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D5.6 Indirect Land Use Change (iLUC) Assessment Report

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EXECUTIVE SUMMARY

The goal of this analysis is to assess the potential risk of negative indirect impacts of camelina production within Spanish and Romanian context. The assessment takes into account the land use requirements for camelina production (including considerations on yields, agricultural model, potential for production on contaminated land, etc.), as well as the different uses of co-products. This analysis is not numerical in nature, the goal is not to calculate ILUC factors for camelina production, but rather it is a qualitative assessment that focuses on the impacts of production practices and choices.

In Spain, camelina is being introduced in cereal rotation schemes in arid and semi-arid regions. In arid regions and regions of low productivity where leguminous crops and other oilseed crops have very low yields, camelina is proving to be a hardy crop with potential to reduce the level of fallowing and increase overall productivity. In addition, camelina meal could result in a net reduction of animal feed imports, and overall have a net ILUC reducing effect. In more fertile and/or less arid (semi-arid) regions in Spain, camelina seems to fulfill a role similar to that of rapeseed oil, and it seems to be treated as interchangeable with rapeseed. While its yield is lower than that of rapeseed, it is more sturdy, potentially having larger yields on low-rainfall years. In these conditions where camelina becomes competitive with other food or feed crops, camelina cannot be said to have net ILUC benefits or low ILUC risk. Camelina is still a nascent crop in Spain, and one that is not yet competitive with higher value oilseed and cereal crops. However, these conditions may change in the future, which would also change the ILUC risk equation.

Thus, the micro-level processes that lead to global-level ILUC through displacement dynamics depend on the specific context and should be assessed case-specifically. At a more macro-level, it is also possible to assess displacement and shifts in production, in retrospect (*a posteriori*). Such an assessment would need to determine whether the prior production of a feed or food crop in a region has been displaced by a growing production of camelina, and to what extent the displacement has been substituted by camelina by-products. In evaluating displacement, the historical (5 or 10 year) trend in previously existent production of food, feed and fiber should be assessed.

In heavily contaminated land, camelina production can be said to have no ILUC risk if it does not displace prior production and if production of food, feed or fiber is not possible due to contamination concerns. Attention should be paid to potential re-exposure of humans, animals and wildlife to contaminants through the use phase of the biofuel. Once land is remediated, through phytoremediation or other means, a new ILUC risk assessment should be carried out.

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Abbreviations

ILUC (iLUC)	*Indirect Land Use Change*
EU RED	*European Union Renewable Energy Directive*
CAP	*(EU) Common Agricultural Policy*

1 Theoretical background on Indirect land use change (ILUC)

In the last decade, the world has seen the production of biofuels increase roughly fivefold (EPI, 2012). In 2012, over 50 percent of Brazil's sugar cane crop and over 30 percent of United States of America (U.S.) corn were used in the production of ethanol, and in the European Union (EU), biodiesel production used almost 80 percent of the EU vegetable oil production (FAO, 2012). Some of the most important policy drivers for biofuel uptake include climate change mitigation, reducing fossil fuel dependence, as well as agricultural and rural development. However, potential negative impacts of biofuel production were recognized early on. Such impacts can be direct, occurring within the boundary or in the vicinity of biofuel operations, or indirect, triggered by market reactions to increased biofuel production. Indirect land use change is one such indirect impact.

1.1 Direct and indirect impacts of biofuels

Direct impacts of biofuel production are the impacts on the directly affected land and population. In some instances "directly affected" refers only to the scope of the biofuel operations (e.g., the plantation, the refinery, etc.), and in others it refers to the surrounding land and peoples who can be affected as a result of the operations, e.g., through irrigation runoff, impacts on downstream water resources, or impacts on the food security of nearby and directly affected populations. Sometimes, direct impacts that occur outside of the boundary of operations, such as pollution of downstream water courses by irrigation runoff, are termed "indirect impacts". In this paper however, we refer to these as direct impacts because they take place in directly affected areas.

The term "*indirect impacts*" refers to the fact that a phenomenon can have effects that are not directly, or physically, linked to it. Such effects or impacts can therefore be distant in time and/or space from the original cause.

Indirect impacts *of biofuel production* happen outside of the boundary of the chain of production of the biofuel and are not linked to biofuel production by geographic proximity. Rather, they are *market-driven*, a result of the global market reaction to an increase in biofuel demand. Indirect land use change is one such impact.

1.2 Direct vs. indirect land use change

Direct land use change occurs if biofuel crops directly cause an existing land use to change, such as when biofuel production displaces existing forest or pasture, releasing carbon from their plants and soils (Searchinger, 2010). *Indirect land use change* (ILUC), however, occurs when increased biofuel demand results in the *conversion of existing, productive agricultural land to biofuel production*, in turn triggering market reactions that lead to land conversion elsewhere (Searchinger, 2010) to *replace the provisioning services, such as food, feed, fiber, or other biofuels that were produced in the land that was originally converted*. This indirectly caused land conversion could take place in any region of the globe that is connected to world agricultural markets; hence, ILUC is also sometimes termed *global land use change*.

It becomes clear why quantifying the indirect impacts of biofuels on land use change is an extremely difficult endeavor. ILUC is a result of *global agricultural market and land use dynamics*, which are affected by a large number of parameters, such as yield intensification elasticity, the role of by-products, land conversion elasticity, yield in converted lands, demand and substitution elasticities, and trade-related issues (tariffs, restrictions, etc.) to cite a few (Khanna, 2011).

Importantly, ILUC can be driven by a large number of non-agricultural factors that have an impact on global commodity prices. For instance, one could talk about the ILUC caused by changing dietary habits and increasing meat consumption; urbanization; global population growth; poor harvests; market speculation; and fluctuations in currency markets among others (HLPE, 2013).

Finally, one of the most important aspects to keep in mind about ILUC is that it is ultimately a result of concrete local, regional and/or national socio-political dynamics that eventually lead to land use change to materialize. Global LUC is DLUC where it takes place; therefore, addressing ILUC also involves addressing DLUC where it takes place through the prevention of deforestation.

1.3 Indirect land use change dynamics

This section describes market dynamics as a result of a "biofuel shock", i.e., the production of an increased amount of biofuel in global markets as a result of increased demand for biofuels. This increase in demand may be triggered by national or supranational policies requiring an incremental use of biofuels in a country's or region's fuel mix. This biofuel can be produced *without displacing* existing agricultural production, or by *displacing* existing agricultural production to a greater or lesser extent. The dynamics triggered by each of these forms of production are described below.

1.3.1 Displacement analysis

Thus, to assess whether the production of a certain agricultural commodity could have impacts on global land use change, this paper is based on the logic of carrying out an analysis of displacement[1]. The premise is that biofuels that do not displace existing provisioning services have a low risk of causing ILUC, as stated above.

A shortcoming of the "displacement analysis" approach is that it does not take into consideration broader market dynamics. I.e., if large areas of previously abandoned land are converted to biofuel feedstock production, how will it affect national trade balances? How may it affect global commodity markets? The simple answer is that producing more commodities should have a price lowering impact, and thus decrease the risk of ILUC. However, it is difficult to make *a priori* predictions. It is important to recognize this as a main limitation of this paper, given that we use the assessment of displacement approach.

[1] Similar and closely related to the displacement assessment is the "additionality assessment": Biomass production projects can be assessed with respect to their "additionality", i.e., it can be determined whether they result in the production of biomass *in addition to* what would have happened in a business-as-usual scenario (Searchinger, 2010). A driver for additional biomass production could be the appearance of new biofuel markets, without which there would have been no incentive to produce the additional biomass. Determining whether a land-use project is additional involves comparing the scenarios with and without the project, and assessing whether the project would have occurred without the increased demand for biofuels, or similarly, whether any barriers had to be overcome to implement the project (barrier analysis).

1.3.2 Biofuel produced by displacing existing provisioning services

Biofuel production can displace existing provisioning services of the land, such as food, feed, fiber, or other biofuels that were produced in the land that was originally converted. This can occur by, e.g., switching the land from crop 1 to crop 2, with crop 2 being used as biofuel; or switching the *use* of crop 1 from food/feed to biofuel.

In reality, farmers' decisions on what to plant is motivated by a number of factors, including current and projected commodity prices, perceptions of risk, subsidies, etc. A "biofuel shock", for instance in the form of a regional biofuel mandate, will generate increased demand of biofuel by end users such as petroleum blenders, in turn increasing demand of biofuels and biofuel feedstock throughout the production chain, thus eventually raising the prices of biofuel feedstocks, thus making them more attractive to the farmer, and potentially resulting in a decision by the farmer to produce (more) biofuel feedstock.

It is important to note that in ILUC modeling, the "shock", in the form of *increased* demand, is what triggers a chain reaction of short-term market price increases, potentially ending up in land use conversion as a reaction of the market to short-term shortages (see below). The reactions below can be expected in the case of increased biofuel production that displaces existing provisioning services.

i. Compensation through co-products

The production of biofuel may result in the generation of a co-product that can be used to satisfy or partially satisfy the previous provisioning function of the crop. For example, the corn ethanol production process yields dried distillers' grains with solubles (DDGS), which can, to a degree, satisfy the previous function of corn as animal feed (IFPRI, 2010).

ii. Substitution

Agricultural commodities are interchangeable to a degree, i.e., there is a certain elasticity of substitution between different commodities, as well as between imported and domestically produced commodities (Khanna et al., 2011). For example, cattle grain supplement can be in the form of corn, soybeans, wheat, etc.; and EU rapeseed oil can be used as biofuel feedstock, triggering the import of palm oil for food/feed to substitute rapeseed oil. The substitutability of commodities and land uses means that local effects on one commodity or land use type can trigger global impacts on a wide range of commodities and land use types.

iii. Demand-Supply imbalance.

