Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia

ROUNDTABLE ON SUSTAINABLE BIOMATERIALS

November 2022 – Final
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<td>ARDPS</td>
<td>Agricultural and Rural Development Policies and Strategies</td>
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<td>ASTM</td>
<td>American Society of Testing and Materials</td>
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<tr>
<td>BCL</td>
<td>Brassica carinata leave</td>
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<td>BCM</td>
<td>Brassica carinata meal</td>
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<td>BCR</td>
<td>Brassica carinata residue</td>
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<td>BCS</td>
<td>Brassica carinata Straw</td>
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<td>BSL</td>
<td>Biofuel Safety Level</td>
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<td>CAPEX</td>
<td>Capital expenditure</td>
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<td>COMESA</td>
<td>Common Market for Eastern and Southern Africa</td>
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<td>CORSIA</td>
<td>Carbon Offsetting and Reduction Scheme for International Aviation</td>
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<td>CSA</td>
<td>Central Statistical Agency</td>
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<td>EABC</td>
<td>Ethiopian Agriculture Business Corporation</td>
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<tr>
<td>ECAA</td>
<td>Ethiopian Civil Aviation Authority</td>
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<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
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<tr>
<td>EIAR</td>
<td>Ethiopian Institute of Agricultural Research</td>
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<tr>
<td>EIC</td>
<td>Ethiopian Investment Commission</td>
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<tr>
<td>EPSE</td>
<td>Ethiopian Petroleum Supply Enterprise</td>
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<td>ESIA</td>
<td>Environmental and Social Impact Assessment</td>
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<td>Abbreviation</td>
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<tr>
<td>ETB</td>
<td>Ethiopian Birr</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organisation</td>
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<td>FDRE</td>
<td>Federal Democratic Republic of Ethiopia</td>
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<td>FOB</td>
<td>Free On Board</td>
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<td>FTA</td>
<td>Federal Transport Authority</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GERD</td>
<td>Great Ethiopian Renaissance Dam</td>
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<td>GHG</td>
<td>Green House Gases</td>
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<td>GOE</td>
<td>Government of Ethiopia</td>
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<tr>
<td>HEFA</td>
<td>Hydrosolvent esters and fatty acids</td>
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<td>HVO</td>
<td>Hydrotreated Vegetable Oils</td>
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<td>IAIP</td>
<td>Integrated Agro Industrial Park</td>
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<td>IATA</td>
<td>International Air Transport Association</td>
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<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<td>International Energy Agency</td>
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<td>ILUC</td>
<td>Indirect land-use change</td>
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<td>ISFM</td>
<td>Integrated Soil Fertility Management System</td>
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<td>LCA</td>
<td>Life cycle assessment</td>
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<td>Life cycle impact assessment</td>
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<td>Acronym</td>
<td>Definition</td>
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<tr>
<td>LGP</td>
<td>Length of growing period</td>
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<td>LHV</td>
<td>Lower heating value</td>
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<td>NBE</td>
<td>National Bank of Ethiopia</td>
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<td>NFREC</td>
<td>North Florida Research and Education Centre</td>
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<td>NOC</td>
<td>National Oil Company</td>
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<td>National Park Services</td>
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<td>NUF</td>
<td>Nufarm</td>
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<td>OPEX</td>
<td>Operational expenditure</td>
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<td>PPP</td>
<td>Public-private partnership</td>
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<td>RSB</td>
<td>Roundtable on Sustainable Biomaterials</td>
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<td>RWEE</td>
<td>Economic Empowerment of Rural Women</td>
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<tr>
<td>SAF</td>
<td>Sustainable aviation fuel</td>
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<tr>
<td>SCS</td>
<td>Scientific Certification System</td>
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<tr>
<td>SDS</td>
<td>Sustainable Development Scenario</td>
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<tr>
<td>SNNPR</td>
<td>Southern Nations Nationalities and People’s Region</td>
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<tr>
<td>UCO</td>
<td>Used cooking oil</td>
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<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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<td>UPM</td>
<td>United Paper Mills</td>
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<td>USDA</td>
<td>United States Department of Agriculture</td>
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EXECUTIVE SUMMARY

Project overview

The rising demand for GHG reduction emissions and the goal for establishing a low-carbon economy by 2050, has led countries towards the exploration of all possible solutions, aiming at reaching that goal. One of the main pathways towards low-carbon economy is the utilisation of low-carbon sustainable biomass feedstock. Biofuels play a key role in the mitigation of CO2 emissions and the increased use of renewable fuels in transport will pave the way towards a low carbon economy. Brassica carinata (or Ethiopian Mustard), an oil crop from Ethiopia, constitute a promising potential biomass feedstock to produce biofuels, especially sustainable aviation fuel (SAF), being able therefore to contribute to the decarbonisation of one of the most difficult sectors to reduce GHG emissions. The present study is considered as a pre-feasibility study and has the purpose of giving a clearer understanding, also by providing up-to-date and detailed information, on the crop’s potential to produce SAF in Ethiopia. Due to lack of information on the industrial part of the value chain, the economic analysis of the present work has been based on the costs of BC oil production. Then it is the potential investor that can decide on the development of the industrial part of the value chain in Ethiopia or the shipment of BC oil to biorefineries abroad. Moreover, the important steps of the value chain describing the process from BC cultivation to SAF production, are discussed. The value chain is in general divided into the agricultural part and the industrial part, where in each part, various by-products are also produced besides the main outcome. It is important to point out that one of the co-products is the leaves of the crop, which are used as a food in Ethiopia. Furthermore, due to the lack of installed units, for the industrial part, more information is focused on the agricultural part.

Ethiopia’s energy sector and economic situation

Due to the Coronavirus pandemic, Ethiopia’s economy fell dramatically, which dropped its GDP rate to the lowest level in 17 years. It is expected to rise, through the help of the investments by other countries, in Ethiopia’s industrial parks, which will help to reduce poverty. A great economic advantage lies in Ethiopia’s plentiful biomass energy sources, with solid biomass being the primary contributor. Oil fields have not yet been explored, and
Ethiopia still relies only on oil imports from other countries. Evidence showed, that during the last 10 years, there has been a steady 8-13% increase in annual fuel imports. To support further growth, the Government of Ethiopia, has proceeded with a "Homegrown Economic Reform Plan" to help the country attract investors. The Ethiopian Investment Commission has also undertaken various tasks to promote the country to new investors.

Furthermore, Ethiopia is an active member of the Common Market for Eastern and Southern Africa and of the African Continental Free Trade Area, which provides a developing framework to promote the country’s development potential and to attract investors.

**Local experience of Brassica carinata**

As far as BC cultivation is concerned, the Ethiopian experience provides evidence of the optimum climate under which the crop is grown, which is cool and moist. Altitudes between the range of 1,700 – 3,200 metres have proven to be ideal. The largest areas cultivating the crop are Arsi, Bale, Wes Shewa, East Wellega, West Gojam and South Gonder. Cultivation processes typically used are monocropping, crop rotation and intercropped with cereals during rainy seasons. Cover cropping is another cultivation process for BC that has been practiced internationally, but has not yet been practiced in Ethiopia. Also, to achieve high yields and enhance productivity rates, federal and regional research centres have studied and released over 10 varieties, with Yellow Dodola being the most promising, hence the most adopted, with an oil composition of 44%.

**International experience of Brassica carinata**

The south-eastern US, Canada, Europe, China, Australia, and Latin America have already begun BC production trials. Canada comprises one of the biggest leaders in the production of BC oil, worldwide, while the United States has become the major buyer of the oil from Canada, resulting in growing interest in production in the US. In Australia and New Zealand, BC is also used as a biofumigant for diseases coming from the soil. Canada uses it to help with soil erosion, herbicide use and nutrient losses.

Growing the crop comes with the advantage of giving greater yields than expected, hence enhancing the overall revenue. As mentioned previously, there are a few by-products
generated throughout the whole process. Thus, significant economic returns can be reached from leveraging these by-products. Moreover, experience has revealed that BC can undergo crop rotation and intercropping with wheat, chickpea, barley, and sorghum. Although, international experience suggests that farmers who lack knowledge of cultivating BC crops, face a real challenge.

Contract farming is a scheme that was first been adopted by the US, and then by Asia and Africa, and has been applied in BC cultivation. Farmers are attracted to the scheme since, the companies provide them with production services and inputs. New markers and novel technologies can be developed through the application of the scheme, which are essential for BC development, as well. This brings employment opportunities and rising income. There are a few barriers such as, unfamiliarity with the crop, competition among the oilseed crops, fitness of BC into existing crop rotations and the selling price.

In addition, the BC crop has shown evidence of being a potential feedstock for Hydrotreated Renewable Jet fuel, thereafter, its development to serve such a purpose is essential. Nuseed is a company that produces various crops among which is carinata, to help industries, growers etc., to develop sustainable solutions. Nuseed carinata helps producers reach the low carbon fuel goals that are set by the government. UPM from the other hand, is one of the biggest pulp and forest industrial companies, accommodating biofuel and feedstock development departments.

Issues to be solved

Regarding Ethiopia, there are a few issues concerning feedstock and SAF production and transport. Firstly, there is the matter of land tenure - according to the Federal Democratic Republic of Ethiopia, land ownership is a subject concerning the citizens and the state. Secondly, the roads are not in a condition to accept heavy trucks, which poses significant challenges when it comes to agricultural activities. Another issue relates to blending and distribution facilities. The main oil companies are Oil Libya, Nile Petroleum, National Oil Company, and Total Ethiopia. However, the blending facility at Nile Petroleum is currently not working, so the other three are the dominant ones. Unfortunately, these companies face various challenges, which hold them back and make the overall process more complicated.
Suitable lands and regions for BC: Criteria

To decide on the suitability of the land, the GIS based multicriteria approach was used, which made use of four categories: high suitable, moderately suitable, marginally suitable, and unsuitable lands.

Analyses showed that in Ethiopia there are lands suitable for BC production. More precisely, 29,902,340 hectares is suitable for BC production. Oromiya has 16,019,728 hectares of land, Amhara has 7,109,188 ha and SNNP has 3,048,600 ha.

Market evaluation

Since there is no organised market, information has been drawn from international reports and studies. For instance, according to IEA’s Sustainable Development Scenario, biofuels
are expected to reach a 10 per cent demand of aviation fuel by 2030, and another 20 per cent by 2040. The Net Zero Scenario aims at a 14 per cent biofuel consumption each year, although this will require stronger policies to be implemented by the countries. Consequently, BC seeds have attracted a lot of attention worldwide. The point being that internationally, SAF is expected to play a role in the future aviation fuel mix and part of SAF will be based on BC. Aviation is an international market, so it can be assumed that a similar picture will develop in Ethiopia.

Hydroprocessed esters and fatty acids (HEFA) has become the trading process for the generation of sustainable aviation fuel, and ICAO has put BC as a renewable fuel feedstock with a rather analogous to waste and residuals GHG footprint. With the objective of Ethiopia reaching a low-carbon footprint, the Government initiated the Climate Resilient Transport Strategy in 2017, aiming at reducing GHG emissions through aviation. Therefore, SAF uptake is the primary goal, however, 586 million litres of SAF will be needed for Ethiopia to achieve that uptake (10%).

Economic assessment

The main assumptions are described in the study including, a sustainable cultivation method based on rotation cropping, and an emphasis on the agricultural stage of the value chain. Data regarding costs and prices was provided by experienced members in the agricultural sector. It was decided that the best solution was to use a minimum and maximum range approach to give a better understanding.

Evidence from fields trials in Ethiopia has shown that Brassica carinata leaves have a strong potential of increasing a farmer’s income, as data revealed 6,944 ETB/hectare of extra earnings. Besides that, revenues from selling the by-products and costs regarding the BC production, currently in Ethiopia, were taken from the local team. A predicted price from selling the co-products was found to be 1,605 USD/ha, containing the carinata leaves and the carinata straws, while BC production costs lie within the range of 410-580 USD/ha. These figures suggest a considerable profit margin. The revenue from carinata leaves is based on the existing market conditions. However, in the case of a significant leaves supply increase due to expansion Brassica carinata cultivation, new market conditions will
be created and most probably the leaves’ price and the relevant revenue will likely decrease.

Regarding the comparison with other world regions for BC cultivation for SAF feedstock production, scattered data was provided in each study; however, the assumptions in each region were different and thus, the comparison cannot be direct. Italy, the US, Canada, and overall Europe, were used as the regions to be compared to Ethiopia, in terms of BC production costs and consequently, farmer’s revenues. Information showed that the cultivation processes used were rotation and cover cropping. The Ethiopian case seemed competitive, in general, and where the benefit of food production of BC sleeves is incorporated, then the economic performance becomes unsurpassed. Although, in the study for Europe, intercropping and biochar were also introduced, because this study concerns the goals aimed to be reached by 2030. Moreover, the costs regarding the industrial part of the value chain were also compared among the US, Canada, and Italy.

Finally, the industrial part, including the seed crushing and the hydrotreatment process is a subject of investment either in Ethiopia or in another country, however, the agricultural part is more complex and comes with risks and problems that are discussed in the study.

**Environmental and Social Impacts**

The identified potential environmental and social impacts associated with the production and processing of Brassica carinata crop in Ethiopia are the following: (a) reduction of CO2 emissions, and (b) less imports, thus enhanced energy security.

Brassica carinata can participate in an integrated crop-livestock system, and provide synergies towards more resilient climate-smart agricultural production systems. Being an intensive crop, Brassica carinata requires soils of relatively high fertility. However, it does not pose any threat to food security, as only leaves are edible, whereas the oil seed crop can be used for biofuels production.

Even though the BC crop will bring less biofuel imports, it will also have a negative effect on farmers living in poor rural areas, since the government will take their land to allocate it to
investors. However, this land tenure impact could be avoided if developers adopt the out-growers scheme rather than acquiring their own land.

Furthermore, child labour is very common in African countries with a percentage of 17.27. Lastly, the cultivation of BC crop for biofuel production will bring employment, either directly or indirectly in other parts, with forward and backward effects. Moreover, the development of Brassica Carinata project in Ethiopia is expected to have an impact on gender equality as well as women are involved in its cultivation.

Important findings of the study

- Brassica carinata crops grow best in cool and moist climates, in altitudes above 1,700 to 3,200 above sea level. The best areas to grow it are Arsi, Bale, West Shewa, East Wellega, West Gojam and South Gonder.

- BC leaves are edible and consumed by Ethiopians while, BC seed are used to grease a traditional clay pan or to be sold to traders for export uses. Therefore, the farmer’s income increases. Carinata meal and the residues from harvesting bring a rise in the income as well.

- BC can be used in crop rotation in wheat farms to reduce herbicide usage. Rotation cropping might be less favourable for farmer’s income, but farmers are more experienced in this process of cultivation. Although, intercropping and cover cropping are more sustainable methods, and they will bring a rise in farmer’s income.

- Commercial scale production of BC seed is small today, and is carried out by the Ethiopian seed Enterprise, the Oromia seed Enterprise, Kulumsa Agricultural Research Center and the Agerfa Technical and Agricultural College, which use crop rotation with cereals.

- Yellow Dodola proved to be the most demonstrated and adopted variety of BC with a 44.1 per cent of oil content.

- Ethiopia has abundant suitable lands for BC cultivation with Oromiya having 16,019.728 ha of land followed by Amhara with 7,109.188 and SNNP with 3,048.900 ha.
• There is no organised market around BC crops today, and the issue of prices of BC leaves is critical, increasing the farmer’s income, particularly in the case of expansion of cultivation.

• This pre-feasibility study focused more on the agricultural aspect, since the industrial element can take place in other countries, and it is a matter concerning the potential investors.

• There are not industrial units installed in Ethiopia for BC seed crushing and SAF production, therefore, a broader economic assessment which will be also based on the market conditions, is required by the potential investor.

• Ethiopian companies could participate in the production of BC and processing to SAF; however, the international companies will be the ones needed to establish the relevant value-chain framework.

• Initial state interventions should concentrate on inviting investors to develop the agriculture and industrial part which will have to be considered as direct investments with economic and social benefits.

• BC’s production development possibilities will increase up to 2035 considering that the EU and other developed countries decided to move faster regarding the decarbonised energy economy.
Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia

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1. Analysis of present situation

1.1. Project identification

In December 2015, COP21 in Paris made an important step forward to address the risks posed by climate change and to keep the global temperature increase to “well below 2°C” and drive efforts to limit it even further to 1.5 degrees. To achieve these goals, many developed countries, or groups of countries in the world, among which the European Union (EU), the USA, Canada, Australia, the UK etc. are included, are exploring different mid-century (2050) scenarios leading to a low-carbon economy by 2050. The recent political developments with the war in Ukraine, have intensified the effort and the political will to abandon fossil fuels and to decarbonise energy use, especially focusing on the most “difficult to abate” sectors like aviation, maritime and the other transport sectors.

Accessibility to sustainable low-carbon biomass feedstock is one of the key drivers to achieve a low-carbon economy by 2050 and consequently, the role of biofuels in the transport sector is recognised in all strategy studies and long-term plans. The recent “Fit-for-55” EU package has proposed an increased target for the use of renewable fuels in transport that are based on advanced biofuels and sustainable low-ILUC biofuels, which is mostly derived from sustainable cultivation of energy crops and from combined exploitation of the value-chain.

Several recent reports1, highlight the different feedstock landscapes, different energy infrastructure and large economic and cultural differences in various regions in the world, which impact the primary sector (agriculture and forestry), infrastructure and scales of operation as well as, the knowledge and organisational skills of local and aggregate biomass suppliers. This means that there is not one size or solution that fits all in the [1 Core Theme 6 “Biomass mobilisation and sustainability” https://www.cares.eu/fileadmin/cares/PublicArea/CARES2FinalPublication/CT_6_Biomass_Mobilisation_Summary_Report_2016.pdf]
continued mobilisation of biomass supply for bioenergy, and that the area of feedstock arrangements with farmers remains the least mature link in the value chain of biofuels production.

The IEA Bioenergy\(^2\), as an example, has acknowledged the challenge for biomass supply and aims to develop, refine, compare, and promote sustainable integrated land management strategies that contribute to increased, competitive biomass mobilisation through engaged stakeholder groups, in existing and emerging agriculture systems. This will be achieved through deployment, application, and management of best practices for integrated biomass production and supply chain systems. These practices should adapt to the local agriculture conditions, particularly in countries, like Ethiopia, where important advantages and disadvantages could be considered at the level of feasibility of developing cultivation of energy crops like Brassica carinata (BC).

Regarding aviation decarbonisation, the CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) has been established as a global scheme which will result in greater levels of CO2 mitigation in international aviation, that could be achieved through domestic policy measures. The CORSIA has applied to international aviation since 1 January 2019, when all airlines were required to report their CO2 emissions on an annual basis. From 2021 until 2026, carbon offsetting requirements will only apply to international flights between states that volunteer to participate in the pilot phase. From 2027, offsetting requirements will apply to all international flights. To meet CORSIA’s sustainability criteria, a specific CORSIA eligible fuel (e.g. sustainable aviation fuel, SAF) needs to achieve GHG emission reductions of at least 10% compared to conventional jet fuel on a life cycle basis. Furthermore, a CORSIA eligible fuel must follow sustainability criteria which are being developed within ICAO (International Civil Aviation Organization) of the United Nations.

