

Life Cycle Assessment of Extract Production from *Cannabis sativa* Inflorescences: A Preliminary Study

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Introduction

Cannabis sativa, commonly known as cannabis, has been recognized by the scientific community for its analgesic, anti-inflammatory, and calming properties. While this plant is characterized by a complex chemical composition, cannabinoids have attracted the greatest attention, particularly tetrahydrocannabinol (THC) and cannabidiol (CBD) [1]. The extraction of cannabis oil traditionally involves the use of butane as a solvent in a solid-liquid extraction system, a dangerous conversion process with relatively low yields (15-20% of total THC/CBD concentration) [2]. The **CannValue project** wishes to develop a safe, reliable and sustainable process for the production of cannabinoid-rich oil from Cannabis inflorescences and investigate potential waste management and valorization routes. This procedure includes the optimization of the ethanol-based extraction, the application of Supercritical carbon dioxide as a possible alternative to the conventional solid-liquid extraction and the valorization of waste streams of the process as to improve environmental and economic performance. The present work consists on the preliminary Environmental Life Cycle Assessment (E-LCA) of the production of edible oil from cannabis inflorescence, focusing on the replacement of the extraction solvent butane with ethanol, generally accepted as a safer operational option.

Materials and Methods

The process model was developed using a cradle-to-gate approach, encompassing all unit processes from plant cultivation up to oil formulation, prior to introduction into the market, adhering to **ISO 14040** and **ISO 14044** standards. Life Cycle Inventory was developed with basis on **primary data acquisition** from the partner companies and, where data could not be acquired directly, such as that related to *C. sativa* cultivation, model information was obtained from published documentation (REF). Calculation was performed according to the **Environmental Footprint impact assessment (EF 3.1)** method.

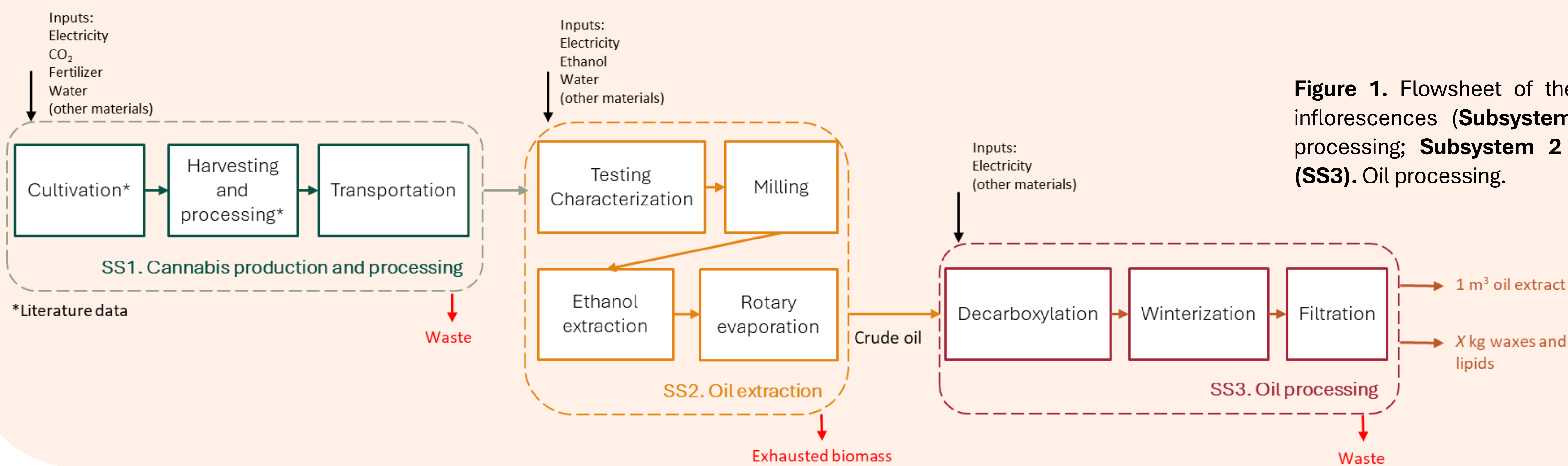


Figure 1. Flowsheet of the Cannabinoid-rich oil from Cannabis inflorescences (**Subsystem 1 (SS1)**). Cannabis production and processing; **Subsystem 2 (SS2)**. Oil extraction; **Subsystem 3 (SS3)**. Oil processing.

Results and discussion

Preliminary result analysis recognized SS2, **oil extraction**, as the process stage responsible for the majority of the environmental impacts in all categories assessed, with the exception of PM, OD and RU. The calculation further identified the following **environmental hotspots**:

- Diesel for agricultural production,
- Application of ethanol as solvent for oil extraction stage
- Incineration of exhausted biomass
- Required polypropylene container for incineration

The exhausted *C. sativa* biomass cannot be valorized or treated through conventional waste treatment systems (such as composting or anaerobic digestion) due to the existence of a legal requirement for maximum cannabinoid concentration. This legislation implies that the exhausted biomass produced in SS2 must be incinerated.