To the extent that displacement is not fully compensated through co-products and substitution, the production of biofuel will reduce the availability of corn feed on the market. This will create an imbalance in the demand-supply equilibrium. More precisely, a study talks about an imbalance between the *rate of growth in demand* vs. the *rate of growth in supply* (HLPE, 2013). For market-traded commodities, this will be a driver for commodity *price increases*.

iv. Reduction in consumption

Price increases and/or decreased availability of a crop in the market will, to an extent, cause people and/or livestock to consume less of the crop, with important impacts on food security. Decreased crop consumption means that people consume less and/or lower in the food chain (less meat, milk, etc.); mostly affected are the poor, who spend a larger portion of their incomes on food (HLPE, 2013). The other side of the same coin is that rising food prices lead to poverty by causing the poor to spend more of their incomes on food (HLPE, 2013).

v. Increased productivity (intensification)

Increased commodity prices and/or reduced crop availability may drive the farmer to increase crop yields or, more generally, to increase the productivity of their land *above and beyond business as usual* to produce additional crop for biofuel feedstock, while maintaining the previous (and steadily growing) output for food, feed or fiber. Higher commodity prices and/or reduced crop availability are a driver for productivity increases, because they make productivity-raising practices worth the extra time and money of the farmer. There are numerous practices that can improve yields and/or productivity, including the use of additional inputs (such as fertilizers), denser planting, use of better seed varieties, use of more efficient machinery, intensification of cattle farming through food supplements, intercropping, double-cropping, etc.

vi. Conversion of land

It may be cheaper or easier to plow up additional land instead of (or in addition to) intensifying in order to produce the extra crop needed. Alternatively, higher commodity prices may make it economically attractive to convert previously uncultivated land into cultivated land. This *indirect land use change* (iLUC) can take place in different places and under different circumstances. A few examples of how higher commodity prices can result in conversion of additional land include:

- Installation of an irrigation system on arid land that was previously uncultivated, thereby transforming it into cultivated land;
- Reducing fallow periods through the increased use of inputs/better management practices;
- Conversion of set-aside land;
- Building a road to connect previously uncultivated lands to new markets, thus making it now economical to cultivate such lands;
- Clearing and plowing up natural land, such as a grassland or forest land, for cultivation - this is especially prone to happen in areas with poor land governance or where conservation of natural ecosystems is not a enforced in regulations.

1.3.3 Biofuel produced without displacing existing provisioning services

If the production of the biofuel or biofuel feedstock can be demonstrated to cause *no or little displacement of existing provisioning services, including food, feel, fuel and fiber*, then it could be argued that it would not trigger a demand-supply imbalance, or any of the subsequent reactions outlined above. Hence, the production of the biofuel would cause no upward pressure on land-based commodities and would not drive land use conversion. It can thus be said to have “no or low risk of causing ILUC”.

Based on displacement analysis, we identify certain biofuel feedstock production categories that could be said to result in no or low risk of ILUC under certain conditions. Two of these categories, **unused land** and **fallow period replacement/reduction** are central to our analyses of the case studies of Spain and Romania discussed below.

i. **Production of commodities where there was previously no production:** Biofuel feedstocks can be considered to be additional if they are grown on land where there was no previous production. For example, if biofuel crops are grown by irrigating the desert or by planting abandoned cropland that would otherwise remain fallow or minimally productive (Searchinger, 2010). Direct impacts from conversion to biofuel production should be taken into consideration. Ideally, biofuel production should not negatively affect carbon stocks, biodiversity and local socio-economic conditions.
    - **Unused land:** Cultivation of feedstock on previously unproductive land (Searchinger et al., 2009), i.e., where no production was taking place. The determination of whether a parcel of land was unused requires close investigation and a detailed methodology on its own. The determination of whether land is “used” or “unused” delves into the subject of land ownership and land rights and must be carefully assessed. In addressing whether land is “unused”, both formal and informal land rights should be taken into account. Shifting cultivation with long fallow periods may lead to the conclusion that land is “unused” if the evaluation period is too short. For instance, a study cites fallow periods eight times longer than the cultivation period (IWMI, 2011). One example of unused land is **degraded land** with formerly no productive function but which can be used to produce biofuel. In this context, the terms “degraded land” and “land restoration” must be clearly defined; some guidance is provided in IPCC (2000).
    - **Fallow replacement / reduction.** Fallow land is arable land that is left bare in between growing seasons in order to allow for soil nutrients and water replenishment. A biofuel crop could be introduced as replacement of some of the fallow periods (Searchinger, 2010).

ii. **Increased yields in existing agricultural fields:** Feedstock produced from land management changes that increase crop yields above and beyond the business-as-usual yield increases for that crop in the given region could in theory be considered to be additional and result in no displacement of existing provisioning services (LIIB, 2012). Historical yield trends could be used to demonstrate the step increase in yield growth rate as a result of the implementation of best management practices, and only the feedstock produced above and beyond the historical yield growth trend would be characterized as having “low iLUC risk” (LIIB 2012). Some yield increase measures may have environmental and social impacts; for instance, increased fertilizer and pesticide use may result in higher GHG emissions and impacts on water quality; increased irrigation may impact downstream access to water; large-scale monocultures may impact biodiversity, etc. These potential impacts should be taken into account when evaluating the direct impacts of biofuel production. However, in practice it is very difficult to distinguish between yield increases that are “additional” and yield increases that are responses to market conditions. Therefore, we consider that in practice it may not be feasible to make a claim of low-ILUC impact through yield increases.

iii. **Waste feedstocks:** Wastes can be defined as materials that were previously discarded, e.g., through incineration, landfill, or other disposal methods (LIIB, 2012); their use as biofuel feedstock is additional (Searchinger T. , 2009), because they would be thrown away in the absence of increased biofuel demand. This can be the case for municipal solid waste (MSW). Agricultural residues could fall under this category, but only if their use as biofuel feedstock does not displace previous uses (e.g., as organic soil inputs, etc.) and their removal does not result in soil degradation (RSB, 2010). Alternatively, residues could be categorized as “low indirect impact risk” if their use as biofuel feedstock is *more efficient* (e.g., with regards to energy efficiency or carbon efficiency) than their previous use; in this case they are not entirely exempt of causing indirect impacts and their categorization as “low risk” feedstocks should be done carefully and according to a methodology that assesses the efficiency of residue utilization.

iv. **Landless feedstocks. Photosynthetic algae**, which require CO_2, light, and nutrients to grow, have been mentioned as possible biofuel feedstocks with a low risk of causing iLUC (Witcover et al., 2012). Photosynthetic algae could indeed be an interesting source of biofuel feedstock when the technology is mature and economically profitable, though their production is not exempt of potential environmental impacts, for instance related to fertilizer requirements and the GHG emissions and potential runoff associated with it – although a beneficial supply of fertilizer inputs could come from nutrient recycling, e.g., through the use of nutrient-rich wastewater and agricultural effluents. It should be noted that heterotrophic algae, as opposed to photosynthetic algae, grow in the dark and use sugar as a feedstock. In this case, the *growth of heterotrophic algae could entail the same risk to indirect impacts than any other sugar-based biofuel*, unless the source of the sugar is a waste in itself (such as a wastewater). Again, the risk of causing indirect impacts would have to be determined on a project-by-project basis and carrying out a displacement analysis.

1.3.4 Strong and Weak Conditions for low risk of ILUC

Taking the displacement analysis one step further, we define "strong" and "weak" conditions for causing low ILUC risk.

A **strong condition** for causing a low risk of ILUC is as follows: Biofuel feedstock production can be demonstrated to cause no displacement of existing provisioning services, such as food, feed, and fiber. For example, biofuel feedstock is planted in land that had no prior productive function.

A **weak condition** for causing a low risk of ILUC is as follows: If feedstock production results in a small amount of displacement of existing provisioning services, such as food, feed, and fiber, then the production of the biofuel feedstock should compensate the loss of provisioning services by exactly substituting them. For instance, if biofuel feedstock is planted instead of fallowing the land, the biofuel should replace all the previous functions of the fallow, including organic matter regeneration, moisture absorption, etc.

1.3.5 Other important considerations

ILUC is not static. ILUC is a dynamic phenomenon that is closely related to commodity markets, population change, land policy, international trade, etc. Hence, it is not static. An ILUC risk assessment conducted today may yield a different result if it is conducted under different conditions in the future. Therefore, ILUC risk assessments should be revisited periodically.

In addition, the *rate* at which market changes occur is very important to global LUC. Short-term changes to market equilibria can lead to price spikes (HLPE, 2013), which can have short-term impacts on land conversion. In contrast, the increased production that would be triggered by a gradual rise in prices could be potentially met by in-place yield increases. Therefore, taking into account the rate of change and displacement, and not just the absolute amount, is important.

DLUC and other direct impacts should be taken into account. It is important keep in mind that the "low indirect impact risk" categories outlined above can entail socio-economic and environmental risks of their own. Any sustainability assessment of "low indirect impact risk" biofuel projects should also the direct impacts associated with the operations, for instance, by conducting a environmental, social and economic impact assessments.

2 Production of Camelina Sativa in Spain's semi-arid agricultural land

The goal of this section is to conduct an assessment of ILUC impacts associated with the production of camelina sativa in Spain's semi-arid agricultural lands.

2.1 Spanish Agriculture: Overview

Spain's agricultural GDP is slightly above 3%, which is at the high end of the spectrum compared to other EU countries (World Bank, 2014). Its agricultural land comprises almost 50% of total land surface, and approximately half of all agricultural land is dedicated to annual crops, which are dominated by cereal grains (**Table 2-1**).

Cereal production comprises 9% of the value of all agricultural production. There has been a downward trend in the area dedicated to cereal production, which decreased by 12% between 2002-2011, but yields improved as well (3.4 t/ha vs 3.2 in the last decade), resulting in a net increase in production by volume. The cereal trade balance is negative, and the country imports cereals in large quantities, especially wheat, oats, and sorghum (MAGRAMA, 2014b).

Since 2010 the only Common Agricultural Policy (CAP) program benefitting cereals is through the National Program for Crop Rotation in Drylands, benefitting cereals in rotation with legumes, "proteaginous" crops, and oilseed crops. Due in part to this program, production has steadily increased over the last 4 years, except for the year 2013 due to the drought that characterized that year.

Legumes cultivated in Spain include various bean varieties for human consumption, as well as vetch (veza; vicia sativa) and "yero" (vicia ervilia) as leguminous cover crops for re-ploughing or animal fodder. Some of them are cultivated in semi-arid agricultural lands as fallow cover crops for their nitrogen-fixing abilities. The latter two combined comprised approximately 70% (or around 175,000 tons) of all legumes produced in 2013. In contrast, Spain imported around 180,000 tons of legumes dedicated to human consumption, vs. a production of around 60,000 tons. Therefore, Spain is a net importer of legumes for human consumption (MAGRAMA, 2014d).

As far as proteaginous crops, peas are the main crop, followed by fava beans, and altramuz beans; only the latter is a dryland crop, located mainly in relatively humid regions such as Castilla y León. The surface dedicated to proteaginous crops has decreased in the last five years, but since yield has increased, the total production has only decreased around 12% (MAGRAMA, 2014c).

