers production is increased by 3.74% in 2006, compared to 2005. 94% of paper produced was exported, an increase of 24% from the previous year (Deslandes, 2007). The following roundup shows the production, imports and exports of wood pulp, and paper among 2004 to 2006.

Table 4 – Commodities from agroforest area (Deslandes,2007)

(1000 ton)	Year	Production	Imports	Exports
Woodpulp	2004	1 949	110	1 009
	2005	1 990	47	735
	2006	2 063	40	1 018
Paper and Board	2004	1 664	840	1 234
	2005	1 577	830	1 234
	2006	1636	934	1539

1.4 Natural conditions in the montado in Alentejo

Alentejo region is located in south Portugal, occupying a third part of the country, though with less then 5% of its population (Santos, 2005). It is therefore a vast and depopulated region, with an average density below 20 inhabitants per square km (Santos, 2005) (A.2) It is one of the poorest regions in the EU, with negative demographic, economic and social dynamics. Formerly dependent on the primary sector almost exclusively, it has undergone major changes over the last two decades (Santos, 2005).

In terms of geomorphology, this region occupies the south western part of the large Iberian structural unit called Maciço Antigo (ancient massif), where metamorphic Paleozoic formations dominate. Low, gently hilly lands are the dominant landscape element, brought by extensive flattening processes, with altitudes ranging 200 to 250 meters a.s.l. in average (Joffre, et al., 1999). This polygenic erosion surface cuts through very different lithologies: clay schists, grauvachs, diorites and gabbros, granites, and quartzites, among others. Extensive Palaeogenic “raña” deposits stand over most of these formations (Afonso, 2001).

Metamorphic formations, dominated by schists, have low susceptibility to chemical weathering, but favor superficial run-off action because of its impermeability. Therefore, drainage network is dense and deep intruded in the relief, while slopes remain steep and straight, originating a “rolling topography” (Claire-Poole, 2005).

Relief forms coming out of this flattened surface are rare, and usually result either of tectonics or of differential erosion. Lithology gives this landscape a certain unity and monotony, originating little developed soils, poor in organic matter, supporting a natural shrub and tree vegetation, mostly composed by well adapted species such as *Cistus spp*.

and dry *Quercus spp*. Soils are mostly poor, with over 50% on classes E and D (bedrock or very thick soils, with no agricultural ability), mainly derived from schists (Afonso, 2001). Soil erosion has extremely high values recorded all over the region, and it is one of the major environmental problems to be faced (Afonso, 2001). Moving to the south in the montado

region, average annual rainfall decreases to less than 500 mm. (Joffre et al., 1999) have shown that across this range in precipitation, tree density change occurs (decreasing from ca. 40 trees ha^{-1} to less than 10 trees ha^{-1}) in a manner that may be interpreted as a shift in an optimum equilibrium between herbaceous vegetation and trees.

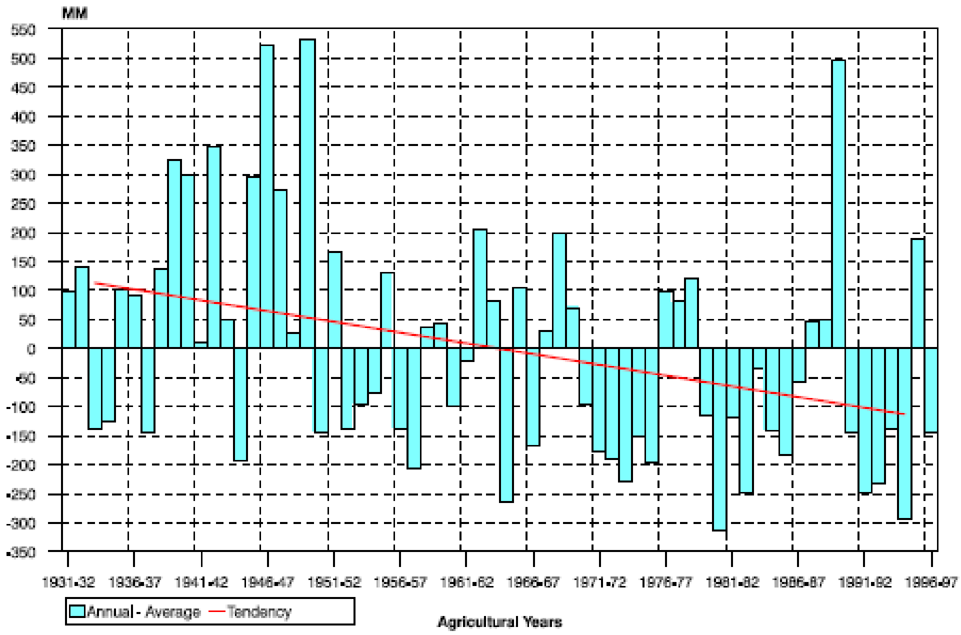

Figure 1 - Annual rainfall, deviation from average tendency, (Joffre, et al., 1999)

Concerning climate conditions, Alentejo is under the major climatic influence of the Mediterranean. Its climate varies from an Atlantic variance at the coast (wetter and milder), and a continental one over most of the region. It is therefore characterized by a dry and very hot season (stretching from May to September/October), high annual temperature amplitude (max.average temperature 27°C and min. 15°C (Trigo-Palutikov, 1999)), and a very irregular distribution of rainfall over the wet season, as well as over the years, with very intense flood peaks and with frequent drought periods (Figure 1 - Annual rainfall, deviation from average tendency, (Joffre, et al., 1999)). Water deficits are of extreme ecological and agronomic importance, especially through the dry season, and such irregular precipitation regime is most conditioning to the dominant rain fed agriculture. Irrigation schemes are being developed to face this problem, but their sustainability is quite discussable, and important environmental problems are posed.

1.4.1 Climate change in Alentejo over the 20th century

Several authors have mentioned significant changes on precipitation regime and temperature patterns in Alentejo, over the past few decades. Such conclusions were drawn from the analysis of long climatic data series and from research on other information sources, such as regional newspapers and archives (Trigo-Palutikov, 1999). One of the most significant changes could be the reduction of precipitation in spring. Such decrease mainly results from a strong reduction of rainfall in March. Comparing the climate normal (30-year average period) of 1931-60 with the one of 1961-90, a decrease of 37.5% is detected for springtime (Figure 1 - Annual rainfall, deviation from average tendency, (Joffre, et al., 1999)). This anomaly – spring deficit – has serious consequences on farming (for example on cereal crops, at the time of grain development, and on natural pastures), and clearly disturbs "natural" vegetation development. Such disturbance occurs over the ideal period for renewing and dissemination of vegetal species, when annual peak is reached for biologic activity (Afonso, 2001). Another major aspect concerning regional climate change is the increasing concentration of rainfall, with a clear tendency for higher precipitation values on each rainfall event, along with a reduction of total annual events (Trigo-Palutikov, 1999). Very intense rainfall events are a major cause for very high rates of soil erosion, mainly when such events occur at a time with most land tilled – which is quite common in March-April and October-November (Afonso, 2001). Increase of average temperature and drought periods is also confirmed through historical research and climate data analysis. Alentejo is one of Europe's most affected regions by such extreme climatic events as droughts, posing very serious social and economic problems, and causing heavy disturbance on ecosystems. The combined effect of a climatic pattern made of great contrasts and a specific and widespread use of land resources by agriculture, has contributed for the present critical level of soil and vegetation degradation, meaning that 25% of the region is severely affected by desertification processes and 45% presents a high sensitivity to desertification (Afonso, 2001).

1.5 Cork oak (*Quercus suber* L.)

Cork Oak (*Quercus suber* L.) is one of the most important forest species in the Mediterranean area (Pinto-Correia, 1993). *Q. suber* is an evergreen tree with sclerophyllous leaves which grows in carbonate-free soils in the Mediterranean Basin. It constitutes forests or open woodlands where it is the main tree species, or coexists with other Mediterranean trees, e.g., *Q. ilex*, *Q. rotundifolia*, *Pinus pinea* and *P. pinaster* (Pausas-Juli G., 1997).

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1.5.1 Botanic characteristic and description

Quercus suber L. is also known as the cork oak. It is a tree which is native to Southern Europe and Northern Africa (Pausas-Juli G., 1997). This genus has more than 600 species, most of which live in the Northern hemisphere. Many of these species are trees that can live up to 250 years old. With age, this tree has a very thick bark, which can be up to 30 cm deep (Cannon, et al., 2004). Leaves - Leaves are evergreen, alternate, entire or slightly dented, and are about 5 cm long. They are dark green on the upper side, and pale grey-green on the lower side. Flowers - Flowers appear in mid to late spring, male and female flowers appearing on the same tree. This tree is monoecious. Fruits - The fruits are oblong-shaped acorns, which are about 2, 5 cm long (Cannon, et al., 2004).

Cork Oak (*Quercus suber* L) is one of the most important forest species in this area. An ecosystem that consists of scattered tree cover dominated by evergreen oaks (cork oak, *Quercus suber,* and holm oak, *Q. rotundifolia*), with pastures and agricultural fields (clover, wheat, barley, oats) as undercover, usually in a rotation scheme that includes fallows (Lourenço et al., 1998). It is a highly diverse system (De Miguel, 1999, Carrión et al., 2000); tree cover does not follow a uniform pattern, as it usually results from natural regeneration, and the varying tree density suggests that these human-made agro-ecosystems have adjusted to local climate (Joffre et al., 1999). Shrubs sprout frequently (e.g., *Cistus, Erica, Lavandula,* and *Ulex* ssp.), and are either cleared out or artificially kept at low densities (Lourenço et al., 1998). In the current time proceed the research which monitoring the present situation of cork oaks, counting them and observe its augmentation and damage after bushfires.

1.5.2 Cork growing and rotation cycle

Cork is harvested in a steady cycle that promotes healthy growth to the tree over its expected lifespan of over 250 years (Expanko, 2005). Typically, virgin cork is not removed from saplings until the 25th year, and reproduction cork (the first cycle) may not be extracted for another 9-12 years (Pausas, 1997). So farmers have invested over 40 years before natural wine corks are produced (Pausas, 1997). The first harvest produces cork of a very irregular structure. This is called virgin cork. The second harvest brings reproduction cork - a material with a more regular structure, less hard, but still not suitable for cork stoppers (A.3). Reproduction cork is usually granulated for use in products such as flooring. It is from the third and subsequent harvests that the cork with the best properties is obtained - the amadia cork - and from this time, the tree will provide good quality cork for about 150 years. This is the type of cork that is used on wine stoppers (Expanko, 2005). In the forestry literature a growth period (i.e. time from when a stand of trees is regenerated until the time when it is harvested) is called rotation (Pinto-Correia 1993). Assuming we have one volume growth curve V (t) = f(t) in all rotations, then it's well known that the cutting time that maximizes the long term volume production is given by the line through the origin tangent to the volume growth curve, i.e. the point where V (t)=t is maximum. This cutting time is called the biological rotation age (Pausas, 1997). If we have one unknown growth curve in all rotations, on which we make observations, then we get to know the biological rotation age better after each rotation (Pausas, 1997). Measurements of the annual diameter growth of each of 24 cork oaks with ages between 41 and 139 years (Surový, 2007) were used.

1.6 Cork

Commercial cork is obtained from the outer bark (phellem) of cork oak (Seth, 2004), Quercus suber, an evergreen tree of the family Fagaceae. It is native to the western Mediterranean region: about 70% of the world's commercial cork comes from Portugal alone (Pausas, 1997). Cork is nothing more than thin-walled but strong cellulosic cell walls, which are heavily coated with suberin, a substance that is impervious to water. Cell lumens, which represent nearly 53% of the total cork volume, are filled with air, thus making cork very light—its specific gravity is 0.15–0.25 (Seth, 2004). Cork is buoyant, light and highly compressible, but it is resilient, chemically inert to moisture and common liquids, resistant to deterioration, an excellent insulator, a nonconductor of electricity, a low thermal conductor and impervious to water and other liquids (Quer, 1977). It imparts no flavor or odor to substances, is slow to catch fire, absorbs sound and vibrations and has a high coefficient of friction. All of these properties render commercial cork invaluable in the world market, and it is used either as natural cork or as composition cork, the latter as linoleum, linotiles, binder-coated cork and cork (insulation) boards. Cork is used in the preparation of stoppers, hats and helmets, tips for cigarettes, carburetor floats, fishing-net floats, golf-club handles, penholders, fishing rods, life preservers, floats and life jackets, surf balls, seals for jars, sealing liners, shoe insoles, sporting goods, picture frames, small cork balls in referees' whistles, etc. (Seth, 2004).