The exhausted biomass is the most important hotspot of the process, as its treatment is responsible for, approximately, **63% of the total CC value**.

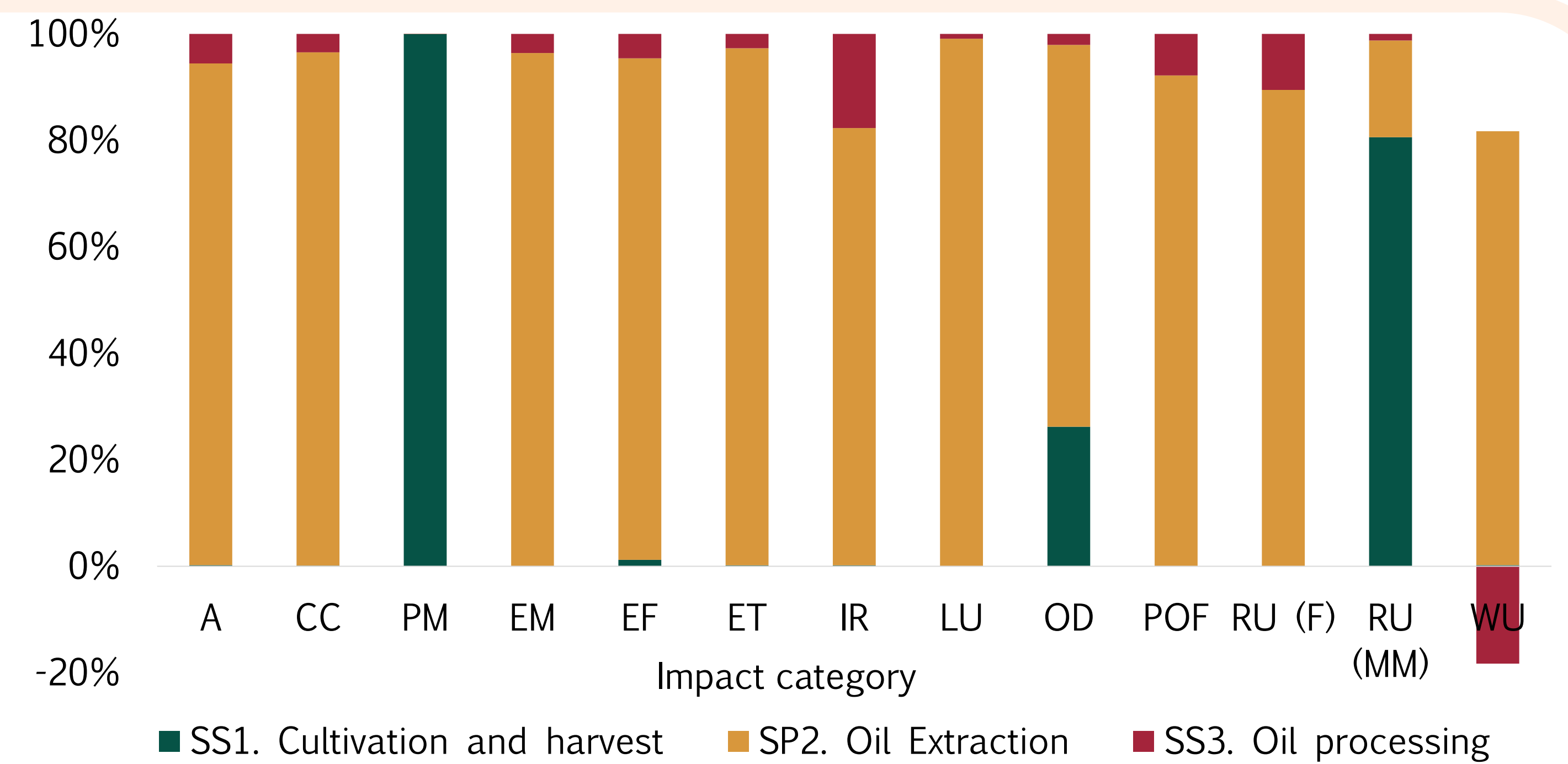


Figure 2. Representation of the environmental impacts of the 3 defined subsystems. A - Acidification; CC - Climate change; PM - Particulate matter; EM - Eutrophication, marine; EF - Eutrophication, freshwater; ET - Eutrophication, terrestrial; IR- Ionizing Radiation; LU- Land Use; OD- Ozone Depletion; POF - Photochemical ozone formation; RU (F) - Resource use, fossil; RU (MM) - Resource use, minerals and metals; WU - Water use.

