Evaluation of hemp potential as a raw material in Portugal

Pedro António Albino Zilhão

pedro.zilhao@tencico.ulisboa.pt

Instituto Superior Técnico, Universidade de Lisboa

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Abstract

This thesis studies Cannabis Sativa L (hemp) plant and its applications in order to assess the viability of hemp as a sustainable raw material. Some considerations regarding hemp biorefining in Portugal (where a heavy pulp and paper industry based in eucalyptus globulus plantations exists) are also made.

Based on the technological review and case study analyzed, its environmental impacts are similar to those of other fibers crops. However, when directly compared to eucalyptus globulus it has higher noxious emissions (N_2O NH_3 NO_x NO_3, CO_2) due to the use of fertilizers and farm equipment. Other environmental impacts such carbon uptake, impact on biodiversity, fire hazards and soil erosion were not considered. In economic terms, hemp seems to be a very profitable plant (single crop- 99.05€/hectare.year; dual crop- 648.16€/hectare.year), especially if it used as a dual crop (harvest of straw and seeds)

Applying the analysis to the Portuguese reality, where eucalyptus globulus represents around ¼ (777 800 hectares) of the planted forest stands, hemp can be a good substitute for part of these stands. In particular, for the abandoned ones, that represent the major fire risks and bring no economic return. At the same time, hemp can be used for paper production, so such a replacement doesn't necessarily mean a negative impact in the supply of pulp and paper industry.

Finally, due to the lack of data, final conclusions about establishing a biorefinery in Portugal, could not be achieved. However, a frame for a case study regarding the impacts of an integrated hemp production and biorefinery was laid out and discussed. Hopefully a proper assessment of this matter will be done in the future.

Key words – *hemp, sustainability, Portugal, eucalyptus globulus, cannabis sativa L*

Introduction

Currently, society deals with a lot of problems. One of them is the sustainability of our actions. From industry to little personal actions, the whole world needs to join efforts to prevent reaching a point of no return in environmental and social issues. *Bergh 2003* concludes that the general growth of the world's society (welfare, economics, technological, etc…) cannot be developed by "simply incorporating new elements in existing practices but requires a completely different set of assumptions". One major class of raw materials is biomass "…renewable organic material that comes from plants and animals" Woody materials (coming from trees in forests and manmade forest stands) represent a heavy share of biomass consumption around the globe. Alternatives must be found to avoid putting more stress on the source of those resources (trees).

In this thesis, hemp (cannabis sativa L) is presented as an alternative raw material. At the same time, the hypothesis of establishing a hemp biorefinery in Portugal is considered and analysed. So, the thesis two main goals are:

- Assessing the viability of hemp as a sustainable raw material
- Making some considerations regarding establishing a hemp biorefinery in Portugal

Literature review

Cannabis Sativa L

From the different constituents of the hemp plant, thousands of different applications can be used (fig.1).

The stalk is made of fibers (one of the strongest in natural world) and hurds (with interesting isolation properties). Applications acrross industries form bio-composites, to paper, to construction or issolation are just some of the possibilities.

Seeds are rich in lipids, fibers, carbonhydrates and proteins. Applications spread scross several sctors from food sulpement, animal feed, medicine/cosmetic, industrial (vernishes and oils) and even biofuels.

The flower is very rich in phytocannabinoids, chemicals with strong medical application, perfect to convert in essential oils for posterior applications.

Leaves, stems and roots are several times reagarded as wastes, but interest in valorize this resources is incresing and many studies with new ways of add value

