# Life Cycle Environmental Analysis of Hemp Production for Non-wood Pulp

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**Abstract**

Hemp is one of the oldest known fibre crops in the world and it has been a traditional crop in Spain, mainly grown in Catalonia (NE Spain) [1]. Its benefits (weeds suppresser, crop free from diseases, improving soil structure and no pesticide consumption) make it an attractive crop for sustainable fibre production [2]. In fact, hemp grown for paper pulp is one of the highest yielding and least intensive crops to cultivate [3].

In this work, Life Cycle Assessment methodology (LCA) was used to quantify the environmental burdens associated to field production of hemp fibre to speciality paper pulp making. Data for hemp production were gathered from one of the biggest producer in Spain and complemented with bibliographic sources. Cultivation was subdivided in five main stages: soil preparation, sowing, growth and development, harvesting and post-treatment according to its chronological development.

The system under study was characterised with CML 2000 methodology[1] in order to identify the *hot spots*. Fertilizers use, production of Triple Superphosphate and Ammonium Nitrate, harvesting as well as scutching were identified as the hot spots of the hemp fibre production process.

The next step will be the collection of data for the processing stage in a representative ‘‘state of art’’ Spanish pulp mill in order to get a complete picture of the non-wood pulp production process.

## 1. Introduction

Hemp (*Cannabis sativa* L.) is an erect, slender and annual herbaceous crop which depending on its handling and its agro-ecological aspects can supply up to 12 tons of dry matter and 2 tons of seed per hectare [4]. The potential of hemp as sustainable fibre production was pointed out in the early eighties. It is a crop with a great adaptability to the climatic conditions and it does not require pesticides, herbicides or irrigation water. The consumption of fertilizers is modest and hemp crop suppresses weeds and some soil-borne diseases so at the end of its cultivation, soil is improved and healthier [5,6].

Hemp has been one of the most important fibre crops in Europe. In the Mediterranean areas of the Ebro valley in Spain, it has been a traditional and popular crop although it almost disappeared in the early seventies. Since that moment, the paper industry started to use hemp fibre as a raw material and therefore there was an increasing interest in this crop. Nowadays, hemp is mainly cultivated in the northeast, in the southern Pyrenees [7].

Fibre from hemp is suitable for paper-making, cigarette papers, plastic composites [8] and could balance or replace wood pulp. In addition to fibre, other products can also be obtained: hurds (used for horse bedding, house building and insulation materials), hemp dust (highly absorbent) and grain (for seed for sowing, birdseed and oil production).

## 2. Goal and Scope

The main focus of this study is to quantify the major environmental impacts associated with the field production of fibre hemp using Life Cycle Assessment (LCA). The results of this study will be used in a future study of non-wood paper pulp production.

The goal of this LCA study was to evaluate the environmental impacts of hemp fibre production.

[1] http://www.leidenuniv.nl/interfac/cml/ssp/projects/lca2/index.html

One hectare of fibre hemp crop, that produces 1 ton (11-14% water content), was used as functional unit. In particular, the region of study was Catalonia (Spain) and the period 2003-2006.

The Figure 1 shows the stages of the life cycle of fibre production included in this study.