The main oilseed crop cultivated in Spain is sunflower (90%), mainly as a dryland crop (non-irrigated) and in rotation with cereal, though only in certain agro-climatic conditions with sufficient rainfall. However, rapeseed oil production has been rapidly increasing (MAGRAMA, 2014c). Imports of oilseed crops and products are considerable. In 2013 net imports of oilseeds (sunflower, soy and rapeseed) were around 6 million tons in the form of seeds, cakes and flour (soy only), and 600,000 tons were exported. Soy imports surpassed 3 million tons, a 5% growth over the 5-year average, and fundamentally from Brazil (MAGRAMA, 2014c).

2.2 Cereal-growing regions in Spain

2.2.1 General overview

Topography and climate play large roles in Spanish agriculture. Despite its relatively low rain levels, most annual agriculture is non-irrigated (i.e., rain-fed), henceforth referred to as "dryland" agriculture (Table 2-1). The central plains and southeast regions are generally characterized by a Mediterranean climate and semi-arid agriculture (**¡Error! No se encuentra el origen de la referencia.**).

In the Mediterranean region (which comprises several countries of similar climatic conditions), **semi-arid agriculture** is generally considered to be rain-fed agriculture in areas that receive less than 500mm annual rainfall (MAGRAMA, 2001). In Spain, these regions concentrate in the southeastern and northeastern portions of the central plateau, and especially in the Autonomous Communities of **Castilla y León**, **Castilla La Mancha**, **Extremadura**, **Murcia**, and **Aragón**. Cereal production, in particular wheat and barley, is predominant in these regions; production of barley tends to be predominant in the driest areas, given that barley is more water efficient than wheat. In addition, the area dedicated to higher value oilseeds or legumes is very limited (¡Error! No se encuentra el origen de la referencia.; ¡Error! No se encuentra el origen de la referencia.).

Figure 2-1: (a) Average rainfall 1971-2000 (AEMET, 2011) (red hexagons indicate camelina focus areas, see section 2.5.3); (b) Spanish autonomous communities and provinces (herramientasgeo.blogspot.com)

Table 2-1: Spanish agricultural land in 2013 [1000 ha] (MAGRAMA, 2013)

	Non-irrigated (dryland ag)	Irrigated	Greenhouse	Total
Agricultural land				
Annuals				
Grain cereals	5498	993	0	6491
Legumes	275	16	0	290
Tubers (root vegetables)	13	44	0	58
Oilseeds	836	73	0	908
"Industrial"	29	132	0	160
Forage	732	254	0	986
Vegetables and flowers	18	183	19	220
Fallow land	2704	81	0	2785
Annuals - subtotal	10104	1776	19	11899
Perennials (groves & vineyards)				
Fruit trees	774	540	5	1319
Olive groves	1845	739	0	2584
Vineyards	623	342	0	965
Perennials - subtotal	3242	1621	5	4868
Prairies and pastures	8429	35	0	8464
Agricultural land - subtotal	21775	3432	24	25231
Forest land				18958
Other				6348
Total surface – Spain				50537

*Industrial includes sugarbeet, spices, aromatic plants, etc.

**Forage includes forage corn, alfalfa, winter cereal, clover, etc.

Fallowing has traditionally been used extensively to allow the soil to replenish both water and nutrients. Fallow periods of 12 or 15 months are not uncommon, and periods of 2 to 3 years are employed in some areas.

Figure 2-2 shows a map of the fallow index in Spain.

Table 2-2 shows fallow management practices in various Spanish autonomous communities. The table shows that traditional and minimum tillage practices are the most common forms of management of fallow land, as well as growing a spontaneous cover.

Figure 2-2: Fallow index; Indice de Barbecho Simplificado (IBS) (MAGRAMA, 2013b)

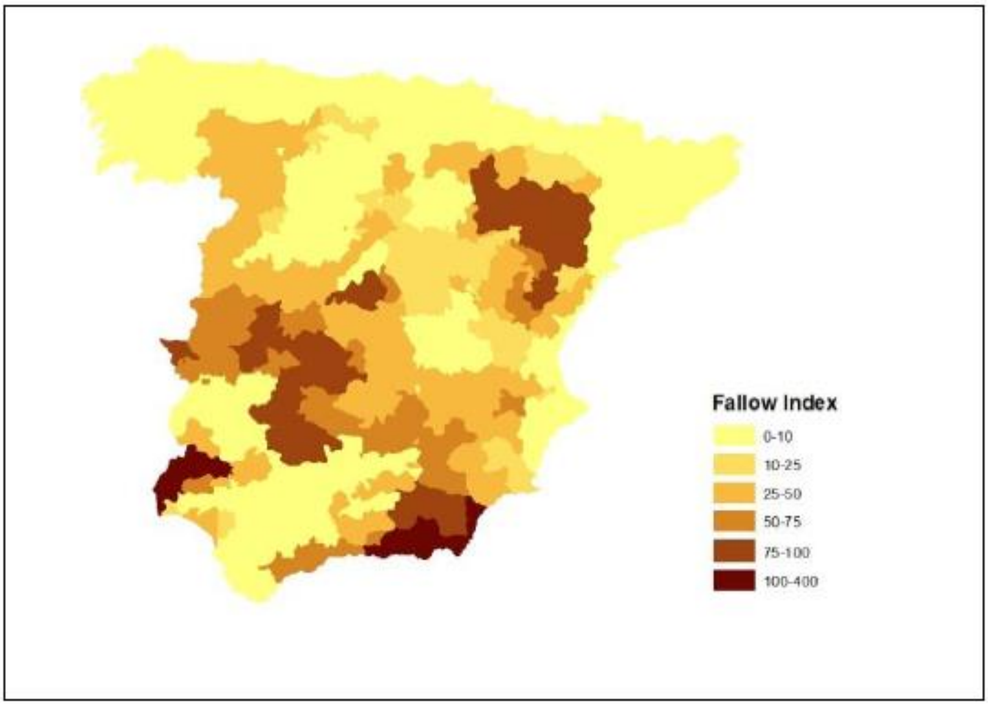

Table 2-2: Management of fallow land by autonomous community [ha] (MAGRAMA, 2013)

	Traditional tillage	Minimum tilling	Spontaneous herbaceous cover	Seeded herbaceous cover	Inert Cover	No maintenance	No tillage	Total
GALICIA	1499	4747	9088			1800		17134
ASTURIAS	315	29	269	160		141		914
CANTABRIA	182		480			19		681
P VASCO	523	1484	1724	7		28		3766
NAVARRA	22070	9049	19222	12		437		50790
RIOJA	7475	1784	4148			1102		14509
ARAGON	252608	97348	43687	251	65	44211		438170
CATALUÑA	7411	10010	11808		22	7451		36702
BALEARES	7118	5526	13145	442		2892		29123
CASTILLA Y LEON	376585	75340	79135	578	2011	76914		610563
MADRID	44876	7787	3319	24		10795		66801
CASTILLA LA MANCHA	399806	223581	112147	51		77256		812841
C.VALENCIANA	9081	15880	13571	9	150	9882		48573
R.DE MURCIA	43179	9420	31841	21	501	6934		91896
EXTREMADURA	87624	9387	141137		47	24094		262289
ANDALUCIA	102375	58981	101941		18	20962		284277
CANARIAS	384	800	4969		1135	1435		8723
ESPAÑA	1363109	531152	591631	1555	3950	286354		2777751

- Traditional tillage: tillage to depths equal or greater tan 20 cm.
- Minimum tilling: tillage to depths less than 20 cm.
- Spontaneous herbaceous cover: no tillage; soil receives a spontaneous herbaceaous cover which is controlled by mechanical means (cutting), chemical means (herbicides), or grazing.
- Seeded herbaceous cover: no tillage; soil is planted with a gramineous or leguminous plant cover which is controlled by mechanical means (cutting), chemical means (herbicides), or grazing.
- Inert cover: soil is covered with Woody residues, rocks, or other inert material. .
- No maintenance: soil has not received any maintenance activity, be it mechanical, chemical or grazing.

2.2.2 Issues

Productivity in dryland regions is limited, to a large degree, by erosion and associated loss of soil and soil organic matter, as well as limited water availability. Research shows that extreme episodes of water erosion cause more than 85% of the total annual soil losses. In Mediterranean environments, extreme erosion episodes not only occur during high intensity rainfall (e.g. convective cells), but also occur in typically winter periods, in which soil is close to saturation and moderate intensity rains are enough to cause great magnitude erosion processes. Ensuring that the soil is covered (either through a cover crop or mulch) is important, especially during these periods.

Some of Spain's semiarid dryland cereal-growing areas Spain's present limited profitability, high erosion rates, an alarming reduction in organic matter content, loss of soluble nutrients and nutrient leaching, all of which, together with very small levels of biodiversity due to elimination of autochthonous flora and fauna, have rapidly increased desertification rates (Carlos Lacasta-Dutoit, 2005). In many instances, farmers would not be able to make a living were it not for the subsidies under the CAP. In addition, being able to afford inputs such as fertilizers and fuel for machinery is becoming increasingly difficult given the rising costs of inputs vs. stagnant prices of commodities (Carlos Lacasta-Dutoit, 2005). Crop rotations (e.g., barley-fallow, barley-sunflower, or barley-vetch[2]) are often suggested as means to improve and productivity (Carlos Lacasta-Dutoit, 2005). However, rotations with oilseed or leguminous crops are not regularly implemented. Rather, cereal-fallow rotations are the most commonly implemented rotations.

Thus, long fallow periods are common in Spain's semiarid cereal systems; through this practice, levels of soil nitrogen and water storage at sowing time and water use efficiency are increased, and weed and disease control are improved in comparison with continuous cropping partially in order to preserve soil water and nutrients (D. Moret, 2007).

2.2.3 Typical rotation schemes

The typical rotation scheme currently performed in these arid regions is to rotate cereal production one year with a fallow period the next (CCE, 2014).

Typical rotation scheme in Albacete (Castilla La Mancha)

Year	Crop	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	Barley												
2	Fallow												
3	Barley												
4	Fallow												
5	Barley												

As another example, in central Aragon, rainfed cropland is located in areas with an average annual rainfall of less than 400 mm. In these areas, the most common cropping system is the traditional cereal–fallow rotation, which extends over about 430,000 ha and involves a long-fallow period of 16–18 months running from harvest (June–July) of the first year to sowing (November-December) the following year. Although the main purpose of long fallowing is to increase soil water storage and the water available for the next crop, the cereal–fallow rotation does not always result in an improved water economy for cereals (D. Moret, 2007).