Besides, the International Air Transport Association (IATA) has set a goal of a 50% reduction in CO2 emissions by 2050. Emission reduction can be achieved in several ways, such as through improvements in the airframe, engine technologies, ground operations,

\(^2\) [https://www.ieabioenergy.com/blog/task/43-2biomass-feedstocks-for-energy-markets/](https://www.ieabioenergy.com/blog/task/43-2biomass-feedstocks-for-energy-markets/)
and use of sustainable aviation fuel (SAF) derived from various biomass feedstocks. The latter is further supported in the recent ICAO Long Term Aspirational Goal\(^3\) (LTAG) for international aviation of net-zero carbon emissions by 2050 in support of the UNFCCC Paris Agreement’s temperature goal, where the significance of biomass-based SAF towards the aviation decarbonisation target is highlighted; Figure 1-1 presents the projected CO\(_2\) emissions from international aviation associated with LTAG Integrated Scenarios, as those are reported in the aforementioned ICAO report, where the role of biomass-based SAF is prominent, especially under the assumptions of IS2\(^4\).

Finally, it should be noted that the dynamic prospects of SAF penetration into the future sustainable aviation fuel mix have already been acknowledged by the legislators, with the prominent example of the EU; the recent REFuel EU Aviation calls for min. 2% overall SAF contribution in the aviation fuel mix by 2025, climbing to 20% in 2030 and 63% in 2050. Notable, the majority of the foreseen SAF is considered to be of bioenergy sources, see Table 1-1. IATA Net Zero Carbon Emissions by 2050\(^5\) also suggests that SAF will account for 65% of total global aviation fuel consumption by 2050.

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\(^3\) [https://www.icao.int/environmental-protection/Pages/LTAG.aspx](https://www.icao.int/environmental-protection/Pages/LTAG.aspx)

\(^4\) Three integrated scenarios (IS) were developed for LTAG to cover a range of “readiness, attainability, and aspiration”. IS1 reflects “high readiness/attainability and low aspiration”, IS2 depicts “middle readiness/attainability and middle aspiration”, and IS3 represents “low readiness/attainability and high aspiration”. For further information on the scenarios and the associated modelling work, the reader is referred to the original publication.

1.1.1. Scope and objectives

Brassica carinata is an important oil crop of Ethiopian origin, and it has been grown in Ethiopia since antiquity, both as an oilseed and vegetable crop. The sustainable aviation fuel (SAF) roadmap for Ethiopia has identified BC as a prominent potential feedstock suitable for SAF production. To this end, this study aims at providing a better
understanding and insights on BC’s potential as a source to produce biofuels, including sustainable aviation fuel.

The main objective of the project was to carry out a pre-feasibility study assessing whether Brassica carinata (Ethiopian Mustard) is a viable feedstock for biofuel (and in particular, SAF) production in Ethiopia.

The work was organised in 6 tasks as described below:

1. Identification and mapping of current production and uses of Brassica carinata, and information on: prices and markets, competition with the food and alcohol markets, current production models, sustainability practices, economics of growing the crop in a small-scale and plantation setting.
2. Identification and mapping of potential production capacity, taking into account agro-ecological considerations including land availability, need for irrigation and other farming inputs and (optionally) current and future climatic conditions.
3. Mapping existing large and small-scale farming operations and co-operatives that could potentially grow the crop.
4. Collection of farming and transport data to enable RSB to perform a greenhouse gas life-cycle assessment (GHG LCA) of a potential biodiesel supply chain using the RSB GHG Calculator.
5. Estimation of the investment required, as well as the potential socio-economic impact, of scaling Brassica carinata production to feed a biodiesel plant, and the necessary requirements (i.e., the necessary licenses) that are relevant to produce Brassica carinata in Ethiopia.
6. Performance of a financial feasibility for a biodiesel plant, identifying ideal location, investment incentives, local barriers, technology availability and human capital (skilled labour) etc.

The key output of the study is the present pre-feasibility report for a BC investment based on the cost of feedstock and the BC oil produced, identifying proper location, investment incentives, local barriers, technology availability and necessary human resources.
The market context of the study will not be restricted to the national borders and the domestic aviation industry needs for SAF, but we will look at the broader perspectives to potentially export SAF or BC oil to the international market, based on the cost of BC feedstock production and the potential volume of production in Ethiopia.

The project team consisting of local and international experts, capitalised on the international assessments of BC utilisation as a biofuel crop in southern Europe in the US, Canada, Australia, and Latin America (Uruguay and Argentina in principle) and recent findings from the studies for Ethiopia.

1.2. Methodology of pre-feasibility study

The present study should be considered as a pre-feasibility study for the value chain of BC for SAF production in Ethiopia. This is the first step towards the understanding of the Ethiopian reality and challenging potential investors to go on with more detailed feasibility studies. Operating in a global market for SAF/biodiesel and bio-oil, the decision of potential investors for a large BC project will consider many other parameters that are influenced by the international conditions among which of the cost of transports of goods and of the availability of biorefinery infrastructures.

Along with the GHG emissions saving criteria, analysing the commercial viability or unit cost of producing SAF or BC oil, is also critical to increase the production and sustain supplies. Major challenges impeding investments in the SAF production are:

- Crude oil price, whereas conventional aviation fuel costed for long time $0.55 per litre, the cost of SAF could range between $0.44 and $8.45 per litre, depending on the choice of feedstocks, yield varied by geographic location, and conversion technology.
- Feedstock availability and cost, that are mostly targeted at this study because reasonable data have been used for certain regions of Ethiopia.
- Conversion technology yields and costs, for which there is no experience and relevant data for the country, but they are based on mature technologies.
- Environmental impacts, following in principle international approaches, the recent EU regime included, and in compliance with the RSB standards.
• Government policies related to supporting measures which might facilitate the BC cultivation, oil crushing units and potential establishment of SAF/biodiesel processing units.

The present study is oriented to the first stages of the value chain which characterise the Ethiopian conditions for BC production. Since there is no infrastructure for BC oil crushing and of biorefineries/HEFA processing, the potential incorporation of these stages in Ethiopia relates to the optimisation that will be carried out by the investor to be able to compete with BC oil or SAF/biodiesel in the international markets. For transportation and commercial reasons, the incorporation of oil crushing is most probable to take place in Ethiopia, whereas the establishment of a SAF/biodiesel industry sounds more complicated and should be treated as an investor’s option.

The consultant also considers, that the uncertainties of the markets of sustainable biofuels production do not allow a narrow single way of biofuels development and although this exercise considers SAF production, the case of biodiesel production, in case the market conditions favour, should be also an option for the potential investor. The industrial process is based on the same technology (HEFA, HVO) and although today we estimate that the perspective of SAF is important, the demand evolution of low carbon fuels is not clear for the next years. Thus, a shift to biodiesel might happen if the demand for SAF delays or there is oversupply.

The BC production is determined by its agronomic requirements. The variety or genotype, also, is determined by its adaptability to specific locations. Genotypes (commercial varieties or local landraces) grow in a wide range of environments depending on their specific agronomic requirements (i.e. moisture/rainfall, altitude, soil type, etc.). In Ethiopia, BC grows in mid to high altitude ranges (1700 – 3200 m above sea level) with diverse temperatures, soil type (fertility), rainfall distribution, biological stress (pests) prevalence/occurrence, etc. Therefore, along BC production places, different biotic and abiotic factors are available, and the crop is adapted to these factors and relevant production yields are achieved. It is worth mentioning that there are also reports on its ability to withstand moisture in drought prone areas. However, this doesn’t mean that BC grows beyond its agronomic boundaries but has a potential to grow and thrive best even in
moisture stress, drought tolerance and low fertile soils. Comparing with cereals, it has an ability to provide fair yield even in low fertile soils with minimum input; though BC requires well drained fertile soil for its ideal production.

Historically, but even at present, BC shows potential for Ethiopia, thus an investigation into the economic feasibility and carbon benefit is required, before large investments are made to create supply chain infrastructures such as storage facilities, crushing mills, and biorefineries/hydrotreatment processing. Using agricultural input data suggested for Ethiopia, we could estimate the break-even price of BC seeds delivered to the crushing mill, contingent upon the variations in fixed costs and variable costs. We could also estimate GHG emissions within the crop production system boundary since oil crushing and HEFA processing industrial units didn’t exist at the time of this study.

Therefore, we consider the viability of a domestic BC cultivation for biofuel production. BC is a non-food and -feed crop for most research cases worldwide, however in Ethiopia its leaves are edible, and this fact increases its sustainability and economic performance. It is endorsed with agronomic features that make it particularly suitable for crop rotation with food plants, such as wheat, and BC cultivation can also be considered suitable for marginal and contaminated areas\(^6\). These features substantially mitigate concerns on the impact of its production regarding the rise of food prices and land use change that have been so prominent in the biofuels debate. BC appears to be a promising candidate as a crop that could be used to stimulate local biofuel production in Ethiopia, provided it is also sustainable from an economic and environmental standpoint.

1.2.1. Value chain of Brassica carinata to SAF

Figure 1-2 shows the status of advanced biofuels technologies based on their TRL (Technology Readiness Level), as well as their status based on the technology development roadmap for all advanced biofuel conversion technologies, i.e. from Research at Lab Scale to Prototype at Pilot Plant, to Demonstration for Technoeconomic Viability and

\(^6\) “Brassica carinata-derived biodiesel production: economics, sustainability, and policies. The Italian case”, Marcello Basili, Maria Alessandra Rossi, Cleaner Production, ELSEVIER

Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final
finally Commercialisation and Market Deployment\textsuperscript{7}. Fig 1-2 also indicates some companies that have reached the last two stages and are either in market deployment or close to commercialisation.

It is worth mentioning that the commercially available conversion pathways for advanced biofuels are: a) hydrotreatment to produce \textit{Hydrotreated Vegetable Oils (HVO)}, and b) anaerobic/aerobic digestion to produce biogas that can be upgraded to biomethane.

Cellulosic ethanol has progressed significantly, and it is close to commercialisation with several commercial plants in commissioning stage in the EU and elsewhere. Thus, the development of the BC project in Ethiopia will be based on the HVO commercially available technology that is implemented by a number of companies such as NESTE, ENI, TOTAL, AXENS, NUSEED, UPM, etc. worldwide.

The mature technology for the current 10-year period will be surely dominated by HEFA/HVO since the other technological options are either not commercially available and/or not competitive enough. The demand for SAF, at present, is at the first commercial step hoping to increase soon (CORSIA, IATA) and therefore to motivate significant SAF supply (from BC or other oil plants) initiatives. Best BC experiences could be found only in the value chain design and optimisation, and such examples are included in the next paragraphs of this section. Regarding the use of SAF at present, it is blended with fossil kerosene as a drop-in biofuel at permissible percentages.

### Figure 1-2: Status of advanced biofuels technologies based on their TRL level as well as their status based on the technology development roadmap

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<tr>
<td>Research Lab Scale</td>
<td>Prototype Pilot Plant</td>
<td>Demo Techno-Economic Viability</td>
<td>Commercialisation Market Deployment</td>
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<td>Aerobic fermentation</td>
<td>Lignocellulosic butanol Amyris</td>
<td>Anaerobic fermentation/BioCH4</td>
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<td>Aqueous phase reforming</td>
<td>Lignocellulosic ethanol Clariant. ENI/Versalis, Pral Industries</td>
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<td>Hydrothermos</td>
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<tr>
<td>Pyrolysis oil upgrading</td>
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<td>TRI/VELOYS, Fulkrom/Marathon</td>
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<td>Gasification &amp; Bio CH4</td>
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Figure 1-3 presents the main stages of the value chain from BC cultivation, transport, storage, seed crushing and processing to SAF and other products and by-products. The presented value chain is generic and adapted to the reality of Ethiopia regarding the agriculture stages. The industrial stages might be considered as optional since they are linked to international market developments.
In the first stage of BC cultivation, the main product is the BC seed which is transported to the area of the mechanical seed crushing factory and then it is stored. There are two by-products: the residue pellets that are directed to animal food or other uses and the carinata leaves that are traditionally used as a food in Ethiopia. The industrial stage comprises the seed crushing unit, which produces the BC oil and as a by-product the carinata meal directed to feed of livestock. The processing (HVO/HEFA) of BC oil to SAF or biodiesel is carried out by a hydrotreatment unit or through a biorefinery by co-processing with fossil oil or other feedstocks. Propane or naphtha are also produced as byproducts of BC hydrotreatment.

The BC oil extraction from the seeds is an essential step in the process of SAF/biodiesel production, as well as the separation between fat and protein components of the seeds subjected to the process. The extraction techniques can be both mechanical (normally cold pressing) and chemical (use of a solvent, usually hexane). The mechanical extraction produces higher fatty quantities and for this reason is preferred when targeting biofuels production.
Hydrotreated Vegetable Oils (HVO) can be produced from a wide variety of materials containing triglycerides and fatty acids. BC oil lies within this range of materials, leading to production of hydrocarbon drop-in products like biokerosene (SAF)\(^8\). Neste was the first company to invest in an HVO refinery (Porvoo 2007). Currently, Neste has a production capacity of 2.7 million tonnes/yr., with stand-alone HVO refineries in Porvoo (Finland), Singapore and Rotterdam (the Netherlands). The Porvoo plant benefits from synergies with the parallel fossil refinery operations regarding utilities, and the Rotterdam and Singapore facilities are stand-alone facilities for renewable diesel production. There are existing (or under construction) dedicated HVO plants in China, USA, United Arab Emirates and other. An HVO industrial unit for SAF production could be established in Ethiopia in case such an investment is economically feasible.

On the other hand, there are a large number of traditional oil refineries, especially in the EU, with refinery technology suitable for HVO conversion, as they have two hydrotreaters which were originally designed for removal of sulphur and nitrogen from fossil feeds by hydrogen treatment. Additional refinery conversions may take place in the future as soon as the market conditions become more favourable for renewable fuels than fossil fuels. In co-processing, biomaterial is fed into refinery units together with fossil feeds typically in low (5%-10% wt.) blends. As the refinery processes are complex and units interlinked, co-processing bio-feeds, in integrated refinery lines, results in fractionation of bio-components in multiple products streams.

In the present pre-feasibility study the focus lies on the agriculture stages of the value chain, since relevant local data could be collected and elaborated. There are no installed units of seed crushing in the country to explore the relevant experience and cost analysis for BC seeds, not even biorefineries or hydrotreatment industrial units. The establishment of the two latter stages of the value chain, it needs to be decided by the potential investor of the BC project. The decision will be influenced by a broader cost optimisation assessment that might also consider the specific market position and the ownership of

\(^8\) “Technology status and reliability of the value chains: 2018 Update” ART Fuels Forum, Edited by: Ingvar Landälv, Lars Waldheim & Kyriakos Maniatis
relevant assets by the investor. For example, an international fuel supplier owning biorefineries which are not operating under full capacity might prefer to export BC oil from Ethiopia and produce SAF abroad that could also fuel the Ethiopian aviation sector. In this case the seasonality and feedstock risk of BC oil production is not a major issue. Otherwise, the investment of a new hydrotreatment unit should be implemented in the country and an absolutely different approach would be followed to cope with feedstock availability risks and seasonality.

The transportation costs of BC seed and the BC oil in long distances is also a factor affecting the decision whether a seed crushing unit will be decentralised or centralised in Ethiopia or installed in another country (more centralised production) abroad.

It is obvious that such decisions could be only considered by a candidate investor in BC and could not be included in the scope of this pre-feasibility study. On the other hand, as mentioned above, the most crucial part of the BC value chain, as in all other feedstock cases, lies around BC seed production which should be well organised to feed properly the industrial part of the BC value chain.

1.2.2. Methodology approach

Therefore, our approach is not oriented to calculate typical cost of SAF produced in Ethiopia, including significant uncertainties in the industrial part of the value chain, but estimate the cost of BC seed feedstock produced in Ethiopia in accordance with acceptable sustainability methods. This latter cost reduces the potential calculation risks and indicates the real competitiveness of the country’s production against similar BC projects in other regions worldwide.

The installation of the necessary industrial units (mechanical oil crushing, HVO hydrotreatment) is up to investment decisions which are related to the investment policy of Ethiopia and the international markets of decarbonised fuel supply. Whatever the decision, the BC seed production and the agriculture part of the value chain are not largely affected, because the produced BC seed or the BC oil could be fairly traded in the international markets.
Due to various uncertainties faced by the study team in assessing the costs of the agriculture stage of the value chain, it sounds reasonable to estimate a min and max cost for most calculation cases and thus to also indicate the relevant cost range. This compilation provides a better overview of costs than providing just the average values.

Brassica carinata should be considered as contributing both to increase of food (traditional use of leaves as vegetable food) and feed (carinata meal from oil production and residues from harvesting). The use of leaves is not reviewed in other BC exercises, in other regions of the world, contributing to low ILUC cultivations on existing and marginal agriculture areas.

Sustainable cultivation approaches have been considered, concentrating on rotation cropping that could be used as the basis of calculation. Rotation cropping is probably less favourable for farmers’ income compared to the other two ones but adapts better to the existing farmers’ experience and decreases potential arguments and resistance due to changes of crop cultivation. However, the cases of intercropping and cover cropping could also be considered by potential investors since they might decrease feedstock risks and smoothen seasonality of cropping.

1.3. Overview of current energy and economic situation in Ethiopia

Ethiopia’s economy has been among the fastest growing in the world, averaging 9.4% a year from 2010/11 to 2019/20, enabling the country to double its per capita GDP (reaching $850 in 2019)\textsuperscript{9}. Ethiopia’s real gross domestic product grew by 6.1% in 2020, exhibiting a reduction from an 8.4% growth in 2019, largely because of the COVID–19 pandemic\textsuperscript{10}. Growth was led by the services and industry sectors, whereas the hospitality, transport, and communications sectors were adversely affected by the pandemic and the associated containment measures to prevent the spread of the virus. Ethiopia’s economy has stuttered since the onset of civil war in the country in November 2020.

\textsuperscript{9} Ethiopia Overview: Development news, research, data | World Bank
\textsuperscript{10} Ethiopia | International Development Association - World Bank | International Development Association - World Bank
Ethiopia’s growth slowed to the lowest rate in nearly two decades in 2021. Ethiopia’s real GDP growth in 2021, at an estimated rate of 2%\(^{11}\), was the lowest in 17 years, reflecting the impact of the drawn-out conflict and the economic fallout from the coronavirus pandemic. Going forward, it is expected that Ethiopia’s growth will accelerate again after losing momentum in 2021. The recent national dialogue to restore political stability and the economic reform package aimed at securing returns on investments in infrastructure by liberalising certain sectors and encouraging international companies to set up operations in the country’s industrial parks, is expected to support a speedy recovery.