1.6.1 History of cork use

Natural cork has been associated with the storage of valuable foods and beverages for thousands of years. Ancient Egyptians, Greeks and Romans referenced cork as a preferred material for stoppers used with wine and olive oil (Pausas, 1997). The most significant development occurred in the 1600s, when Dom Pérignon, developed his method champenoise. The wooden stoppers used to store still wines had considerable disadvantages when applied to sparkling wine. Dom Pérignon successfully adopted cork stoppers and cork soon became essential for wine bottling. Over the next two centuries the spread of mass-produced glass bottles and standardized neck dimensions greatly advanced the use of cork, not just for wine, but a wide range of liquids and foodstuffs (Pausas, 1997).

1.6.2 Cork harvesting

The European cork industry produces 340,000 tones of cork a year, with a value of €1.5 billion and employing 30,000 people. Wine corks represent 15% of cork usage by weight but 66% of revenues (Pinto-Correia, 1993).

Cork consists of the thick outer bark of the cork oak (*Quercus suber L.*). Harvesting cork is the operation of removing bark from the tree during spring or summer (A.3). This is the time of year that the tree is engaged in rapid growth. The tender, newly generated cork cells break away from the cambium easily and without damage (Pausas, 1997). The process is temporarily debilitating but the outer bark quickly regenerates and the tree continues to flourish. Studies show that regular harvesting generally improves the trees health and vigor. Stripping cork is a delicate operation that is performed by hand with traditional tools and methods. Despite periodic attempts, there is no mechanized or automated process that can compare to traditional harvesting techniques. Harvest difficulties occur if the process is not carried out when the tree is in full growth (De Miguel, 1999, Carrión et al., 2000). As soon as it is evident that the cork is being stripped too early or too late in the season the stripping is brought to a halt, a year's delay in cork extraction is preferred to damage to the tree. The delicate operation of stripping cork has been performed in the same way for decades. Today, cork stripping with a special axe continues to be the quickest and cleanest method available (Pinto-Correia, 1993).

1.6.3 Cork and socio-economic situation

Most of them are slow growing, long-lived, and when mature are stately sturdy trees with wood that is strong, tough, durable, and valuable for many purposes. The Cork Oak, native in Mediterranean countries, is a notable exception. It, too, becomes a large majestic tree but the wood, although dense and hard, is of little use as lumber because it tends to check and crack (De Miguel, 1999, Carrión et al., 2000). The bark, however, is unique and from it we obtain cork, a material with innumerable uses. So far, few substitutes for it have been found. All kinds of trees build a new layer of inner bark each year but on a cork oak these additions gradually form a homogeneous mass of soft spongy material -- several inches thick -- with a remarkable combination of desirable qualities. Each layer is composed of rows of brick-shaped, air-filled cells so tiny that a one-inch cube of cork contains approximately 200 millions of them (Thomson, 1971). More than 50 % of it is air (Seth, 2004). The thin walls of those cells are saturated with a fatty waxy substance, called suberin, which makes cork almost impervious to water and air. Cork is also very light, buoyant, elastic, compressible, and a poor conductor of heat. Cork oaks become from 9 to 17 meters tall, with trunk diameters of 1 and half meters or more and thick wide-spreading branches. The oval leaves, about 9 centimeters long, are evergreen (Natividade, 1950). About half of the world's annual crop of cork comes from forests in Portugal but the tree is also abundant in Spain, Morocco, Algeria, Tunisia, Corsica and southern France. The highway from Bordeaux to the Pyrenees is lined with gnarled old cork oaks with deeply furrowed bark. Some trees live to be 500 years old. Cork oaks are cultivated on plantations in India and, since 1940, in California, Arizona and New Mexico (Seth, 2004).Young trees are about 20 years old when they yield their first crop but that "virgin" cork, coarse and woody, is of little value except for insulation. As this is replaced by new annual layers, subsequent sheaths of outer bark are removed every 8 or 10 years (Seth, 2004). The quality of the crop continues to improve until the fifth or sixth stripping, after which it remains stable (Thomson, 1971).The stripping is usually done in July or August (Natividade, 1950). Using a sharp hatchet, with great care not to injure the inner bark, a cut is made around the trunk near the base and another just below the first branch. These are joined by two or more vertical cuts and the workman then pries off the slabs of cork. On large trees the lower limbs yield thin sheets of high quality (Natividade, 1950). Until about 1900 the principal uses of cork were for stoppers in bottles and jugs, life preservers, floats, tropical helmets, and in linoleum. Artificial limbs, baseball centers, and badminton "birds" were made of cork. Then it was discovered that by grinding the poorer grades and combining them, under heat and pressure, with other materials, a great variety of products could be manufactured. For example: corkboard for soundproofing and as insulation in refrigerators and cold storage plants; gaskets and washers in engines and motors; pipe coverings; polishing wheels; floor and wall coverings, beverage bottle caps; etc (Thomson, 1971).

1.6.4 Forest fires

Fire is the most important natural threat to forests and wooded areas of the Mediterranean basin. It destroys many more trees than all other natural calamities: parasite attacks, insects, tornadoes, frost (Paulo, 2002). Today, the average annual number of forest fires throughout the Mediterranean basin is close to 50 000, i.e. twice as many as during the 1970s (Paulo, 2002). It is not easy to form an accurate picture of the overall increase, however, owing to the varying collections of statistics. In the countries where data have been available since 1950s, a large increase in the number of forest fires can be observed from the beginning of the 1970s: Spain (from 1 900 to 8 000), Italy (from 3 400 to 10 500) Greece (from 700 to 1 100), Morocco (from 150 to 200), Turkey (from 600 to 1 400). Only former Yugoslavia deviates from the general trend (from 900 to 800) (Aipanjiguly, 2004). The annual cumulated burnt area in the Mediterranean countries can be estimated to be approximately 600 000 ha again almost twice as much as during the 1970s (Aipanjiguly, 2004). The trend observed is, however, much less uniform than for fire incidence. A worsening situation is clear in Greece (from 12 000 to 39 000 ha), Italy (from 43 000 to 118 000 ha), Morocco (from 2 000 to 3 100 ha), Spain (from 50 000 to 208 000 ha) and former Yugoslavia (from 5 000 to 13 000 ha) (Aipanjiguly, 2004). In Portugal the situation has also worsened, although its statistical series starts later. In Algeria and Cyprus, no apparent trend emerges from the statistics, but some years present a very high maximum (e.g. 1957, 1958 and 1983 in Algeria; 1974 in Cyprus) (Aipanjiguly, 2004).Finally, the total burnt area has remained relatively stable in Croatia, France, Israel and Turkey (Claire-Poole, 2005).

The reports show that forest fires are threatening critical areas in the Mediterranean. For example, in the Monchique and Caldeirao mountains in Portugal - amongst the 10 forest hotspots in the region were identified - forest fires are destroying the habitats of the Iberian lynx, the Bonelli eagle, and many endemic plant species. The summer fires in 2003 (A.4) were the worst for Portugal in 25 years, destroying 425,000 hectares of vegetation, and damaging 2,500 houses and buildings at a cost of 1 billion Euros (Claire-Poole, 2005). Government declares a national calamity as forest fires sweep across vast areas of woodland. Officials say an area the size of Luxembourg has been lost to the fires. At least 18 people are Miller (Seth, 2004).

1.6.5 The couses of fire

Unlike other parts of the world, where a large percentage of fires are of natural origin (especially lightning), the Mediterranean basin is marked by a prevalence of human-induced fires. Natural causes represent only a small percentage of all fires (from 1 to 5 %, depending on the country), probably because of the absence of climatic phenomena such as dry storms.

In Portugal conditions, the country passed from 80 % of fires being attributed to unknown causes to less than 20 % (Delattre, 1993). This experiment, moreover, made it possible to show that the great majority of fires were due to negligence (43 %), followed by arson (34 %) (Delattre, 1993). Europe all have approximately one airborne unit per 100 000 ha of Mediterranean forest. International cooperation in this area is therefore a high-priority issue and a concern of the European Union (EU) (Goldammer, 1994; Delattre, 1993).

1.7 Biomass

Biomass means non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms. This shall also include products, by-products, residues and waste from agriculture, forestry and related industries as well as the non-fossilized and biodegradable organic fractions of industrial and municipal wastes. Biomass also includes gases and liquids recovered from the decomposition of non-fossilized and biodegradable organic material (UNFCCC, ??).

The tables which are situated below presents the cost and support in the Czech crown in the year 2004 (1 Euro was equivalent to 32 CZK, (ČNB, 2004)) for the energetic phytomass production alongside selective crops (Strašil-Hutla, 2004). Same crops like *Reynoutria* and *Phalaris* are planted directly for energetic use.

Table 5 – Donation and costs for diferent crops (Strasil-Hutla, 2004)

	indicator	unit	*Triticale*		*Phalaris arundonaceae*		
			press	collector semitrailer	press	cutter	collector semitrailer
growing + harvest	**Growing + harvesting costs**	CZK/ha	13 181	11 723	9 178	9 416	7 838
	Donation	CZK/ha	492	492	5 277	5 277	5 277
	Market production	CZK/ha	9 120	9 120	–	–	–
	Energy biomass costs	CZK/ha	3 569	2 111	3 901	4 139	
packets chopped straw	**Production of Energy products**	t/ha	4,5	4,5	7,5	7,5	7,5
	Fuel costs in total	CZK/t	793	469	520	552	–
	Energy price in fuel	CZK/GJ	56	33	36	38	–
briquetes	**Briquetting costs**	CZK/t	–	800	–	–	800
	Fuel costs in total	CZK/t	–	1 269	–	–	1 141
	Energy price in fuel	CZK/GJ	–	85	–	–	76
pellets	**Pelleting costs**	CZK/t	–	700	–	–	700
	Fuel costs in total	CZK/t	–	1 169	–	–	1 041
	Energy price in fuel	CZK/GJ	–	79	–	–	69

Table 6 - Donation and costs for diferent crops (Strasil-Hutla, 2004)

	indicator	unit	*Reynoutria*		Sorrel		Wheat	Corn
			press	cuttre	press	cutter	cutter	cutter
growing + harvest	**Growing + harvesting costs**	CZK/ha	12 045	13 968	10 815	11 394	12 966	3 664
	Donation	CZK/ha	0	0	5 277	5 277	3 277	492
	Market production	CZK/ha	–	–	–	–	–	–
	Energy biomass costs	CZK/ha	12 045	13 968	5 538	6 117	9 689	3 172
packets chopped straw	**Production of Energy products**	t/ha	12,2	12,2	7,1	7,1	7,9	6,2
	Fuel costs in total	CZK/t	987	1 145	780	862	1 226	512
	Energy price in fuel	CZK/GJ	64	75	51	56	82	36
briquetes	**Briquetting costs**	CZK/t	–	800	–	800	800	800
	Fuel costs in total	CZK/t	–	1 945	–	1 662	2 026	1 312
	Energy price in fuel	CZK/GJ	–	122	–	104	130	88
pellets	**Pelleting costs**	CZK/t	–	700	–	700	700	–
	Fuel costs in total	CZK/t	–	1 845	–	1 562	1 926	–
	Energy price in fuel	CZK/GJ	–	115	–	98	124	–

1.7.1 Energetic crops

It seems that in the field of plants biomass is profitable to use residual biomass after harvest as a side profit. From an economic point of view growing of energetic crop is hard to promote due to lack of donations. With utilization of grants it would be easier to increase the economy of energetic crops as well as their competitive advantage in the fuel marketplace. Perennial energetic crops appear to be more profitable. Preparation and realization of a long term business plan meets definite problem related to the guaranty of donations support (Strašil-Hutla, 2004). The development of energetic crops all over the world it's a reality we are still observing. The interest in this kind of crops lies not only on the possibility of their utilization as a renewable source of energy, but also on the possibility to make use of set aside land, limiting erosion risks. Energy crops offer clear ecological advantages over fossil fuels, such as a positive carbon balance (due to the photosynthesis of the biomass used as raw material) which contributes to the reduction of greenhouse gases emissions and the low sulphur content, which contributes to the reduction of acidifying gases emissions (Gosse, 1995). However they also have some disadvantages. For instance, agricultural production of biomass is relatively land intensive. So, there is a risk of polluting water with nitrates, phosphates and pesticides and also the danger of reducing the biodiversity when biomass is cultivated in monocultures

(Kaltschmitt et al., 1996). Among the biomass crops, *Miscanthus*, is one of the most interesting, since it can transform solar energy into electricity, and due to its high content in cellulose it can also be used for paper pulp production (El-Bassam, 1996).