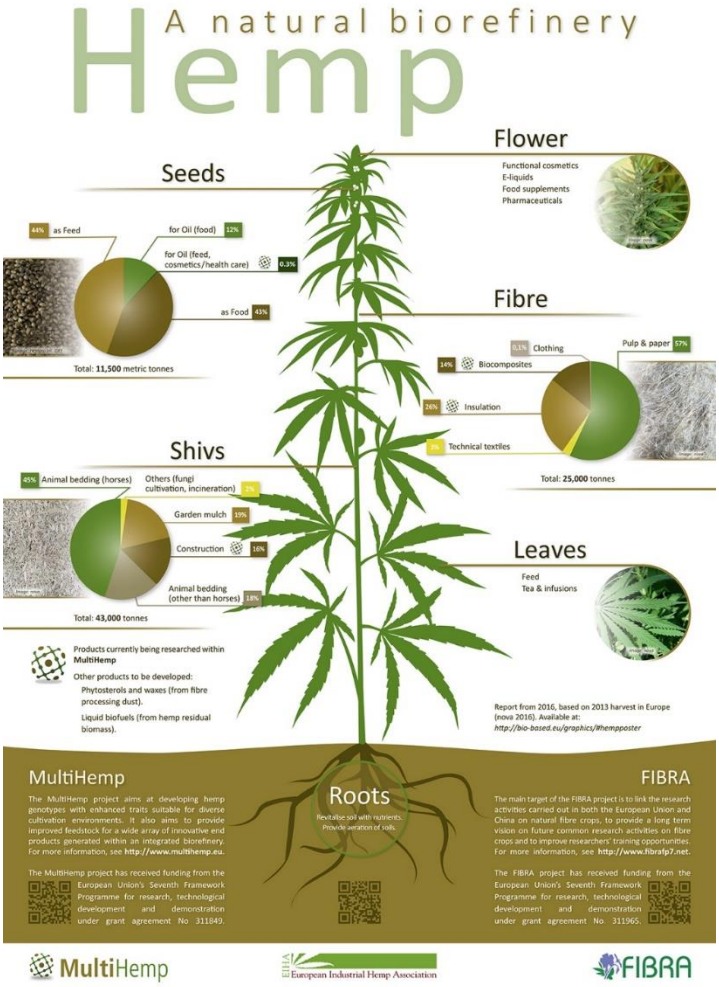

Table 1 Figure Schematic of hemp different constituents and their applications [12]

to them for posterior applications are more and more common.

Regarding the plantations, they can very a lot (seed density, indoor/outdoor, complete growth cycle, females or males), depending of the final goal (seeds, fibers, flowers). In terms of soil is a plant with a high adaptability, but loamy soils are the preferred ones. In soil preparation is like other spring crops, however, doesn't need pesticides/herbicides application during the growing season. It prefers moderate to cold climates, despite having a good adaptation, and water needs (500-700mm/year) are considered low for an annual crop.

Unfortunately, hemp industry is very small and undeveloped in Portugal (estimations of only 14.2 hectares planted between 2015-2018), mainly due to its association with marijuana. Nevertheless, in the last years, as is occurring around the globe, the interest in this plant is growing and several changes are being made in a legislative level to facilitate the integration of this crop.

Eucalyptus Globulus

Eucalyptus is the second most common tree type used in plantations around the world due to its high adaptability, fast growth, and high economic value. Plantations cover over 1.5 million ha in the Iberian Peninsula alone, having replaced native mixed forests over large areas. Generally, for industrial pulpwood plantations, a rotation system between 8-14years old is used. Also, due to the characteristics of the tree itself, three cutting cycles can be done without stump removal.

E. globulus, was first planted in Portugal in the 19th century for timber production. Nowadays (2020), represents around 777.8 thousand hectares of the national territory (roughly 25% of the forest stands in Portugal). only 145.8 thousand hectares (18.7%) were managed by companies of the forest industry, complying with strict environmental parameters.

Eucalyptus globulus, as all short rotation wood crops has intense use of ground resources. Grows well on a wide range of soils, but requires good drainage, low salinity, and a minimum soil depth of 60cm. Productivity is highly influence by the management of the stands. Regarding biodiversity, is almost unanimous the negative impact on the natural species.

Both crops can be used for production of paper, however the papers obtained will have different final characteristics, as seen in figure 12, due to the different chemical composition of the raw materials (table 3).