Long fallowing is a somewhat controversial practice because of its relative inefficiency in terms of soil water storage (D. Moret, 2007) and the potential soil loss to erosion if the soil is not properly covered. Some farmers in these regions have introduced leguminous plants such as peas due to their nitrogen-fixing ability. However productivities are usually very low and crops are not always harvested (CCE, 2014).

[2] « veza » in Spanish ; a leguminous crop.

Rainfall is generally considered the limiting factor in reducing fallow periods; traditionally, an annual rainfall less than 300 mm was considered insufficient to be able to reduce fallow period because there were no identified crops, leguminous or otherwise, that would result in stable grain or fodder yield. Between 300-450mm, there are possibilities for reducing fallow periods, such as using leguminous crops (Fernández-Quintanilla, 1975).

However, while intecropping of oilseed crops (like sunflower and rapeseed) and cereals is a common practice in more fertile and humid regions, it is practiced only to a limited extent in semi-arid regions because of their low productivity. In fact, intercropping between barley and oilseed or leguminous is done in a very limited manner in the driest regions. This is shown, for example, by the crop rotation survey data for the harvest years 2012-2013 (Table 2-3). Murcia and Aragón, with some of the most arid cereal land in Spain, produce a very limited amount of leguminous and oilseed crops in rotation with cereal. Castilla La Mancha and Castilla y León have higher levels of cereal-oilseed or cereal-leguminous rotations, but still around 10-15% for oilseed, and less than 10% for leguminous crops.

Table 2-3: 2012-2013 main crops and crop rotations in semiarid cereal producing autonomous communities

Autonomous community	2012 crop	2013 rotation	
Murcia	Barley	3%	Wheat
		32%	Barley
		44%	fallow
		0%	leguminous
		0%	oilseed crops
	Wheat	30%	wheat
		20%	Barley
		34%	Fallow
		0%	leguminous
		0%	oilseed crops
Aragón	Barley	10%	wheat
		48%	Barley
		25%	Fallow
		3%	leguminous
		1%	oilseed crops
	Wheat	28%	wheat
		18%	Barley
		35%	Fallow
		2%	leguminous
		1%	oilseed crops
Castilla la Mancha	Barley	29%	barley
		30%	Fallow
		7%	leguminous

		15%	sunflower
	Wheat	14%	Wheat
		15%	Barley
		39%	Fallow
		7%	leguminous
		6%	sunflower
Castilla y León	Barley	12%	Wheat
		46%	Barley
		12%	Fallow
		4%	leguminous
		12%	sunflower
	Wheat	36%	wheat
		20%	barley
		15%	Fallow
		3%	leguminous
		11%	sunflower
	Fallow	24%	Wheat
		12%	Barley
		39%	Fallow

2.3 Relevant agricultural policies

2.3.1 Program for the promotion of crop rotations in dryland agriculture

The Spanish Ministry of Agriculture implements the directives of the EU Common Agricultural Policy. Under the *National Program for the Promotion of Crop Rotations in Dryland Agriculture* (Programa Nacional para el Fomento de Rotaciones de Cultivo en Tierras de Secano, **PNFR**), minimum fallow indices are stipulated. For dryland (non-irrigated) regions with regional yield indices (Índice de Rendimiento Comarcal, IRC) of less than 2 t/ha, there are minimum fallow indices that producers need to respect to obtain the full subsidy receivable under PNFR (

Table 2-4).

If the percentage of fallow land implemented by a farmer is smaller than the one stipulated under PNFR, a producer's subsidy is adjusted downwardly accordingly. Under the regulation, fallow land can have a cover crop, but the crop is not to be harvested for sale or seed production; it can, however, be grazed (BOE, 2014). However,

Figure 2-2 shows that the fallow indices applied in many semi-arid regions are well above the minimum fallow index established by the government. Effectively, the reason for such high incidence of fallow is the limitation to productivity caused by limited rainfall and limited soil quality.

Table 2-4: Minimum fallow index (BOE, 2014) (MAGRAMA, 2009)

Yield (t/ha) ("IRC" acronym in Spanish)	Minimum fallow hectares per 100 ha receiving PNFR subsidy ("IBS" acronym in Spanish)
1,2	25
1,5	20
1,8	15
2,0	10

An additional requirement to obtain the full subsidy amount under PNFR (60 euros/ha) is to dedicate *20% of agricultural land to an oilseed, "proteaginous", or "leguminous" crop* (BOE, 2014). For instance, in order to encourage crop rotations in dryland agriculture, In 2011/12, Spain specifically directed €50M for the implementation of rotation schemes between cereals and oleaginous, proteaginous, and leguminous plants; over fifteen-thousand producers benefitted from this aid, comprising a total of around 670,000 ha, nearly 70% of which was located in Castilla la Mancha and Aragón Autonomous Communities (Vida Rural, 2012).

2.3.2 Greening

Furthermore, "greening" policies aim to improve the environmental impact of farming systems and impose additional requirements to agricultural areas that qualify for CAP subsidies. The most relevant aspects of this policy, which comes into effect in 2015, are the requirements for diversification; preservation of existing permanent pastures; and implementation of ecological interest surfaces or SIE (MAGRAMA, 2014).

- **Diversification:** Requirement to cultivate 3 or more different crops (2 or more if the area is less than 30 ha). Different botanical geni and species count as "differentiated" under the regulation (e.g., cereals like barley, wheat, corn, etc.; brassicaceae like cauliflower, broccoli, etc.) Furthermore, fallow land also counts as a “crop” towards diversity. Spring and winter crops are also differentiated, but not if they occupy the same area of land

- **SIE:** Requirement to dedicate at least 5% of arable land to SIE, where the following categories count as SIE: fallow, forested land, agroforestry, or nitrogen fixing crops (1.43 ha nitrogen fixing crops counts as 1 ha SIE).

The government thus intends to encourage diversification, low intensity practices, and semi-natural areas in order to enhance ecosystem services provided by agriculture. The alternative to produce nitrogen fixing crops is considered to result in fewer ecological benefits than the SIE other categories.

2.4 *Camelina Sativa*: Background

Camelina sativa is a flowering plant in the mustard family (Brassicaceae) and is usually known in English as camelina, gold-of-pleasure, or false flax, also occasionally wild flax, linseed dodder, German sesame, and Siberian oilseed. It is native to Europe and to Central Asian areas. This plant is cultivated as oilseed crop mainly in Europe and in North America (Wikipedia, 2014).

2.4.1 Historical, current and potential uses

Camelina was first cultivated in northern Europe during the Bronze Age for food, medicinal use, and lamp oil. Camelina is native from Finland to Romania and east to the Ural Mountains. Although it was widely grown in Europe and Russia until the 1940s, camelina was largely displaced as higher-yielding crops became available after WWII. Its decline in Europe was accelerated by farm subsidy programs that favored the major commodity grain and oilseed crops and high yields (PSU, 2010). Camelina is a relatively common weed in much of Europe; globally it is produced in small quantities for commercial use, mainly in the US and Europe. At this point it is considered a developing market (PSU, 2010).

Interest in expanding camelina production include uses as a low-cost feedstock for biodiesel and a premium meal value-added product for animal feed that can be used to produce high omega-3 eggs, broilers, or dairy products. Given its high content in omega-3 oils and tocopherol (Vitamin E), it would appear to have a good potential as an edible oil. However, given its high contents of glucosinolates (sulfur containing compounds) and erucic acid (22:1), the meal market is currently limited, with only certain specified recent approvals for animal feeding.

Camelina oil also contains unusually high levels of cholesterol, which has been mentioned to be a strong barrier for human consumption (CCE, 2014). For instance, (Shukla, Dutta, & Artz, 2002) find that it has 188 ppm of cholesterol, vs. lower levels for other high-cholesterol oils such as cocoa butter (59 ppm), coconut oil (23 ppm), linseed oil (42 ppm), palm oil (26 ppm) and palm kernel oil (40 ppm). In contrast, because of its high concentration in Omega-3 acids, and in particular alpha-linolenic acid, Camelina oil has been found in one study to have lowering effects on “bad” (LDL) cholesterol in humans comparable to the cholesterol-lowering effects of rapeseed and olive oils (Karvonen, Aro, Tapola, Salminen, Uusitupa, & Sarkkinen, 2002). Thus, its potential use for human consumption is not ruled out and has spurred research activities to breed varieties with oil composition of commercial interest. A 2007 research paper refers to it as a “crop with promising food and non-food applications due to an unusual fatty acid composition of its seed oil" (Vollmanna, Moritza, Kargla, Baumgartnerb, & Wagentristl, 2007).

Camelina also has a value as animal feed. The byproduct of camelina oil production is camelina meal, a high quality protein animal feed. Camelina meal has recently been approved in 2009 in the US for feeding to broilers and beef at levels up to 10 percent, while in 2011 camelina meal has been included in the EU Catalogue for animal feed. Camelina meal, as approved, will compete primarily with the flax (or linseed oil) markets, due to the omega-3 oils it contains (PSU, 2010). For instance, pigs whose diet had been supplemented with camelina oil were found to have reduced blood lipid levels (Eidhin, Burke, B.Lynch, & O'Beirne, 2003).

2.4.2 Economics

Refinements of existing commercial technologies that enable the isolation and extraction of camelina's oil components could have a significant positive economic impact. The value is theoretically comparable to that of canola (10–20 US cents per pound or US $5–$10 per bushel) (PSU, 2010).

Like other oilseed crops, camelina offers some rotational and legume cover cropping opportunities that justify its economic competitiveness. In the northeastern US, it has been experimented with as an early harvested spring crop in a rotation with corn, followed by a red clover crop following camelina harvest to provide nitrogen and prepare a field for corn production in the following year (PSU, 2010).

Since the drastic reduction in cereal and sunflower prices in the last two years, camelina has become more competitive, though it generally results in fewer net revenues than cereal and other oilseeds. However, the equation may change in bad weather years. For instance, on a particularly dry year in which rapeseed oil yields were very low, camelina yields were steady, and a producer stated that the only crop that resulted in positive revenues was camelina (personal communication, producer in Guadalajara, January 2015).

In Spain, camelina crop is still not traded in markets, and therefore it has not yet attained a market price. This may change in the future if production increases.