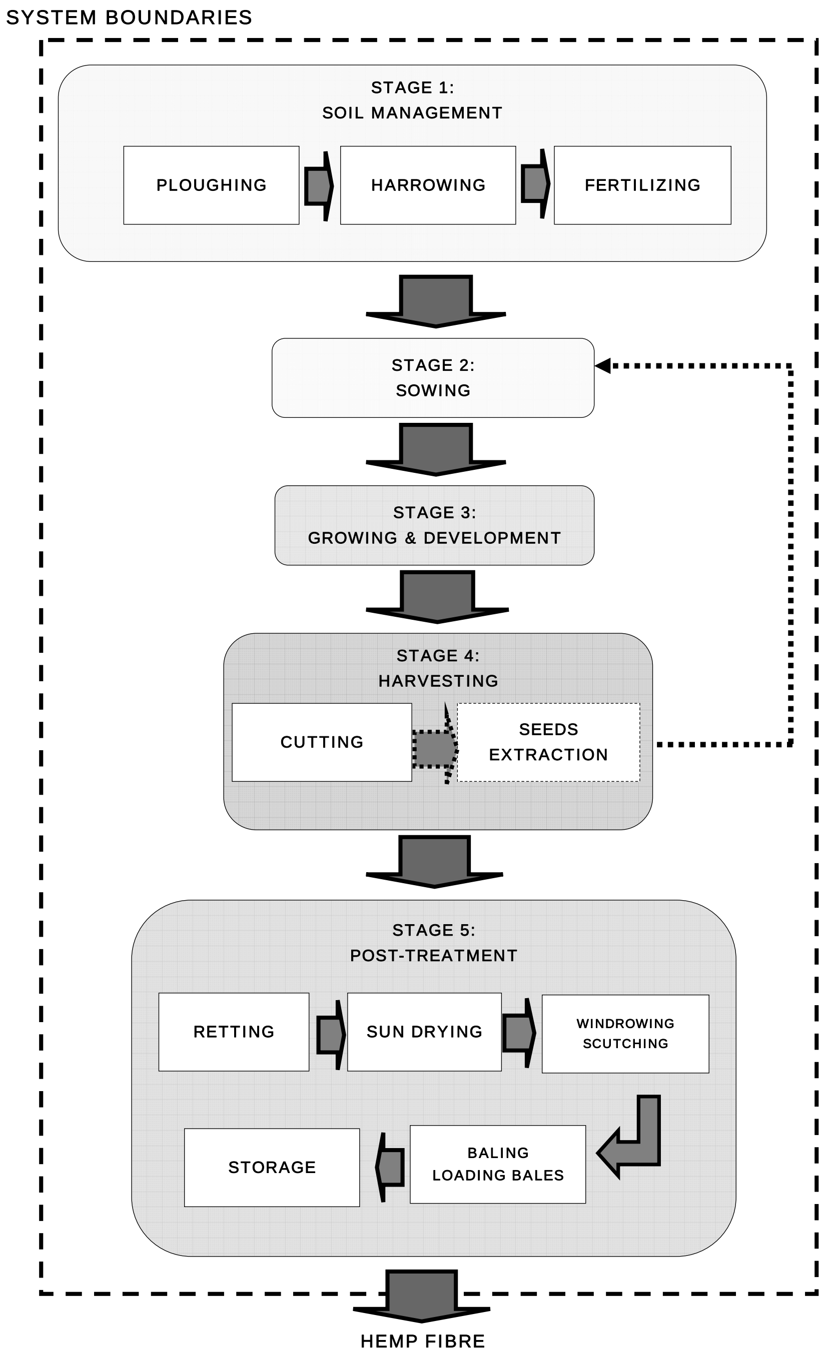


Figure 1: Flow chart of hemp crop

The present study deals with the field production of hemp crop considering fibre production as main product. Only the processes up to (and including) storage of fibre bales as well as co-products were considered. Inside the field, the cultivation process was divided in five stages according to the chronological development of a typical crop:

**Stage 1: Soil management.** The seedbed is prepared using a chisel or plough and rotary harrow in order to obtain a fine surface free of compaction. Prior to sowing, soil is fertilized.

**Stage 2: Sowing.** The sowing date is April. A cereal drill is usually used (12-17 cm between rows and 1-2 cm deep) but direct drilling (no tillage) is also used if rainfall is adequate although the seeding rate must be increased. Production of hemp seed for sowing requires the same inputs than the crop appointed to fibre although harvesting is slightly different. During the sowing stage, there is no consumption of chemicals.

**Stage 3: Growing and Development.** Hemp crop is rarely threatened by dangerous pest so no pesticides or herbicides are required. Supply of irrigated water is unnecessary, being rain water enough.

**Stage 4: Harvesting.** Hemp crop does not require specialised machinery. Equipment designed for forage harvest is used to cut straw. If seed and straw are simultaneously produced, seeds must be extracted.