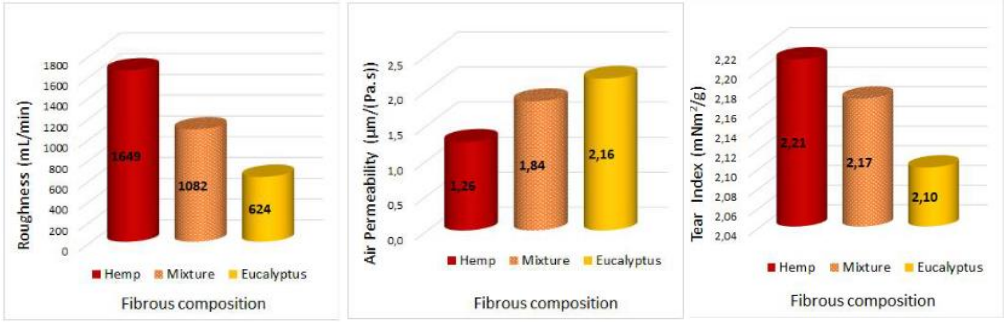

Figure 2 Physical properties (Tear index, roughness, air permeability) of: 100% hemp paper, 50/50 hemp and eucalyptus paper and 100% eucalyptus paper). [13]

	Cellulose	Total Lignin	Extractives
Eucalyptus globulus wood	40.6-51.3	21.9-28.48	1.3-6.0
Hemp fibers	55.66	8.89	1.55
Hemp whole steam	53.25	21.8	2

Table 1 Comparison between chemical compositions of hemp fibers and eucalyptus wood. Based on [13,14]

Hemp Biorefinery

“Biorefinery” is a concept based on the definition of a regular oil refinery, but applied to the refining of biomass, instead of oil, into multiple products. These products can be in various forms, such as chemicals, energy, fuels, fibers, oils and others. As stated in *Paone E, 2020* “lignocellulosic biomass, ranging from softwood to agriculture and forestry wastes, represents the most abundant resource for modern biorefinery”, biomass can be the future of biorefinery.

A Hemp biorefinery is something that already has been theorized but is yet to happened. Several studies have been done, where critical evidence shows how hemp regular crops (seeds and fibers) can be done, while maximizing profits and sustainability with the valorization of residues. (hemp hurds, stems, leaves, flowers and roots). [1–5]

Methodology

The inputs taken into account were hours of labor, diesel, fertilizers, equipment and seeds. The outputs were tons of dried material and emissions to the environment, as it can be seen in figure 3

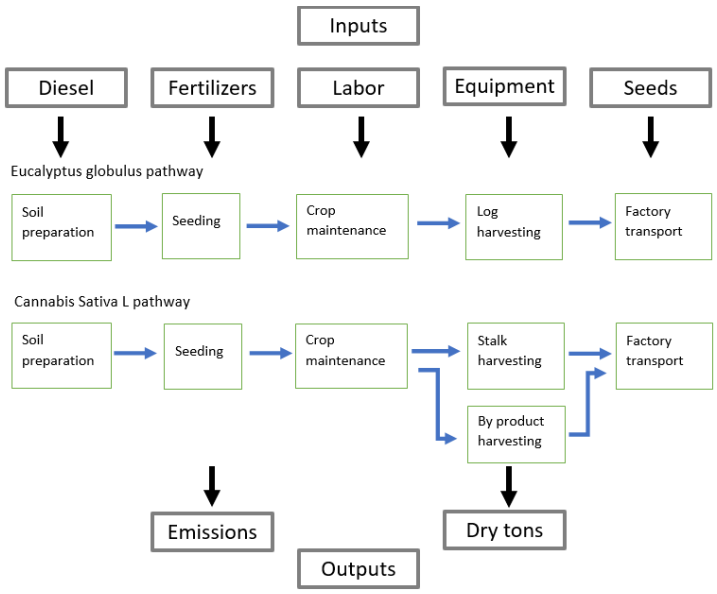

Figure 1 Inputs and outputs taken in consideration in the LCA

In the hemp case study, the two scenarios chosen were: 1- harvest of the stalk; 2- harvest of the stalk and seeds. Other possibilities like the harvesting of leaves or inflorescence can also occur, but due to the lack

In the hemp case studies, the inputs: cost of equipment and hours of labor: transport information (table 2), fertilizers requirements (table 3), are directly taken from the MultiHemp project, [2]. Due to considerable differences between the cost of labor/diesel and fertilizers in Portugal vs the Multihemp project, those value were taken from other references, originating table 4 The cost/h of labor was taken from [6] and fertilizers/pesticide cost was taken from [7,8]. The cost of diesel, due to the current war economy, is assumed as a high value of 2euros/liter.