2.4.3 Agronomy

While camelina is generally grown as an early summer annual oilseed crop, it can be grown as a winter annual in milder climates. It is a shortseason, cool climate adapted crop that matures in 85–100 days. It germinates at low temperature, and seedlings are very frost tolerant. The plant performs well under drought stress conditions and is thought to be better suited to low rainfall regions than most other oilseed crops (PSU, 2010). Trials in Pennsylvania, US have shown that it has not performed well on wet and poorly drained soils (PSU, 2010). Its adaptation to drought conditions helps explain its attractiveness as a potential cover crop in dryland agricultural regions.

2.5 Integration of Camelina rotations in Spain's semi-arid agriculture

2.5.1 The potential of camelina sativa as a rotational crop in arid and semi-arid agriculture

As stated above, Camelina is a relatively hardy and non-demanding crop in terms of water and fertilization requirements. It can be grown and harvested with current commercial machinery employed for cereal crops. Additionally, camelina can be cultivated with little land preparation (CCE, 2014). This makes it well-suited for arid regions with ongoing problems of low productivity and erosion. It also potentially makes camelina a low-cost and low-GHG emissions crop, given that it is claimed to require moderate machinery and fertilization (CCE, 2014).

Due to these characteristics, camelina seems to have a good potential as a rotational oilseed crop produced in a rotation scheme with a cereal crop, reducing in this way the duration of fallow periods. Unlike more productive, but also more input-intensive crops such as sunflower and rapeseed, camelina may be more easily and readily integrated as a rotational crop in arid regions.

Indeed, Spain could have a large potential to introduce camelina plantations as a rotation crop with traditional cereal in the arid dryland farming areas. According to the Spanish Ministry of Agriculture (MAGRAMA), Castilla La Mancha (South-East) and Aragón (North-East) present 1.5 million hectares of fallow land in arid and semi-arid dryland regions every year.

The benefits of crop rotations on biodiversity and soil health are well known. Rotations with a leguminous plant are especially beneficial given its nitrogen fixing characteristics, which is likely to reduce subsequent fertilizer use. The greening subsidies in the CAP are precisely geared towards increasing rotation schemes, and indeed fallow land is considered a diversified category in a rotation scheme. The benefits of fallowing reside in the higher soil moisture and nutrient retention potential of soil. The potential negative impacts of fallowing include increased erosion rates and loss of soil organic matter, especially if the land does not have a cover during the fallow period and if traditional (as opposed to minimal) tilling methods are employed. Fallowing can thus result in substantial loss of soil quality. The elimination of fallow periods could therefore be beneficial for erosion control purpose, but so would the implementation of minimum tilling practices and maintaining a soil cover.

2.5.2 Rough estimation of camelina production potential in arid regions

To provide an order-of-magnitude estimate of camelina potential in Spain, we used the following assumptions:

- Camelina is planted in dryland cereal-producing regions with annual average rainfall between 300-400 mm, i.e., they do not receive enough rain to grow a more lucrative oil crop, such as sunflower; these regions produce cereal as their main herbaceous agricultural crop, and in particular barley in larger quantities than wheat. They are also characterized by large fallow indices. In particular the following provinces stand out: Albacete (Castilla La Mancha) and Murcia (Murcia); to a lesser extent also: Toledo and Ciudad Real (Castilla La Mancha), and Huesca (Aragón).
- Camelina is planted in dryland (non-irrigated) areas;
- Camelina replaces a percentage of the fallow periods in cereal rotations; in the estimation below, we assume replacement of 1 fallow period out of 2, or 50% of fallow. This is a high estimate and just for the purpose of obtaining an order-of-magnitude approximation.

Table 2-5: Dryland agriculture: Main provinces identified in this study as having theoretical potential for camelina, and order-of-magnitude estimation of camelina potential based on an assumption of 50% of fallow replacement [dryland ha]

	Cereals	Leguminous	Tuberculous	Industrial*	Forage	Vegetables	Total herbaceous	Fallow*	Fallow %	Fallow Replace-ment (calc'd)
HUESCA	212098	11171		1728	23449	34	248480	67920	27%	33960
ZARAGOZA	291732	15897	2	5877	10801	45	324354	218712	67%	109356
ALBACETE	254693	29889	26	2981	2886	159	290633	175427	60%	87713.5
CIUDAD REAL	271002	13917		646	12889	1087	299540	264237	88%	132118.5
TOLEDO	289162	24697	2	1920	21168	154	337103	205087	61%	102543.5
MURCIA	63194			249	242	2604	66289	79720	120%	39860
Total										505552

Source (columns 1-8): (MAGRAMA, 2013); * the vast majority of "industrial" is sunflower.
*Fallow % represents the fraction of fallow with respect to total cultivated land. Values larger than 100% represent regions where there is more fallow land than cultivated land; this is not uncommon in dryland regions.

With an estimated yield of 800 kg/ha of camelina seed, and an approximate oil content of 35%, yielding about 280 kg/ha, this would be equivalent to a high estimate of 140,000 tons of oil. Note that this is a very rough estimate. It assumes production in only the driest regions, but it also assumes an unrealistically high level of camelina penetration.

2.5.3 The Camelina Company España (CCE) Model

Camelina Company España (CCE) is a Madrid-based company that focuses on the promotion of camelina plantations in some of Spain's semi-arid agricultural regions. CCE contracts with farmers, supplying camelina seed and purchasing farmers' total camelina production. CCE engages directly with farmers throughout the agricultural production cycle, providing technical support, and encouraging certain low-impact management practices such as minimal tilling. CCE has established a sustainable camelina processing value chain, leveraging on existing infrastructure, for the production of camelina oil and meal.

The oil produced in such CCE value chain is non-food grade and is sold at this point exclusively to the biofuel industry. The camelina meal is sold to the animal feed sector at a price competitive with rapeseed meal.

2.5.3.1 Location

CCE contracts with farmers located in various Spanish provinces, but mainly focusing on the provinces of Albacete, Cuenca, Guadalajara and Zaragoza – see Figure 2-1.

The provinces of Albacete (Castilla La Mancha) and Zaragoza (Aragón) can be considered to be on the arid end of the spectrum, where annual rainfall usually ranges between 300 and 400 mm. Cuenca and Guadalajara (Castilla La Mancha) have greater rainfall; the regions targeted by CCE are around the 400-600 mm rainfall geographic area.

2.5.3.2 Theoretical rotation schemes

A typical camelina production scheme involves introducing the crop into the existing cereal rotation scheme. Camelina is typically a winter crop in Spain, being planted in October/November, and harvested around June. It can also be planted in Winter (January-March), which would result in a shorter growth period.

In arid land

In Albacete and other arid regions, a common agricultural practice consists of cultivating traditional cereal (mainly barley or wheat) followed by a fallow period of one year. In these regions, leguminous crops have poor yields and are produced in small numbers, mainly due to their nitrogen-replenishment capacity. The same can be said for typical oilseed crops such as rapeseed and especially sunflower seed, which are hardly produced in arid regions. The rotation scheme implemented by CCE with camelina involves replacing all or some of the fallow periods with camelina production. Various rotation possibilities are described below.

For instance, all fallow periods could in theory be replaced by camelina plantations (Rotation 1, below). However, in practice, it may not be advisable to fully replace all fallow land or fallow periods with camelina plantations. The necessity of a fallow period depends mainly on the amount of moisture that can be available for the next crop. In areas or years where moisture is really low, introducing some fallow periods could be necessary. In addition, the fallow period, especially when it involves keeping a cover on the soil, allows for the soil to replenish its nutrients and biological activities. Therefore, a similar rotation scheme can be performed including fallow land periods every x years, depending on moisture availability (Rotation 2).

After a dry year, it may be more recommendable to leave the land fallow after a cereal crop, although planting camelina has the advantage that it reduces weed proliferation and thus the need for tilling or herbicide application.

Alternatively, camelina could be intercropped with cereal production, as well as with a leguminous crop for nitrogen replenishment due to the nitrogen-fixing characteristics of leguminous crops (Rotation 3). From an environmental perspective, this is the ideal rotation scheme, given that some of the nutrient replenishment activities are performed biologically (i.e., through nitrogen fixing crops) rather than chemically through mineral fertilizer inputs.

Though the yield of the leguminous crop may be very low and it may not be worthwhile to harvest it, farmers still plant leguminous crops occasionally because their nitrogen-fixing ability reduces fertilizer requirements and increases cereal yields in subsequent years.

Figure 2-3: Typical rotation scheme in Albacete and rotation schemes proposed by CCE

Typical rotation scheme in Albacete

Year	Crop	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	Barley												
2	Fallow												
3	Barley												
4	Fallow												
5	Barley												

Rotation scheme with Camelina 1: Full fallow replacement

Year	Crop	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	Barley												
2	Camelina												
3	Barley												
4	Camelina												
5	Barley												

Rotation scheme with Camelina 2: Partial fallow replacement

Year	Crop	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	Barley												
2	Camelina												
3	Barley												
4	Fallow												
5	Barley												

Rotation scheme with Camelina 3: Ideal rotation scheme incorporating camelina and a leguminous

Year	Crop	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	Cereal												
2	Legume												
3	Cereal												
4	Camelina												
5	Cereal												

It should be kept in mind that the above figure is a simplified schematic that does not reveal the full picture of crop rotations. In reality, a producer with a certain amount of land, which could be broken up in various parcels, is annually faced with the question of what to plant, and where. The decision is based on weather, what was planted the previous years, the quality of the soil (which is often heterogeneous throughout the producer's parcels), market conditions, regulations such as the CAP, the producer's machinery (e.g., direct seeding requires specialized equipment that not all producers possess), and local and regional norms and customs, among other things.

Following CAP requirements, a producer will dedicate at least the required minimum to meet the 5% ecological interest surface area (generally through planting a leguminous crop or leaving the land fallow) and the minimum fallow index, if applicable. The rest of the parcels follow rotation schemes that vary depending on the region (and thus depending on the weather), and which are in part also determined by the CAP's minimum diversification requirements. Generally, a larger portion of the land is dedicated to cereal, and a smaller portion of the land dedicated to fallow and a leguminous crop.

In arid contexts, leguminous crops have very low yields, and sometimes they are planted simply for their nitrogen-fixing properties, but the crop is not harvested if yields make the harvest non-economical[3]. Camelina can thus present an interesting additional crop to add to rotation scheme. This is also highlighted in the case study (below).

[3] Personal communication with cereal cooperative, Albacete, Spain. December 2014.

In semi-arid land

In less arid regions, the typical fallow index is smaller. In those regions where sunflower seed oil is not feasible due to low rainfall, rapeseed oil is a common oilseed variety cultivated in rotation with cereal. In these regions, Camelina can be introduced as an additional rotation crop.