The per capita gross domestic product (GDP) of the country signals continued economic expansion following a long period of impressive growth achieved mainly because of the government’s bold and ambitious economic development strategy, which incorporated, among other things, a big push in public investment, particularly in agriculture and infrastructure development, strong investment promotion, and a devotion of a high share of its budget to pro-poor programs.

Ethiopia’s energy sector relies heavily on traditional biomass energy sources. Solid biomass is the primary source of energy in Ethiopia, with an 89% share of Ethiopia’s total energy supply in 2018. Biomass distribution across the country is uneven, with the northern highlands and eastern lowlands having low biomass cover. Petroleum supplies about 8% of total primary energy, with electricity and coal supplying only 2% and about 1% respectively. Nearly 90% of Ethiopia’s total energy utilisation is accounted for by household use\(^{12}\).

Ethiopia’s total electricity production reached 4,478 MW in 2021. This accounts for 4,069 MW from hydropower, 384 MW from Wind and 25 MW from municipal waste\(^{13}\).

Hydropower is the most important energy source to Ethiopia, as it is cheaper than other sources and nine of the country’s major rivers are suitable for hydroelectric power generation. The country’s hydropower potential is estimated up to 45,000 MW. Out of this,

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\(^{11}\) Ethiopia Economic Outlook | African Development Bank - Building today, a better Africa tomorrow (afdb.org)

\(^{12}\) MOWIE (2016) National Energy Balance

\(^{13}\) Ethiopia Development Plan (Road to Prosperity), 2021-2031, Ethiopia Plan and Development Commission, 2021
30,000 MW is estimated to be economically feasible. The country is currently constructing several large hydroelectric projects which include, 2,160 MW Gilgel Gibe IV (Koysha) project and the 5150 MW Great Ethiopian Renaissance Dam (GERD) being built on Blue Nile River\textsuperscript{14}.

Ethiopia’s economic expansion has led to a rapid increase in the consumption of fossil resources. It is not yet an oil-producing country, but the government has indicated plans to explore oil fields. The country’s fuel demand is met entirely through imports. Ethiopian Petroleum Supply Enterprise (EPSE) is a government monopoly that supplies petroleum products to domestic distributors after purchasing them from international suppliers.

As shown in Figure 1-4, the country’s annual fuel import volume has been growing steadily at an average annual growth rate of 8–13 % in the last 10 years. The annual total petroleum products import, in the 2019/20 fiscal year, reached around 3.8 million tonnes, which is worth 2.2 billion US dollars (USD)/85.6 billion Ethiopian birr (ETB). Imported petroleum products account for most of the total import expenditure for the country and absorb around 60% of the total export earnings. More specifically, the import of aviation fuel has increased by 49.4 % and that of diesel fuel by 111 % within 2010–2018.

1.4. Overview of legal, policy and institutional framework for investments, agroindustry and agriculture

Ethiopia is ranked 159 among 190 economies in the ease of doing business in 2020, according to the World Bank annual ratings, an indicative of the various challenges facing investors in the country. The rank of Ethiopia remained unchanged from 2019. Ethiopia is the second most populous nation in Africa with about 120 million, and still the fastest growing economy in the region. Low-cost labour, a national airline with well over 100 passenger connections, and growing consumer markets are key elements attracting foreign investment.

15 Ethiopia Overview: Development news, research, data | World Bank
The Government of Ethiopia (GOE) unveiled its “Homegrown Economic Reform Plan” in September 2019, aimed at unlocking the country’s development potentials designed to propel Ethiopia into becoming the African icon of prosperity by 2030, with a focus on enhancing the role of the private sector in the economy and attracting more foreign direct investment. The ambitious plan prioritises growth in five sectors: mining, ICT, agriculture, tourism, and manufacturing. The government has also begun implementing the public-private partnership (PPP) proclamation, to boost private investment.

The Ethiopian Investment Commission (EIC) is mandated for promoting and facilitating foreign investments in Ethiopia. To accomplish this task, the EIC is charged with:

1. promoting the country’s investment opportunities to attract and retain investment;
2. issuing investment permits, business licenses, and construction permits;
3. issuing commercial registration certificates and renewals;
4. negotiating and signing bilateral investment agreements;
5. issuing work permits; and
6. registering technology transfer agreements\(^{16}\).

EIC has launched a new proclamation recently (Regulation No. 474/2020) and have been restructured to promote investment to the country and to provide a one-stop shop service for issuing an Investment Permit, TIN certificate and Business License. For agro-processing Industries, the commission issues duty free, work and residence permit. The EIC also provides additional services to process acquisition of land, utilities (e.g., water, electrical power and telecommunication services) and bank loans (Annex 2).

The government is also working to improve business facilitation services by making the licensing and registration of businesses easier and faster. In February of 2021, the Ministry of Trade and Regional Integration launched an eTrade platform (https://etrade.gov.et) for business registration licensing, to enable individuals to register their companies and acquire business licenses online.

\(^{16}\) Home (investethiopia.gov.et)
Ethiopia also became a member of the African Continental Free Trade Area (AfCFTA) in April of 2020. The AfCFTA aims to create a single, continental market for goods and services, with free movement of businesspersons and investments. Ethiopia is also a member of the Common Market for Eastern and Southern Africa (COMESA), a regional economic block, which has 21 member countries, and has introduced a 10 percent tariff reduction on goods imported from member states.

Regarding land acquisition, a land application should be submitted at EIC, directly after securing the investment license and the authority will issue a letter to Regional State Investment Commission, to facilitate for the land acquisition. When submitting the letter, investors are also expected to submit a project proposal that clearly demonstrates profitability, employment opportunities and technology, to be evaluated by a team of experts. If accepted, the Regional Administration for Urban Land and Environmental Protection, and the Land Administration office for Rural Land, will liaise with city and district authorities, to engage current users of the land and to process compensation.

The Industrial Park Proclamation 886/2015 mandates that the Ethiopian Industrial Parks Corporation develop and administer industrial parks under the auspices of government ownership. The law designates industrial parks as duty-free zones, and domestic as well as foreign operators in the parks are exempt from income tax for up to 10 years. Investors operating in parks are also exempt from duties and other taxes on the importation of capital goods, construction materials, and raw materials for production of export commodities and vehicles.

Investors can also benefit from easily accessible and efficient one-stop-shop services at EIC and Industrial Parks (IPs) (EIG). Industrial Parks Development Corporation (IPDC) and private developers are developing IPs throughout the country. It is specifically the

Integrated Agro Industrial Parks (IAIPs) that are of interest. These are part of the Ethiopian Agro-Industry Sector Strategy, developed in 2009 to address the major identified constraints, such as weak infrastructure, underdeveloped agricultural commodity value chains and limited farm support services. Annex 3 summarises the 20 operational, state-of-the-art IPs in Ethiopia and shows the specific locations of the IAIPs.

2. Brassica carinata as an energy crop

2.1. Ethiopian experience of Brassica carinata (BC) cultivation (varieties of BC, regions, yields)

In Ethiopia, Brassica carinata grows best in the cool moist climates in the tropics from mid to high altitudes above 1,700 to 3,200 m, above sea level. However, it grows best in areas within the range of 2,000-2,600 m above sea level and seasonal rainfall of 600-900 mm. Soil pHs ranging from 6.0 - 7.5 are most favourable. The current major growing areas are Arsi, Bale, West Shewa, East Wellega, West Gojam and South Gonder.

**Brassica carinata grows in monocropping, crop rotation and intercropped with cereals notably with maize, sorghum, and teff.** In most cases, Brassica carinata is grown during the main rainy seasons of Ethiopia ‘Meher’ (May to September) or ‘Belg’ (February to April). Although irrigation is practiced in few areas, it is very limited. Low input application and minimum tillage are also the major characteristics of Brassica carinata growing fields in Ethiopia.

Brassica carinata is an excellent crop for **crop rotation with major food crops** (like wheat and barley), particularly to control grass weeds and disease incidence.

The rotation frequency for carinata with cereals and pulses is one or two growing seasons depending on environment conditions and pest prevalence, indicatively:

- Option 1: Brassica carinata - Cereals (wheat/Barley)/ Pulse - Brassica carinata
- Option 2: Brassica carinata - Cereals - Pulse (Fava bean/Fieldpea) - Brassica carinata
The production of Brassica carinata in Ethiopia is characterised by many producers, with more than 423,273 households of fragmented smallholdings averaging 0.02 ha in size\textsuperscript{20}. The total production hectarage of the crop during the main Meher and Belg seasons was steadily decreased from 45,167.81 to 7,917.47 ha in the last decade. Similarly, the total volume of production has decreased from 74,666.356 tons in 2011/12 to 12,575.789 tons in 2020/21 (Figure 2-1), mainly because of land competition with cereals especially barley and wheat when grown as a monocrop and lack of inputs, improved seed varieties, inadequate extension service and large-scale mechanisation\textsuperscript{21,22}.

\textbf{Figure 2-1 Area coverage and production trend of carinata in Ethiopia for the last ten years (2011/12 to 2020/21)\textsuperscript{20}}

\textbf{Ethiopian farmers produced Brassica carinata seed to sell it to local communities to be used for greasing traditional bread-baking/injera-baking clay pans (ovens) or to}

\textsuperscript{22} Girma Chala and Misteru Tesfaye 2017. Response of Applied Nitrogen Fertilizer and Seeding Rate on yield and yield Components of Ethiopian Mustard (Brassica carinata) in the Central Highlands of
be sold to traders for export purposes\textsuperscript{23}. Ethiopia exported a record of 10,089.3 tonnes in the fiscal year (FY) 2013/2014\textsuperscript{24}. However, the export trend was erratic in the last couple of years because of political instability. For example, the export amount in FY2020/21 was only 5,541 tonnes (Annex 4). Local retailer price of Brassica carinata seed in Addis Ababa is currently about 48 ETB/kg (0.91 USD/kg) whereas producer price is around 27 ETB (0.51 USD/kg)\textsuperscript{25}.

Figure 2-2 shows the use of BC seeds to grease a traditional clay pan and BC leaves being used for food.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2-2.png}
\caption{Use of BC seeds to grease a traditional clay pan and BC leaves used for food.}
\end{figure}

Even though growing Brassica carinata as a cover crop is a common practice in many parts of the world; it has not yet been adopted as such in Ethiopia. The main reasons for this include the following:

- There is a lack of experience and technical advice on conservation of agriculture practices;
- There is a limited extension service to promote Brassica carinata to be used as a cover crop;

\textsuperscript{23} Ethiopia. International Journal of Research in Agricultural Sciences Volume 4, Issue 5, ISSN (Online): 2348 – 3997
\textsuperscript{24} Ministry of Trade and Regional Integration (MOTRI) 10-year export data
\textsuperscript{25} Personal communication with retailers and producers
• There is a lack of awareness on the benefits of cover crops (most farmers have no experience to use Brassica carinata as a cover crop and some are not familiar about its benefits);
• Cover crops are considered by many farmers to add extra economic costs, as it requires additional time, labour, seed, and management costs;
• Free animal grazing is a common practice in most parts of Brassica carinata growing areas during offseason, which makes it difficult to plant a cover crop before the main cropping season.

Actually, there is a limited practice of crop cover farming for Brassica carinata or other crops like chickpea. In the case of Brassica carinata, as our interest is to produce both the leaf and the seed, cover cropping is not a suitable practice unless it is supplemented by irrigation, as its growing season lasts about 5 months and it is difficult to obtain sufficient rainfall to support optimal growth of the crop.

It should be noted that Brassica carinata requires optimum moisture for growth, particularly during the flowering and grain filling period and in Ethiopia, it is difficult to obtain sufficient rainfall to support optimal growth of the crop after September.

On the other hand, and despite its potential benefits, intercropping may be undesirable when a single standardised product is required, and might lack economies of scale for labour and time management. Intercropping has not usually been seen as suitable for large scale mechanisation in an intensive farming system, as expected in Brassica carinata production for SAF.

**Besides the smallholder farmers, there are few states that own commercial farms in Ethiopia**, see Table 2-1. At present, Ethiopian Seed Enterprise and Oromia Seed Enterprise, Kulumsa Agricultural Research Centre and Agerfa Technical and Agricultural College are the only commercial scale producers of Brassica carinata seed. These companies used mechanisation and produce Brassica carinata in crop rotation with cereals. However, their area coverage is limited to < 150 ha/year. In 2019/20, Brassica
carinata was grown in 3,889.42 ha of land by commercial farms in crop rotation and 6,824.28 tonne grain was obtained with productivity of 1.8 tonne/ha 26.

To improve the production and productivity of Brassica carinata, more than 10 varieties were released by federal and regional research centres. However, from the released varieties, Yellow Dodola is the most demonstrated and adopted variety. This variety is characterised by yellow seed colour, high seed productivity (2 ton/ha) and high oil content (44%), while it is stable and adapted to major growing areas of Ethiopia. The list of improved varieties was listed in Table 2-27 and Table 2-3.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Company Name</th>
<th>Owner</th>
<th>Mode of production</th>
<th>Area covered by Brassica carinata per year (ha)</th>
<th>Location of the farm</th>
<th>Are they volunteer to supply seed if market linkage created</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oromiya Seed enterprise</td>
<td>Government</td>
<td>Certified seed production and Crop rotation</td>
<td>&gt;150 ha/year</td>
<td>Arsi and Bale</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Ethiopian Seed enterprise</td>
<td>Government</td>
<td>Certified seed production and Crop rotation</td>
<td>&gt;150 ha/year</td>
<td>Arsi</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Kulumsa Agriculture</td>
<td>Government</td>
<td>Certified seed production</td>
<td>100 ha/year</td>
<td>Arsi</td>
<td>Yes</td>
</tr>
</tbody>
</table>

27 Ethiopian Institute of Agricultural Research (EIAR)
Table 2-1: List of Commercial farms growing Carinata (Source: Project data survey)

<table>
<thead>
<tr>
<th>I Research Centre and Crop rotation</th>
<th>Bale</th>
<th>Yes. They have experience on Malt barley (pre contractual agreement with malt factory)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agerfa TVET Collage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop rotation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>170 to 200 ha/year</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2-2: Carinata improved varieties released for wider adaptation by federal research centres

<table>
<thead>
<tr>
<th>Name of Variety</th>
<th>Year of release</th>
<th>Productivity (Q/ha)</th>
<th>Oil Content (%)</th>
<th>Days to Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tesfa</td>
<td>2018</td>
<td>24</td>
<td>-</td>
<td>147</td>
</tr>
<tr>
<td>Derash</td>
<td>2018</td>
<td>23</td>
<td>46.8</td>
<td>145</td>
</tr>
<tr>
<td>Holetta-1</td>
<td>2005</td>
<td>30.3</td>
<td>39.1</td>
<td>150</td>
</tr>
<tr>
<td>Yellow dodola</td>
<td>1986</td>
<td>30.2</td>
<td>44.1</td>
<td>156</td>
</tr>
<tr>
<td>S-67</td>
<td>1976</td>
<td>30</td>
<td>40.5</td>
<td>157</td>
</tr>
</tbody>
</table>

Table 2-3: Carinata improved varieties released for wider adaptation by federal research centres

<table>
<thead>
<tr>
<th>Name of Variety</th>
<th>Year of release</th>
<th>Productivity (Q/ha)</th>
<th>Oil Content (%)</th>
<th>Area of recommendation for production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawassa-1</td>
<td>2006</td>
<td>9.4</td>
<td>38</td>
<td>Hawassa</td>
</tr>
<tr>
<td>Kokiet-1</td>
<td>2006</td>
<td>10.6</td>
<td>33.5</td>
<td>Hawassa</td>
</tr>
</tbody>
</table>

Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final
Table 2-3: Carinata improved varieties released for specific adaptation by regional research centres

<table>
<thead>
<tr>
<th>Region</th>
<th>Year</th>
<th>Variety</th>
<th>Yield</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muger</td>
<td>2002</td>
<td>15.3</td>
<td>3.3</td>
<td>West Gojiam</td>
</tr>
<tr>
<td>Tule</td>
<td>2002</td>
<td>15.4</td>
<td>15.2</td>
<td>West Gojiam</td>
</tr>
<tr>
<td>Shaya</td>
<td>1993</td>
<td>18</td>
<td>14-16</td>
<td>Bale</td>
</tr>
</tbody>
</table>

2.2. International experience of Brassica carinata

Brassica carinata (BC) is a semi-wild species originating in the Ethiopian plateau of north-eastern Africa, where it is believed to have been cultivated since 4,000 BC for use as a cooked leafy vegetable. **BC is often selected as a non-edible winter biofuel crop because it has higher cold tolerance and greater yield potential, compared to some other crops such as rapeseed, camelina, etc., while it has also a suitable oil profile for biofuel production.** BC, as a biofuel feedstock, is a new crop to many regions worldwide, therefore, limited information on agronomic practices for successful production is available. Preliminary findings suggest that BC provides ecosystem services similar to other winter cover crops, including reduced leaching and soil erosion, suppression of weed populations, improvement of soil fertility through the addition of organic matter, and provision of a food source for pollinators.

**Cultivation of BC is planned for or is being carried out in the south-eastern U.S., Canada, Europe, China, Australia, and Latin America.** It can be well adopted in the Mediterranean climate areas, and it is a drought and heat tolerant oilseed crop. It is used as a feed (carinata meal) and oilseed crop, especially in the arid and semi-arid areas. BC has been grown commercially for several years on the Canadian prairie, in the south-eastern US, the US northern plains and Uruguay. Canada is one of the global leaders in BC oil production and covers 20% of the world’s supply resulting to $11 bil. in economic value. The U.S. has become the largest buyer of BC oil from Canada and therefore has led to increased interest in BC production in US regions.
Commercial production of BC in the south-eastern US first began with 4,000 ha during the winter-spring growing seasons, from 2015 to 2018. This expansion followed previous small-scale industry-led attempts in 2014, that introduced the crop via individual contracts with interested early adopters. Multiple years of weather variability during early commercial production have provided learning opportunities on the limitations of the existing commercial variety. On the other hand, BC has also proved to be challenging for producers who first began growing the crop. BC displayed higher than average yields than other oilseeds like canola and camelina, suggesting greater economic opportunities for increasing overall revenue. Additional benefits for farmers, by improving several metrics of soil quality, such as organic matter, soil structure, microbial biodiversity, while reducing soil erosion and compaction, have been also identified.

New commercial cultivations were started recently in Uruguay and Argentine by major businesses around biofuels.

### 2.2.1. BC cultivation characteristics

Brassica carinata has **high concentration of erucic acid (40%–45%)**, a fatty acid that allows the production of biofuels having similar physical and chemical properties and performance compared to fossil kerosine. Due to its high protein content and low fibre content, carinata seed can also be used to **produce meal for animal feed after oil extraction**, if it has undergone necessary processing, thus strengthening the overall economics of the BC value chain. Besides this, the BC leaves are used as a food in Ethiopia, and the BC pellet made from crop residues is modestly suited for energy use in terms of pellet quality, compared to wood pellet, further contributing to sustaining the local agro-energy chains.