**Stage 5: Post-treatment.** Once harvested, straw is lied down in rows during a period of two weeks in order to be ret. Next hemp straw is dried under sun action (2-6 weeks) and a windrower is used to turn over the straw to ensure an uniform quality. When moisture content is optimum (11-14%) straw is scutched to separate the fibre from the wood core (hurds) in a mechanical process. Dried round bales, obtained from a round baler, are finally loaded and stored.

**Ancillary activities:** Production, maintenance and disposal of machinery as well as energy and fossil fuel consumption were included for each field operations. The production of fertilizers and their transport from the factory to the farm were also considered.

## 3. Life Cycle Inventory Analysis

The inventory data of the global process of hemp crop are shown in Table 1. Bibliographic research [1,2,7] as well as field data supplied by one of the biggest Spanish hemp farms considered representative of the 'state of art' were used to carry out the Life Cycle Inventory (LCI). Inventory data of fertilizers, transport, source of electricity and machinery involved were taken from Ecoinvent database[2].

The production of seeds for sowing was also taken into account, assuming similar inputs to those used for fibre hemp cultivation as for example fertilizers and diesel consumption.

Table 1: Fibre Hemp crop inventory data (per hectare).

| **INPUTS from the TECHNOSPHERE** | | |
|---|---|---|
| Materials | Units | Value |
| Seeds (type: DELTA 405) | kg | 50±10 |
| Fertilizers | | |
| *Ammonium nitrate* | kg N | 85 |
| *Triple superphosphate* | kg $P_2O_5$ | 65 |
| *Potassium chloride* | kg $K_2O$ | 125 |
| Diesel | kg | 74.36 |
| Agricultural machinery | kg | 16.61 |
| Energy | | |
| Electricity for scutching | kWh | 360 |
| Transportation | | |
| Fertilizers | t·km | 90.48 |
| **OUTPUTS to the TECHNOSPHERE** | | |
| Products and co-products | Units | Value |
| Straw (11-14% moisture) | kg | 3000 |
| Fibre | kg | 1000 |
| Woody core | kg | 1500 |
| Hemp dust | kg | 500 |
| Seeds[3] | kg | 0 |

*Direct emissions*

Emissions associated with crop production were calculated according to [9, 10, 11]. The loss of nitrate to groundwater was estimated to be 77.13 kg/ha which corresponds to a moderate nitrate loss [2]. Emissions to air estimated of ammonia, dinitrogen monoxide, nitrogen oxides and carbon dioxide were 2.55 kg/ha, 3.06 kg/ha, 0.31 kg/ha and 1,467 kg/ha, respectively. In addition, it was assumed that 1 kg of methane is released to air per each 150 kg of N applied as ammonium nitrate [12].

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[2] http://www.ecoinvent.org/ecoinvent-documents/

[3] Hemp cultivation can generate seeds as well as fibre however, in this study this situation was not considered since the maximum fibre yield was the main objective.

*Allocation principles*

The allocation of environmental impacts in the case of the co-products was based on the economic value since it represents a measure of the incentive for production (in fact, although fibre production only represents a small fraction of the straw in mass, its production is the main driver of hemp cultivation). Current market prices were considered in order to calculate allocation factors [7]. The allocation factors are 68% for fibre, 29,1% for woody core and 2,9% for hemp dust.

## 4. Life Cycle Impact Assessment

SimaPro 7.0[4] was used for the evaluation of the impact and characterization factors obtained from a midpoint methodology (CML 2000) were considered[5]. In addition, energy consumption was included following the Ecoindicator 95[6]. Four impact categories were selected: eutrophication, acidification, global warming and photochemical oxidants formation and energy use as flow indicator, since they are generally studied in agricultural life cycle analysis [2, 13, 14, 15].

All the operations carried out in the farm were classified in three groups: seed production, fertilizers (production and use) and finally field operations (ploughing, harrowing, sowing, cutting, seeds extraction (when required), retting, drying, windrowing, scutching, baling, loading bales and storage. Figure 1 illustrates the contribution of each group to the life cycle of fibre hemp.