Miscanthus x giganteus crop presented a clear positive energetic budget. Energy inputs represent only around 5% of the energy output (Kaltschmitt et al., 1996). Machinery used for cultivation is the major energetic input (theoretical average values). Concerning outputs, productivity is the most important item to be considered. So, all the conditions that could be improved in order to achieve a better yield should be applied, even if this implies an acceptable increase in the energetic inputs. The energy inputs increased with the level of nitrogen fertilizer but the increase of the energy output (derived from better yields) compensates largely the difference and the result is a much higher net energy gain(Gosse, 1995). Concerning CO2 emissions and net avoided emissions of greenhouse gases, all computed net budgets are positives. N2O emissions, which contribute not only to the greenhouse effect but also to the ozone depletion, are relatively small during crop cultivation. The differences observed between the two levels of nitrogen, follow the same pattern mentioned for the energy inputs and outputs (Gosse, 1995)

1.7.2 Miscanthus in Portugal

Miscanthus x giganteus is a promising energy crop in the south of Portugal due to the high yields obtained in this region, if water is available in significant amounts. In terms of soil erosion, the highest risks occur during winter, before growth starts, when there is a lack of soil cover and when the rainfall is usually more severe, but due to the perennial character of this crop this risk is minimum compared with other crops (Kaltschmitt et al., 1996). On the other hand, the danger of reducing the biodiversity might exist due to the fact that *Miscanthus* is cultivated in monoculture. In any case the balance of the environmental impacts can be considered positive and represent a gain in primary energy sources consumption, which is essential for sustainable development in poor regions like southern European areas, in general (Kaltschmitt et al., 1996).

1.7.3 Others energetic crops in Mediterranean basin

The crops could be divided on the species proposed as non-food crops into two groups. The first group includes species already cultivated to supply products for different uses (beets, potatoes, etc.); with a few changes in the cultural or varietals techniques, these species can become potential source of non-food products (Kartha, 2006). In principle these species are already available for experimentation at pilot level. The second group comprises spontaneous species, mostly exotic, not well-known and never utilized, which, due to the characteristics of their products, are proposed for introduction into farming. However, from the agronomic viewpoint, they still require considerable applied research for their productive and economic optimization (Bartolelli, 2006). Considering this last group of plants, generally it can be stated that many of them (often of tropical and sub-tropical source) can find greater possibilities of diffusion in southern Portugal, since the environmental characteristics of these regions are particularly favorable for their cultivation (high temperatures, high light intensity, long vegetative seasons) (Talbot, 2006). The main research topics regarding the energetic crops are the following ones: Species and cultivation screening for productivity in the different environments, methods for propagation and planting, identification of minimum cultivation practices (tillage, irrigation, fertilisation, phytosanitary control), setting up of methods for mechanical harvesting, processing and storing biomass, study on influence of biomass crops on soil fertility, environmental impacts, both negative and positive, of biomass plantations (Bartolelli, 2006), particular attention is dedicated to the data collection for energetic and economic analysis, including accurate evaluation of the energy budget for each growing trial, and allocation of all the costs for production (Talbot, 2006).

The investigation focuses on the following species:

- Annual species: fibre sorghum (*sorghum sp.*); kenaf (*Hibiscus cannabinus*);
- Perennial herbaceous species: cynara (*Cynara Cardunculus*); miscanthus (*Miscanthus sinensis*); giant reed (*Arundo donax*); topinambour (*Helianthus tuberosum*)
- Perennial woody species: ailanthus (*Ailanthus altissima*); black locust (*Robinia pseudo- Acacia*); broom (*Spartium junceum*); eucalyptus (*Eucalyptus sp.*); willow (*Salix alba*); poplar (*Populus sp*) (Bartolelli, 2006).

1.7.3.1 Anual species

The annual species present the advantage of being cultivated on annual rotational set-aside lands. They are very similar to usual food crops, so they can be easily "accepted" by farmers. Among the annual species fibre sorghum is considered one of the most interesting in Italy for producing solid biofuel. It has been grown with conventional agronomic techniques at various Italian Regions (Sardegna, Toscana, Friuli, Emilia-Romagna) (Bartolelli, 2006). The productivities obtained were up to 25 oven dry tonnes (odt) per hectare. The annual habitus, the resistance to drought, the high productivity and the easy mechanization are the main advantages of this energy crop. Another annual species considered is kenaf, a non-woody species suited for paper-making, that in comparison to fibre sorghum, appears to have greater water needs and often lower biomass productivity.

1.7.3.2 Perennial species

Perennial species, both herbaceous and woody, are a more complex case in comparison with annual crops. First of all they occupy the soil for many years and therefore they have a considerable impact on the farm organization. The planting cost is generally high because these plants can be propagated through rhizomes or cuttings or seedlings(Váňa et al., 2002)). On the other hand, once the crop is established, it can produce biomass for several years with substantially lower costs in comparison with the annual species. The environmental impact is also lower because perennial crops require a lower use of chemicals and only little tilling.Among perennial herbaceous crops miscanthus, which has some perspectives for paper-pulp industry, has shown a good adaptation to the climatic conditions of south Portugal. The productivity obtained from the second year after planting are 10-30 t/ha, with the maximum values achieved in experimental plots. An advantage of this species is the possibility of natural drying of the standing biomass during winter without major losses of weight. This fact greatly facilitates the harvest and storage operations (Paula, J. M., 2002). The cultivation trials on Cynara cardunculus have not yet given sufficient indications for evaluating the potentiality of this species as biomass crop for electricity production in Italy. An advantage with respect to other perennials crops is the low planting cost due to the possibility to sow directly the seeds. However, it seems that the productivity achievable is lower in comparison to other perennial crops like miscanthus or giant reed (Bartolelli, 2006).

Following table presents the yield of plants from agricultural sector. Could be devaded into two groups: convention food crops and energetic crops. In this table were observed and presented following values and columns: total yield, grain and grain with straw together (t/ha).

Table 7 – Summary of agricultural crops and quantity values (Vana-Ustjak, 2002)

Crops	Representative production (t/ha)		
	grain	Flower - green mass	Flower - complete ripeness (grain + straw)
Triticum aestivum	4,07	22,00	9,90
Triticum durum	3,05	20,00	7,70
Secale	3,22	25,00	8,80
Hordeum vulgare	3,32	20,00	7,20
Hordeum	3,34	18,00	7,20
Triticale	3,18	25,00	8,70
Avena nuda	2,46	20,00	6,50
Brassica napus	2,31	20,00	6,80
Zea mais	5,68	27,00	11,50
Pisum sativum	1,89	–	–
Solanum tuberosum	20,88	–	–
Beta vulgaris	48,64	–	–
poaceae	–	24,03	
Fodder crops	–	22,00	5,67
Trefoil var.red	–	24,00	6,78
Trefoil	–	22,00	5,67
Grassland	–	10 až 12	2,65
Lucern	–	25,00	4,39
Elephant grass	–	–	12,00
Absinthe	–	–	15,40
Fagopyrum esculentum	–	–	3,40

1.7.4 Growth and development *Cistus silviifolius L.* in montado

The montado is ecosystem of shrubs (Scarascia-Mugnozza, et al., 2000) while trees are not dominant and their density is average 20 trees per ha (Herrera, et al., 1995). The most dominant species in shrubs land is *Cistus* (Simoes, M. P., et al., 2004).

This species is usually most density in the first year after damage. In optimal condition the density could be 220-350 plants of *Cistus* per one m square. The maximum leaf weight ration is in the first year, decreasing after ward (Simoes, et al., 2004). But if were using deep ploughing or if roots of *Cistus* were damage so the plants recruitment require one year more (Simoes, et al., 2004). Five years after ploughing the disturbances, size, and leaf weight ration were similar like on control sample. However, while the density of shrubs were after five years still higher than the registered before treatment (Cruz, et al., 2002).

1.8 Pellets

Wood pellets are perspective, highly compressed, strewn phyto fuel (up to the 1, 4 kg/dm3) (Vana-Ustjak, 2002), with high heating power (up to the 18 MJ/kg), low ash content (0, 5 when 1 %), low water content (about 10 %) (Vana-Ustjak, 2002). The average diameter is from 6 to the 20 mm, with length up to the 40 mm (Appendix 18). It is crashworthy, with low cost of storage and it is susceptible to automatization in incineration process (Vana-Ustjak, 2002). In the beginning of production phyto fuel was accepted with considerable skepticism. Prognosis for a long time gave chance only to wood chips, logs and possibly to luxury briquette fuel. But during several years everything has changed to the behoof of pellets, in 2000 Austria had already manufactured 60 000 tons, in 2001 90 000 tons and by the year 2005 has Austria burnt incredible 350 000 tons pellet of all kinds (Petříková, 2008). Sweden annually produces about 700 000 tons and pellet. Sweden doesn't only burn pellets in small hearths, but also in big heating plants .During the heating season in 2000/2001in the United States were sold 730 000 tons of pellets. In 2000 USA produced and sold approximately 47 000 heating system on pellet. In 2001 Czech Republic manufactured about 20 000 tons of pellet, partly designated for export to Austria as well as to Bavaria (Petříková, 2008). It seems that in the field of vegetable biomass is profitable to use residual biomass after harvest as a side profit. From an economic point of view growing of energetic crop is hard to promote due to lack of donations. With utilization of grants it would be easier to increase the economy of energetic crops as well as their competitive advantage in the fuel marketplace. Perennial energetic crops appear to be more profitable (Vana-Ustjak, 2002). Preparation and realization of a long term business plan meets definite problem related to the guaranty of donation support.

1.9 Portugal's energetic strategy and potential

In 2001, Portugal has adopted the Climate Change National Strategy, which contains the principles and objectives that will guide the policy making process to combat climate change.

The strategy recognizes that additional measures need to be implemented in all activity sectors, mainly transport, energy production and consumption, the services and residential sectors as well as to control emissions from agriculture and forestry (Hulme-Sheard, 1999).

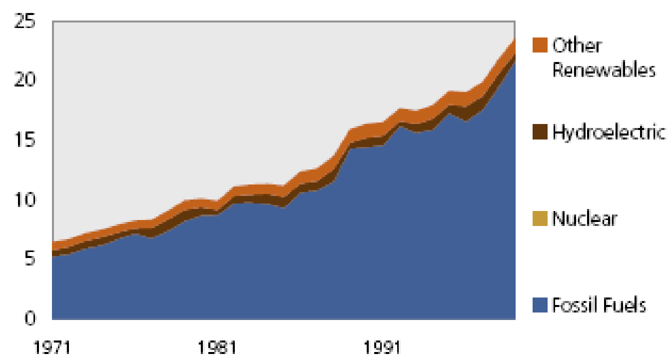


Figure 2 – Energy consumption by source in Portugal

Vertical axis of Figure 2 presents million tons of oil equivalents so we could see the trend of usage energy.

Portugal is currently about 90% dependent upon foreign energy sources (note that inter-annual fluctuation is significant due to a large component of hydroelectricity in the energy mix) (Earth Trends, 2003). In fact, endogenous resources are mainly renewable energy resources, with hydroelectric energy ranking first by far. In 2000, the gross consumption of primary energy in Portugal was 25.5 million tones of oil equivalent (Mtoe). Most of the primary energy is currently obtained from petroleum products (around 71% in 2000). Natural gas was introduced in 1997. Holding currently about 9% of share it is foreseen that its share will grow in coming years (23% of share by 2010) (Hulme-Sheard, 1999). Coal was insignificant up to mid-eighties, but now became a significant portion of the primary energy (about 14% by 2000, DGE) (Earth Trends, 2003). The contribution of renewable energies sensu lato, i.e. including large hydroelectric power (larger than 10 MW systems) and wood products, represented about 14% in 2000. In the context of the energy sector the electricity production has a much larger share in the final energy consumption, as a part of the primary energy sources are transformed into electricity (about 17.8% in 2000 compared to15.1% in 1990). In 1999, the final energy consumption was 19.3 Mtoe (more 27.9% than 1990). Transport and Industry dominate energy consumption, holding a share of about a third each. The Transport sector has increased its consumption of final energy about 40% compared to

1990. In 1999, the share of final energy consumption in the main activity sectors was, 33% in Industry, 38% in Transportation, 13% in Domestic and 16% in Others sectors (services and agriculture) (Earth Trends, 2003).