For the eucalyptus case study, information was gathered totally from the literature. The economic assessment is from *Gabinete de planeamento, 2018* [9], and the environmental data are taken from *Dias, 2012* [10]..

	Unit	Value
Travel distance	km	30
Average speed	Km/h	50
Average time to load/unload	h	0.5
Truck consumption	L/km	6
Truck capacity	ton	9

Table 2 Transport information for the hemp case study

Pesticide and Fertilizers	Amount (kg/hectare)
Gylsophate	3
K_2O	130
Urea (N)	60
P_2O_5	40

Table 3 Pesticides and fertilizers requirements per hectare for hemp plantations

	Unit	Value
Labor cost	€/h	5
Fertilizers		
P_2O_5	€/Kg	1.52
Urea (N)	€/Kg	1.29
K_2O	€/Kg	0.82
Gylsophate	€/Kg	19.08
Diesel	€/l	2

Table 4 Inventory of the extra data used and applied to the hemp case study

In table 5, the selling cost of raw material is shown. The information regarding hemp came from the MultiHemp project [2], while the price of the eucalyptus wood is from *Gabinete de planeamento, 2018.* [9]. In table 6, the conversion factors used are shown. CO_2 emissions per liter of diesel consumed was taken from [11], while the density of eucalyptus wood is from *Gabinete de planeamento, 2018* [9].

Raw material	Unit	Selling price
Eucalyptus wood	€/ton	47
Hemp stalk	€/ton	130
Hemp seeds	€/ton	800

Table 5 Selling price of the materials harvest

	Conversion factor	Value
CO_2 emissions from diesel consumption	Kg/l	2.68
Density of eucalyptus wood	Kg/m^3	850

Table 2 Conversion factors used

Case Studies

Eucalyptus globulus crop impact: Alcochete case study

Here an analysis of the eucalyptus crop is done, with the goal of understanding what are the environmental and economic impacts of such crop.

First, there is the need of soil preparation with plowing and fertilizer application, to make a good bed for the young plants that are sowed. When the site already has trees (forest or previous crops), the action of stump removal is also necessary, in order to have space for the new trees.

During the growing phase, around the 6th year, there is the need of clearing the forest floor. This, to prevent fire by cleaning debris, but also to control infestations and competitor plants. From there, a close canopy is formed, making hard for the new growth of plants since the floor is totally in the shade. Regarding the rests of leaves and bark that fall, a balance must be obtain between self-feeding, generating the missing nutrients to complete the eucalyptus cycle, and the accumulation of debris that represent fire hazard.

On the 12th year happens the first cut, but there is no removal of the stumps since this tree has the ability of sprouting from the stump after being cut. Non the less, this is the most expensive part, since it evolves heavy machinery to cut down the trees, turning them into movable logs and respective transportation. After the cycle is repeated, with the exclusion of the soil preparation and sowing, non the less new doses of fertilizers are added.

Cannabis Sativa L crop impact: Multihemp case study adapted

Using a major European project called as source Multihemp, here the environmental and economic assessment of the hemp crop is done. At the same time, in order to approximate the results to the Portuguese reality, some values (presented in the methodology) are from other sources Two scenarios are analyzed:

Scenario 1 – The harvest of the stalk of the plant, where the main goal are the fibers and hurds.
Scenario 2 – The harvest of the stalk and the seeds, where the main goal are the fibers, hurds and seeds.

In hemp crops, as in all annual crops, soil preparation is needed. The use of glyphosate is common to kill any weeds that may prior exist. Before sowing, a tractor is used to plow the field. As said before, hemp does not need any pesticides/herbicides during its growth, but to further enhance the yield, fertilizers are used before sowing. Finally, the sowing occur. This all with the help of common farm tractors. [2]

4 Discussion of the Results

In this chapter a critical comparison between the results obtain in the previous chapter is made. At the same, considerations about the lack of data and/or hardness to evaluate certain aspects are also considered. Here are only presented the resume.