The successful development of a BC supply chain relies on the rotational or cover fit of BC into existing cropping systems, respecting land competition with food and feed crops. BC could potentially be produced in a cover-crop system in most of the potential regions, though it would require significant research to efficiently integrate crop biology with agronomy. The benefits of growing BC as a winter crop are two-fold:

- increased revenue for farmers;
Growing BC following summer row crops and pastures, may be a viable option for many farmers. Therefore, the BC crop has the potential to supplement part of the renewable energy demand, without displacing feed and food crops as recently used by some countries, such as the USA, Canada, Italy, and Spain. BC is now a new promising energy crop for most Mediterranean, arid, and semi-arid climate countries. The presence of high yield levels requires fewer inputs, and the ability to adapt and resist abiotic and biotic stresses that makes it valuable in terms of agronomy and energy balances. For instance, its adaptation has considerably expanded and increased its production in some drier areas of the USA (California), Canada, Italy, Spain, and South Asian countries, due to the increasing demand for bioenergy and oilseed productions in these countries, and the incidence of global climate change effects on sustainable agricultural production and environmental systems.

**BC is suitable for crop rotation and intercropping with food crops, such as wheat, chickpea, barley, and sorghum.** It also has a role in the low farming systems as a potential rotational crop for cereals and pulses since BC is widely used as a biofumigant to break soil-borne diseases and pests in Australia and New Zealand. Health-related phytochemicals of BC can be modified by intercropping with Nightshade, an African indigenous vegetable crop. Moreover, **BC is mostly unsuitable for rotation with other energy crops**, as it it may be exposed to diseases such as sclerotinia.

In Canada BC helps as a cover crop (green manure) to reduce soil erosion, herbicide use and balance nutrient losses. The traditional practices of mixed cropping systems involving BC, have been preffered by farmers in recent years using intercropping with suitable modifications in planting patterns. The intercropping of BC with chickpea in the semi-arid tropics of India has improved tolerance to plant diseases and moisture conditions. It can be emphasised that BC can be grown under limited environmental conditions and a lower cost of production.

Among botanical species yielding high quantities of erucic acid, BC is among the most important crops in the production of this type of oil per hectare. In the 1990s, European countries, such as Italy, searched and collected BC lines from India, Germany, and the
Netherlands in order to screen for better agronomic performance and high potential oil productivity in winter conditions and marginal soils. Meanwhile, the BC cultivar “Sincron” was established as a candidate biodiesel production oilseed crop in Italy. In parallel, the North Florida Research and Education Centre (NFREC) also developed a new commercial variety of BC called AAC A120, which has a high yielding performance (both in seed and oil production), and has adapted well in the southeast USA. Hence, this variety may increase diversification, generate revenue and improve ecosystem sustainability. However, this was picked up to develop region-specific agronomic traits and targeted for double crop production in the south-eastern USA.

The BC growth requirements regarding the variability of soil and climatic conditions in different zones within various regions of the world, is yet to be determined. It has been reported that plants growing in different environments are exposed to variable climatic conditions which directly affect yield, oil content, and composition of the oilseed crops, and in turn its overall agronomic performance. Yield stability under different environmental conditions is an important aspect of crop production, and a key component for identification and development of cultivars. In the case of BC, little is known about how genetic diversity can be used to increase the compatibility with growing conditions during the winter or summer seasons, and relevant research is ongoing for many promising regions in America and Europe. Therefore, genotypes grown at different locations are tested to investigate the effects of environment on genotype performance, with the emphasis on those that are early maturing, high yielding with high oil content.

2.2.2. Contract farming and barriers in adopting BC

Contract farming is an important component of many current public-private partnerships (PPPs) in developing countries, including the G8’s New Alliance. Such schemes often appeal to farmers because the company/counterpart of contract farming often provides inputs and production services. In addition, farming incomes can rise, and such schemes often open new markets and provide new technology, as required in the case of BC development. Contract farming has been implemented in the United States back to the 19th century and in the recent years has expanded to developing countries in Africa and Asia. One of Ethiopia’s policy commitments, in its Cooperation Framework on G8’s New Alliance...
for Food Security and Nutrition, was to refine land law, to encourage long-term land leasing and to strengthen contract enforcement for commercial farms.

Contract farming is one type of farming that can be described as a contract or an agreement between a farmer/cooperative and a buyer/company. Due to this agreement or contract between two entities, there would be terms and conditions involved in production as well as marketing. In this type of farming, the farmer will come to an agreement with the buyer that they would produce the quantities of particular agricultural products which they have agreed to. The farmer would need to produce the promised quantity of the crop at the specified time, w set by the buyer. At the same time, the buyer would need to provide the farmer with the necessary inputs required for the farm like preparation of land, technical aspects, etc. They also would need to make sure that they would be buying the products.

Consequently, contract farming enables poor farmers to transform away from outdated cultivation and management practices towards market-oriented commercial production, as with BC, resulting in increased employment and income.

Today there are three main types of contract farming:

- Contracts that stipulate only sale and purchase conditions. This type is usually referred to as a “Marketing Contract” or a “Market Specification Contract”;
- Contracts in which only some of the inputs are supplied by the contracting firm and production is bought at pre-agreed prices, called a “Resource Providing Contract”;
- Contracts under which the contracting firm supplies and manages all the inputs on the farm and the farmer becomes just a supplier of land and labour, called a “Total Contract” or a “Management and Income Guaranteeing Contract”.

Many varieties based on the above-mentioned types of contract farming have been implemented depending on the type of buyer (multinational company or SME), the type of crop (BC in our case), type of financing, type of management, etc.
The most significant barriers of BC value chain development are related to the expansion of BC cultivation and its adoption by the farmers. Some of the barriers are mentioned in the following paragraphs.

The major barrier of farmers, as it was surveyed in the US and mentioned in other regions, in adopting BC is unfamiliarity with the crop. This issue is reasonable and common for new crops such as BC, since farmers may vary in their knowledge of the crop, including those with no knowledge of BC whatsoever.

Historical crop failures or bad experiences with other oilseed crops have given BC a negative reputation among some farmers in the south-eastern US, a barrier that evidently seems to consider the competition among the oilseed crops and the relevant development industries which come into contracting agreements with the farmers. This fact suggests that a troubled history with oilseed companies might make potential growers hesitant to sign contracts with the BC industry.

Growers in various categories illustrate the need for more research on the fitness of BC in existing crop rotations, by particularly mentioning the challenges related to the timing of the BC growing season, which might interfere with the planting and harvesting of summer cash crops. Relevant concerns regarding various agronomic factors, including effects on BC’s growth by chemicals used in the management of row crops, accompany this argument.

Finally, a satisfactory selling price is always a very critical parameter for potential growers of BC, because the assessment of the overall viability conditions and the fair allocation of the relevant risks will surely influence crop adoption.

2.2.3. Use of BC as feedstock for biofuel

Increasing the demand for high erucic oils for industrial feedstocks, forces researchers to develop relevant BC cultivars with increased proportions of erucic acid and very-long-chain fatty acids to fulfil the industrial oil market needs. BC has also shown promise as potential Hydrotreated Renewable Jet fuel feedstock. Therefore, the advocacy and development of
BC as an alternative biorefinery and bio-industrial oil platform using traditional and molecular breeding techniques and tools is essential.

In 2018, the Australian Qantas Airways, together with Canadian agro-tech company Agrisoma Biosciences, flew the first dedicated biofuel-powered flight between Australia and the USA, using a jet biofuel produced from the BC oilseed. In recent years and due to increasing interest and demand for sustainable aviation fuel (SAF) from big airlines, there are substantial initiatives from developers and producers of biofuels to involve BC and create the relevant value chains. The significant cases of Nuseed and UPM will be presented in the following sections.

Nuseed

Established in Australia in 2006, Nuseed has grown to offer industry-leading germplasm, advanced molecular capabilities, regional R&D and commercial trials with dedicated teams in Australia, Europe, North America and South America, and sales in more than 30 countries. The company develops canola, carinata, sorghum and sunflower to deliver new, sustainable plant-based solutions to growers, industry, and end-use customers, adding value at every step and for each participant in the value chain. The company develops plant input traits with agronomic benefits that ensure delivery of top seed and service in all regions. Then, through development of plant output traits, it provides growers with new opportunities to produce sustainable plant-based solutions, with specific consumer benefits.

Over 250 employees work across global locations including three world-class Nuseed Innovation Centres. Nuseed is a wholly owned subsidiary of Nufarm Limited (AVRDC: NUF)

Nuseed Carinata crop production practices, as well as resulting grain logistics, are managed following regulatory and certification requirements from field to fuel, for best-in-class greenhouse gas (GHG) reduction. This includes independent SCS Global audit and certification by the Roundtable on Sustainable Biomaterials (RSB). The company is scaling commercial production, first in South America, where the Nuseed team continues to meet
growth goals and is increasing hectares grown, and within the next few years in the Southern United States.

Today Nuseed Carinata is a drop-in feedstock solution to help European biofuel processors start producing the low-carbon fuel that government climate change goals require, without displacing food production. The 2021 Nuseed Carinata harvest, a non-food cover crop grown between main crops in Argentina, recently shipped to Saipol, the largest biodiesel producer in Europe for processing at their facility in France.

The Nuseed Carinata contract provides growers with additional revenue from existing farmland without disrupting typical crop rotation or food production and rewards sustainable farming practices to supply the low-carbon biofuel feedstock. The Nuseed team is closely supporting growers and contractors, who are keen to take the next step in adding Nuseed Carinata to their crop rotations.

Nuseed Carinata growers gain soil benefits and an additional income opportunity by adopting certified sustainable farming practices. From after harvest right to next season’s planting, when weather limits growing main crops, Nuseed Carinata covers typically exposed land to protect against soil erosion and weed pressure while increasing biodiversity, soil carbon and overall soil health. It’s also a new contract opportunity that rewards growers for adopting RSB sustainable farming practices to produce certified Nuseed Carinata low-carbon fuel feedstock.

Recently, Nuseed and BP Products North America Inc., entered into a long-term strategic offtake and market development agreement, that will see BP, or its affiliates, purchase Nuseed Carinata oil to process or sell into growing markets to produce sustainable biofuels and help decarbonise challenging transportation sectors, such as aviation, supporting the production of sustainable aviation fuel (SAF) and other biofuels.

The agreement is for an initial 10-year term and will see Nuseed continue to develop and expand its existing network of growers, channel, and supply chain partners to deliver Carinata oil to BP, with key steps of crop production independently audited and certified. The BC oil will be processed by BP through its bio-refining footprint and sold into growing markets to produce sustainable biofuels. This agreement is expected to assist with the
rapid expansion of production, with BP standing as a committed buyer of feedstock and marketer of resulting fuels.

BP is already an active participant in the biofuels supply chain. It produces renewable diesel from biomass-based feedstocks, including in the United States where it recently announced a project to expand renewable diesel production capability to an estimated 2.6 million barrels a year in 2022. Globally, the BP group aims to more than double its bioenergy portfolio by 2025 – and to quadruple it by 2030 – compared to 2019.

**UPM**

UPM, established in Finland, is a major forest and pulp industrial company with specific department for biofuels and relevant feedstock development and production. It invests in businesses that offer attractive long-term fundamentals for profitability and growth, as well as opportunities to achieve a sustainable competitive advantage. UPM has invested €179 million in the world’s first biorefinery producing wood-based renewable diesel and naphtha called UPM BioVerno. The UPM Lappeenranta Biorefinery produces UPM BioVerno diesel and naphtha from crude tall oil, a residue of UPM’s own pulp production.

The commercial production of BioVerno diesel and naphtha started in January 2015 and the annual capacity is 120 million litres of advanced, renewable biofuels. The biorefinery is based on UPM’s own innovations and it employs 75 people directly and 150 people indirectly.

UPM entered the industrial forest market of Uruguay in the late 80s and had a dual purpose: to promote forest plantations and to protect natural forests. Ever since, Uruguay has successfully made progress in consolidating the forestry sector, which has had a positive impact on the country’s production chain, creating over 25,000 jobs. Plantations have widespread socioeconomic impacts through around 235 contractor companies and more than 580 suppliers in rural areas. Introduction of cultivation of BC to produce BC oilseed and biofuels is a new initiative of UPM in the country.

Therefore, UPM has over 450,000 ha of land ownership for eucalyptus plantations in Uruguay and therefore the farming community is well-known to the company. Also, UPM
has developed carbon farming practices for over six years in Uruguay, planting approximately 10,000 ha of cover crops (BC in principle) annually.

Nowadays, only 30% of the agricultural land is productive during winter in Uruguay. For farmers, BC yields extra income as an excellent option for winter crop seeding. Under local law, the fields always have to be covered. If farmers are not seeding a harvestable crop during winter, they have to at least seed a cover crop to protect the soil from erosion caused mainly by rain. This is important for the ecosystem, but without any profitable harvest, it is an additional cost for producers.

Farmers in Uruguay have begun cultivating BC under contract with UPM. UPM provides the seeds to the farmers, buys the entire harvest, and sells it all in the international market so everything is handled through UPM. The price is transparent as it is adjusted in line with an international market price index. When farmers sow a crop, they know the approximate costs in advance. With a clear grain price, they will be able to better foresee the return on their investment.

Another argument in favour of UPM carinata initiative is the RSB certification system, which promotes the best agricultural practices and sustainable operations. It lays down several obligations and some specific norms, but many requirements are already included in the current regulations. As part of the requirements, farmers must show relevant land ownership or rental papers, and must present a plan for the use and management of the land. In addition, they must have started their farming operations before January 2008. In the certification process, an auditing company carries out the auditing process and verifies the information provided by the farmer, and the results are reported to UPM.

UPM is developing the project together with the faculty of Agronomy and INIA. Collaboration with UPM for around five years testing and evaluating the crop in different locations across Uruguay, explains the need for local research institutions support. For example, they have tried different planting seasons in early May and as late as July. The obtained experience indicates that the early planting season gives the best results, as the latter one reduces production by almost 50%. The harvesting season will be in November and sometimes at the beginning of December, so it makes a perfect match with soy. In addition, the advantage of BC is that it is harvestable in one operation. Therefore, the loss
of grain is minor when compared to canola, for example, which requires sometimes two harvesting operations. In addition, also the yield seems to be higher than that of canola, at least in our experiments. The most popular winter crops in Uruguay are currently wheat and barley, and now canola. Farmers that are used to cultivating in winter do not need to make any additional special investments because the cultivation of BC is similar to canola. In addition, BC produces a lot of biomass residues, so it useful for preventing erosion and improving soil. It requires no changes in the land use.

The weather has been very difficult during the last few years in Uruguay. Also, with international prices decreasing, farmers are looking for alternative crops. Many farmers that have tried BC are expanding the crop acreage because it shows local potential and is obviously profitable as well. In 2020, BC crops totalled 7,200 hectares of farming land in Uruguay. Now UPM is increasing the commercial acreage in collaboration with local farmers. All areas are cultivated by local contracted farmers.

UPM makes a supporting technical team available to help farmers who are keen to start cultivation of BC. The farmers can send an e-mail to UPM, and the experts will explain the different forms of seeding and all the necessary documents needed. The cropping concept meets all possible sustainability requirements in compliance with RSB certification.

The references on the basis of which the information presented above in Section 2.2 are listed in Annex 1 under a separate heading for the convenience of the reader.

2.3. Organisational and institutional issues related to efficient and sustainable value chain to SAF and biofuel production

The SAF value chain network consists of feedstock production, feedstock transportation, SAF production, blending and fuel distribution and SAF end-use. Table 2-4 shows the key actors and their role along the value chain in Ethiopia.

For the pre-feasibility calculations of this study, we consider that crop rotation provides a fair overview for Brassica carinata cultivation in Ethiopia for SAF production. Rotation cropping might prove less favourable for farmers’ income, but considering that farmers are more experienced in this process of cultivation, rotation cropping is more realistic at present.
It is up to the investor and the collaborating farmers to select the optimal, and sustainable cultivation method using clear criteria.

Then, in the sections that follow, a brief description of the organisational and institutional issues in each part of value chain is provided.

2.3.1. Feedstock production

Land tenure

Regarding land tenure, the existing constitution of the Federal Democratic Republic of Ethiopia (FDRE) states that the right to ownership of land is completely vested in the state and in the people of Ethiopia. In order to implement this provision, a Rural Land Administration Law has been further enacted with the following major features:

<table>
<thead>
<tr>
<th>Feedstock Production</th>
<th>Actors</th>
<th>Roles</th>
<th>Government Mandated Bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Smallholder farmers, Cooperatives, Large scale farm owners</td>
<td>Seedlings, Land preparation, planting, Fertiliser application, production, harvesting and storage</td>
<td>Ministry of Agriculture, Ethiopian Investment Commission, Rural Energy Promotion and Development Centre</td>
</tr>
<tr>
<td>Feedstock Transport</td>
<td>Transport Enterprises</td>
<td>Transportation to the biorefinery facility</td>
<td>Ministry of Transport</td>
</tr>
<tr>
<td>SAF Production</td>
<td>Government and Private biorefinery companies</td>
<td>Feedstock Processing for SAF production and storage</td>
<td>Ministry of Trade and Regional Integration, Ministry of Industry, Ministry of Innovation and Technology</td>
</tr>
<tr>
<td>Blending and Distribution</td>
<td>Blending companies and Distributors</td>
<td>Storage, blending, transportation</td>
<td>Ethiopia Petroleum Supply Enterprise</td>
</tr>
</tbody>
</table>
Table 2-4: Key actors and their role along the value chain in Ethiopia

- Land is a common property of the Nations, Nationalities and Peoples of Ethiopia and it shall not be subject to sale or to other means of exchange;
- Regions shall administer rural land in accordance with the general provision of this proclamation and each regional council shall enact a law on land administration of its region.

Accordingly, a land application would be submitted at the Ethiopian Investment Commission directly after securing the investment license. The authority would issue a letter to Regional State Investment Commission to facilitate for the land acquisition. If accepted, the Regional Administration would liaise with city and district authorities, to engage current users of the land and process compensation.

The Fertiliser Blending Program

The Fertiliser Blending Program was launched in February 2013 to oversee the establishment of four high-capacity blending facilities. The Integrated Soil Fertility Management System (ISFM) and the Ethiopian Soil Information System (EthioSIS) are designed to map and assess the soil nutrient needs of each area, aiding the creation of optimal fertiliser blends and informing application rates.

Ethiopian Agricultural Business Corporation

The Ethiopian Agricultural Business Corporation (EABC), established in December 2015, is the largest field crop seed producer and supplier in Ethiopia, in addition to supplying other agricultural inputs. Being state-owned, the company is supervised by the Ministry of Agriculture.
EABC imports fertiliser under a Free on Board (FOB) agreement in which it assumes the responsibility of shipping the fertiliser itself, once it is bought from the provider, and distributes it among farmers at below-market price through the network of cooperative unions.