Table 8 – Energy consumption (http://earthtrends.wri.org/pdf_library/country_profiles/ene_cou_620.pdf)

Energy production and consumption	Portugal	Europe	World
Energy Production by Source, 1999 (in thousand metric tons oil equivalent)			
Total Fossil Fuels	21,761	2 117,484	7 689,047
Coal and coal products	3,789	480,313	2 278,524
Crude oil and natural gas liquids	13,757	906,066	3 563,084
Natural gas	1,939	786,787	2 012,559
Nuclear	0,000	303,885	661,901
Hydroelectric	626,000	60,847	222,223
Renewable, excluding hydroelectric	1,257	64,845	1 097,889
Primary solid biomass	1,158	56,374	1 035,139
Biogas and liquid biomass	1,000	1,919	14,931
Geothermal	69,800	4,886	43,802
Solar	18,000	390,000	2,217
Wind	10,600	1,227	1,748
Tide, wave and ocean	0,000	50,000	53,000

1.9.1 ENERGY in Portugal

In 2006 the Government launched a public tender to award 15 licenses for biomass power stations with total capacity of 100 megawatts (MW), and announced the award of the first two licenses (2 MW and 3 MW) (Pontes, 2006). Portugal has set a target to reach 150 MW of electric energy produced from biomass in 2010 (Hulme-Sheard, 1999). New biomass based energy facilities are under construction and concern for higher costs for raw materials exists. Energy policies providing subsidies for green KWh produced will further mobilize wood for energy production. Higher energy prices and climate change related policy are affecting competitiveness of industry. In the meantime there has been considerable external demand (from Italy, Belgium and the UK) for forest biomass for energy production as a result of the existing differential in “green” electricity prices (106 euros/Mwh in Portugal, versus 170 euros/Mwh in Italy, 135 euros/Mwh in Belgium and 130 euros/Mwh in the UK) (Hulme, Sheard, 1999). Forest industries are further involved in activities along the wood for energy chain and energy production.

2 OBJECTIVE OF THE WORK

The main purpose of this work is to monitor and evaluate the growth and the structure of the biomass under the cork plantation in the area Alentejo in Portuguese. Results of this thesis would give replies to questions: in what vegetative ages of phytomass should be reaped and what quantity of biomass we can expect for the harvest. At first part we were focused on maximum yield then our research was oriented on the structure, moister and energetic contain of these phytomass. The last part of this thesis was the evaluation of energetic potential and to compare the phytomass with traditional energetic plants and fuels.

3 MATERIALS AND METHODS

3.1 Site description

A valuable complementary set of information on another *montado* stand was obtained at a site near Evora, Alentejo there were realization our research. This site on the University farm at Mitra is at 38º32’26” N, 8º00’01” W, 243 m asl, and lies some 150 km southeast of Lisbon (Silvestre, 2003). Site topography is slightly undulating with vegetation consisting of a sparse and scattered *Q. rotundifolia* stand, with 35-45 trees ha^{-1}, with spots of *Quercus suber*. The wide and shallow shape of the crowns reflects the traditional pruning performed to increase fruit production and shadow for cattle. The understory consists of a mixture of shrubs and grasses, dominated by *Cistus* spp., grazed by cattle. The climate is of the Mediterranean type, with hot and dry summers. According to long-term averages (1951-1980), mean annual rainfall is 665 mm (90% of which falls from autumn to early spring) and mean annual open water evaporation is 1760 mm (INMG, 1991). Mean annual air temperature is 15 ºC, ranging from 8.6 ºC in January to 23.1 ºC in August. The soil is a very shallow sandy Cambisol (FAO, 1988) overlying a gneiss rock. Soil water retention capacity is rather low. An automatic weather station was installed on the top of a 25 m high metallic tower giving data on: solar radiation (CM6B, Kipp and Zonen, Delft, The Netherlands), dry and wet bulb temperatures (aspirated psychrometer H301, Vector Instruments, Rhyl, UK), wind velocity (anemometer A100R, Vector Instruments, Rhyl, UK), wind direction (wind vane W200P, Vector Instruments, Rhyl, UK) and gross rainfall (tipping-bucket raingauge recorder ARG100, Environmental Measurements, Gateshead, UK). These data were recorded at 10-minute intervals in a CR10 data-logger (Campbell Scientific, Shepshed, UK). Sapflow density was measured by the *Granier* method in a sample of 8 *Q. rotundifolia* trees and of 3 *Q. suber* trees. Meteorological and sapflow data are available at 10 min intervals. Water vapor fluxes from the ecosystem were monitored by the eddy covariance technique using a three dimensional sonic anemometer (R3A, Gill Instruments, UK) and a krypton fast response hygrometer (Campbell Scientific).

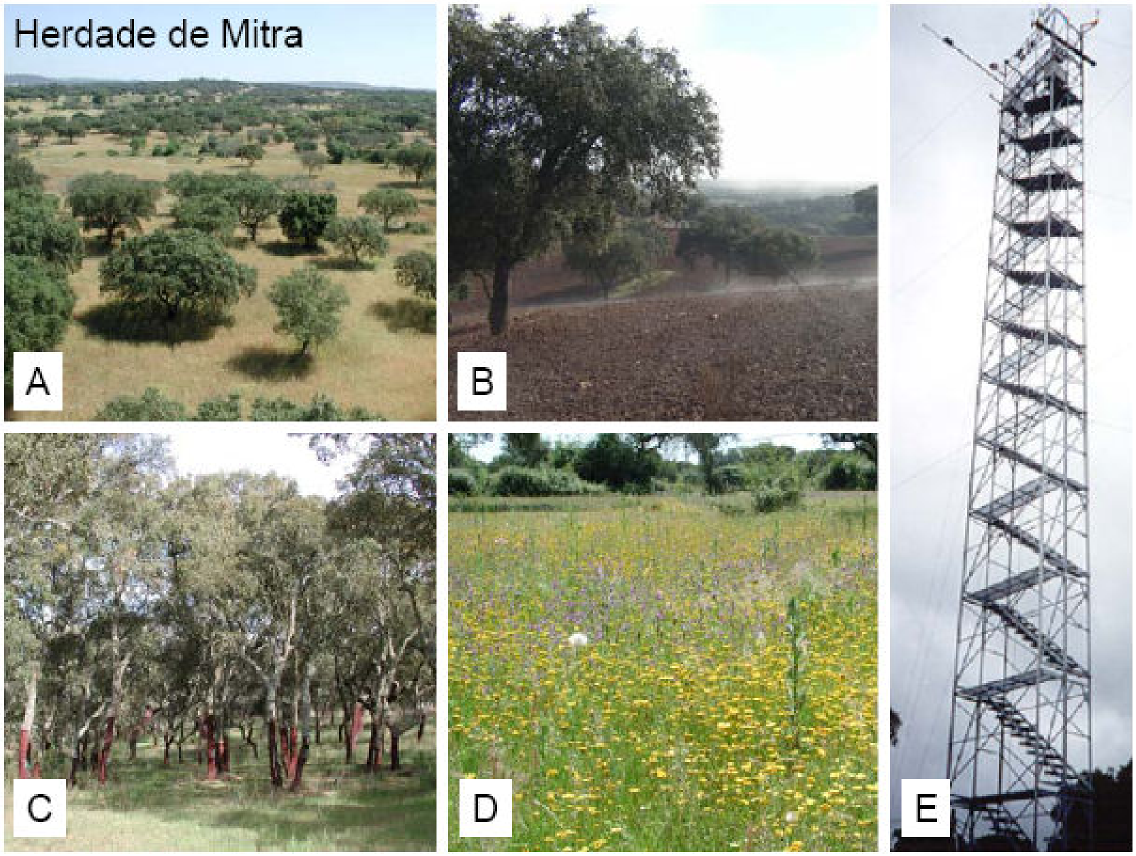


Figure 3 – Picture from the site description: pastures, Cork oaks and automatical meteorologic station, (Tenhunen et al., 2007)

A) Montado has everage density of oaks, pastoral areas with many species of weeds

B) Ploughing area could help against fires, today is necessary (obligation of farmers) to carry about montado but isn't know in which period

C) Montado has high trees density, further picture shows pastoral areas and oaks after harvesting

D) Montado has low density of oaks, pastoral areas with many species of herbs

E) There is tower for meteorology and ecology research

Data gathering and the fundamental research took place on the property of Evory University (Figure 3).

The basic of this thesis was to collect representative samples from three different locations. To have the samples representative and valid they were selected randomly. The gathered of samples were made in Mitra. This location is near the Portugal's city Evora. The research was conduct on fenced 50 ha large area with Cork oaks plantations divided into three parts: A, B,

C. The fence is essential for the validity of our measurements and is a guarantee that no animals were not allowed to graze in the areas.

3.1.1 Area A

Area A was ploughed 1, 5 years ago and now it looks even. The weed seems to be in lead and represents the most of the biomass, the pines and oaks looks submissive. The total area is 20 ha (Appendix 19, Appendix 20).

3.1.2 Area B

Area B was ploughed 9 years ago. We can recognize 3 groups of plants. The dominant vegetations are trees and scrubs. From a first sight is evident that pines grow faster than oaks. Lots of different plant families are included in weed floor. Compared with Zone A it is not dominant.

3.1.3 Area C

This Area is located little bit further from the other areas. The plowing in Area C took place 12 years ago. This zone is oriented to the south. The vegetation is mostly characterized by oaks and scrubs. The high number of well grown scrubs had limited the growth of the weed furthermore its narrows natural restoration of cork oaks. This region is made of mixed culture of pine-trees, oaks and weed invasive plants. Piece of land is oriented south-west and in few areas it has moist subsoil and underground water can be found there (Appendix 21, **Error! Reference source not found.**).

3.2 Fieldwork

In the area was planted mixed culture of oaks and pine trees (ratio 3:1) (Surový, 2007), the other plants growth uncontrolled and is important to find out some resolution.

Deep ploughing was carried out in the area, which was applied into 40 cm depth (Surový, 2007). All vegetation bindings were destroyed so the new flora could appear and take over the area. Ploughing has a liquidating effect on all weed biomasses and it limits the danger of bushfires and its spreading.

The selection was done in a following way: firstly we printed the map of location which represented the working area that was marked as well as the well grown pines and corks to allow us better orientation in the area. Into those maps we marked and numbered points 1-14

(Surový, 2007), the points were selected randomly. Each point symbolized an area of 1 square meter from which the samples were collected.

The map with marked areas and well grown trees was used for better orientation. Used equipment: map, machete, off road vehicle, saw, garden scissors, sack for phytomass, cord, camera, gloves, hat, and paper, and pen, sun cream and insect repellent.

Each point symbolized an area of 1 square meter from which the samples were gathered. For our research we collected all available phytomass from designed areas. Gathered phytomass consisted not only from fresh biomass but also of "dead" biomass located in the marked areas. The proportion of each point was 1 or 2 square meter in dependence of local conditions and quantity of biomass. Actual dimension were noted for future statistic analyses.

After collection the samples were immediately transported to laboratory of Evory University and were weighted on laboratory scales. Later they were put back into sacks and numbered 1-14 (Surový, 2007). All measured figures were written into tables. Afterwards the samples were carried to a phytomass drier, where it was let dry for 48 hours in 105°C (Janásek, 2005). When the drying process was over the samples were scaled again and measured figures were written into a table. In this phase we divided samples into woody and leaf parts in order to find out if their ratio correlates with the weight prior drying.

3.3 Estimation of phytomass caloricity

Due to next research the phytomass dried in Evora had to be transported to Prague, where next measurements took place in the laboratories of CULS Prague. For our following research was not needed to have all the samples complete, but only 10g from each sample (Fuksa, 2007). Before transportation to CULS (Czech University of Life Sciences Prague) the all samples were shred and then sended to CULS. Crashing process was necessary in order not to send them in original quantity (Appendix 22).

3.3.1 Calorimeter

A calorimeter is a device used for calorimetric, the science of measuring the heat of chemical reactions or physical changes as well as heat capacity. The word calorimeter is derived from the Latin word calor, meaning heat. Differential scanning calorimeters, isothermal microcalorimeters, titration calorimeters and accelerated rate calorimeters are among the most common types. A simple calorimeter just consists of a thermometer attached to an insulated container. To find the enthalpy change per mole of a substance X in a reaction between two liquids X and Y, they are added to the calorimeter and the initial and final (after the reaction has finished) temperatures are noted. Multiplying the temperature change by the mass and specific heat capacities of the liquids gives a value for the energy given off during the reaction (assuming the reaction was exothermic). Dividing the energy change by how many moles of X were present gives its enthalpy change of reaction. It doesn't however account for the heat loss through the container or the heat capacity of the thermometer and container itself. In addition, the object placed inside the calorimeter show that the objects transferred their heat to the calorimeter and into the liquid, and the heat absorbed by the calorimeter and the liquid is equal to the heat given off by the metals.