Economical assessment

As it can be seen in the figure 3, in terms of costs, hemp plantations always are more expensive, however, depending on the scenario, the profit can be bigger than eucalyptus plantations. Being the reason of the extra profit, the possibility of harvesting and selling two separate raw materials. An important note, in the eucalyptus scenario present in figure 3, the transportation cost is included in the harvest, and not bundled with soil preparation and sowing, as in the hemp case.

Regarding eucalyptus, fig 3. shows the appealing economical side of eucalyptus plantations, that with minimal investment of money and time, can bring profits. Unfortunately, data about a site with low to no care was not possible to find out. But, even so, it was possible to conclude that, most likely, most of these abandoned/minimal care eucalyptus plantations, probably doesn't achieve breakeven and are in a very big number!

Regarding hemp, variation of profit comes basically from the possibility to use hemp plantations as a multi-goal crop. The capability of harvesting more than 1 material (straw and seeds), with virtually no increase in the production costs (2.96% increase), leads to a big increase in the profit margin (650%).

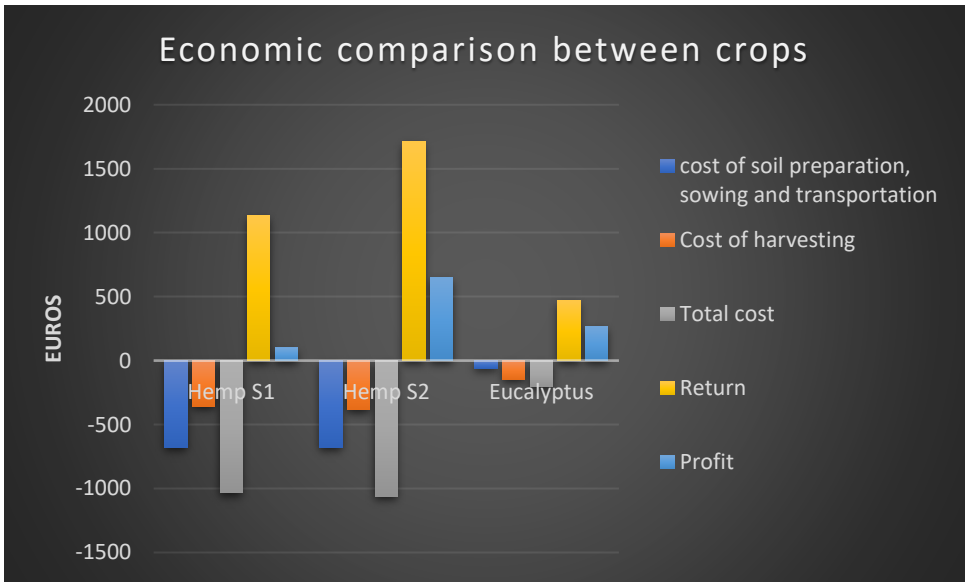

Figure 3 Economic comparison between crops.
Note: in the eucalyptus scenario the transportation cost is included in the harvest, and not bundled with soil preparation and sowing, as in the hemp case

To conclude, in an economical point of view, hemp as a dual crop is in fact more profitable than eucalyptus (244% more) and can contribute to extra added value (creation/fortification of jobs, increase value of the land itself) in the agricultural sector, and even fight rural exodus. At the same time, brings return faster than eucalyptus globulus plantations. However, this comes at a cost, not just a bigger investment, but also time (increased labor).

Environmental Assessment

Between the parameters evaluated in these case studies, it's easy to see, that hemp, when compared directly to eucalyptus, has a bigger impact on the environment, when regarding noxious emissions (fig.4). Regardless of the intensity scenario choose of eucalyptus plantations. Despite the hemp case study didn't considered emissions of CH4, SO2 and CO. Depending on the chosen gas emitted, up to 10 times more! (ex: N_2O and NO^{3-}). However, carbon uptake, usage of hemp as a break crop, stump removal of eucalyptus, biodiversity loss, soil erosion, fire risks and land saved were not taken into account.