Fertiliser prices are set by the Ministry of Agriculture in consultation with stakeholders. Prices and margins from the port to cooperative warehouses are determined by costs incurred by EABC, the sole importer, while cooperatives and farmer fertiliser prices are determined by regional agricultural bureaus in consultation with cooperatives.

2.3.2. Feedstock transport

Feedstock transport is an important factor in SAF development. In Ethiopia, most of the rural roads are in poor condition and there is a shortage of heavy truck in the country. This has imposed significant challenges on the agricultural activities in general and increased the price of crops produced. The Government of Ethiopia has embarked on various programmes at one time or another to address the issue by allocating up to 5 % of the GDP every year but, Ethiopia’s rural road network is still one of the least developed in Africa.

Recently, with the hope of easing problems in the logistics sector brought on by a shortage of heavy trucks, the Federal Transport Authority (FTA) under Ministry of Transport in collaboration with the National Bank of Ethiopia (NBE) initiated a credit system for importing heavy trucks. With the new initiative, the private sector will procure the trucks through a supply credit modality approved by the National Logistics Council.

2.3.3. SAF production

The Government of Ethiopia is trying to transform the country from an agriculture-dominated economy to an industry-dominated one. Ethiopia’s Ten-Year Perspective Development Plan (2021 –2030) highlights the manufacturing industry as one of its priorities in national development. The focus areas in manufacturing industry development include: utilisation of locally available inputs; value chains; linkages and interdependencies; and private sector participation and partnerships.
However, the sector is still in its infancy and needs to be developed to support the country’s rapidly growing economy. One of the major constraints for the sector development is lack of standardisation for products. Fostering product quality upgrading and awareness of and adherence to international product standards is crucial. Many tests and certifications requested by buyers are not provided by any internationally recognised domestic institution, requiring firms to pay enormous costs to have tests done abroad, if they want to comply. The state-owned Ethiopian Standard Agency under the Ministry lack capacity in human resources, the facility to ensure accurate measurement, well-equipped laboratories to meet the industries’ demands.

Various incentives have been initiated to support the sector development including equities on joint ventures, and access to credit. However, if Ethiopia is to develop a green economy and to compete in an increasingly globalised market, it needs to create a special supporting policy for the establishment of Biorefineries. It is important that the government facilitates private sector growth by providing special incentives for domestic and foreign investors engaged in the development of biorefineries.

2.3.4. Blending and distribution

It is expected that the SAF produced will be sold to the fuel blending wholesaler petroleum companies, where blending can be done at their depots. As Ethiopia already started ethanol-blending, blending facility is available and the relevant experience can be used for SAF blending also. In Ethiopia, the wholesaler companies who actively engaged in blending and distribution at present are Oil Libya, Nile Petroleum, National Oil Company (NOC) and Total Ethio. Since Nile Petroleum has closed its blending facility, the remaining three are the sole companies that are responsible for the distribution of blended fuel recently. The four blending facilities have a total storage of 550,000 litres of blended fuel.

Ethiopian wholesale petroleum companies face several challenges, among which are low fuel profit margin, recurrent foreign exchange shortages, difficulty in meeting operational and safety standards, and operating under an outdated regulatory framework that is no longer in step with the sector’s growth. Moreover, the scattered regulatory roles bestowed
upon multiple government organs have made the decision-making process highly complex\textsuperscript{28}.

2.3.5. SAF End-use

Ethiopia launched its Climate Resilient Transport Sector Strategy in 2017 to support the government’s vision, outlined in the Climate Resilient Green Economy Strategy. The strategy states specific targets on reducing or offsetting emissions of GHG produced from land, air, and sea transport, among which is the introduction of up to 10\% biofuels into the aviation fuels mix by 2030.

The Ethiopian Civil Aviation Authority, as an aviation regulatory body, is currently revising Ethiopia’s state action plan\textsuperscript{29} — a voluntary reporting tool for relaying information on actions to address CO\textsubscript{2} emissions from international aviation to the ICAO to include SAF utilisation. Hence, there is a strong desire and commitment in the utilisation of SAF for air transport in the country.

2.4. Criteria for identification of suitable lands for BC

Suitability analysis can answer the question, “what to grow and where?” The suitability will be a function of crop cultivation requirements and land characteristics, and it is a measure of how well the qualities of a land unit match the requirements of a particular form of land use\textsuperscript{30}. In order to define the suitability of an area for a specific practice, several criteria need to be evaluated.

The point of this study was primarily focused on the identification of a suitable land for Brassica carinata production in Ethiopia. In order to define the suitability of an area, GIS based multicriteria evaluation approach is used for the assessment of land suitability. A weighted overlay analysis method was used to customise and reclassified each raster

\textsuperscript{28} Study report by Ethiopian Oil Companies Association  
\textsuperscript{29} Personal communication with Ethiopian Civil Aviation Authority representative  
\textsuperscript{30} FAO report, 1976
criteria layer into four categories with associated suitability classes of highly suitable, moderately suitable, marginally suitable, and unsuitable lands for carinata production in Ethiopia. **ModelBuilder** application of **ArcGIS** used for constructing, editing, executing workflows and spatial analysis.

The distinct parameters used in the analysis were: length of growing period (LGP); altitude; slope; soil properties (such as soil type, pH, texture, drainage, and soil depth); and the climate layers (including rainfall and temperature) during a growing period. Furthermore, the land use/land cover like lakes and parks was also considered during the analysis and weights for each of the selected criterion were calculated. Lakes, parks/protected areas, and lands with greater than 30% slope were excluded from the suitability computation altogether assuming that such land may not be used or available for agriculture in favor of other ecological services.

### 2.5. Mapping of suitable Ethiopian regions for BC cultivation

The result of a crop suitability map analysis for Brassica carinata showed that **Ethiopia has abundant suitable land for its production. It is identified that 29,902,340 hectares of land is suitable for Brassica carinata production.** Based on the suitability class and the estimation of the project experts, 3,124,044 ha are highly suitable, 22,714,012 ha are moderately suitable, whereas 4,064,284.00 ha are marginally suitable and 79,838,004 ha is defined as unsuitable land.

The analysis of this study also shows that **Oromiya has large proportion of suitable land** with 16,019,728 ha, followed by **Amhara** and **SNNP** with 7,109,188 ha and 3,048,600 ha respectively. Following the estimations of the project experts, Fig 2-3 shows the land suitability map of Brassica carinata production in Ethiopia and the regional distribution and available area of land based on suitability class is tabulated in table 2-5.
Figure 2-3: Suitability map of Brassica carinata in Ethiopia
<table>
<thead>
<tr>
<th>No.</th>
<th>Regions</th>
<th>Area in hectares</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unsuitable</td>
<td>Marginally suitable</td>
<td>Moderately suitable</td>
<td>Highly suitable</td>
</tr>
<tr>
<td>1</td>
<td>Addis Ababa</td>
<td>136.00</td>
<td>-</td>
<td>53,008.00</td>
<td>224.00</td>
</tr>
<tr>
<td>2</td>
<td>Afar</td>
<td>8,062,564.00</td>
<td>4.00</td>
<td>8,708.00</td>
<td>372.00</td>
</tr>
<tr>
<td>3</td>
<td>Amhara</td>
<td>8,060,740.00</td>
<td>469,112.00</td>
<td>5,509,880.00</td>
<td>1,130,196.00</td>
</tr>
<tr>
<td>4</td>
<td>Benishangul Gumuz</td>
<td>4,352,408.00</td>
<td>230,884.00</td>
<td>396,808.00</td>
<td>336.00</td>
</tr>
<tr>
<td>5</td>
<td>Dire Dawa</td>
<td>105,228.00</td>
<td>-</td>
<td>116.00</td>
<td>4.00</td>
</tr>
<tr>
<td>6</td>
<td>Gambella</td>
<td>2,853,960.00</td>
<td>65,840.00</td>
<td>80,080.00</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Harari</td>
<td>36,812.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Oromia</td>
<td>15,908,404.00</td>
<td>2,696,448.00</td>
<td>11,867,680.00</td>
<td>1,455,600.00</td>
</tr>
<tr>
<td>9</td>
<td>Sidama</td>
<td>123,080.00</td>
<td>24.00</td>
<td>449,944.00</td>
<td>93,264.00</td>
</tr>
<tr>
<td>10</td>
<td>SNNP</td>
<td>3,117,708.00</td>
<td>69,828.00</td>
<td>2,572,112.00</td>
<td>406,660.00</td>
</tr>
<tr>
<td>11</td>
<td>Somali</td>
<td>30,552,896.00</td>
<td>-</td>
<td>1,180.00</td>
<td>16.00</td>
</tr>
<tr>
<td>12</td>
<td>Southwest Ethiopia</td>
<td>1,807,284.00</td>
<td>530,636.00</td>
<td>1,504,884.00</td>
<td>2,688.00</td>
</tr>
<tr>
<td>13</td>
<td>Tigray</td>
<td>4,856,784.00</td>
<td>1,508.00</td>
<td>269,612.00</td>
<td>34,684.00</td>
</tr>
<tr>
<td></td>
<td>Total (ha)</td>
<td>79,838,004</td>
<td>4,064,284</td>
<td>22,714,012</td>
<td>3,124,044</td>
</tr>
</tbody>
</table>

Table 2-5: Regional distribution and available area of land based on suitability class for Brassica carinata in Ethiopia (ha)
3. Market assessment

3.1. HEFA and biofuel demand in Ethiopia

As of today, and for the foreseeable future the sole commercial pathway to produce SAF is HEFA. HEFA is produced by the conversion of vegetable oils or waste oils — such as used cooking oil (UCO) and fats. It can be used as a ‘drop-in’ blending component to produce diesel and aviation fuels. The hydrotreatment process consists of thermal decomposition, hydrogenation, and isomerisation reactions to produce diesel, and an additional selective cracking process to produce aviation fuel (i.e., synthetic paraffinic kerosene). It is worth noting that ICAO very recently included Brassica carinata (grown as a secondary crop that avoids displacement of other crops) as a renewable fuel feedstock for hydroprocessed esters and fatty acids (HEFA) sustainable aviation fuel (SAF), with a similar greenhouse gas (GHG) footprint as waste and residuals — such as used cooking oil (UCO) for SAF.

Ethiopia’s economic expansion has brought a tremendous consumption of fossil fuels at an ever-increasing rate in general. Ethiopia is not an oil producing country yet. The country’s fuel demand is met totally through imports. More specifically, the import of aviation fuel has increased by more than 50% in the last ten years.

The national airline (Ethiopian Airlines) is currently implementing a 15-year growth strategy, planning to transport more than 15 million tourists to Ethiopia by 2035. It is also building a new airport in Bishoftu, at a cost of 5 billion USD. Based on this expansion plan, it has predicted that its aviation fuel demand will reach about 5.86 billion litres by 203031.

With the intention of achieving a low-carbon footprint, Ethiopia has launched its Climate Resilient Transport Sector Strategy in 2017 to reduce or offset emissions of GHG produced through air transport as much as possible, which include the following target: ‘Introduce the use of biofuels for aviation (up to 10% of mix)’.

31 Ethiopian Airlines, Personal communication with Steering committee member
The introduction of this blending mandate by 2030 would provide the strong business case required to develop this capacity. However, a range of SAF production pathways will need to be jointly harnessed to maximise SAF output and emissions reduction. From the projected fuel demand, it can be noted that about **586 million litres of SAF are required to enable Ethiopia to reach the 10% SAF uptake.**

![Figure 3-1: Ethiopian airlines fuel forecast](image)

3.2. Worldwide market trend by 2030 and until 2050

IEA has published various reports regarding different fuels and technologies, among which a few have been used to point out the importance of biofuels in the market. More specifically, according to the **IEA’s Sustainable Development Scenario (SDS)**, biofuels will reach at a global scale a 10 per cent of aviation fuel demand by 2030 and a 20 per cent by 204032. A 28 per cent increase in biofuels demand by 2026, which translates to 41 billion

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32 “Are aviation biofuels ready for take-off?”, Pharoah Le Feuvre, IEA
[https://www.iea.org/commentaries/are-aviation-biofuels-ready-for-take-off](https://www.iea.org/commentaries/are-aviation-biofuels-ready-for-take-off)
litres, with an expectancy to reach 186 billion litres, which is highly probable\(^{33}\). Furthermore, renewable diesel, biojet and biodiesel accounted for a 15 per cent overall demand or 7 billion litres, in 2021\(^{34}\). This increase was due to the elevated demand for renewable diesel and biodiesel in the United States and Asia respectively. The need for biojet is expected to reach 6 billion litres in 2026.

Starting from 2010 all the way to 2019, there was a steady 5 per cent increase in worldwide biofuel consumption, each year\(^{35}\). However, according to the Net Zero Scenario\(^{31}\), biofuel consumption should increase up to 14 per cent, each year, starting from 2021 and until 2030. For this to be achievable, countries around the world need to adopt stronger policies. For instance, Europe and the United States, tripled the renewable diesel demand between 2022 and 2026, by implementing stronger relevant policies.

Lastly, the International Air Transport Association (IATA) estimates that it is of crucial importance to reduce emissions coming from the aviation industry, while continuing to add more flights to serve the needs of the 10 billion people, by 2050\(^{36}\). A plan to reach this goal is proposed by IATA, however, in order to make it work, cost efficient solutions need to be considered. The plan aims to achieve the following goals:

- **2025**: With appropriate government policy support, SAF production is reaches 7.9 billion litres (2% of total fuel requirement).
- **2030**: SAF production is 23 billion litres (5.2% of total fuel requirement). ANSPs have fully implemented the ICAO Aviation System Block Upgrades and regional programmes such as the Single European Sky.

\(^{33}\)“Biofuel demand forecast to increase 28% over the next 5 years”, IEA Bioenergy [https://www.iea.org/fuels-and-technologies/bioenergy](https://www.iea.org/fuels-and-technologies/bioenergy)


\(^{35}\)“Stronger policy support and innovation to reduce costs are required to get on track”, IEA Bioenergy, [https://www.iea.org/fuels-and-technologies/bioenergy](https://www.iea.org/fuels-and-technologies/bioenergy)

• **2035:** SAF production is 91 billion litres (17% of total fuel requirement). Electric and/or hydrogen aircraft for the regional market (50-100 seats, 30-90 min flights) become available.

• **2040:** SAF production is 229 billion litres (39% of total fuel requirement). Hydrogen aircraft for the short-haul market (100-150 seats, 45-120 min flights) become available.

• **2045:** SAF production is 346 billion litres (54% of total fuel requirement).

• **2050:** SAF production hits 449 billion litres (65% of total fuel requirement).

Export of carinata seeds from all over the world has gained a lot of attention, due to the European market’s strong need for renewable and environmentally friendly fuel production. Uruguay and Argentina are the leading countries in the cultivation/production of carinata, while sponsors think of expanding the production to Southern Europe and South-eastern Australia.

Finally, India has also emerged into the oilseed production trials with a notable progress. The IATA study revealed that in 2016-2017, the import of vegetable oil was 11.2 per cent of a total world import, with a cost of approximately 103.2 million US dollars. Given the fact that there was greater consumption of edible oils, there were also increased imports. Between 2000 and 2017, consumption increased from 9.7 million tonnes to 25.4 million tonnes, while production elevated from 5.5 million tonnes to 10.1 million tonnes. This difference among consumption and production, is met by the higher import observed between 2000 and 2017, which started from 4.2 million tonnes in 2000 and reached 15.3 million tonnes in 2017.

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38 “Oilseed brassica in India: Demand, supply, policy perspective and future potential”, R.S. Jat, V.V. Singh, Pankaj Sharma, P.K. Rai, OCL (Oilseeds & fats Crops and Lipids), edp sciences
3.3. Brief presentation of secondary markets of BC leaves, residues and carinata meal

**Brassica carinata Leaf (BCL)**

Ethiopian farmers have a long tradition in using Brassica carinata as a dual-purpose crop. In its early stage of development, leaves will be collected by thinning or topping during the rainy season (July to September) and then seeds will be harvested later in December from the same plant. It is worth mentioning that the use for food of Brassica carinata leaves is not common in other parts of the world.

Boiled leaves of Brassica carinata are an excellent source of vegetable relish. Especially for the small holder farmers, it is also a security-crop, since the time of its lush vegetative stage often coincides with periods of grain shortages, which occur sometime in the middle of the rainy season when all the cereals are still at booting. In addition to consuming the defoliated leaves, farmers sold them to generate income after a month of sowing. Brassica carinata leaf lacks bitterness, is rich in vitamins C, beta carotene and calcium as well as cancer-fighting antioxidants.
The Brassica carinata leaf has an important nutrient composition for human health. It is a rich source of minerals, vitamins, trace elements, dietary fibre, and protein.

Table 3-1 shows nutrient composition of young carinata leaves per 100 g fresh weight

<table>
<thead>
<tr>
<th>Nutrient type</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (g)</td>
<td>11.3</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>3.37</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>1.48</td>
</tr>
<tr>
<td>b-carotene (mg)</td>
<td>0.29</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>183</td>
</tr>
<tr>
<td>Vitamin E (mg)</td>
<td>1.8</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>153</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>1.39</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>0.72</td>
</tr>
<tr>
<td>Antioxidant activity (µmol Trolox)</td>
<td>849</td>
</tr>
<tr>
<td>Total phenols (mg)</td>
<td>260</td>
</tr>
<tr>
<td>Oxalates (mg)</td>
<td>13</td>
</tr>
</tbody>
</table>

Based on the demonstration experiment conducted on the small holder farmers’ field in 2016 and 2017, the farmers got 6,944 ETB/hectare additional income from selling the Brassica carinata leaves. The number of leaves obtained from 1 hectare was estimated at about 3472kg/ hectare. The average leave selling price is currently 15 ETB/kg (about 0.3 USD/kg). To avoid the effect of leave defoliation on seed yield, two times of harvesting.

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leaves are recommended - when the plant reaches 30 cm and 50 cm height. In most cases Ethiopians consume carinata leaves at the green stage, and in rare cases they feed the leaves to their animals as a fodder.

**Brassica carinata residue (BCR)**

BC residues are the fibrous parts of crops that remain after the leaves and seeds are collected. This BC residues have been used as livestock feeds in Ethiopia since time immemorial. Fibrous agricultural crop residues constitute important and often major feed resources, and are frequently utilised by smallholder farmers in Ethiopia's livestock feeding systems. The BC residues can be left on the field as grazing for ruminants or can be transported and retailed in the open market for stall feeding, or used for alternative purposes such as fencing, building, and roofing materials or as fuel.

**Brassica carinata meal (BCM)**

Another co-product obtained after the extraction of oil is Brassica carinata meal (BCM), which is of increasing interest to animal nutritionists. The use of agriculture co-product from B. carinata as an animal feed ingredient has become increasingly important in achieving cost-effective animal production globally.