3.3.2 Preparing pellets and estimating energy

We prepared one pellet from each of 14 samples which were sended from Portugal. At first before weighing out 1g, we had to shred the samples again. The biggest part of phytomass material had to be smaller than half of millimeter (Fuksa, 2007). So we had to use laboratory shredder again (Appendix 23) and then the phytomass looked like flour (Appendix 24). The next step was preparing pellet from the first sample, using the press machine and moulding the first one. Using the same way were done others pellets. Total was prepared 14 pellets. From area A were prepared 4 pellets, from area B were prepared 7 pellets and from area C 3 pellets. Whole pellets were packed into the smoking paper (vazka, which was standard) and marked. Then were measured samples from 1 to 14 gradually in the calorimeter and values were noted. It was necessary consecutively inspect the calorimeter and note process of measurement.

3.4 Models example

We were interested in what amount of phytomass was destroyed by the bushfires in 2003 in Portugal. The damage was calculated on 1 billion Euros. Using the measured figures and find out facts we will try to show how much phytomass could have been ruined. We were also interested in how much energy was released during those bushfires and we will establish this figure. This example can be only done under the condition that phytomass in destroyed areas was developing according our ideas. We have also realized that even the areas with character that is not interesting for our research be included in area damaged by bushfires. The area ruined in 2003 in Portugal was in total 425 000 ha (Claire-Poole, 2005). As a results of these example will indicate amounts of phytomass within certain years and brute energy of this amount of phytomass. Than we will compare the amount of energy release and total burned phytomass. Also on this example could be demonstrated and compared using and producing biomass with other energetic sources.

4 RESULTS AND DISCUSSION

4.1 Data evaluation

In total 14 different samples were collected from the area of 23 square meters. The final weight of collected samples after drying was 38kg. In the average was collected more than 12 kg from each area. On the one sample accrue about 2, 71 kg and the average was 1, 65 kg/m^2. Those values will be used later in illustration.

4.1.1 Biomass moister estimation

The first column presents the order in which were samples collected, the second shows vegetative age of phytomass, the third displays format of area in m^2 other columns show: undried weight, dried weight, weight of the juta-bag, amounts of water in grams and percentage values of humidity relatively. The difference between samples from the same group (A, B, C) were be the cause of ration of soil moisture (Simoes, M. P., et al., 2004). But that is why we gathered from the one group 9 samples. Then we could calculate with 95 % accuracy (Surovy, 2007). Average total water content is 45% from the all samples but the deviation is higher (Table 9). These deference should had been original from the methodology of selection samples, some random or from the group which could not been together. The most probably is that in the tree groups of different vegetative ages could be expecting differ values. The next table (Table 10) will show the ration of water content according to groups A, B, C. Back to the previous table (Table 9), and the rest of the characteristics have to be seen in the same context.

Table 9 – Basic datas which were gathered and measured in Mitra (May, 2007)

samples	vegetative age of biomass	area size	undried weight	undried weight / m	dry mass	dry mass / m	Weight of juta-bag	Water content in sample	moisture content
	year/ group	(m^2)	(g)	(g/m^2)	(g)	(g/m^2)	(g)	(g)	%
1	9/B	1	3922	3922	1984,8	1984,8	108,3	1 828,9	46,63
2	9/B	1	2142	2142	1700,5	1700,5	111,2	330,3	15,42
3	1,5/A	2	2086	1043	817,7	408,85	112,2	522,0	50,04
4	9/B	1	5386	5386	2768,3	2768,3	109,7	2 508,0	46,57
5	1,5/A	2	4177	2088,5	1895,1	947,55	107,6	1 033,4	49,48
6	9/B	1	3564,7	3564,7	1477,8	1477,8	110,1	1 976,8	55,45
7	1,5/A	2	6906	3453	2701,9	1350,9	109	1 993,1	57,72
8	9/B	1	4117	4117	2421,2	2421,2	108,4	1 587,4	38,56
9	1,5/A	2	3511,8	1755,9	1659,5	829,75	107,5	818,7	46,62
10	9/B	1,96	12447	6350,5	8080,6	4122,7	217,6	2 010,2	31,65
10a	9/B		6387		4257		107,9		
10b	9/B		6060		3823,6		109,7		
11	12/C	1	5496	5496	3044,7	3044,7	108,1	2 343,2	42,63
12	12/C	3,2	7722	2413,1	4484	1401,2	108,5	903,4	37,44
13	12/C	3,12	6149	1970,8	2925,1	937,53	109,3	924,0	46,88
14	12/C	1	4044	4044	1999,2	1999,2	107,8	1 937,0	47,90

The table (Table 10) shows average moister of phytomass in different vegetative ages. The most complicated samples come from vegetative age of nine years. These categories of samples were the least homogenous group. After first calculation it was necessary to add samples. But we can see that standard deviation in these categories is more and less three times higher than the other two. Even that in the two groups we can predicated that from the statistics point of view the results are for 95 % valid and last category should be valid for 85 %. The table 9 evidently shows trend decrease content of water in the phytomass after eighteen months. From these could be predict certain evolution of phytomass structure, the changes in proportion of woody and green part. Data collected from all areas were unambiguously proved what was expected. The highest water ratio was located in the Area A (51 %) compared with Area B where was found only 40, 5 %.

Table 10 – Average ration of water according group

Vegetative ages/group	Everage water content (%)	Standart deviation
1,5/A	50,97	4,74
9/B	40,53	15,25
12/C	43,71	4,77

4.1.2 Phytomass evolution and yield calculations

It is generally expected that an increase of phytomass is relevant to the time. But the reality is mostly different because the local environment and external conditions influence increase of phytomass. The productivity of the pasture at any time during the grazing season is determined primarily by the types of pasture plants, weather, and soil conditions. This productivity is also influenced by grazing management, leaf area, rest periods, and the vigor of the pasture plants. Our monitoring proves this fact (Figure 4).

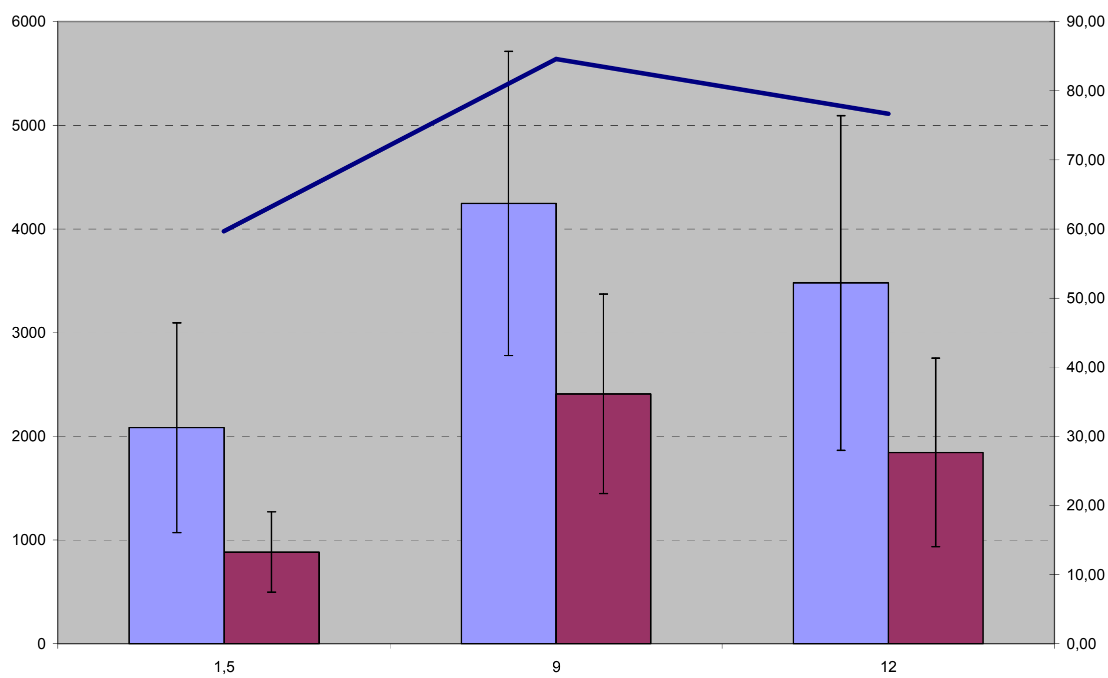


Figure 4 - Yield per hectare

Fig (Figure 4) by the visual demonstration shows differences during vegetative ages. The blue columns represent fresh weight after harvesting and the magenta weight after drying. The evolution during the time can be observed in the upper part of figure (Figure 4). There is line shape which demonstrates that after ninth year the total amount of phytomass is decreasing.

From measured values (Table 9) was calculated potentional yield per hectare in different vegetative cycles. The highest yield was measured in the area B in of average 23 t/ha.

On the other hand the lowest yield was found in the area A in average of 8.84 t/ha. In the area C was gathered lower amount of phytomass than was expected the average was 18 t/ha

The peak figure was found in the area B where was collected 4.122 kg/m2 which would be equivalent of 41.2 t/ha. Absolutely lowest quantity was gathered from area A which was only 0.41 kg/m2. If we compare the yields in the areas A, B and C could suppose, that the most benefits time for harvesting phytomass will be between the ages 1,5 and 9. Regarding to line shape from figure (Figure 4) and field experience it is assumed that time to harvest phytomass become between 6 and 7 vegetative ages. We expect that amounts of harvest phytomass will be near the average of category B.

According to table (Table 10) the samples from the group B had the lower water ration which could relate to the proportion of wood and green (leaf) parts (Figure 5).

Table 11 – Average yield per group

vegetative age of biomass	Average fresh mass for group		Average dried mass for group	
	(g)	(g / m^2)	(g)	(g / m^2)
1,5	2085,1	1010,85888	884,275	387,638658
9	4247,03503	1465,68479	2412,55918	960,747334
12	3480,98958	1612,26077	1845,67051	909,847619

Previous table (Table 11) shows diference among the vegetative groups. Follow that after ninth year the quantitative amount of biomass will decrease.

4.1.3 The ratio between wood and green part

So that we could assert some coleration among content of water and ration of wood and green part of phytomass should compare the express percentage values. We suppose that wastage in bulk of water will colerate with augment of wood part. Gathered phytomass was divided into two parts the green and wood one. The wood part represented almost 85% in the area B compared to the area C which had 76%. The lowest figure was found in the area A (60%). It is evidently that the most wood in phytomass was harvested in the area B coexistence with well balance ration in majority of samples. Even from these data are also implicit that the higher potential of phytomass will be among the vegetative ages A and B. Further the most interesting is the result of the group B which influent from the table (Table 12) where were measured almost 85% of wood for sample. This is the most important from the point of energetic view, particularly if we could harvest phytomass every 5 year (Simoes, et al., 2004). But on the basic of our monitoring could recommend the harvesting or ploughing after 6-7 vegetative ages of phytomass. In this evolution period of phytomass is higher possibilities of utilizing the potential, because the amount of phytomass is on the peak. After this period become decrease of potential phytomass and simultaneously higher risk of bushfires. Both of negative appearance could proceed with the right treatment.

Table 12 – Ration of wood and green part in each sample

samples	vegetative age of biomass	total	weight green part	wood part	deficiency	wood part	green part
	type	(g)	(g)			%	
Bag1	9/B	148,9	17,6	131,6	-0,3	88,38146	11,82001
Bag2	9/B	242,8	2,8	241,1	-1,1	99,29984	1,153213
Bag3	1,5/A	122,8	63	58,6	1,2	47,71987	51,30293
Bag4	9/B	242	8,4	233,7	-0,1	96,57025	3,471074
Bag5	1,5/A	315,6	84,1	232,9	-1,4	73,79594	26,64766
Bag6	9/B	183,7	59	128,4	-3,7	69,89657	32,11758
Bag7	1,5/A	159	66,9	91,9	0,2	57,79874	42,07547
Bag8	9/B	338,9	89,6	251	-1,7	74,06315	26,43848
Bag10	9/B	456,3	94,6	363,3	-1,6	79,61867	20,73197
Bag11	12/C	283,7	85,6	199,4	-1,3	70,28551	30,17272
Bag12	12/C	274,3	23,2	252,4	-1,3	92,01604	8,457893
Bag13	12/C	239,1	76,9	161,8	0,4	67,67043	32,16228
Bag13	12/C	210,1	23,8	186,5	-0,2	88,76725	11,32794
total	1,5/A					59,66	40,17
total	9/B					84,63832	15,95539
total	12/C					76,65733	23,59763

Proceed of relation among the water content and ration of wood and green part will follow.