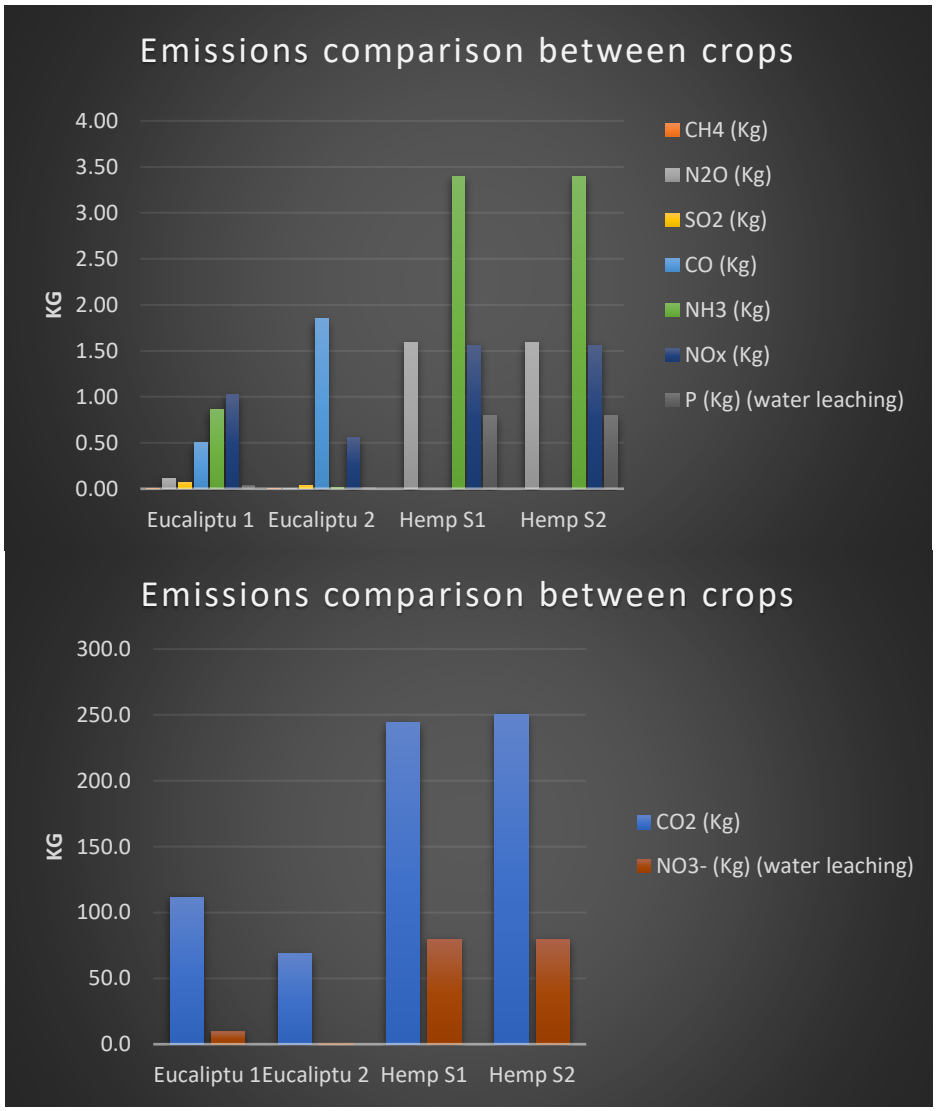

Figure 4 Emissions comparison between crops

So, in environmental terms, is hard to correctly compare the 2 crops, not just because of the available data, but due to the inheritance differences between the species and respective crops. A proper study, that would not just take into account the neglected situations here referred, but also with real case data from Portugal would be necessary to firmly conclude which crop has a bigger impact.

Conclusion

In environmental terms, is hard to correctly compare the 2 crops, not just because of the available data, but due to the inheritance differences between the species and respective crops. A proper study, that would not just take into account the neglected situations referred (carbon sequestration, use of hemp as a break crop, biodiversity loss, soil erosion, phytoremediation, and fire hazards), but also with real case data from Portugal would be necessary to firmly conclude which crop has a bigger impact.