There is a high demand for animal feed in Ethiopia in general, and for a quality animal feed in particular. It can be said that the demand is critical. Feed scarcity in terms of both quantity and quality (particularly the quality issue even with the available feed) is the main limiting factor hampering productivity in the Ethiopian livestock and poultry sector. Even if there is available technology for different raw materials (forage species such as legume, grass, annuals, etc.), the country is not producing adequate animal feed.

The agro-industrial units that supply animal feed are limited (Only spent grain from brewery industries and molasses from sugar industries are currently used as animal feed in small quantities). Thus, complementing the traditionally available low quality feed resources with other alternative feed resources and improved utilisation, is currently critical for the livestock sector. The country is widely using crop residues as animal feed, which are generally characterised by a low crude protein content. The crude protein content is lower than the threshold required for maintaining the N balance of an animal in the positive side.
Considering that carinata meal is obtained as oil residue, Brassica carinata meal contains high protein (~40% crude protein; CP). A quintal (100 kg) of cattle feed has nearly tripled to around 3,000 Br (60 US dollar) over the past year.

4. Supply chain and financial analysis

4.1. Estimation of the supply chain and the associated costs for reasonable option

Personal communication with Brassica carinata growers and field data collected from research plots were used to estimate the cost of Brassica carinata production in Ethiopia (Table 4-1). The seed application rate, the rate of fertilisers, pesticides, herbicides, and fungicides are standardised according to Ministry of Agriculture recommendations. Other data (such as cost for land preparation, labour, transport, and fuel) used in the estimation were obtained directly from the growers. The estimation was made for best-case and worst-case scenario (considering minimum and maximum costs).

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Cost components</th>
<th>Unit</th>
<th>Price/unit (ETB)</th>
<th>Amount required /hectare</th>
<th>Min Cost (USD/ha)</th>
<th>Max Cost (USD//ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land Clearing</td>
<td>man days</td>
<td>100</td>
<td>7.61</td>
<td>8.1</td>
<td>20.9</td>
</tr>
<tr>
<td>2</td>
<td>Ploughing and harrowing</td>
<td>man days</td>
<td>140</td>
<td>31.1</td>
<td>40.6</td>
<td>104.0</td>
</tr>
<tr>
<td>3</td>
<td>Planting/sowing</td>
<td>man days</td>
<td>100</td>
<td>5.7</td>
<td>10.0</td>
<td>30.5</td>
</tr>
<tr>
<td>4</td>
<td>Weeding</td>
<td>man days</td>
<td>110</td>
<td>30</td>
<td>54.3</td>
<td>60.0</td>
</tr>
<tr>
<td>5</td>
<td>Harvesting and Threshing</td>
<td>man days</td>
<td>110</td>
<td>9.66</td>
<td>6.2</td>
<td>34.3</td>
</tr>
<tr>
<td>6</td>
<td>Fuel</td>
<td>litre</td>
<td>22.6</td>
<td>8.51</td>
<td>3.1</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Units</td>
<td>Quantity (kg)</td>
<td>Rate</td>
<td>Amount</td>
<td>Rate</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------</td>
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<td>---------------</td>
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<td>-------</td>
</tr>
<tr>
<td>7</td>
<td>Loading unloading</td>
<td>man days</td>
<td>20</td>
<td>8.01</td>
<td>2.9</td>
<td>3.3</td>
</tr>
<tr>
<td>8</td>
<td>Cleaning</td>
<td>man days</td>
<td>110</td>
<td>28.36</td>
<td>59.2</td>
<td>59.6</td>
</tr>
<tr>
<td></td>
<td><strong>Sub total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>184.4</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Input costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Seed</td>
<td>kg</td>
<td>63-65</td>
<td>5-7</td>
<td>6</td>
<td>8.7</td>
</tr>
<tr>
<td>2</td>
<td>Urea</td>
<td>kg</td>
<td>30-35</td>
<td>50</td>
<td>28.5</td>
<td>33.3</td>
</tr>
<tr>
<td>3</td>
<td>NPS</td>
<td>kg</td>
<td>35-40</td>
<td>181</td>
<td>120.7</td>
<td>137.9</td>
</tr>
<tr>
<td>4</td>
<td>Herbicide (Super gallant)</td>
<td>Litre</td>
<td>1400</td>
<td>1</td>
<td>22.9</td>
<td>30.5</td>
</tr>
<tr>
<td></td>
<td>Post emergency herbicide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Herbicide (Dual Gold)</td>
<td>Litre</td>
<td>984</td>
<td>1</td>
<td>18.5</td>
<td>19.0</td>
</tr>
<tr>
<td></td>
<td>(Pre-emergency herbicide)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Pesticide (Foratie/Chortie)</td>
<td>Litre</td>
<td>750</td>
<td>1</td>
<td>13.9</td>
<td>14.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Sub total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>210.5</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Other costs</strong></td>
<td></td>
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<tr>
<td>1</td>
<td>Transport</td>
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<td>Miscellaneous costs</td>
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<td></td>
<td></td>
<td>10.5</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td><strong>Sub total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>14.9</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Grand Total cost (USD/hectare)</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>409.8</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 4-1: Estimated cost of Brassica carinata production in Ethiopia

Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final
The total cost of production for Best-Case scenario is about 410 USD/hectare whereas for the Worst-Case Scenario, it is estimated at 580 USD/hectare.

4.1.1. Revenue from selling Brassica carinata leaves (BCL) and Brassica carinata straw (BCS)

To estimate the revenue that can be obtained from selling the byproducts (Brassica carinata leaves and Brassica carinata straw), the following data was used:

- Average yield of Brassica carinata leaves (BCL) per hectare: 3,500 kg;
- Average yield of Brassica carinata straw (BCS) per hectare: 4,000 kg;
- Current average selling price of Brassica carinata leaves (BCL): 0.31 USD/kg;
- Current selling price of Brassica carinata straw (BCS): 0.13 USD/kg.

Thus, the total revenue that can be obtained from selling the byproducts is estimated at 1,605 USD/hectare. However, it should be noted that this benefit might not continue if extensive cultivation brings large quantities of carinata leaves and straw into the local market. It is a conservative assumption that at least 10% of the BC leaves can be effectively collected and sold to the market for about 160 USD/hectare or more.

4.2. Definition of main assumptions

As already mentioned, a pre-feasibility study examining the value chain of BC to SAF is endorsed with many uncertainties requiring reasonable assumptions. The assumptions create the framework on which, calculations on yields, performances and costs characterise the feasibility scope of the present exercise. On the other hand, the study complies with the present global priority for need of convenient feedstock, like BC, to be used for biofuels production and especially for SAF. This trend will become more intensive given the decarbonisation policies of most of the developed countries and the leading initiatives of the United Nations (UNFCCC). Especially, after 2025, significant demand for biofuels and SAF is expected.

The main assumptions considered are:
1. The emphasis is placed on the agricultural stage of the value chain, considering that this is the strong point of the exercise for Ethiopia, rather than on the industrial stage, which could be optionally considered in the country or abroad, following the specific investment specifications, and the prevailing market and technological conditions. There is need for bioenergy feedstock, since technology for biofuels production, including SAF from hydrotreatment units, has reached the commercial availability levels and further improvements are expected in the forthcoming years.

2. The sustainable cultivation method based on rotation cropping is used as the basis of the calculations. Rotation cropping, is less favourable for farmers’ income, compared to the options of intercropping and cover cropping, but adapts better to the existing farmers’ experience, and decreases potential arguments and resistance due to changes of crop cultivation. These two optional methods provide better economic results and could also be considered by potential investors, since they might decrease feedstock risks and smoothen seasonality of cropping.

3. Sustainability and low-ILUC criteria are in general considered at the level of the assessment and the main economic and agriculture assumptions, given that the project does not aim only at the Ethiopian market, but BC products could be marketed and used in various world regions under restrictive regimes for biofuels and bioenergy feedstocks.

4. All potential cost items (direct BC seed production and side products) of BC cultivation are considered. BC contributes to both increase of food (traditional use of leaves as vegetable food) and feed (residues from harvesting carinata and likely BC meal from oil production). It is worth considering that the food use of leaves is not reviewed in existing BC exercises in other similar feasibility assessments worldwide.

5. The farmers’ income from the sales of the leaves for food is significant and alters the overall cost/benefit analysis for the farmer, in case the existing market prices are maintained in conditions of high supply during a production period that is not so long; for this reason, this income for farmers is presented separately.
6. The pre-feasibility exercise uses the criteria of the **BC seed cost as biofuel feedstock cost at the gate of the farm**, or incorporating a transportation cost for normal decentralised destinations within the country, i.e., to the potential crushing mills of BC.

7. The **data used for the analysis of BC cultivation costs come from local stakeholders and local research**, absolutely reflecting the situation in Ethiopia, and based on existing cultivation experience and development of BC. Therefore, any comparison with similar cases in other regions of the world is worthwhile and indicates the comparative advantage or disadvantage of such a project.

8. **Large area of cultivation of BC** (indicatively of more than 100,000 ha) has been considered on the contrary to the existence of present smaller cultivations. This new situation might require upgrading of agro-machinery used and its greater availability during critical cultivation periods. Such a development, which might decrease the cultivation cost and change the conditions for farmers, has not been considered in the scope of this assessment.

9. **Sustainability training and verification costs** are not included, because there is not such experience in the country at present. However, these costs are not high if the activity is addressed to large areas and big numbers of farmers. The cost is normally undertaken by the investor and/or the aggregator of BC products.

10. **Diversification of feedstock supply** is of utmost importance for the potential investor/aggregator to cope with various economic, weather risks and seasonality conditions of harvesting and off-taking feedstock. Thus, the feedstock production reality might not be based on one plant or even one variety of BC. A situation based on diversification of feedstock supply, might influence the conditions of BC production and has not been considered in the scope of this assessment.

11. **The involvement of farmers in such a project** is of utmost importance, and relevant information campaigns and training is necessary to persuade them for the benefits of cultivation change. In our assessment these costs have been incorporated within the
miscellaneous costs and are very conservative. For an extensive production of BC in short period, this is an investment cost and should be undertaken by local institutions in collaboration with the investor or feedstock aggregator.

12. Incorporation of marginal lands in BC cultivation is a prominent and encouraging option for Ethiopia that has not been thoroughly considered in this pre-feasibility assessment because many cost items need to be adapted and changed. However, at a second stage such developments should be examined and thus enlarge the BC cultivation potential in the country.

4.3. Definition of approach for cost sensitivity

One of the most important issues tackle in this pre-feasibility assessment, was the uncertainty in estimating the precise values of cost items in the agriculture stage of the BC value chain, since the collected data came from farmers and agriculture associations with experience in the cultivation of BC. The general and high-level scope of the BC development project indicates a range of cost values for each activity contributing to BC cultivation in Ethiopia. This might be attributed to:

- differing sizes of work and cultivation land for each case of cost analysis;
- differing specifications of soil and land surface;
- differences in mechanisation level for crop cultivation;
- differences in the variety of BC cultivated; and/or
- different climatic conditions during the cropping period of BC.

It was considered that using average or median values the result could not provide proper information about the range of the values estimated in the study. On the other hand, the scope of the project didn’t allow for a statistical assessment of the costs in relation to the above-mentioned factors. Thus, the adoption of a min-max approach was selected to also indicate the range of values and provide better information of the expected minimum and maximum costs for each activity but also cumulatively for the best and worst cases. At a cumulative level average values could be approximated.
This approach was selected as a proper solution covering the ranges of cost items and potential uncertainties contributing to the Ethiopian agricultural reality, as far as possible.

4.4. Pre-feasibility assessment of investment financial situation

It is of great importance to present and discuss the financial situation for both cultivation and industrial processes. This economic assessment will help the investor obtain a clearer picture of the production costs and the expected revenues concerning the cultivation process, as well as costs related to the industrial processes.

Four different regions were compared to Ethiopia, in terms of the cultivation process, estimated costs, and the farmer’s net revenue, as shown in Table 4-2. Relevant information coming from published data for USA, Canada and Europe, as a whole, was utilised where possible to indicate comparable prices. This compilation of costs was challenging, because there was no common basis for the cost estimation in the four exercises and so necessary assumptions were made. It can be observed that the estimated oil seed costs for Ethiopia, were competitive in comparison to those estimated in the US and Canada, whereas relevant costs in the Italian and European cases were lower. This could be justified because the study in Europe refers to the expected production costs in 2030 while the prices regarding the rest of the regions refer to the last 2-3 years. In Italy, the selected production conditions are rather more favourable (yield). In both cases, the goal is to reach lower production costs, considering that there will be developed mechanisation and serious improvements accommodating the various cultivation processes. Furthermore, active farming land was considered instead of land with natural constraints, because there was no evidence regarding land with natural constraints and, it was not included in the scope of this study. However, there is perspective for cultivation of such land, but significant research needs to be conducted first. On the other hand, the estimated nett revenue for the Ethiopian farmers looks very attractive compared to the Europe case study. Our comparison was not able to estimate farmers’ nett revenue in other cases focusing more on the holistic viability of the BC investment.
Moreover, for the purpose of estimating the production cost and the farmer's net revenue, prices were converted from €/T to USD/ha, where necessary. Euros to USD were converted using the average exchange rate in 2021, while for the conversion of tonnes to hectare, conversion factor of 1.8 T/ha\(^2\) was used, which accounts for the productivity of Brassica carinata. In order to estimate the net revenue, the production cost was taken out from the expected income of the farmer sale of BC seeds and the by-products. It is worth mentioning that, regarding the expected net revenue in Ethiopia, an additional source of income comes from sales of carinata leaves, as considered above (10%), which was

<table>
<thead>
<tr>
<th>Region</th>
<th>Cultivation process</th>
<th>Estimated feedstock cost (USD/ha)</th>
<th>Farmer net revenue (USD/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy(^{40})</td>
<td>Rotation</td>
<td>329.20</td>
<td>n.a.</td>
</tr>
<tr>
<td>United States(^{41})</td>
<td>Cover cropping</td>
<td>537.95-903.66</td>
<td>n.a.</td>
</tr>
<tr>
<td>Canada(^{42})</td>
<td>Cover cropping</td>
<td>680</td>
<td>n.a.</td>
</tr>
<tr>
<td>ETHIOPIA</td>
<td>Rotation</td>
<td>410-580</td>
<td>677-847</td>
</tr>
<tr>
<td>Europe (2030)(^{43})</td>
<td>Intercropping, cover cropping, rotation, biochar</td>
<td>220-508</td>
<td>360-685</td>
</tr>
</tbody>
</table>

Table 4-2: Indicative comparison of cultivation process costs and revenues (Source: Data elaboration by Project Team)

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40 “Brassica carinata-derived biodiesel production: economics, sustainability, and policies. The Italian case”, Marcello Basili, Maria Alessandra Rossi, Cleaner Production, ELSEVIER

41 “Break-even price and carbon emissions of carinata-based sustainable aviation fuel production in the Southeastern United States”, Asiful Alam, Md Farhad Hossain Masum, Puneet Dwivedi, Original Research

42 “Financial analysis and risk assessment of hydroprocessed renewable jet fuel production from camelina, carinata and used cooking oil”, Pein Lin Chu, Caroline Vanderghem, Heather L. MacLean, Bradley A. Saville, ELSEVIER

43 “Opportunities for Low Indirect Land Use Biomass for Biofuels in Europe”, Calliope Panoutsou, Sara Giarola, Dauda Ibrahim, Simone Verzandvoort, Berien Elbersen, Cato Sandford, Chris Malins, Maria Politi, George Vourliotakis, Vígh Enikő Zita, Viktória Vásáry, Efthymia Alexopoulou, Andrea Salimbeni and David Chiaramonti, Applied Sciences

Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final
included in the estimation of the net revenue. The development of food market for carinata leaves is a complicated issue subject to many parameters and assumptions. By considering that only 10% of the production will be earned by the farmers, we make a very conservative estimation for the needs of this study. It is noted that such large-scale production needs particular policy measures to be supplied to the food market or to be further processed to other products. Error! Reference source not found. Figure 4-1 presents the cost of the processes as percentages, considering Ethiopia's average price as the common base, for comparison. For the purpose of it, each country's estimated cost was taken out from Ethiopia's cost, and that difference is represented as a percentage. This provides a clearer picture of the different prices in each case. For example, in Canada and the USA, the estimated cost is higher compared to Ethiopia, showing a ca. 40 per cent increase in relation to Ethiopia. On the other hand, studies from Italy report information on a lower price, which results ca. 35 per cent reduction as compared to Ethiopia. This difference can be attributed to the fact that CAPEX (capital expenditure) and OPEX (operating expenditures) are not included in the final price in the relevant study for Italy, whereas Canada and the US considered them in their final costs. As far as Europe is concerned, it was mentioned before that, information on the costs refer to expected prices in 2030. This explains the lower costs reported in the original study, as cost items are expected to drop significantly by 2030.

Figure 4-1: Estimated cost percentages of the processes in each country, having Ethiopia's cost as the common base
Table 4-3 represents the estimated costs of the industrial processes, given that such information does not exist in Ethiopia. In this exercise, information was available only in the three regions presented in Table 4-3. The cost was converted to USD/litre of SAF using the average currency exchange rates in 2021, and consequently tonnes were converted to litres. In order to convert the oil into biofuel a conversion factor of 0.87 was used. This represents the composition of carinata oil and includes the HEFA SAF and the by-products, naphtha, and propane, which all comprise 87% of carinata oil per mass unit. This information was available in the research conducted in the US, and it was used to estimate the costs for both Italy and Canada as well as for the US. Also, the Italian exercise provides information allocating the seed crushing cost as well, as it can be observed in Table 4-3. The estimated cost for HEFA production was almost half in the Italian exercise, thus indicating use of existing manufacturing units and in general cost optimisation for SAF production. Finally, it is worth mentioning that in the calculations to estimate the final cost, the oil composition of the carinata seed was considered, and that was 44%.

<table>
<thead>
<tr>
<th>Region</th>
<th>Process</th>
<th>Cost (USD/litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States(^{44})</td>
<td>HEFA</td>
<td>0.33-0.54</td>
</tr>
<tr>
<td>Canada(^{45})</td>
<td>HEFA</td>
<td>0.42</td>
</tr>
<tr>
<td>Italy(^{46})</td>
<td>HEFA</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>Seed crushing</td>
<td>0.10</td>
</tr>
</tbody>
</table>

\(^{44}\) “Break-even price and carbon emissions of carinata-based sustainable aviation fuel production in the Southeastern United States”, Asiful Alam, Md Farhad Hossain Masum, Puneet Dwivedi, Original Research

\(^{45}\) “Financial analysis and risk assessment of hydproprocessed renewable jet fuel production from camelina, carinata and used cooking oil”, Pein Lin Chu, Caroline Vanderghem, Heather L. MacLean, Bradley A. Saville, ELSEVIER

\(^{46}\) “Brassica carinata-derived biodiesel production: economics, sustainability, and policies. The Italian case”, Marcello Basili, Maria Alessandra Rossi, Cleaner Production, ELSEVIER
4.5. Elaboration of problematic areas and implementation risks

The BC project, as it is assessed in this pre-feasibility study, assumes a large size of BC rotation cultivation in fertile Ethiopian regions with centralised collection of seed production and decentralised use of leaves and residual by-products. As already mentioned, the industrial part of SAF production including seed crushing and BC oil hydrotreatment could optionally take place under necessary investments in the country or abroad. The organisation of the agriculture part is very complicated, and endorsed with problems that are related to the relevant risks for the investor. The main problems and risks are:

1. **Difficulty in the collaboration between the investor, the pertinent authorities, and farmers’ associations**, which is necessary and experience in other regions indicates that it is crucial, to increase access to farmers who will be called to collaborate and decide to cultivate BC as a new crop in may instances. The relevant risk is alleviated by initial and substantial involvement of national and regional authorities in the project, especially in the first steps of market opening. The elaboration of an action plan on setting up the project and involving the appropriate stakeholders is needed.