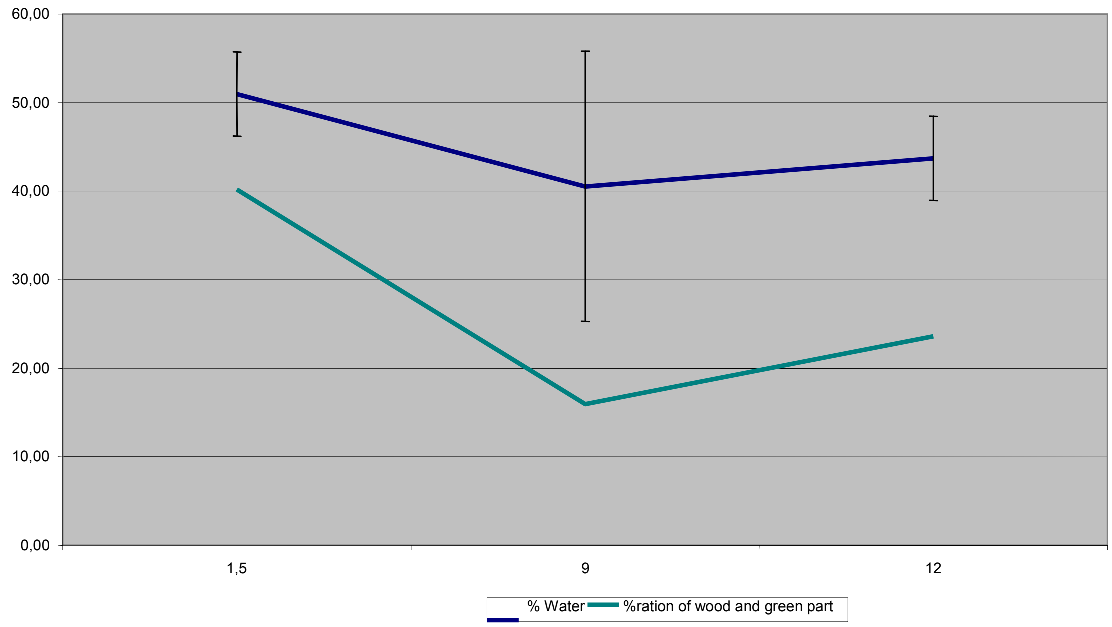


Figure 5 – Green curve – kation of wood and green part; blue curve - % water in phytomass

The green line is express by the ration among the wood and green portion of phytomass and could monitoring the behavior through vegetative ages. In the same figure could sight the blue line what express water content in the same phytomass. These two lines have a similar development in the time and we can see connection between decreasing process of green part and the lowering content water portion in the phytomass during first period. In the case that will use the phytomass for energetic exploitation will found the lower water ration. On the basis of our monitoring will recommend the harvesting among 6-7 year vegetative ages of the phytomass.

4.2 Phytomass heating value

According to laboratory measurements it's possible to say that samples taken from area B have the higher energetic value. The highest figure was collected from this area its value was 18, 8 KJ/g and the average figure sits on 18, 18 KJ/g. The lowest figures is 17, 58 KJ/g. The most samples become from the area B, the results from this group have less balanced character. Compared with samples from the area C which had well balanced values but heating value (BE) was unambiguously lowest.

Table 13 – Heating values of the samples

sample	vegetative age / area	weight	heat step	Heating value (BE)
	Years	(g)		(KJ/g)
1	9/B	0,6324	1,20731	17,81415952
2	9/B	0,7325	1,47913	18,84340656
3	1,5/A	0,8732	1,64527	17,58152124
4	9/B	0,6871	1,34254	18,23287111
5	1,5/A	0,6903	1,35699	18,34378546
6	9/B	0,6218	1,24148	18,63139268
7	1,5/A	0,6951	1,37266	18,4275535
8	9/B	0,6601	1,29455	18,30030563
9	1,5/A	0,7695	1,49385	18,11521751
10a	9/B	0,8046	1,53385	17,78855517
10b	9/B	0,7684	1,45492	17,66797516
11	12/C	0,7462	1,45626	18,2108816
12	12/C	0,7757	1,46226	17,58992567
13	12/C	0,7218	1,38936	17,96137831
total average				**18,10778065**

The differences in measured figures do not show significant difference. That is right but it is necessary mention the other crops ant its heating values. Ours measured values could be compare with other energetic crops and no significant difference will be found. For the production phytomass is the most import the quantity of harvesting material and its water content. And during the burn off process is water content the most limits factor. Higher ration in phytomass mean lower heating value (Fuksa, 2007).

Table 14 – Heating value for each group

vegetative age	BE_1	BE_2	BE_3	BE_4	BE_5	BE_6	BE_7	average BE
Years	(KJ/g)	(KJ/g)	(KJ/g)	(KJ/g)	(KJ/g)	(KJ/g)	(KJ/g)	(KJ/g)
1,5	17,582	18,344	18,428	18,115	–	–	–	**18,117**
9	17,814	18,843	18,233	18,631	18,3	17,789	17,668	**18,183**
12	18,211	17,59	17,961	–	–	–	–	**17,921**

The average from all gathered samples is 18 KJ/g which can be compared with other crops used for energy. In the following table could be compared our phytomass with convention fuels. There is evidently seen that phytomass could be competitive fuels among wood and fossil coals. The heating value (BE) of wood and brown coals is lower then phytomass from Mitra other fossil fuels have higher potencial of heating value but phytomass - its processing and utilization will bring job and some profit to farmers.

Table 15 – Heatin value of our phytomass in compare with competitive fuels (Jiricek-Rabl, 2005)

type of fuel	kJ/g
phytomass (Mitra 2007)	18,8
wood (25% H_2O)	13
brown coal	12-15
black coal	25
Antracit	30
oil	42,9
gas	36

4.3 Examles from the Mitra's data

The results from the table (Table 16) compare amount of yield phytomass through the vegetative ages and convert its values to various fuels. For simplification will discussed only middle column. Could be significant that the mostly quantity of phytomass is in the middle column. The total area (245 thousand ha) could produce 102,4 PJ it is present almost 8 mil tone of wood or almost 3,5 million tones of black coal (antracit).

Table 16 - Phytomass to conversion to another alternative fuels

Vegetative age	value/year	1,5	9	12
Average yield	t/ha	8,84	23,00	18,00
Total amount per 245 000 ha	t	2 165 800,00	5 635 000,00	4 410 000,00
Brute energy	GJ/t	18,12	18,18	17,92
Yield	GJ/ha	160,15	418,21	322,58
Total potencial energy from area	GJ	39 237 798,60	102 461 205,00	79 031 610,00
Total area	PJ	39,20	102,40	79,00
Equivalent to wood in	t	30 182 292,20	7 881 631,15	6 079 354,62
Oil	t	934 233,30	2 439 552,50	1 881 705,00
Antracit	t	1 307 926,62	3 415 373,50	2 634 387,00

The previous table (Table 16) shows the importance of using phytomass and its relevant value regarding to fossil fuels. In the case of montado is the most important aspect of costs and sustainable development. The current research shows and my thesis could also confirm the fact that this ecosystem (like every ecosystem) is develop in periods. In the natural condition in montado the breake point is presented like bushfire. After that everything could start to develop again. We have to verify thousand times this thesis before will using natural ecosystem for the human benefits and prevent from the worst demage that was presented in Portugal's montado during bushfires in the year 2003.

5 CONCLUSION

Our work tries to show the possibilities of using natural region in montado for energetic use. That is why our aim was to model a situation based on figures measured in Portugal. Basically it was found out that ecosystem generates significant amount of biomass, which is important to keep under control. We have discovered the time periods after which are most suitable for harvesting from economic and sustainable develop points of view.

The advantage of measured phytomass was high ratio of dry matter when it was gathered that means the cost of transport, drying and storage was very low. Based on this fact it is possible to transform into any kind of phytofuel.

Energetic value of measured biomass is on the same level as traditional energetic crop that means it offers high potential for next technical use. We suggest joining care of oaks with harvest of phytomass with following energetic use.

According the phytomass' structure and changing the moisture content during season is necessary to optimize harvest timing. As a result from measured figures the best time for collecting phytomass is between 7 and 9 years since the foundation and than repeat pruning every 7-9 year based on local conditions and accessible mechanization.

Collecting phytomass in the cycles is the best way to protect environment against bushfires, simultaneously keep the invasive phytomass undercontrol moreover Cork oaks have better conditions for recruitment.

We suggest this outlet phytomass using as an alternative source of energy (eg. for producing pellets). This possibility of using weed phytomass in an alternative way should motivate local farmers to better environmental approach to the montado area as well as to preserve natural character of local landscape. Simultaneously it can also bring financial help for the farmers and other people involved in this project.

Further we determinate total energy of gathered phytomass and compare it with competition products.

LITERATURE

Books

[1]Afonso do O, Roxo, M. J., (2001), *Driving forces of land use changes in Alentejo and its impact on soil and water*, Lisboa

[2]Acacio, V., Holmgren, M., Jansen, P. A., Schrotter, O., (2007), *Multiple recruitment limitation cause arrested succession in Mediterranean Cork oak systém*, Lisboa

[3]Aipanjiguly, S., (2004), *Forest fires in the Mediterranean*, WWF Mediterranean Programme Office

[4] Bartolelli, V., Alfani, F., Baldeli, C., Pignatelli, V., Polito, P., (2006), *Environmental and economic performance of biofuels*, Roma

[5]Beenackers, A.C.M, Grassi G., *Pergamon Press*, (1995) 52-62

[6]Biewinga, E.E., Bijl, G., (1996), *Sustainability of energy crops in Europe. A methodology developed and applied*. Centre for Agriculture and Environment, Utrecht, CLM 234 -1996

[7]Canger, S., Erikson, G., Kleinschmit, J., Turok, J., (1996)*, Noble Hardwoods Network. Report of the first meeting,* 24-27 de marzo de 1996. Escherode, Alemania y Roma, IPGRI

[8]Cannon,Ch. H., Manos, P.S., Zhou, Zhe-Kun, (2004), *Systematics of fagaceae: Phylogenetic test sof reproductive trait evolution*, Department of Biology, Duke University, Durham, North Carolina 27708, U.S.A.

[9]Christien, A., Vogt, R., (2001), *Direkt measurement of dispersive fluxes within a cork oak plantation,* Basel, Switzerland

[10] Claire-Poole, J., (2005), *Mediterranea area with buschfires impact,* Lisboa

[11] Costa, A., Pereira, H., Oliveira, A., (2007), *Variability of radial growth in cork oak adult trees under cork production*, Instituto Superior de Agronomia, Lisboa

[12] Delattre, E., (1993). *Évaluation des actions communautaires: vers une coopération internationale. Incendies de forêts en Europe du Sud.* 271 pp

[13] Deslandes, L., (2007), *History of using Cork oaks (Quercus suber L.) from the view of its improvement, harvesting and rotations cycles,* Technical support 800.345.6202, Lisboa, Portugal

[14] El-Bassam, N., (1998), *Energy Plant Species, Their use and impact on Environment and Development*, James & James, London

[15] Fernando, A.L., Oliveira, J. F. S., (2006), *Some aspects of Environmental Impact Assessment of Miscanthus x giganteus*, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, Portugal

[16] Fuller, H.J., (1961), *The plant world,* 3rd ed. New York, Holt, Rinehart & Winston

[17] Gil, L., (1998), *Cortiça, Produção, Tecnologia e Aplicação*. INETI (Instituto Nacional de Engenharia e Tecnologia Industrial), Lisboa, 384 pp.