A typical rotation scheme could be: Cereal-legume-cereal-oilseed-etc.

In the above scheme, camelina and rapeseed can be alternated as oilseed crops. This is typical of semi-arid regions like Guadalajara. This is also highlighted in the case study (below).

Productive vs. less productive land parcels

It is important to note that, within the same region, a producer may own a property with more and less productive areas, with different quality soils and thus different productivity levels. Rotation schemes will be different in different areas of the parcel. For instance, in Guadalajara, a portion of the property (say, 30-50%, or more) may be dedicated to barley-sunflower oil seed production. The rest of the parcel may be dedicated to the cereal-camelina rotation scheme mentioned above (CCE, 2015).

Sunflower seed is planted in march-april and is considered more risk-prone than crops planted in Autumn, given that rainfall in the Spring is becoming more erratic. Thus, in the future, and due to climate change, winter oilcrops like camelina may be at an advantage compared to spring oilcrops.

2.5.3.3 Agricultural practices encouraged by CCE

CCE works closely with its contract farmers and provides guidance and suggestions on preferred agronomic practices to grow the camelina crop. Some of the practices suggested by CCE have induced changes in the overall management practices of producers (CCE, 2015). For instance, CCE encourages minimal tilling (<20 cm) or no-tilling; some producers have switched from traditional tilling to no-tilling (a.k.a. direct seeding) since introducing camelina in their rotations. The advantage of less or no tilling is the reduction of soil erosion and the likely reduction in soil nutrient loss as a result of less erosion. The disadvantage is the increased amount of weeds, which need to be controlled with increased doses of herbicide.

CCE also encourages the use of certain nitrogenated fertilizers such as urea or ammonium sulfate that result in less nitrate runoff. In addition, as a result of introducing camelina in cereal-fallow rotation, weed resistance is diminished, generally resulting in less herbicide use (CCE, 2015).

2.6 Camelina production case studies: Albacete and Guadalajara

Two Spanish camelina producers with a contractual relationship with CCE were interviewed about their experience producing camelina. The producers are located in two characteristic regions targeted by CCE for camelina production, namely Albacete, less productive and more arid, and Guadalajara, more productive due to higher rainfall.

2.6.1 Albacete case study

An Albacete producer, Juan Andrés, was contacted by phone in January 2015. He has been producing camelina for four years, normally dedicating 100-150 ha to camelina production out of the total of 1000ha. In the words of this producer, it is impossible to implement cereal-cereal schemes because the land is not productive enough, and because weeds resistance becomes a very big problem if crops are not rotated. Fallow is an alternative, but it is not ideal, since it leads to erosion. Camelina has thus been an "interesting" alternative for this producer, who has introduced camelina in the cereal rotation and has reduced fallow to a minimum, just enough to meet CAP requirements (5%); if it were not for this requirement, he would replace all fallow with camelina. This has resulted in less tilling and less consumption of herbicides. Prior to the introduction of camelina, leguminous crops were introduced in the cereal rotation scheme, but harvests were very low due to low rainfall characteristic of the area.

While leguminous crops have the advantage of being nitrogen fixing, thus replenishing soil nutrients, and hence being more preferable than leaving the land fallow, planting leguminous crops entails a certain risk, in his opinion, given the high possibility that the yield will be low. Thus, camelina has been a welcome addition to this producer's rotation scheme. An additional advantage of camelina is its long root system (longer than for cereal crops), which reduces fertilization and rainfall requirements and renders is hardier. Thus a typical rotation scheme now looks like: barley-wheat-camelina-etc. with occasional leguminous crop plantings.

While one section of the property is classified as having a yield index less than 2 tons (the policy threshold determining certain minimum fallow requirements, see above), this fact has not influenced the introduction of camelina as a rotation crop.

The producer emphasized the limited options available in Spain's arid dryland agriculture. Producers are faced with the question of what crops to introduce in their cereal rotation, and options are very limited. Sunflower seed does not grow, and neither does rapeseed in that area. Fallowing is an option, but with the above-mentioned disadvantages. Leguminous crops have very poor yields. Since the CAP incentivizes the production of three different crops (fallow is considered as a crop), camelina works well as a third crop in the rotation scheme.

The producer has recently been innovating and testing no-till agriculture, which requires a different seeding machine.

With respect to data gathering, this producer typically maintains data on annual tons of production for each crop produced, and average yields per crop for his property.

2.6.2 Guadalajara Case Study

A 700ha property in Guadalajara, managed by the agronomic company Gesitec, was visited in January 2015. The property is mainly dedicated to the production of cereal (barley and wheat), with around 10% of the area dedicated to rapeseed oil, and another 10% dedicated to camelina. The typical rotation scheme is as follows:

Wheat-barley-oilseed (camelina or rapeseed)-wheat-barley-leguminous-etc. OR

In this context, camelina and rapeseed are almost interchangeable. While rapeseed has a greater market price and higher yields, it also requires more inputs, and is thus more expensive to produce. In addition, in low-rainfall years, rapeseed yields drop significantly, while camelina may continue to be productive. Hence, camelina is increasingly interesting to this producer, especially since rainfall is becoming progressively more erratic.

This producer practices direct seeding (no-till), having purchased a specialized machine a couple of years ago. For weed control, they use glyphosphate.

With respect to data gathering and record keeping, the management company keeps detailed data on each parcel's production, yield, and destination of grain (e.g., sale vs. conditioning and replanting).

2.7 Displacement and indirect impact considerations

2.7.1 Weak and strong conditions of low ILUC risk: Examples

From our discussion in Section 1, a "**strong condition**" for causing a low risk of ILUC is as follows: "Biofuel feedstock production can be demonstrated to cause no displacement of existing provisioning services, such as food, feed and fiber".

In the case of camelina production in Spain, a strong condition for causing low ILUC risk is therefore that the *introduction of camelina in a rotation scheme does not result in a reduction in production of other crops*. I.e., the introduction of camelina does not substitute a prior food or feed crop, *and* it does not lead to lower yields of food/feed crops in years following camelina production. In the examples mentioned above, this would be the case if the introduction of camelina strictly displaces only fallow land, and if the introduction of camelina does not result in lower cereal yields in years following camelina production.

Also from our discussion above, a "**weak condition**" for causing a low risk of ILUC is as follows: "If feedstock production results in a small amount of displacement of existing provisioning services, then the production of the biofuel feedstock should compensate the loss of provisioning services by exactly substituting them".

This could be the case, for instance, if camelina is planted as a substitution of a fallow with spontaneous cover, where the previous practice had been to graze the cover. The same function could perhaps be fulfilled if camelina stubs are grazed by animals (granted that the stubs provide the same nutritional functions as the prior spontaneous cover, which would need to be assessed).

This condition can be tested for the case where camelina replaces other crops in a rotation scheme; for instance, if camelina is planted instead of rapeseed or instead of a leguminous crop. If camelina is planted instead of rapeseed in a rotation scheme, it can be assumed that the camelina meal will fulfil more or less the same function of the rapeseed meal, i.e., animal feed[4].

[4] To be perfect substitutes, camelina and rapeseed meal would need to have the same nutritional yields, including macro (e.g., proteins) and micronutrients (e.g., vitamins, Omega-acids, etc.) While the protein content is similar [(Cherian, 2012); (Rutkowski, 1971)], their nutritional value is different due to different levels of beneficial elements, e.g., high Omega-3 and tocopherol in camelina meal (Cherian, 2012) and detrimental elements, e.g., high fiber and glucosinolate level in rapeseed meal (Rutkowski, 1971). Thus, both meals are not directly comparable, but generally speaking, both are used as animal feed and are thus relatively substitutable.

The question is whether camelina oil can replace rapeseed oil. If camelina oil is used for biofuel production, and rapeseed oil was previously used as biofuel feedstock as well, then both feedstocks entail the same (non-zero) risk of ILUC. If rapeseed oil was being used for human consumption, then its displacement causes additional risk of ILUC. In either case, camelina cannot be said to be free of ILUC risk in this particular example.

2.7.2 ILUC risk discussion

Camelina production can thus entail a different ILUC risk depending on the context of its cultivation. Camelina as a replacement of fallow land, be it through direct seeding or in traditional rotation cycles, could be a promising option to increase the overall productivity and economic activity in arid regions that are otherwise characterized by low productivities and very low agricultural margins. However, camelina production should not result in a net reduction of the production of other crops, including cereals, leguminous crops, and other oilseed crops. Put differently, in order to be qualified as a “zero-ILUC crop”, the introduction of camelina should result in a net reduction of fallow land while maintaining previous production of food and fodder crops, and while maintaining (or increasing) the productivity of the land – i.e., the production of camelina should not result in lower land productivity in future harvests. Thus, replacing fallow land with camelina should not result in lower yields of the subsequent cereal crop. Similarly, replacing leguminous crops with camelina, which is not a nitrogen-fixing crop, could entail fewer natural addition of nitrogen to the soil. A “zero-ILUC” addition of camelina to a rotation scheme should take these factors into consideration. An important benefit of producing camelina (or other oilseeds such as rapeseed) in Europa is that it reduces the pressure to import soybeans as animal feed. Furthermore, the camelina oil directed to biofuel production could potentially substitute some of the vegetable oil imports (largely soybean from Brazil and palm oil from Malaysia) that are currently dedicated towards the production of biofuel.

However, in those instances where camelina is planted interchangeably with other oilseeds such as rapeseed (e.g., in regions where oilseed crops have traditionally been part of the rotation scheme), it can no longer be stated that camelina has a low risk of ILUC.

It is also worth noting that market conditions may change in the future. For the moment, Camelina is envisaged as a crop that can be introduced in cereal (barley, wheat) rotations in arid and semi-arid regions. Camelina is not a crop that is currently produced in more fertile and humid regions, or in irrigated areas. However, market conditions could change, and camelina could become cost-competitive with higher value food crops and potentially result in their partial displacement.

As the examples above show, the micro-level processes that lead to global-level ILUC through displacement dynamics depend on the specific context and should be assessed case-specifically. This can be done through a project-based certification of low ILUC, which is similar, for example, to certifications of additionality done in the context of carbon markets. However, it would be cost-prohibitive to assess the ILUC risk of all camelina operations in a particular region or in all of Spain, unless all producers were willing to undergo an assessment of displacement.