Optimization scenarios

Within the foreground system, two hotspots can be addressed directly through the optimization of the production process. Namely, the introduction of secondary extraction for **removal** of reminiscent biomass cannabinoids and **ethanol recirculation** (up to 98%).

Scenarios

1. Reduced cannabinoid concentration
2. Ethanol recirculation

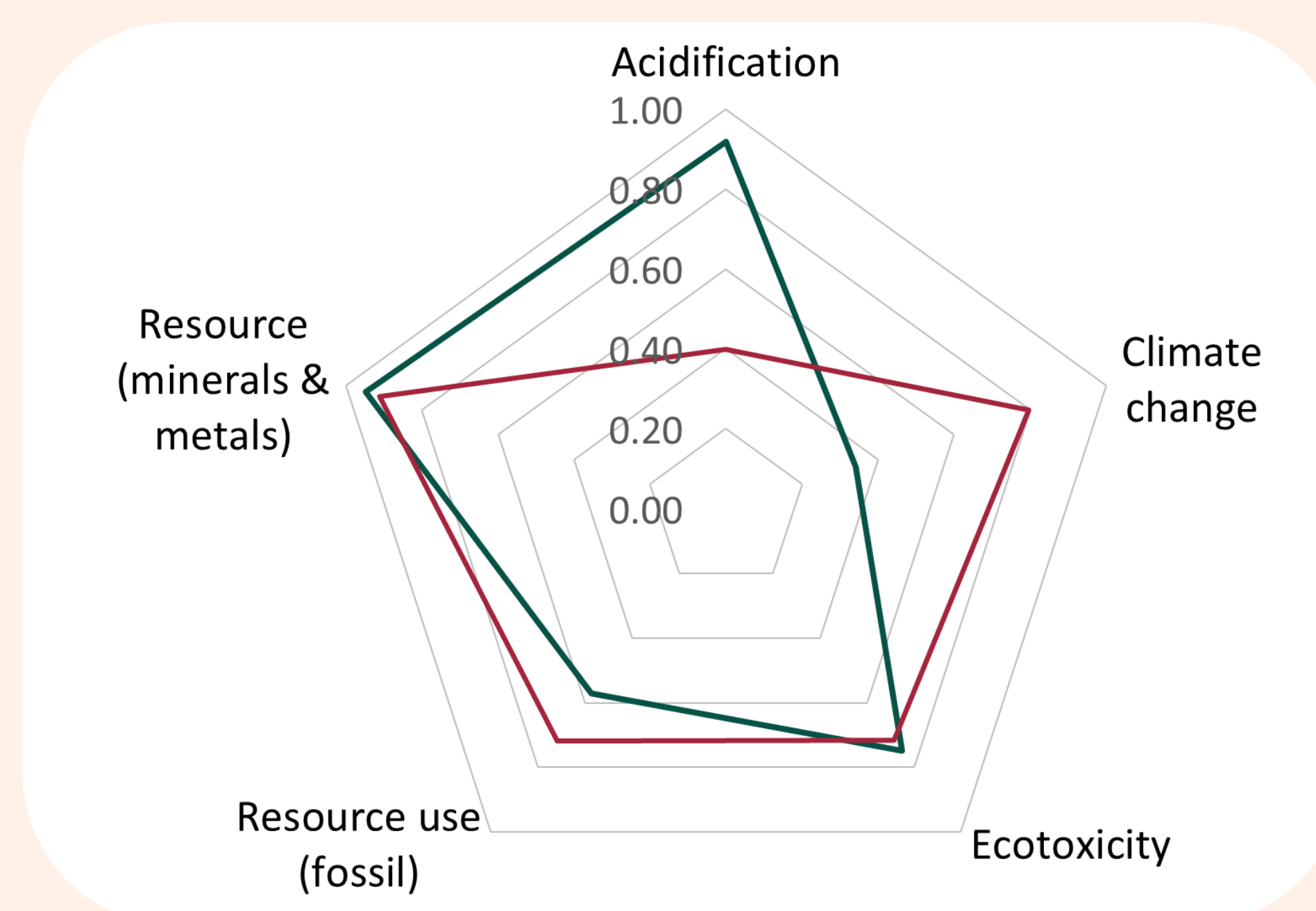


Figure 3. Radar representation of the impact of the reduction of potential cannabinoid concentration (Scenario 1) and ethanol recirculation (98%) (Scenario 2) in the oil production process.

The combination of both optimization measures can lead to a potential decrease of up to **86 % in climate change impact**.

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Take-away message

Preliminary findings of the LCA analysis underscore the value of conducting **this evaluation iteratively during process development** and optimization. Underused or non-exhausted residues can, in many cases, be an issue which will impact greatly the environmental performance of a given product. It is of utmost importance to identify, characterize and plan for their proper end-of-life procedure as to promote sustainable and environmentally friendly production processes.