[18] Gilbert, A., (1978), *Le Portugal méditerranéen à la fin de l'ancien régime.* Lisbon, Inst. Nacional de Investigaçâo Cientifica

[19] Goldammer, J.G., (1994), *Les incendies de forêt dans le sud de l'Europe. Survol des mesures prises par la CEE: Cooperation internationale en vue. Nouvelles internationales sur les incendies de forêts,* 11 (July)

[20] Gosse G., *Environmental Issues and Biomass, Biomass for Energy, Environment, Agriculture and Industry*, Proceedings of the 8th European Conference, Vol.1

[21] Hansen, M.C., Varela, J. Turok, (1997) Quercus suber *Network. Report of the third and fourth meetings,* 9-12 June 1996. Sassari, Sardinia, Italy, and 20-22 February 1997, Almoraima, Spain. Rome, IPGRI

[22] Henius, S. Hultberg, Sachau, J., Wiinbald, M., *Pergamon Press*, (1996), *Performance of C4 plant species as energy sources and their possible impact on environment and climate*. In Proceedings of the 9th European Conference on Biomass for Energy and the Environment

[23] Hulme, M., Sheard, S., (1999) *Climate Change Scenarios for the Iberian Peninsula*, Climatic Research Unit, Norwich, UK, 6pp

[24] Hutla, P., Strašil, Z., (2004), *Chrastice rákosovitá – pěstování a možnosti využití*, Biom 2008

[25] Chartier ,Ed. P, Beenackers, A.A.C.M., Grassi, G., *Pergamon Press*, (1995), 52 - 62.

[26] Janásek, F., (2005), *Dried matter determination and methodology*

[27] Jiricek, I., Rabl, V., (2005), *AZE, Energie z biomasy*, Prague

[28] Kaltschmitt M., Reinhardt G.A., Stelzer T., *LCA of biofuels under different environmental aspects. Biomass for Energy and the Environment*, Proceedings of the 9th Europien Bioenergy Conference, Vol.1, Ed. P. Chartier, G.L. Ferrero, U.M.

[29] Lopez, A. A., Gomez, A., Pintos, B., Martin, J. P., Aquinagalde, I., Bueno, M. A., (2005), *Characterization of cork oak (Quarks suber L.) genetic resources for tree improvement,* Madrid

[30] Moreira, F., Duarte, I., Catry, F., Acacio, V., (2007), *Cork extraction as a key factor determining post-fire cork oak survival in a mountain region of southern Portugal*, Lisboa

[31] Munoz Jans, J.O., Havrland, B., Krepl, V., (2004), *The Implementation of Renewable Energy Resources for Greenhouse Mitigation in Developing Countries: The Case of Biomass*, University of Agriculture Prague, Institute of Engineering, Economics and Rural Development in the Tropics and Subtropics, Czech Republic

[32] Nativadade, J., (1950), *Subericultura.* Lisbon, DGSF

[33] Neseper, J., Dias, S.G., Pons, J., Pausa, J.G., Ribeiro, E., (2006), *Regeneration of a marginal Quercus suber forest in the eastern Iberian Peninsula,* 1CEAM Fundación Centro de Estudios Ambientales del Mediterráneo, C/ Charles R. Darwin 14, Parc Tecnológic

[34] Oliveira, A., Pereira, H., Costa, A., (2002), *Variability of radial growth cork oak adult trees under cork production*, Lisboa, Portugal

[35] Paulo, Maria Jo~ao, (2002), *Statistical sampling and modeling for Cork oak and Eucalyptus standing,* Lisboa

[36] Pausas, Juli G., (1997), *Resprouting of Quercus suber in NE Spain after fire*, Sweden

[37] Pereira, C., Caldeira, F. J., Ferreira, J. M., Irle, M. I., (2006), *Characterization the setting of maritime pine, growth in Portugal, temperature profiles and compatability indices*, The Japan wood society

[38] Petříková, V., (2008), *Renewable resources, chance and challenge,* Prague

[39] Pinto-Correia, T., Mascaranthus, J., (1999), *Contribution to the extensification/intensification debate: new trends in the Portuguese mont*ado, Evora

[40] Quer, P. Font, (1997), *Dicionário de Botânica,* 6th ed. Barcelona, Spain, Ed. Labor.

[41] Ribeiro, F., Tomé, M., (2002), *Cork weight prediction at tree level. Forest Ecology and Management*, 171 (3): 231-241

[42] Robbins, W., Weier, T. & Stocking, C., (1958), *Botany, an introduction to plant science.* New York, John Wiley

[43] Roxo, M.J., (2001), *Driving forces o fland use changes in Alentejo and its impact on soil and water*

[44] Ryan, D., Mann, R., Thompson, D.H., (2007), *Fighting forest fires with cork in Portugal*

[45] Santo, F.T., (2005), *Human cupital, labour dynamics and regional development*, Faculty of Science and Technology – University Nova of Lisbon

[46] Seigue, A., (1985), *La forêt circumméditerranéenne et ses problems.* Paris, GP Maisonneuve & Larose

[47] Seth, M.K., (2004), *Cork oak (Quarks suber L.) and its economic importance in alentejo region, Evora*

[48] Schonenberger, J., Petersen, K.R., (2001), *Normapolles flowers of fagalean affinity from the Late Cretaceous of Portugal*, Plant Syst Evol 226:205–230

[49] Strašil, Z., Hutla, P., (2004), *Growing and possibilities of energy and other utilization of reed canary grass*, Prague

[50] Surový, P., Ribeiro, N. A., Oliveira, A. C., Scheer, L., (2007), *Discrimination of vegetation from the background in high resolution colour remote sensed imagery*, Journal of forest science, 50, 2004 (4): 161–170

[51] Talbot, N., (2006), Diffences between sedges and grasses, ??

[52] Tanaka, T., (1976), *Tanaka's Cyclopaedia of Edible Plants of the World.* Keigaku Publishing

[53] Tenhunen, J., Zeyer, R., Banza, J., Carreiras C.Besson, Dinh, N. Q., Herd, A., Mirzae, H., Otieno, D., Owen, K., Pereira, J.S., Reichstein, M., Ribeiro, N., Schmidt, M., Wenigmann M., Xiao, X., (2007), *Assessing Ecology, Vulnerability and Ecosystem Services of Mediterranean Oak Woodlands*, New Hampshire, Durham, NH 03833 USA

[54] Thomson, D.H., (1971), *Forest preserve district of Cork country,* London?

[55] Trigo, R. M., Palutikof, J.P., (2004), *Simulation of daily temperatures for climate change scenarios over Portugal:* a neural network model approach, Climatic Research Unit, University of East Anglia, Norwich, NR4 7TJ, United Kingdom

[56] Turok, J., Varela, M.C., Hansen, C., (1997), *Quercus suber Network. Report of the third and fourth meetings,* 9-12 de junio de 1996. Sassari, Cerdeña, Italia, y 20-22 de febrero de 1997, Almoraima, España. Roma, IPGRI.

[57] Váňa, J., (2002), *Phytomass energy from the plants sources*

[58] Varela, M.C., (2001), *Cork and the cork oak systém*, *An evaluation of the role and potential of cork oak* (Quercus suber) *and its products in the Mediterranean region, including consideration of a proposal to develop an identifiable imprint for products made from cork.,* Oeiras, Portugal

Internet links

[59] www.fao.org

[60] http://en.wikipedia.org/wiki/History_of_Cork, 2008

[61] http://www.cork.pt

[62] http://www.panda.org/climate/

[63] http://cdm.unfccc.int/EB/020/eb20repan08.pdf

[64] http://www.kurzy.cz/kurzymen/kurzy.asp?A=H&KM=EUR&D1=27.4.2004&D2=27.6.2004&I=10

[65] http://www.panda.org/climate/

[66] The Climate Impacts LINK Project: http://www.cru.uea.ac.uk/link/

[67] The IPCC Data Distribution Centre (DDC): http://ipcc-ddc.cru.uea.ac.uk/

[68] Portugal and the Kyoto Protocol: http://gasa3.dcea.fct.unl.pt/gee/index.htm

[69] http://cdm.unfccc.int/EB/020/eb20repan08.pdf

[70] Expanko, (2005): http://www.metaefficient.com/flooring/expanko-regenerative-flooring.html