2. **Specific effort in persuading the farmers to adapt to BC model of cultivation**, that is probably the most time consuming and sensitive task of the investor when addressing to groups of farmers and their associations, which might influence their decision. Experience has shown that this activity should be targeted to categories of farmers who are willing to try the proposed BC cultivation model and the relevant long-term commitment. In general, the new crops like BC cannot compete with traditional cultivations of cereals. This problem may not be so acute in Ethiopia, because the cultivation of BC is not new and there is

<table>
<thead>
<tr>
<th>Region</th>
<th>Process</th>
<th>Cost (USD/litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>HEFA</td>
<td>0.33-0.54</td>
</tr>
<tr>
<td>Canada</td>
<td>HEFA</td>
<td>0.42</td>
</tr>
<tr>
<td>Italy</td>
<td>HEFA</td>
<td>0.28</td>
</tr>
</tbody>
</table>

*Table 4-3: Industrial costs regarding the HEFA process and seed crushing (Source: Data elaboration by Project Team)*

**Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final**
already a wealth of experience. However, the cropping conditions should change to ensure sustainability and the required relevant verification. To cope with this risk, the investor should consider the BC project as a new business and organise training courses and information dissemination actions which will respond to the questions of the farmers.

3. Establishment of proper links between the availability of BC feedstock and the demand from the industrial part of the BC project, that is referred as “feedstock management” by biofuel production companies and surely incorporates the relevant risks. The cultivation of BC offers the BC seeds in a period of one month within the year in case rotation cropping is selected. On the other hand, industrial units require a smooth supply of feedstock monthly. This imbalance might be tackled partly by appropriate storage of seeds and by diversification of feedstock supply that is based on other oil producing crops and different type of cultivation, e.g., cover cropping. For this reason, the potential investor may not consider BC feedstock as a single supply option in case they intend to establish the industrial part in the country. Therefore, there is a particular risk in ensuring that BC seeds, resulting from the normal cultivation period, are coupled with additional feedstock from alternative crops, and meeting the sustainability criteria set by the investor and the markets.

4. Proper adaptation to the international energy markets evolution and the decarbonisation policies of key countries and international organisations influencing biofuels demand, that characterise the international conditions for BC seed/oil demand and activity development, because the attractiveness of the BC project in Ethiopia is strongly associated with its competitiveness worldwide. Currently, we are experiencing an abnormal situation in terms of energy prices and energy supply conditions due to the Ukrainian war and the increased demand after the end of the pandemic. We expect that this situation will settle and that the energy supply companies will reconsider their plans for the decarbonisation period up to 2030 and 2050. This external risk of volatility of energy prices influences the decisions of potential investors who prefer to make business under more foreseeable conditions. An indicative measure to cope with this risk is the partial link of BC buying prices from farmers with the international prices of bioenergy
feedstock. This development contributes to more equitable revenue for farmers, but also includes uncertainty about prices and farmers’ participation in the relevant risk sharing.

5. Alleviation of market changes in agricultural products, expected due to extensive Brassica carinata cultivation, that should be considered at national and regional level. For example, the big quantities of BC leaves, which will be produced in a short period (1-2 months) within a year, might drop the prices since this by-product should be consumed in the fresh vegetable market. A supply increase might worsen the estimated revenue of farmers. On the other hand, reduction of production in other crops might create opposite price situations in the country. This risk is very difficult to assess in this study, however, measures improving trading are necessary and should be implemented.

5. Environmental and socioeconomic analysis

5.1. Potential environmental and social impacts

The identified potential environmental and social impacts associated with the production and processing of Brassica carinata crop in Ethiopia are summarised in Table 5-1. Among the identified environmental and social criteria, several are also linked directly to the RSB sustainability standards, against which the Brassica carinata project in Ethiopia will ultimately have to be measured, for example:

- principle 3: GHG emissions;
- principle 4: Human and labour rights;
- principle 5: rural and social development;
- principle 6: local food security;
- principle 7: conservation;
- principle 8: soil;
- principle 9: water;
- principle 10: air; and
- principle 12: land rights.
Table 5-1: Potential environmental and social impacts associated with the project

Generally, agricultural production, processing, trade and consumption contribute up to 40% of the world’s emissions when forest clearance is included in the calculations. Therefore, it is imperative that a Life cycle impact assessment (LCIA) is performed in the framework of an Environmental and Social Impact Assessment (ESIA) study, in order to quantify the overall impact of resource consumption and environmental emissions at different stages of a product life cycle. The LCIA will focus on the relevant impact categories, including indicative climate warming, depletion of abiotic resources, acidification, eutrophication, ecotoxicity, stratospheric ozone depletion, land use, water depletion, depletion of minerals and use of fossil fuels, and evaluate the magnitude and significance of potential environmental emissions of the Brassica carinata system in each of them.

Changes in soil carbon and soil structure have a further impact on GHG emissions from cultivation, generally yielding to increased emissions that need to be set off against the sequestration achieved. Decline of organic carbon and increasing erosion rates are the
potential risks for soils associated with agricultural activity realised through three major pathways, i.e. residue removal, tillage, and land use change. In general, soil erosion and the resulting agricultural land degradation are the most severe environmental problems in the Ethiopian highlands, jeopardising the sustainability of agricultural production and ultimately national food security. The causes underlying land degradation are a combination of climate conditions and extreme weather events, such as heavy rainfall and droughts, population pressure, unsustainable agricultural land use practices (Overgrazing, cultivation of steep slopes, and no or limited fallow periods), as well as a lack of institutions to enact regulations or laws that enhance sustainable land management practices.

**Water availability**, as well as **water quality**, could suffer from agricultural operations. The water stress induced by a crop can be multi-dimensional, as the activities might add an extra burden on the already limited water supply and/or severely deteriorate its quality due to the deployed pesticides.

**Air pollution** due to agricultural activities can be attributed to particulates associated with burning of crop residue, emissions from fertilisers, and chemicals associated with crop spraying. The application of pesticides could also have an impact of air quality.

**Biodiversity impacts** vary significantly with the location of crop plantations. Key drivers in the biodiversity impacts are **previous land use** and **crop type and management** (e.g. cultivations, levels of pesticide and fertiliser inputs used). Most importantly, the replacement of any semi-natural habitat by a dedicated bioenergy crop would result in significant biodiversity losses. On the contrary, perennial cultivations provide relatively stable habitats

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49 https://academic.oup.com/bioscience/article/54/9/817/252974
50 A. Tesfaye, R. Brouwer, P. van der Zaag, W. Negatu, Assessing the costs and benefits of improved land management practices in three watershed areas in Ethiopia, International Soil and Water Conservation Research, Volume 4, Issue 1, 2016, Pages 20-29
for supporting wildlife and the cultivation of energy crops on either low-productive or marginal lands can improve the landscape design.

Ethiopia has experienced massive deforestation due to a rapidly growing population, with over 80% living in rural areas, and relying on rain-fed agriculture. 70 million livestock have also put pressure on land and forests. The deforestation risk associated with this project relates to the potential clearing of land to be used for plantations.

Social infrastructure refers to schools, churches, markets, hospitals and similar structures. In Ethiopia there are more than 50 government and private universities and colleges, 338 hospitals owned by government, 43 hospitals owned by private organisations and a total of 4,063 government health Centres, as well as 3,867 private primary, medium and specialty clinics. Collection and analysis of broad characteristics about groups of people and populations and how those may be affected by the project, is a further component of the impact assessment. Demographics is of particular importance, as a potential migration effect linked to the project’s activities needs to be explored, considering also the potential areas for BC cultivation.

Economy and livelihood are also important parameters to be included in the impact assessment in the prism of whether or not livelihoods become environmentally sustainable and economic growth is preserved despite the project’s activities.

Land tenure and use is especially important in the case of Ethiopia, as land grabbing constitutes a prevailing threat. To this end, the impact of the project on land governance, land use and land cover should be critically assessed.

Food security is particularly emphasised, as energy crops occasionally compete with food production.

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Gender issues in agriculture in Africa and in Ethiopia specifically are prevailing, despite the fact that women play a central and critical role in the agricultural sector, as 62% of the women are involved in farming. Although they are on the frontline of agriculture and play an active role in a series of agricultural activities, including land preparation, sowing, hoeing, weeding, harvesting, etc., they are not being acknowledged, neither do they enjoy the same rights as men. In general, despite the fact that land tenure situation in Ethiopia is problematic, women do have the right to have access to land (Rural Lands Proclamation Article 4(1)) but equitable systems of land distribution are not in place and, thus, women occupy a rather tenuous position with regards to access to land. To further illustrate the situation in Ethiopia, land owned by women is often of lower quality with less access to irrigated land, and female farmers have limited access to information and to agricultural inputs and technologies\(^{52}\). The above situation could support the finding that women produce a third less per unit of land than male farmers\(^{53}\).

5.2. Preliminary Environmental and Social impact assessment of Brassica carinata

The preliminary impact assessment will examine the impact of the cultivation of BC for SAF production also on the identified social indicators.

5.2.1. Synergies

Brassica carinata can participate in an integrated crop-livestock system, and provide synergies towards more resilient climate-smart agricultural production systems. As already known, crop residues are a major source of feed for animals in mixed crop-livestock systems and, thus, integrating crops and livestock can enhance the climate resilience of farming systems. At the same time, manure from the livestock can be applied to fields and improve the moisture and nutrient retention contributing, thus, to higher yields.

\(^{52}\text{FAO, Leaving no one behind. Empowering Africa’s Rural Women for Zero Hunger and Shared Prosperity, 2018}\)
\(^{53}\text{www.acdivoca.org/site/ID/success-cooperatives-hold-economic-promise-women-Ethiopia}\)
Even though the ecosystem services such as pest control and pollination are poorly understood, its cream to yellow petal colour of Brassica carinata attracts a diverse insect community. Therefore, integrating honeybee with Brassica carinata cultivation is expected to improve the environmental sustainability, as it provides nectar for the bees and Brassica carinata yield is very positively affected by pollinators, since the more pollinator visitation occurs, the higher yield is achieved.

5.2.2. Food security considerations

Being an intensive crop, **Brassica carinata requires soils of relatively high fertility**, which in Ethiopia are made available for food production. Currently, there is no competition for food, as only the leaves are edible. Traits like late maturity, long and profuse vegetative growth, tall plant stature, low oil content, high erucic acid content, low harvest index, and unattractive seed coat colour are major constraints for its adoption as an oilseed crop for edible purposes.

5.2.3. Gender issues

Given the fact that the agriculture sector in Africa in general and in Ethiopia specifically is strongly linked to gender issues, the development of Brassica carinata project in Ethiopia is expected to have an impact on this category as well. It is noted that although Ethiopia has enforced constitutional and legal protection for woman’s right to equality with men and equal protection before the law in the FDRE Constitution. However in regional state constitutions (e.g., Oromia, Tigray, SNNPR and Amhara regions), family law and land law, much remains untouched regarding the implementation of the law, especially in rural areas. It is advised that Brassica carinata project will strive to contribute towards the empowerment of Ethiopian women, potentially through entering into business with women’s cooperatives that own farmlands. To this end, the project developer is encouraged to investigate opportunities of unlocking the potential of rural women in Ethiopia through

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liaison with relevant initiatives and programmes, similar to the UN Women-GoE joint programme on “Accelerating Progress towards the Economic Empowerment of Rural Women” (RWEE JP) that was launched in 201455.

5.2.4. Land tenure and land use

The objective of the *Biofuel Development and Utilisation Strategy*, is the supply of locally produced biofuel without affecting food self-sufficiency. To this end, the introduction of an indigenously sourced bioenergy crop (i.e. Brassica carinata crop) in Ethiopia will positively contribute to the energy self-sufficiency of the country and replace imports. At the same time, however, it could have a land tenure impact, as poorer rural people may lose land access in regions and locations, depending on where a developer decides to grow Brassica carinata. Changes to land access for poor people can be realised through two routes: direct linkages (i.e., involving direct land use change to biofuels crop production from other uses) and indirect linkages (i.e. involving changes in land use triggered by biofuels expansion elsewhere). These two pathways are discussed in more detail below56.

A straightforward example of a direct link between Brassica carinata cultivation and change of land access, is the case when the government takes (or “expropriates”, “dis-allocates”, “withdraws”) land from local users and allocates it to biofuel producers, based on the assumption that biofuel crop production is more economically viable than existing forms of land use. A possible way for the developer of Brassica carinata to avoid a negative impact on the land access, is to adopt an outgrowers scheme instead of acquiring its own land. At the same time and irrespective of the adopted business model, efforts should be dedicated to intensive land use rather than more extensive land use. Intensive land use is synonymous to technical improvements in production (e.g., more efficient processing) yielding to higher yields of feedstocks per unit area and possibly to exploitation of marginal land.

55 [Unlocking The Potential of Rural Women in Ethiopia Key Results and Human Interest Stories, 2017](https://pubs.iied.org/sites/default/files/pdfs/migrate/12551IIED.pdf)
56 [https://pubs.iied.org/sites/default/files/pdfs/migrate/12551IIED.pdf](https://pubs.iied.org/sites/default/files/pdfs/migrate/12551IIED.pdf)
5.2.5. Child labour

Child labour is extensively reported in African countries. For instance, child labour is observed at a significant extent based on the findings of relevant households surveys in East African countries; at least 17.27% of the surveyed households with the dominant activity being banding, nursery preparation and planting. Considering the fact that Brassica carinata cultivation practices in Ethiopia is labour intensive, the risk of engaging children as workers should be considered and assessed.

5.2.6. Job creation

The impact on employment includes direct employment in the project activities, plus indirect effects on other parts of the national economy. These indirect effects include backward effects (new employment required to supply project inputs) and forward effects (new employment required to meet the demand of goods and services generated by the project). In both cases, there is a first-order impact (new jobs created by the direct suppliers of inputs and the direct-suppliers of goods and services purchased with project benefits) and there are higher-order effects (jobs created as the primary effects cascade throughout the economy).

5.3. Identification of compliance to sustainability criteria of RSB for Brassica carinata crop production in Ethiopia

The RSB standard covers the widest scope of environmental, social, and economic sustainability criteria. Its list of principles and criteria is therefore suitable as a comprehensive directory, covering almost all relevant topics. As there are no installed industrial units of oil extraction for Brassica carinata and biorefineries or hydrotreatment industrial units in the country, the assessment was made only for the Brassica carinata crop production.

57 https://idl-bnc-idrc.dspacedirect.org/handle/10625/44888
Thus, Brassica carinata crop production in Ethiopia was evaluated using the 12 RSB’S sustainability principles and the results are shown in table 5-2.

<table>
<thead>
<tr>
<th>Principle</th>
<th>Requirement</th>
<th>Existing situation</th>
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| **Principle 1: Legality** | Biofuel operations shall follow all applicable laws and regulations. | • Ethiopia’s regulatory system is generally considered fair. The Constitution is the highest law of the country.  
• The new Proclamation 1180/2020 and Regulation No. 474/2020 launched by Ethiopia Investment Commission states all the requirements for an investor |
| **Principle 2: Planning, Monitoring and Continuous Improvement** | Sustainable biofuel operations shall be planned, implemented, and continuously improved through an open, transparent and consultative impact assessment and management process and an economic viability analysis. | • Except the need for specific directives that enforce conducting impact assessments, the Environmental Impact Assessment (EIA) Proclamation (No.299/2002) is adequate for meeting this principle. |
| **Principle 3: Greenhouse Gas Emissions** | Biomass and biomaterials shall contribute to climate change mitigation by significantly reducing life cycle GHG emissions as compared to fossil fuels. | • Detailed analysis of the life cycle GHG emissions is required for this principle. The required data for analysing greenhouse gas emissions for Brassica carinata crop production using RSB GHG tool is presented on Annex 5. |
| **Principle 4: Human and Labour Rights** | Biofuel operations shall not violate human rights or labour rights and shall promote decent work and the well-being of workers. | • Ethiopian Labour proclamation no. 1156-2019 states that an employer has an obligation to respect the worker’s human dignity. In addition, Ethiopia has ratified the Convention on Forced or Compulsory Labour No. 29, adopted by the International |
| Principle 5: Rural and Social Development | In regions of poverty, biofuel operations shall contribute to the social and economic development of local, rural, and indigenous people and communities. | **Labour Organisation through the provision of the International Labour Organisation Conventions’ Ratification Proclamation No. 336/2003 Article 2(2).**  
• Thus, the existing law is adequate for meeting this principle if implemented successfully. |
| Principle 6: Local Food Security | Biofuel operations shall ensure the human right to adequate food and improve food security in food insecure regions. | **Agricultural and Rural Development Policies and Strategies (ARDPS, 2002) address some of the requirements. However, no explicit standard is stated in the document to enforce the provision of rural development benefits to the local community by investors. Hence, additional directives are required.**  
• Brassica carinata crop production in Ethiopia contributes both to an increase of food (traditional use of leaves as vegetable food) and of feed (residues from harvesting).  
• In addition, it can be grown in crop rotation and doesn’t compete with food crops. Hence, it satisfies the requirement on this principle. |
| Principle 7: Conservation | Biofuel operations shall avoid negative impacts on biodiversity, ecosystems, and conservation values. | **Development, Conservation and Utilisation of Wildlife Proclamation No. 541/2007 and Forest Development, Conservation and Utilisation Proclamation (No.542/2007) address the standard requirement in this principle.** |
Principle 8: Soil  
Biofuel operations shall implement practices that seek to reverse soil degradation and/or maintain soil health.  
- Brassica carinata is a very potent grass weed suppressor that if it grown in crop rotation, decreases the use of herbicides and maintains soil health. Thus, Brassica carinata production as rotational crop is in line with the requirement in this principle.

Principle 9: Water  
Biofuel operations shall maintain or enhance the quality and quantity of surface water and groundwater resources, and respect prior formal or customary water rights  
- Ethiopian Water Resources Management Proclamation (No. 197/2000) meets the standard requirement regarding this principle, which states that biofuel operations shall include a water management plan which aims to use water efficiently and to maintain or enhance the quality of the water resources that are used for biofuel operations.

Principle 10: Air  
Air pollution from biofuel operations shall be minimised along the supply chain  
- The existing Pollution Control Proclamation No. 300/2002 is adequate for meeting the standard requirement regarding this principle.