At a more macro-level, it is also possible to assess displacement and shifts in production, in retrospect (*a posteriori*). Such an assessment would need to determine whether the prior production of a feed or food crop in a region has been displaced by a growing production of camelina, and to what extent the displacement has been substituted by camelina by-products. In evaluating displacement, the historical (5 or 10 year) trend in previously existent production of food, feed and fiber should be assessed. The following trends are generally in line with low ILUC risk:

- Production ***growth rate*** of existing food, feed and fiber crops is steady or rising.
- Exports of existing food, feed and fiber crops is steady or rising.
- Imports of existing food, feed, and fiber crops is steady or decreasing.

2.8 Potential positive and negative direct impacts

As a replacement crop for fallow, camelina could take up moisture and nutrient resources from the soil, thus potentially lowering the yield of the subsequent cereal or legume crops. The result could potentially be a higher need for fertilization rates of the cereal or legume crops. However, there are important advantages to planting a living cover crop instead of leaving the soil as “traditional fallow”, which means it undergoes regular tillage at the end of the fallow period and is not covered by a cover crop. Around 50% of fallow land in Castilla La Mancha, for instance, is “traditional fallow”. Such land is prone to erosion and nutrient leakage. Having a cover crop has been shown to address these two issues; thus planting a crop instead of fallowing the land may have positive impacts on soil carbon and nutrients. It is important that agronomic studies be carried out to evaluate the impact of fallow replacement by camelina on soil moisture levels, nutrient leaching, bioavailable nutrients, and carbon content.

Furthermore, planting a cover crop is beneficial from the point of view of soil carbon, given the addition of organic matter through root growth, and as long as minimal tillage is employed.

From a perspective of chemical input usage, planting camelina will result in nitrogen and pesticide applications that would not have taken place during a fallow period. Thus, its impact on biodiversity may be adverse. Yet on the other hand, camelina is a flowering plant and thus presents pollination potential and potentially habitat for other beneficial insects. Thus, again, its direct impacts should be the subjected to further analysis in field trials.

2.9 Documentation and verification

Documenting and proving that camelina has not resulted in net displacement can be done at different levels. Using agricultural census data, crop production can be assessed over a historical period, ideally over the previous 5-10 years, to assess trends and shifts. This it is relevant to contrast this with shifting imports and exports of commodities to identify how these correlate with the changing agricultural landscape. This is, of course, an approach *a posteriori*.

A priori, it is difficult to prove that the production of a certain crop will not negatively affect global land use change. Such an assessment is generally performed by looking at historical trends at a concrete location, and within a concrete context, and extrapolating future production based on historical data. If the planned change in production (e.g., introduction of camelina) results in no displacement compared to the projected trend, then the estimated ILUC risk is minimal or zero.

This is the approach employed, for instance, in the Low Indirect Impact Biofuels (LIIB) methodology (LIIB, 2012). LIIB identifies four biofuel production pathways, in line with the "low ILUC" categories listed in Section 1, which have a certifiably low risk of causing indirect impacts related to displacement of provisioning services. The methodology outlines the project acceptance requirements, the baseline calculation methodology, and the calculation and monitoring methodology to determine the amount of LIIB-compliant biofuel in a given biofuel project. I.e., this methodology is intended assess the level of ILUC risk posed by a concrete project.

It is in principle possible to apply a similar approach to the camelina scenario discussed above. For instance, a farmer's 5-year production history could be ascertained from their CAP documentation, which specifies acreage planted per land use type. However, the CAP documentation does not specify production in terms of mass or volume.

3 Production of biofuel feedstock in contaminated land – case study of Romania

3.1 Degraded and contaminated land in Romania

Romania's total surface comprises 23.8 million hectares, out of which 14.8 million hectares are agricultural land and 6.7 million ha are forested areas (EPA, 2000). Around 95% of agricultural land is comprised of arable land, pastures, and hayfields; the rest being dedicated to vineyards and orchards (ANPM, 2011).

A national-level research on soil quality carried out in Romania between 1994-98 and cited in a report on the state of the environment prepared by the Romanian Ministry of the Environment in 2011 found that soil degradation to a larger or smaller extent affects 12 million hectares of agricultural land, of which approximately 7.5 million hectares of arable land (about 80% of the arable surface) (ANPM, 2011). Agricultural land is classified according to five class categories corresponding to the level of soil quality damage, from slight (Class I) to excessive (Class V). The worst of this soil degradation categories corresponds to soil that is "practically unproductive" (ANPM, 2011).

Table 3-1: Classification of agricultural land into quality classes. Adapted from: (ANPM, 2011)

	Total mapped area	Quality Class					
		Class I	Class II	Class III	Class IV	Class V	
Usage category	ha % of total	ha % of total	ha % of total	ha % of total	ha % of total	ha % of total	ha % of category
Arable	9242977	591776	2641198	3555901	1776952	677150	
	100%	6%	29%	38%	19%	7%	63%
Pastures & Hayfields	4801491	86426	413535	1322148	1832571	1146811	
	100%	2%	9%	28%	38%	24%	33%
Vineyards	264248	8113	64106	82171	84235	25623	
	100%	3%	24%	31%	32%	10%	2%
Orchards	248509	1728	26279	80483	105338	34681	
	100%	1%	11%	32%	42%	14%	2%
Total agrarian	14557225	688043	3145118	5040703	3799096	1884265	
	400%	5%	22%	35%	26%	13%	100%

According to the same pre-1998 report, physical-chemical and chemical pollution of the soil affects about 0.9 million ha.

Table 3-2: Surface of agricultural land affected by degradation (ANPM, 2011)

Name of the factor	Affected surface* (thousand ha)	
	Total	Arable
Drought	7,100	
Periodical excess of humidity in the soil	3,781	
The erosion of the soil by water	6,300	2,100
Landslides	702	
The erosion of the soil by wind	378	273
Excessive frame on the surface of the soil	300	52
Salting of the soil	614	
• of which with high alkalinity	223	135
The secondary consolidation of the soil due to improper works ("plough sole")	6,500	6,500
The primary consolidation of the soil	2,060	2,060
Formation of the crust	2,300	2,300
Small/extremely small reserve of humus in the soil	7,485	4,525
Severe and moderate acidity	3,424	1,867
A poor and very poor supply of mobile phosphorus	6,330	3,401
A poor and very poor supply of mobile potassium	787	312
A poor supply of nitrogen	5,110	3,061
A lack of microelements (zinc)	1,500	1,500
The physical-chemical and chemical pollution of the soil, of which:	900	
• pollution with substances carried by the wind	363	
• the destruction of the soil by various excavations	24	
Covering of land with wastes and solid residues	18	

The most important sources of soil pollution identified by the Research Institute for Soil Science and Agro-chemistry (RISSA) are as follows (Simule, Rozenberg, & Baga, 2010):

- Soil pollution and degradation due to mining activities;
- Pollution caused by discharge ponds and non-compliant landfills;
- Pollution by inorganic waste (minerals, metals, salts, acids, alkaline);
- Soil impurities caused by airborne substances (hydrocarbons, ethylene, ammoniac, sulfur dioxide, chlorine, fluorine, nitrogen oxides, lead, etc.); and
- Pollution by salty water and oil from oil industry.

In particular, pollution from mining activities is mostly due to heavy metals pollution (especially Cu, Pb, Zn, Cd) and sulphur dioxide. The most critical areas are Baia Mare, Zlatna, and Copsa Mica (ANPM, 2011). Furthermore, degradation by soil impurities caused by airborne substances affects 0.363 million ha (ANPM, 2011).

An illustrative case is the bioremediation of the Copşa Mică contaminated land area. Copşa Mică is the location of one of the most important non-ferrous ore processing plant, operated by S.C. Sometra S.A., and it has been listed as one of the “World’s Worst Polluted Places” due to high cadmium levels in the soil (RECARE, 2014). Other pollutant heavy metals include copper, lead and zinc (RECARE, 2014). The polluted areas where the pollutant content in soil (0-20cm) exceeds the alert thresholds for sensitive use of land include 7040 ha for zinc (content in soil exceeding 300 mg/kg); 10320 ha for cadmium (content in soil exceeding 3 mg/kg); 22565 ha for lead (content in soil exceeding 50 mg/kg) (RECARE, 2014).

While a number of industrial units that originally led to heavy metals pollution have been closed and others have reduced their activity, soil pollution remains high in the strongly affected areas (ANPM, 2011). In particular, direct soil damage by excavation (mining) works (categories 1 and 3 below) affects around 24,000 ha and it constitutes the most serious form of soil contamination; an example is the mining basin of Oltenia. This number, together with around 1,600 ha due to excessive soil pollution from air-transported particles (category 4 below) gives us an estimated 25,600 ha of soil with "excessive" damage. Adding up soils in the strong, severe, and excessive damage categories 1, 3 and 4 below yields an approximate 74,100 ha. Another important source of contamination is pollution from confined animal feeding operations. An estimated 5,000 ha are affected by this form of contamination (ANPM, 2011).

Another report by the Danish Environmental Protection Agency (EPA) cites the number of registered contaminated sites or contaminated land areas as 1634 sites in the year 2000, comprising a total of 164,000 ha (EPA, 2000). Nevertheless, this estimate is noted as being "provisional", and the report does not state the exact source of the numbers.