[71] http://unfccc.int/2860.php

[72] http://earthtrends.wri.org/pdf_library/country_profiles/ene_cou_620.pdf

Consultation

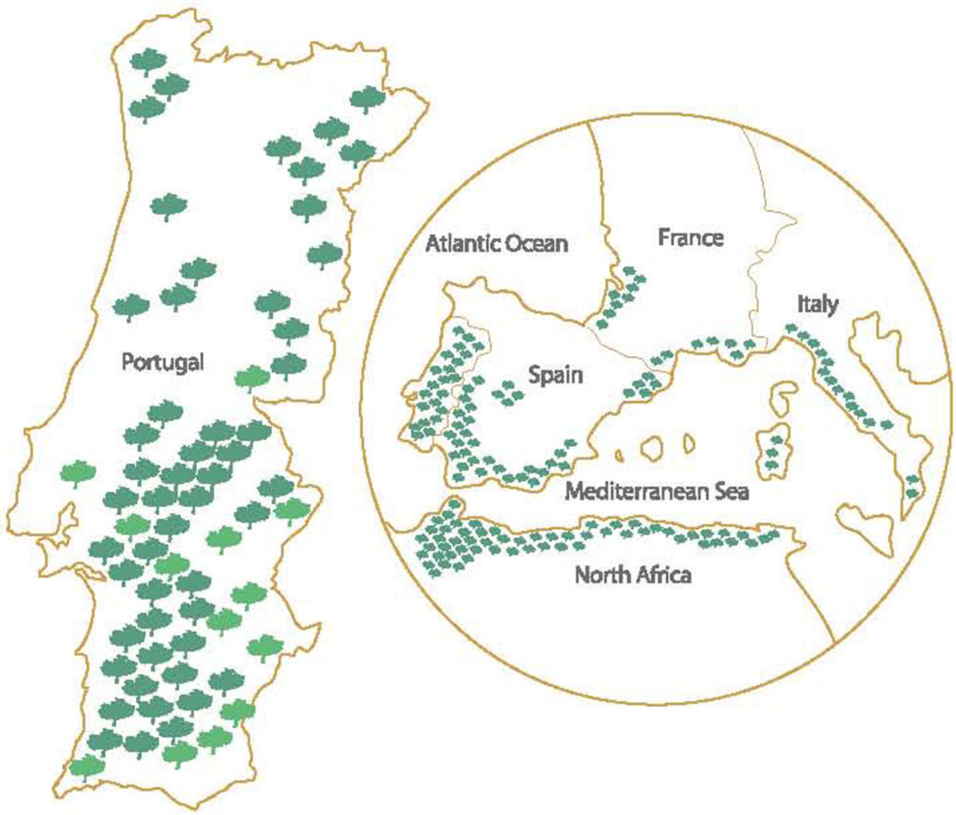
Fuksa, P., (2007), CULS

Surový, P., (2007), University of Evora

Banout, J., (2007-2008), CULS

A APPENDIX

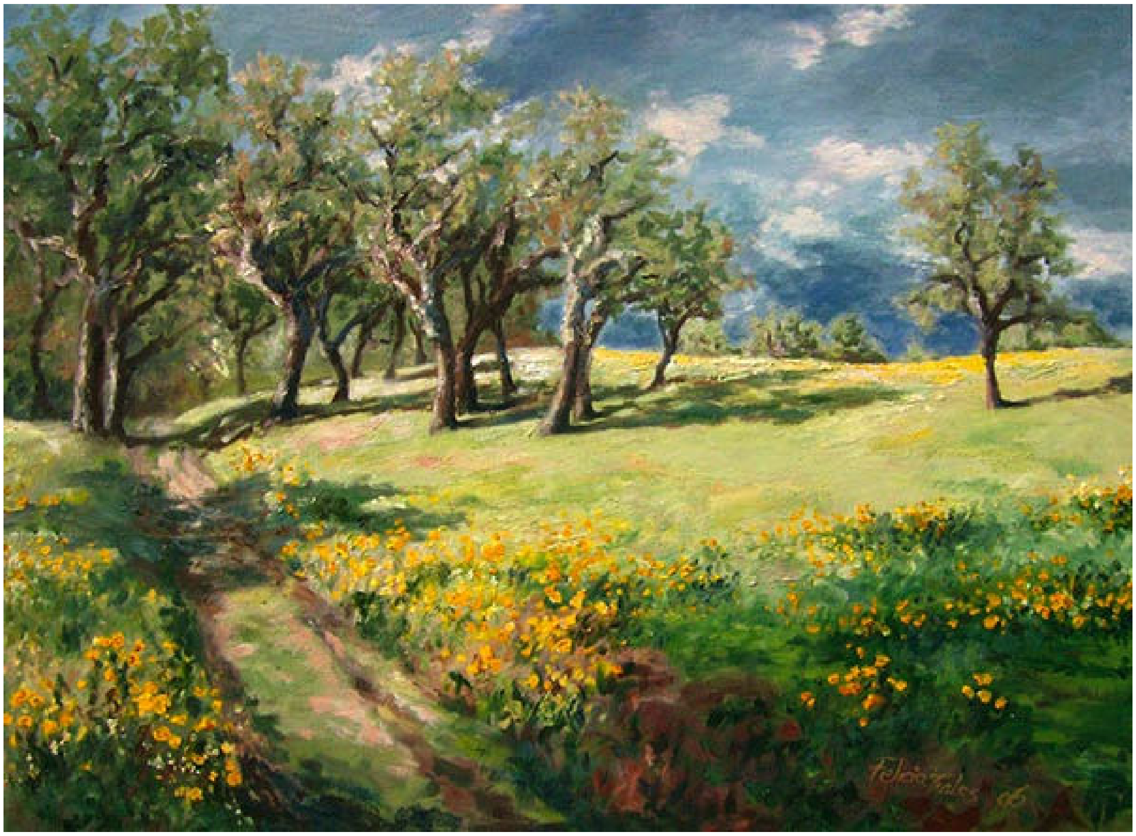
A.1 Maps



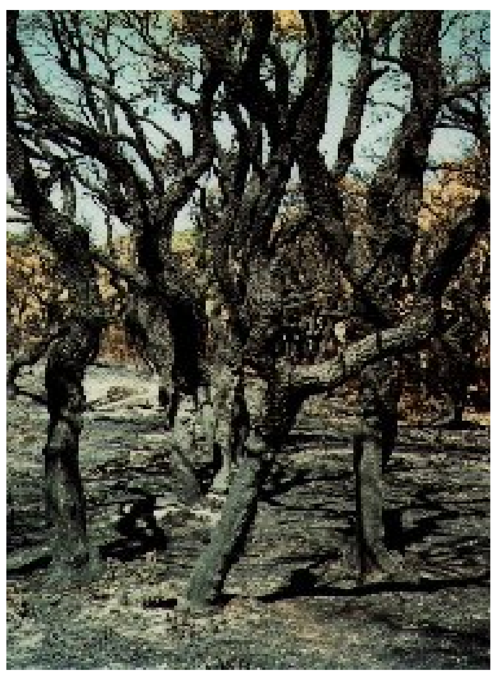
Appendix 1 - The widespread of montado in Portugal, www.realcork.org/artigo.php?art=32

A.2 Ecosystem montado

Appendix 2 – Ration of herbs ond trees, filsergiosimoes.com/index.php?cPath=216, 27.4.08



Appendix 3 – Cork oaks after harvest, filsergiosimoes.com/index.php?cPath=216, 27.4.08



Appendix 4 - Buschfires in motado, filsergiosimoes.com/index.php?cPath=216, 27.4.08

A.3 Cork harvesting

Appendix 5 - Cork harvesting, www.fao.org/docrep/x1880s/x1880s08.htm, 27.4.08

Appendix 6 – Stock of cork, www.fao.org/docrep/x1880s/x1880s08.htm, 27.4.08

A.4 Bushfires in Portugal 2003

Appendix 7 - Bushfires in Portugal, www.traveljournals.net/pictures/135186.html, 27.4.08

Appendix 8 - Bushfires in Portugal, (www.greenpeace.org/international/photosvideos, 27.4.08)

Appendix 9 - Bushfires in Portugal, www.traveljournals.net/pictures/135186.html, 27.4.08

Appendix 10 - Bushfires in Portugal, www.thewe.cc/weplanet/poles/antarcti/ozone.html, 27.4.08

A.5 Energy crops

Appendix 11 - Sunflower, www.ratemyscreensaver.com/nature/sunflowers/, 27.4.08

Appendix 12 - *Papaver somniferum* L., www.narcotics.gov.bn/research_heroin.htm, 27.4.08

Appendix 13 - Fueles from renewable resources,
www.dailyiowan.com/news/2007/02/06/Photos/Tod, 27.4.08

Appendix 14 - Phytomass for energy, www.enviweb.cz/?env=_slovnik___p

A.6 Herbs and shrubs in montado

Appendix 15 – Plantation of *Cistu sp., www.mtsn.tn.it/russulales news/in_ecology.asp*

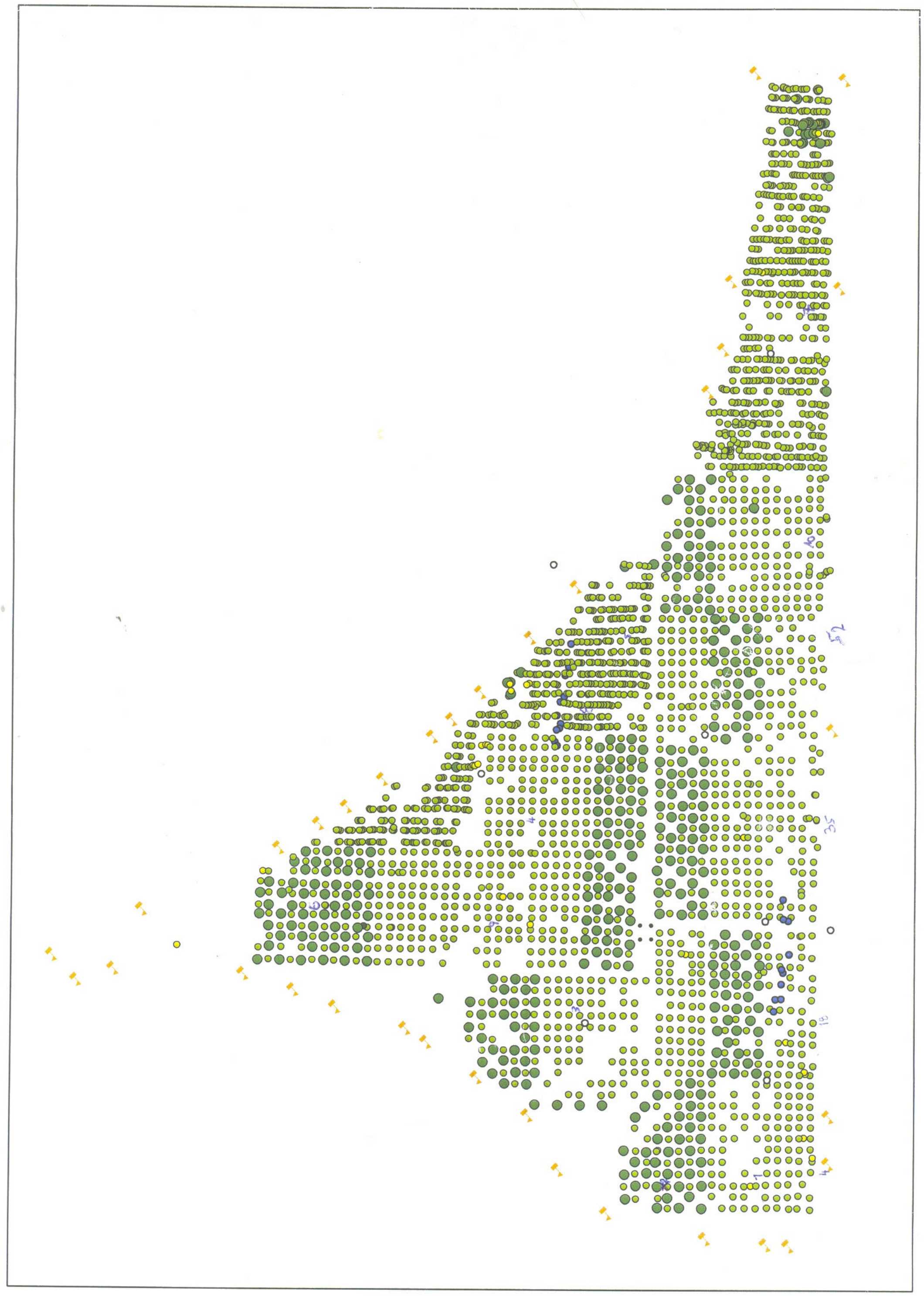
Appendix 16 - *Cistus crispus* L. , www.isa.utl.pt/wateruse/PT_field_sites.html, 27.4.08

Appendix 17 - *Briza sp.,* (www.isa.utl.pt/wateruse/PT_field_sites.html, 27.4.08

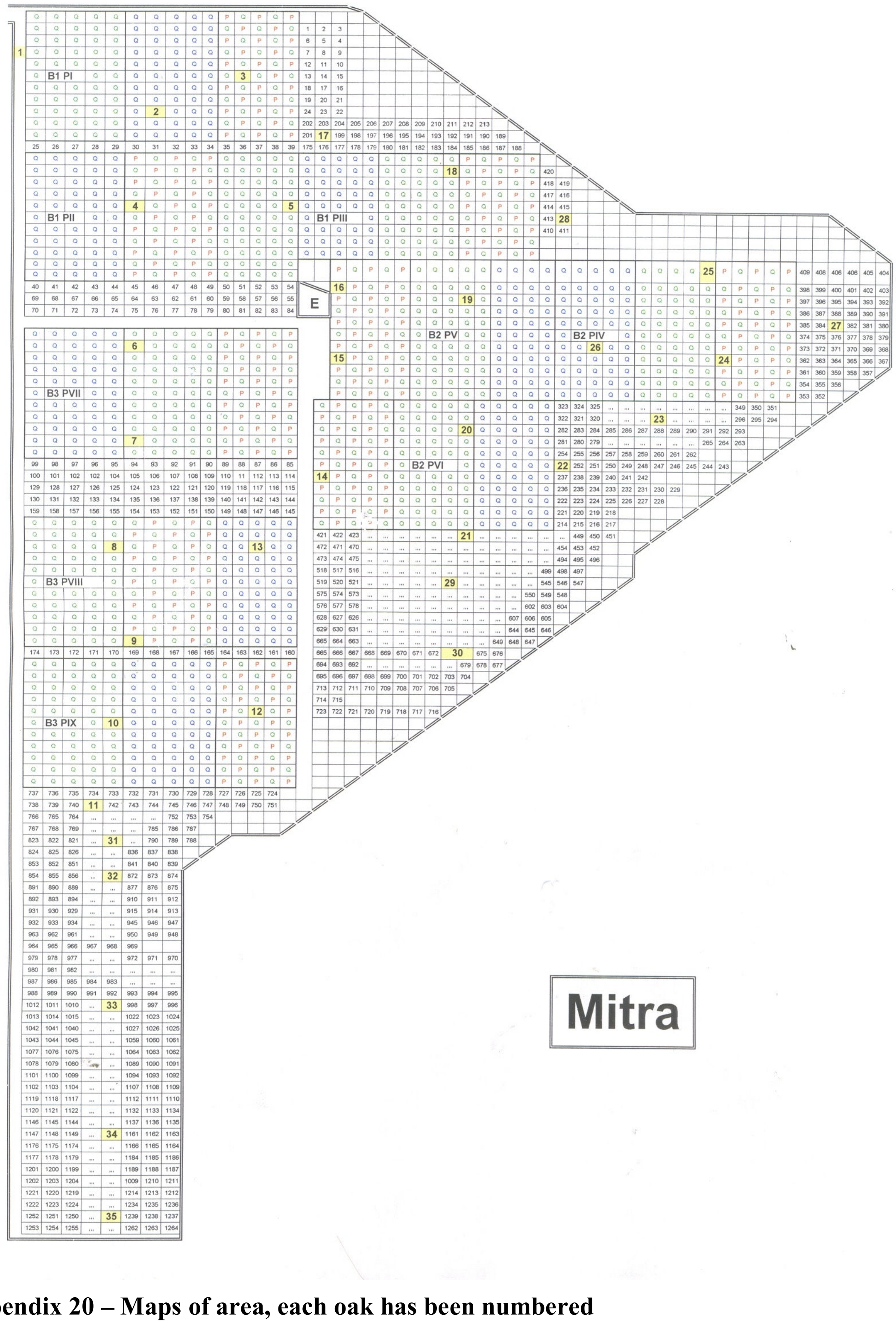
A.7 Pellets

Appendix 18 - Pellets from biomass, home.new.rr.com/pelleduster/, 27.4.08

A.8 Maps for orientation in the area



Appendix 19 – Orientation map; light green-oaks, dark green-pinus



Appendix 20 – Maps of area, each oak has been numbered

Appendix 21 - Gathering phytomass in Mitra, (May 2008)

Appendix 22 - Crush phytomass

Appendix 23 - Laboratory shredder

Appendix 24 - Crushed phytomass