In an economical point of view, hemp is in fact more profitable and can contribute to added value (creation/fortification of jobs, increase value of the land itself through phytoremediation) in the agricultural sector, and even fight rural exodus. At the same time, brings return faster than eucalyptus globulus plantations. However, this comes at a cost, not just a bigger investment, but also time (increased labor).

After all the data gathered and discussed, here is presented an "ideal" hemp project (plantation + biorefinery), using hemp as a dual crop. Where the factory and plantations would be all part of a major endeavor, maximizing the sustainability of the project and minimizing intermediate steps. In fig. 5, a sketch flow chart is present of the project, partly based on the "total fiber line" of the Multihemp project [2]. However, further transformation of the resources obtained (into composites, medicines, cosmetics, paper, hempcrete, isolation material, etc...) or different transformation paths for the initial raw materials (seeds and straw) should also be evaluated in a future work and should be chosen accordingly to the final goal of such work.

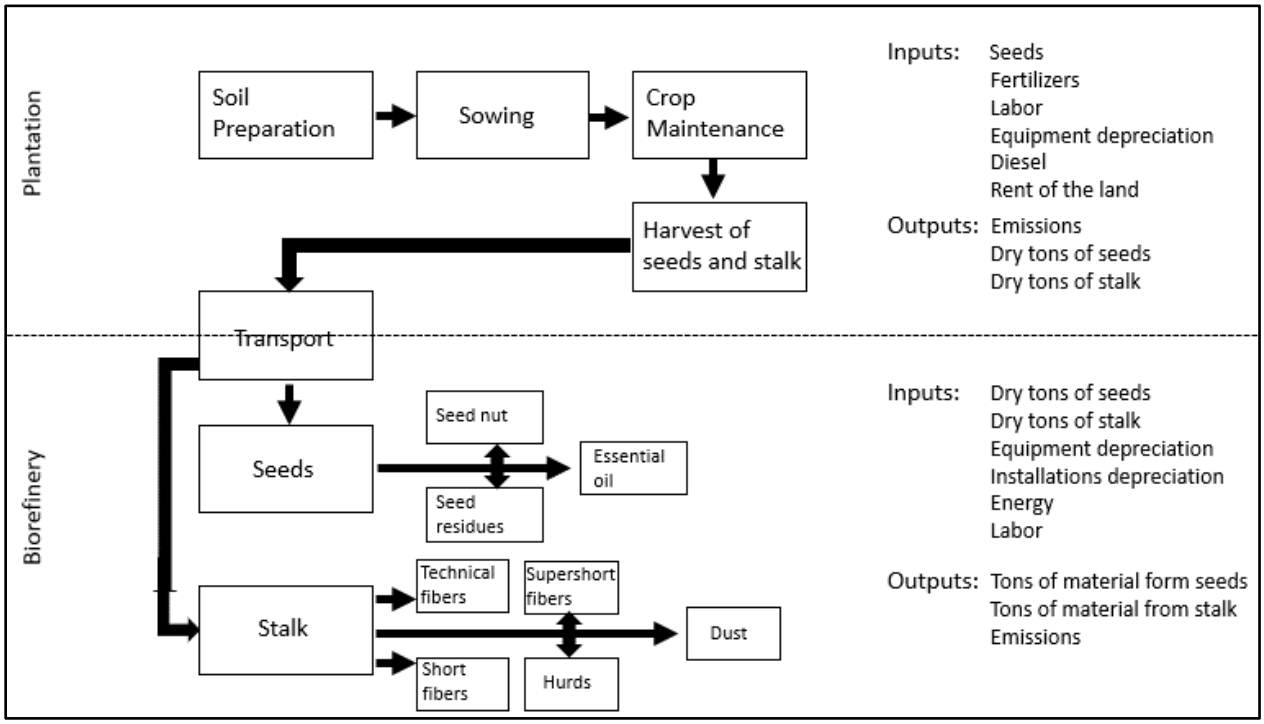

Figure 5 Flow chart of an integrated hemp project (plantation + biorefinery)

In my opinion, Portugal can be a major player in the European hemp industry in the future. Not just in terms of seizing the opportunities this revitalized industry will have, but also to improve the already established industries, all while improving the countries environmental impacts and economics!

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