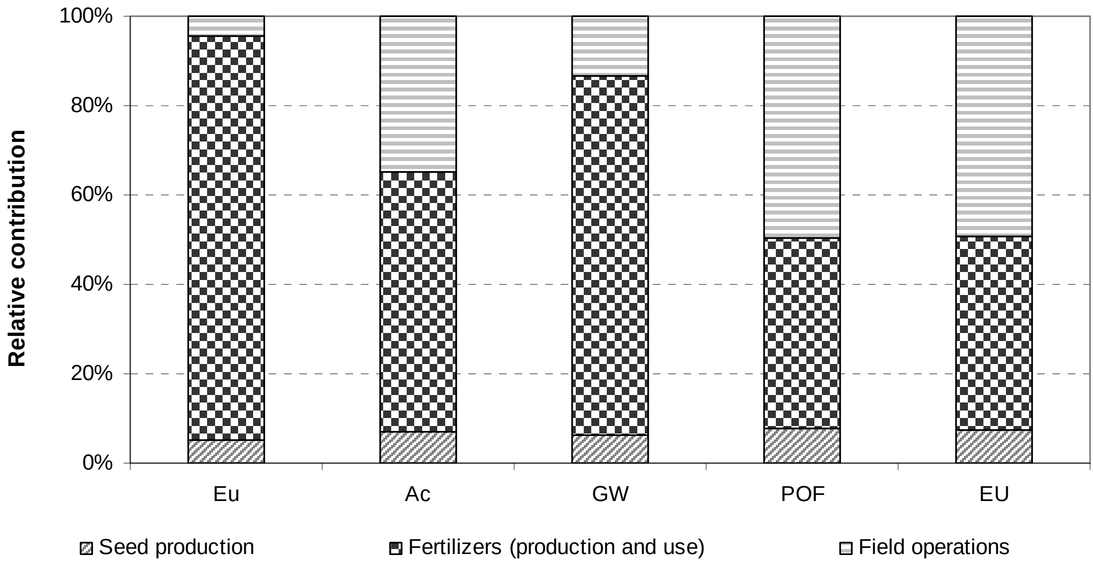


Figure 1: Contribution to the environmental impacts associated with production activities of hemp fibre (expressed in percentage terms). Impact category acronyms: Eu=Eutrophication, Ac=Acidification, GW=Global warming, POF=Photochemical oxidants formation and EU=Energy use.

The activities that take place at field (excluding seed production) as well as production and use of fertilizers account for the major percentage in all the impact categories and energy use.

Emissions associated to fertilizers use, Ammonium nitrate and Triple superphosphate production, harvesting and scutching were the main responsible so they were considered the *hot spots* of this crop production.

## 5. Interpretation of results

Eutrophication was largely (91%) caused due to production and use of fertilizers and nitrate emissions to groundwater produced in the application of fertilizers contributed to 80%. Acidification was mainly generated by $SO_2$ emissions (76%) associated to production of the Triple superphosphate. The emissions of carbon dioxide (biogenic) emitted from soil as well as dinitrogen monoxide mainly produced in the Ammonium nitrate manufacturing are the responsible of 74% of the Global warming. Field

[4] http://www.pre.nl
[5] http://www.leidenuniv.nl/interfac/cml/ssp/projects/lca2/index.html
[6] http://www.pre.nl/download/EI95FinalReport.pdf

operations were responsible of 50% of Photochemical oxidants formation mainly due to $SO_2$ emissions to air (94%) generated as a consequence of diesel combustion. Regarding to energy consumption, the fertilizers and field operations represented 92% of this indicator. The consumption of oil crude contributes to 76% of Energy use.

## 6. Conclusions

This study dealt with the field production of hemp crop considering fibre as main product. Special attention was paid to the inventory analysis stage of hemp cultivation. Data from a representative Spanish hemp farm as well as bibliographic and electronic sources were gathered excluding the transport of product and co-products from farm to pulp mill.

Taking into account the evaluation here carried out, special attention will be focused on the field operations as well as suggestion of best alternatives for hemp fibre production. Other types of non-wood fibre crops are being studied in order to determine which of them present less environmental impacts associated. In addition, future work will be concentrated in the paper pulp production with hemp fibres.

## 7. Acknowledgements

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