Table 3-3: Sources of soil degradation in Romania (ANPM, 2011)

General name of the processes		Code	Surface (ha) and degree of damage					
			Slight	*Moderate*	*Strong*	*Severe*	*Excessive*	***Total***
I	Diverse processes of soil pollution caused by industrial and agricultural activities	**1.** Pollution due to daily excavation works (daily mining exploitation, ballast-holes, careers, etc.).	2	16	255	519	23,640	**24,432**
		2. Pollution with landfills, heaps, sludge beds, mine dumps rubbish dumps etc..	247	63	236	320	5,773	**6,639**
		3. Inorganic wastes and residues (minerals, organic matters, including metals, salts, acids, alkalis), from industry (including the extraction industry)	10	217	207	50	360	**844**
		4. Substances carried by air	215,737	99,494	29,436	18,030	1,615	**364,348**
		5. Radioactive materials		500			66	**566**
		6. Organic wastes and residues from the food, light and other industries	13	19	12	17	287	**348**
		7. Agricultural and forestry wastes and residues	37	65	90	642	306	**1,140**
		8. Animal faeces	2,883	993	363	265	469	**4,973**
		9. Human faeces		689	11		33	**733**
		17. Pesticides	1,058	650	224	77	67	**2,076**
		18. Contaminated pathogenic agents		505			117	**617**
		19. Salted waters (from oil extraction)	952	497	408	205	592	**2,654**
		20. Oil products		473	248	5	25	**751**
		TOTAL I	**220,939**	**104,176**	**31,490**	**20,130**	**33,350**	**410,121**
II	Soils affected by slope porcesses and other processes	**10.** Superficial and deep erosion, landslides	944,763	1,013,854	749,420	454,150	210,729	**3,372,916**
		15. Primary and/or secondary compacting	543,371	544,556	251,268	125,555	88,526	**1,553,276**
		16. Pollution by sediments caused by erosion (mudding)	4,088	2,389	4,808	1,178	836	**13,299**
		TOTAL II	**1,492,222**	**1,560,799**	**1,005,496**	**580,883**	**300,091**	**4939491**
III	Soils affected by natural processes and/or anthropic processes	**11.** Salt soils (saline and/or alkaline)	264,163	80,639	52,488	36,867	50,678	**484,835**
		12. Acid soils	1,766,295	1,926,886	716,794	186,023	18,132	**4,614,130**
		13. Water excess	640,738	1,075,063	420,208	199,479	185,785	**2,521,273**
		14. Excess or deficiency of nutrients and organic matter	8,358,147	11,604,450	7,549,319	3,306,533	1,373,196	**32,191,645**
		TOTAL III	**11,029,343**	**14,687,038**	**8,738,809**	**3,728,902**	**1,627,791**	**39,811,883**
TOTAL			**12,742,504**	**16,352,013**	**9,775,795**	**4,329,915**	**1,961,232**	**45,161,495**

3.2 Remediation of contaminated sites

3.2.1 Overview

There exist various remediation and stabilization options for contaminated land, and broadly they can be classified as in-situ (on-site), where the remediation or stabilization takes place at the location of contamination, or ex-situ, where the contaminated land is excavated and removed to be treated elsewhere. In the year 2000, no facilities existed for the treatment of proper depositing of contaminated soil (EPA, 2000). In-situ remediation is thus likely a preferred strategy.

Indeed, biological reconstruction (bioremediation) of contaminated land is included as a priority in the Romanian strategy on environmental protection (EPA, 2000).

3.2.2 Phytoremediation

Phytoremediation is a relatively recent sub-field of bioremediation that uses plants to clean up pollutants (metals and organics) from the environment. Within the field of phytoremediation, the utilization of plants to transport and concentrate metals from the soil into the harvestable parts of roots and above-ground shoots is usually called *phytoextraction* (Garbisu & Alkorta, 2001).

Most existing remediation physicochemical technologies are meant primarily for intensive in situ or ex situ treatment of relatively highly polluted sites, and thus are not very suitable for the remediation of vast, diffusely polluted areas where pollutants occur only at relatively low concentrations and superficially (Garbisu & Alkorta, 2001). In this context, phytoremediation appears as a very valid option since it is best suited for the remediation of these diffusely polluted areas and at much lower costs than other methods. While the most heavily contaminated soils may not support plant growth, sites with light to moderate toxic metal contamination could be remediated by growing metal-accumulating plants (Garbisu & Alkorta, 2001).

Metal-enriched plants could be disposed of as hazardous material or, if economically feasible, used for metal recovery (Garbisu & Alkorta, 2001). Another potential use is as fuel for bioenergy or biofuel (Dimitru, 2014).

There are a number of categories of phytoremediation potentially useful for remediation of contaminated soils, including (Garbisu & Alkorta, 2001):

- *Phytoextraction*: the use of plants to remove contaminants from soils. Pollutant-accumulating plants are utilized to transport and concentrate contaminants (metals or organics) from the soil into the above-ground shoots; the term is mostly used to refer to metal removal from soils. In some cases, roots can be harvested as well.
- *Phytostabilization*: the use of plants to reduce the bioavailability of pollutants in the environment. Plants stabilize pollutants in soils, thus rendering them harmless and reducing the risk of further environmental degradation by leaching of pollutants into the ground water or by airborne spread.
- *Phytovolatilization*: the use of plants to volatilize pollutants. Plants extract volatile pollutants (e.g., selenium, mercury) from soil and volatilize them from the foliage.
- *Phytodegradation*: the use of plants and associated rhizospheric microorganisms (*plant-assisted bioremediation*) to degrade organic pollutants.

The term “phytoextraction” mainly concerns the removal of heavy metals or radionuclides from soil by means of the uptake capabilities of plants. Plants can accumulate heavy metals essential for growth and development such as Fe, Mn, Zn, Cu, Mg, Mo, and possibly Ni. In addition, some of them have the capacity to accumulate heavy metals with no known biological functions, such as Cd, Cr, Pb, Co, Ag, Se and Hg (Garbisu & Alkorta, 2001).

The ideal plant to be used in phytoextraction should have the following characteristics (Garbisu & Alkorta, 2001):

- be tolerant to high levels of the metal;
- accumulate high levels of the metal in its harvestable parts;
- have a rapid growth rate;
- have the potential to produce a high biomass in the field; and
- have a profuse root system.

Phytoextraction can be enhanced with the addition of a chelating agent to the soil, or it can happen without addition of external chemicals, merely through the natural ability of some plants to accumulate- the so-called "hyperaccumulators". The number of metal-accumulating taxa identified to date has been reported to be 397; and the largest numbers of temperate-climate hyperaccumulating species belong to the Brassicaceae (Garbisu & Alkorta, 2001), of which *camelina sativa* is a member.

3.3 Regulations

The following Romanian regulations are relevant with respect to contaminated land (EPA, 2000): (i) Law on Environmental Protection (Law no. 137/1995); (ii) Law on Waters: Comprises provisions on contaminated sites and land.

An EU Directive, 2004/35/CE on environmental liability with regard to the prevention and remediation of environmental damage came into force in April 2007 and establishes a framework for preventing significant environmental damage or rectifying damage after it has occurred.

In 2014, the EU issued (draft) "detailed definitions for severely degraded land and heavily contaminated land for the purpose of Annex IV of Directive 98/70/EC [Fuel Quality Directive] and for the Council and Annex V of Directive 2009/28/EC [Renewable Energy Directive]". The draft document was retrieved from the website of a UK NGO specializing in contaminated land (Claire, 2014). The draft definitions stipulate that heavily degraded land is significantly salinated or eroded. Heavily contaminated land is defined as "land that is unfit for the cultivation of food and feed, that is to say land that is contaminated in such a way, through a build-up of hazardous substances, that no vegetation can grow on it".

Furthermore, while the RED and the FQD had originally incorporated "provisions for encouraging the cultivation of biofuels in severely degraded and heavily contaminated land as an interim measure for mitigating against indirect land-use change" by attributing a bonus of 29 gCO2eq/MJ to biofuels grown on severely degraded and heavily contaminated land, the EU later issued a Communication eliminating these provisions (EU, 2012). Instead, biofuels considered to have zero ILUC are biofuels that are not cereals or other starch-rich crops, sugars, or oil crops, as well as biofuels for which direct land use change emissions have been calculated (EU, 2012). There are no special provisions for biofuels on heavily contaminated land.

3.4 Trials of camelina sativa production in contaminated land

As part of ITAKA, trials have been conducted in heavily contaminated land in Copsa Mica, Rovinari, and Campina field sites (see ITAKA Deliverable 1.7; briefly described below).

- In the Copsa Mica-Axente Sever village, Sibiu county: heavy metals resulting from non ferrous metallurgy have polluted the atmosphere and the soil. The test site is located 1 km from the industrial operations. The crop prior to camelina plantation was maize (corn).
- In Rovinary-Targu-Jiu, Gorj county: pollution sources include sterile dumps from coal extraction, ash dumps from power station activity, which are required to be used for agricultural purposes, and acid rain from regional SO2 emissions. The trial site is located 2 km from the Garla coal extraction site. The land started to be cultivated a few years ago. The crop prior to the sterile dump was maize, while the crop prior to the ash dump was grass. Camelina trials were carried out in both sites.
- In Campina, Prahova county: in the past, pyrite was deposited on the land and subsequently removed, the hole being covered by debris from building demolition. A nearby lake is polluted with oil. The land was not being cultivated prior to the introduction of camelina.

Preliminary results (see ITAKA Deliverable 1.7) show that camelina production in heavily contaminated land is possible, though in many instances the plants show signs of distress and malformation, which is not surprising given the unfavorable growth conditions. The breakdown of pollutants in the different parts of the plant is still under evaluation.

3.5 Displacement and indirect impacts consideration of biofuel production in contaminated land

From our discussion in Section 1, a “strong condition” for causing a low risk of ILUC is as follows: Biofuel feedstock production can be demonstrated to cause no displacement of existing provisioning services, including food, feed, fuel and fiber.

If the land on which biofuel is produced was previously not producing any food, feel, fuel and fiber, then using the land for the purpose of new biofuel production should have a minimum ILUC risk. This would be the case if camelina is produced on contaminated land where there was no prior production of food, feed, or fuel.

The cultivation of camelina sativa on heavily contaminated land can be said to have two purposes: (1) feedstock production, and (2) phytoremediation if its cultivation results in a reduction of contaminants in the soil.

Applied to the case of production of camelina in contaminated lands in Romania, the following conditions could be stated to ensure that the production has essentially zero ILUC risk:

Conditions for feedstock production with low ILUC risk	Explanation / Notes
The land has not been used for a provisioning service of any kind in the recent past due to heavy contamination from industry; and	In other words, the land has not been used for agricultural purposes since it was found to be contaminated.
The land has not been cleaned up and restored yet, and thus cannot be used at present for the purpose of producing food or feed.	The land may be unproductive due to contamination, or it may have been classified as too contaminated to safely produce food and feed products.

3.6 Direct effects and considerations

If camelina sativa is cultivated for the purpose of phytoremediation, and concretely phytoextraction, and thus results in a net reduction of contamination in the soil, this would entail positive direct impacts, both environmental (associated with a cleaner environment) and social (associated with fewer risk of disease and improved real estate value, among others). In addition, this action would have a positive impact on ILUC, since it would, in the longer term, regenerate and restore agricultural land.

Note that if there was prior production of feed, food or fuel in contaminated land, it would have probably resulted in the production of contaminated products, with obvious negative social consequences. In this case, the production of a biofuel is a preferred choice of usage of the soil, as long as the use of the biofuel does not result in re-exposure (of humans, animals, wildlife and other biodiversity) to pollutants.

3.7 Timeline considerations

The ILUC risk assessment of a feedstock production process needs to be reconsidered periodically, e.g., every 5-10 years. Once (and if) the contamination on the land is reduced to levels where agricultural production would be safe and feasible, it would be recommended to carry out a new ILUC risk assessment.

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