Principle 11: Use of Technology, Inputs and Management of Waste  
The use of technologies in biofuel operations shall seek to maximise production efficiency and social and environmental performance, and minimise the risk of damage to the environment and people  
- Low input application and minimum tillage are major characteristics of Brassica carinata growing fields in Ethiopia.  
- There is generally a lack of agricultural inputs, improved seed varieties, adequate extension services and large-scale mechanisation.  
- Hence, the above issues should be addressed to meet the standard requirement regarding this principle.
Table 5-2: Identification of compliance to sustainability criteria of RSB for Brassica carinata crop production in Ethiopia

6. Conclusions and recommendations

6.1. Overview of all required implementation conditions

The overall implementation conditions and a reasonable roadmap are included in the recent report of the project "Development of a Sustainable Aviation Fuel Roadmap for Ethiopia", which was prepared by EXERGIA for RSB. Based on this report, the most significant implementation issues, as they have been adapted to the BC case, are mentioned in the following paragraphs.

6.1.1. Exploitation of Ethiopia Investment Proclamation (2020)

Ethiopian Investment Commission (EIC) has launched a new proclamation recently (Regulation No. 474/2020) and been restructured to promote investment to the country and to provide a one-stop shop service for the issuing of an Investment Permit, TIN certificate and Business License. For agro-processing industries, the commission issues duty free, work and residence permits. The EIC also provides additional services to process acquisition of land, utilities (e.g., water, electrical power, and telecommunication services) and bank loans.

In the framework of Ethiopia’s strategy to attract foreign investors, the government has offered various incentives, including exemption from income tax for a period of between three and five years, depending on agricultural value added and proportion of exportable products, and a 100 per cent import duty exemption for most capital items. Export taxes are also waived for most products.

Principle 12: Land Rights

| Principle 12: Land Rights | Biofuel operations shall respect land rights and land-use rights | The existing Rural Land Administration and Utilisation Proclamation (456/2005) is adequate for meeting the standard requirement regarding this principle |

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*Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final*
If a decision is taken at government level to support the Brassica carinata development, the EIC should try proactively to investigate the interest of market actors, and launch a procedure starting from the phase of "Expression of Interest" up to "Final Offers" for the development of the BC project. The announcement should distinguish the two major stages of the BC project, namely the agriculture stage which is indispensable, and the industrial stage which is optional. The agriculture aspect of the project is of major importance and should be also considered as a key part of the investment and not as supplementary to the industrial part.

6.1.2. Feedstock transport

In Ethiopia, most of the rural roads are in poor condition and there is a shortage of heavy trucks in the country. This has imposed significant challenges on the agricultural activities in general, and it has increased the price of crops produced. The Government of Ethiopia has embarked on various programmes, at one time or the other, to address the issue by allocating up to 5% of the GDP every year in the agriculture sector, but Ethiopia’s rural road network is still one of the least developed in Africa.

Recently, with the hope of easing problems in the logistics sector brought on by a shortage of heavy trucks, the Federal Transport Authority (FTA) under Ministry of Transport in collaboration with the National Bank of Ethiopia (NBE), initiated a credit system for importing heavy trucks. With the new initiative, the private sector will procure the trucks through a supply credit modality approved by the National Logistics Council.

Independently of the BC investor design for centralised or decentralised collection of BC seeds and optional installation of BC seed crushing units to produce BC oil, the need for transportation improvement sounds considerable and should not be ignored. For this reason, part of the project development will surely be included in the upgrading of the necessary transportation routes from production sites to collection centres or oil crushing units.
6.1.3. Blending and local distribution of SAF

It is expected that the SAF produced will be supplied to the fuel blending wholesaler petroleum companies in which the blending is done at the depots of the companies. Ethiopia already has some blending facilities (Oil Libya, National Oil Company and Total Ethiopia) with a total storage of 550,000 litre of blended fuel which is used for ethanol. The relevant facilities and experience can also be used for SAF.

The Ethiopian wholesale petroleum companies face several challenges, among which are low fuel profit margins, recurrent foreign exchange shortages, difficulty in meeting operational and safety standards, and operation under an outdated regulatory framework that is no longer keeping pace with the sector’s growth. Moreover, the scattered regulatory roles bestowed upon multiple government institutions has made the decision-making process very complex.

The involvement of the local/international SAF suppliers and the major SAF consumers may relax the business risks and facilitate some of the decisions of the investment plan. However, it is up to the investor to estimate the optimum approach and propose it to the Ethiopian government. Regarding the upgrading of the legal framework, this is a necessary task given the new obligations and commitments for climate change policies. Within this effort, the regulatory roles could be amended to comply with the forthcoming decarbonisation era.

6.1.4. Research on BC cultivation and biofuel/SAF production

Energy crop selection, productivity, management, and other affiliated activities are performed by the Ethiopian Institute of Agricultural Research. The Environment and Forestry Research Institute also performs research on 2G-ethanol and biodiesel raw material. Melkasa Agricultural Research Centre has conducted research on jatropha and palm oil and released two palm oil varieties which are drought resistant and grow to a low height, which makes them suitable for harvesting. Wondo Genet Agricultural Research Centre is also actively engaged in research on different bioenergy feedstocks.

Although research has been done on biofuel production at MSc and PhD level, so far almost the largest part of it focused on biofuel production for land transport and domestic

Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final
cooking. Consequently, the country is at very infant stage in terms of technology development – an essential ingredient for industrial development.

The critical factors of BC cultivation and optimisation of its performance for Ethiopian conditions are the key priorities. This orientation could also be supported by the investor in offering know-how and experience from other world regions. It is expected that improvements in the BC cultivation methods and cropping will increase the expected revenue of the farmers and investors, and so facilitate the fast expansion of cultivation in the targeted regions of Ethiopia.

6.1.5. Development of farmers’ capacity building

Human resources are vital for the BC project development in the country. High-skilled farmers are required particularly in the BC feedstock cropping and processing, hence the country must continuously invest in human resource development in this sector. On the other hand, the BC project, even regarding only the agricultural part, has the characteristics of an investment by itself, part of which should be the capacity building of farmers and other workers, through targeted training and other supporting activities, to be able to participate efficiently.

In addition, the investor has to consider the mechanisation of BC cropping and should intervene with supporting measures addressed to farmers and their relevant associations. This action would be accompanied with necessary capacity building, using the new machinery.

6.2. Proposals of organisational and legal/institutional measures

The prominent pathway and mobilisation of the main actors and decision makers mentioned in the project “Development of a Sustainable Aviation Fuel Roadmap for Ethiopia,” are implementable in the case of the BC development as bioenergy feedstock for SAF production. However, taking into consideration the recent developments in the decarbonisation policies, a change in the priorities set in the “Roadmap” project it is herein proposed; namely, it is believed that the procedure to search for the BC investor should start immediately. The selected investor will be the BC project manager and with the
assistance of the national and local stakeholders will open the BC market in the country by initiating a major "BC-to-SAF" activity. Therefore, the most significant actions to be undertaken are:

- **Attracting foreign investments becomes the major priority** to launch the "BC-to-SAF" project. The country should run campaigns to attract foreign capital, even if all of the following elements are not in effect:
  - enabling policy and regulatory environment,
  - strong institutional governance with clear responsibilities and agenda,
  - elucidated potential in terms of specific sustainable feedstock availability
  - adequate supporting infrastructure,

As part of this exercise, the Ethiopian Investment Commission should also investigate and assist the potential foreign investors with the acquisition of **Africa Trade Insurance**, which is a type of insurance against political risks and serves to protect investments, projects, assets and contracts against risks associated with questionable government actions that could lead to payment default and financial loss. To this end, it is very important the Ethiopian Investment Commission also identifies how and to what extent, the public sector will engage with the foreign private sector (For example, joint-ventures, public private partnerships, loan guarantee programmes, etc.).

- **RSB compliance** for the produced SAF should also be obtained, as this will enable operators to claim emissions reductions under CORSIA and/or the EU framework. Obviously, the efforts to obtain the necessary certifications are on-going activities and will be undertaken at a certain stage by the investor.

- **Establishment of strong linkages among the farmers’ associations and the agro-industry institutions.** To this end, the presence and operation of **Integrated Agro-industrial Parks** (IAIP) should be exploited to the fullest, towards a successful integration of smallholder farmers, small-scale processing enterprises and allied industries in commercial value chains. This action will probably contribute to the transformation of Ethiopia into a significant BC oil feedstock producer; a necessary prerequisite for the country to be able to deliver significant quantities of oil feedstock to the biorefineries/hydrotreatment units in a reliable manner and in a realistic timeframe.
A rather horizontal action is the initiation of **curriculum programmes at the universities** to train the human resources required at the various stages of the value chain.

**Updating the policy and regulatory frameworks** that will enable and foster the sustainable production of non-fossil-based aviation fuels. Updating the outdated Biofuels Strategy, inclusion of the air transport in the Energy Policy, finetuning the Biofuels Development and Utilisation Strategy to become more effective, are a few examples of actions to be taken in the policy and regulatory framework of the country. For example, considering the available options from the arsenal of measures, the introduction of a modest blending mandate could have a catalytic effect as it will incentivise the industry players to explore potential supply-chains that are necessary for SAF production, while having a negligible impact on the jet fuel price.

**The Institutional Governance** is also of paramount importance and should be enforced benefitting from the already formed SAF Steering Committee and its members representing various key players in the public sector of the country. However, emphasis should be placed on including entities with leading roles across the whole supply chain, i.e., feedstock production, utilisation, industrial processing, distribution, supply and use of liquid biofuels. Once this is achieved, the SAF Steering Committee will gain a spherical understanding of the interests and challenges in the SAF sector and, consequently, promote the country's best interest. As part of the governance exercise, it is important that the regional and governmental authorities align their positions and separate their responsibilities.

The scale up of the **few existing pilot projects** should be completed and oriented to cover the case of BC. Additionally, **liaison with farmers cooperatives and the conduct of capacity building** is mandatory to raise awareness and ensure a well-receiving environment.
6.3. Elaboration of considerable findings and conclusions

This project examined the pre-feasibility of SAF production from Brassica carinata crops cultivated in Ethiopia. The value chain of this business incorporates an agriculture part including Brassica carinata cultivation, seed production and transportation at the gate of the industry’s storage. The stages of seed crushing, hydrotreatment and biofuels production constitute the industrial part of the value chain. At present, the main problem in the sustainable biofuels production industry worldwide, lies in the agriculture phase of the value chain where significant challenges and risks have to be overcome.

Competition with other crops, personal preferences of farmers, stability of feedstock market conditions, long-term perspective of business, and cultivation risks, are some of the reasons confirming this argument. Therefore, the business developers in biofuels and the low carbon fuels producers and suppliers are seeking opportunities to minimise their production risks and diversify their feedstock supply. In this context, the Ethiopian case could be considered as satisfying the criteria to attract the interest of international companies in this sector initially, and in parallel to provoke the interest of local demand for SAF.

In the following paragraphs, some of the most significant findings and conclusions are presented:

• In Ethiopia, Brassica carinata grows best in the cool moist climates in the tropics from mid to high altitudes above 1,700 to 3,200 m above sea level. However, it grows best in areas within the range of 2,000-2,600 m above sea level and seasonal rainfall of 600-900 mm. Soil pH ranging from 6.0 – 7.5 are most favourable. The current major growing areas are Arsi, Bale, West Shewa, East Wellega, West Gojam and South Gonder.

• Ethiopian farmers have a long tradition of using the Brassica carinata as a dual-purpose crop. At its early stage of development, the leaves will be collected by thinning or topping during the rainy season (July to September) and then seed will be harvested later in
December from the same plant. The leaves of the plants are used as a vegetable relish while the seeds are locally used to grease a traditional bread-baking/injera-baking clay pan (oven) or sold to traders for export purposes. It is worth mentioning that the food use of Brassica carinata leaves is not common in other regions of the world and therefore are not incorporated in the farmers’ income.

- Brassica carinata also plays an important role in crop rotation to control grass weeds in large scale wheat farms such as in Arsi and Bale. It was found that Brassica carinata is a very potent grass weed suppressor, and that cereals following it in a rotation face little competition and so it decreases the need for herbicides. This cultivation approach is considered in the present pre-feasibility, whereas intercropping and cover cropping could also be used in the future expansions of Brassica carinata cultivation, as sustainable approaches bringing likely higher income to farmers than using crop rotation.

- Sustainable cultivation approaches have been considered concentrating on rotation cropping that could be used as the basis of cost calculations. Rotation cropping is probably less favourable for farmers’ income compared to intercropping and cover cropping but adapts better to the existing farmers’ experience and decreases potential arguments and resistance due to changes of crop cultivation. However, the cases of intercropping and cover cropping could also be considered by potential investors since they might decrease feedstock risks and smoothen seasonality of cropping.

- The production of Brassica carinata in Ethiopia is practiced by many farmers, comprising more than 423,273 households of fragmented small holdings averaging 0.02 ha in size. The total production hectarage of the crop steadily decreased from 45,167.81 to 7,917.47 ha in the last decade with average productivity of 1.8 ton/ha. The total production has decreased from 74,666.356 tons in 2011/12 to 12,575.789 tons in 2020/21, mainly because of land competition with cereals, especially barley and wheat, when grown as a monocrop, and lack of inputs, improved seed varieties and large-scale mechanisation.

- At present, the Ethiopian Seed Enterprise and the Oromia Seed Enterprise, of Kulumsa Agricultural Research Centre and Agerfa Technical and Agricultural College are the only
commercial scale producers of Brassica carinata seed. These companies used mechanisation and produce Brassica carinata in crop rotation with cereals. However, their area coverage is limited to < 150 ha/year.

- To improve the production and productivity of Brassica carinata, more than 10 improved varieties were released by federal and regional research centres. However, from the released varieties, Yellow Dodola seems the most demonstrated and adopted variety. This variety is characterised by yellow seed colour, high seed productivity (2 ton/ha) and high oil content (44%), is stable and adapted to major growing areas of Ethiopia. The performance of Yellow Dodola is highest if compared to many other varieties developed in other regions of the world.

- Crop suitability map analysis for Brassica carinata showed that Ethiopia has abundant suitable land for its production. It is identified that 29,902,340 hectares of land is suitable for Brassica carinata production. Based on the suitability class; 3,124,044 ha is highly suitable, 22,714,012 ha moderately suitable, 4,064,284.00 ha marginally suitable and 79,838,004 ha is unsuitable land. The analysis of this study also shows that Oromiya has large proportion of suitable land with 16,019,728 ha followed by Amhara and SNNP with 7,109,188 ha and 3,048,600 ha respectively.

- Brassica Carinata cultivation should be considered as contributing both to increase of food (traditional use of leaves as vegetable food) and feed (carinata meal from oil production and residues from harvesting), in addition to the production of Brassica carinata oil, and then SAF or other biofuels. The consideration of by-products contributes to a significant increase of farmers’ income and the improvement of sustainability performance.

- The calculated cost of cultivation for seed production in Ethiopia is competitive to similar costs in other regions of the world. What makes the Brassica carinata more attractive in Ethiopia is the use of leaves for food by local populations. This farmers’ benefit might not continue, as extensive cultivation is expected to bring large quantities of Brassica carinata leaves into the local market. On the other hand, an organised market
for Brassica carinata seeds and oil will likely result to higher prices for these products, close to international prices.

- **The emphasis of the pre-feasibility assessment was placed on the agricultural part of the value chain**, considering that this is the strong point for Ethiopia, and not on the industrial part, which could optionally take place in the country or abroad following the specific investment specifications and the prevailing market and technological conditions. These conditions are changing due to international commitments for decarbonisation of fuels and the present situation may not characterise the forthcoming evolution in the next five years.

- There are no installed industrial units of seed crushing suitable for Brassica carinata in the country to explore the relevant experience and cost analysis for Brassica carinata seed production, not even biorefineries or hydrotreatment industrial units. For the establishment of the two latter phases of the value chain need to be decided by the potential investor of the Brassica carinata project. The decision will be influenced by a broader cost optimisation assessment that might consider also the specific market position and the ownership of relevant idle assets by the investor.

- From an organisational viewpoint, there is a need for the first steps of the active development of a strong project management governance reflecting and the interest of an international company, to establish a reasonable framework for the Brassica carinata feedstock production and processing for the next stages of SAF and/or biofuels production. Local companies interested in being involved in this project could also participate at a certain level in the value chain activities and biofuel final consumption. In addition, the role of agriculture associations is of utmost importance and together with the state services should support this new cultivation and contribute to relaxing the concerns and reasonable uncertainties of farmers.

- In case there is a state decision to develop the Brassica carinata project, the major and direct initial intervention, should concentrate on inviting potential investors to develop the agriculture and potentially the industrial part of the value chain in Ethiopia. Both
the agriculture and the industrial parts could be considered as investments with significant economic and social benefits, thus eligible for strong state support.

- The next steps of Brassica carinata development will absolutely depend on international market evolution for SAF and the development of alternative solutions for low carbon fuels in transportation. **Given the decision of the EU and other countries to move faster to a decarbonised energy economy, the possibilities for success in the Brassica carinata project increase**, particularly for the period up to 2035.
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ANNEX 2: Application producer for investment permit by a foreign investor

- Fill out a paper-based or online application and submit it to the EIC accompanied by the documents:
  - A copy of a valid authorisation document if application is filed by an agent
  - A copy of bio-pages of a valid passport showing his identity and two recent passport photos size photographs if application is filed by a sole proprietor
  - Document evidencing the financial position or profile of the investor, when deemed appropriate by the Commission.

- Documents originating outside of Ethiopia must be authenticated by foreign and domestic bodies authorised to authenticate documents.

- Upon receipt of the application, the appropriate investment organ:
  - Issues the permit to the applicant or investor if the application is successful
  - Notifies the applicant or investor in written within 3 working days from the date following the date of the application and states the reason for the rejection if the application is rejected

- The appropriate investment organ, after issuing the investment permit, notifies the concerned institutions for the necessary follow up.

A holder of an investment permit may not be required to obtain a business license until the commencement of production or rendering of service upon completion of the project.
ANNEX 3: Integrated Agro Industrial Parks (IAIPs) in Ethiopia

Location of IAIPs in Ethiopia


Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final
### Government-Owned Industrial Parks

<table>
<thead>
<tr>
<th>Operational</th>
<th><strong>Bole Lemi I IP</strong></th>
<th><strong>Hawassa IP</strong></th>
<th><strong>Mekelle IP</strong></th>
<th><strong>Adama IP</strong></th>
<th><strong>Kombolcha IP</strong></th>
<th><strong>Jimma IP</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Location: Addis Ababa – capital of Ethiopia</td>
<td>Location: SNNPR Regional State</td>
<td>Location: Tigray Regional State</td>
<td>Location: Oromia Regional State</td>
<td>Location: Amhara Regional State</td>
<td>Location: Oromia Regional State</td>
</tr>
<tr>
<td></td>
<td>Total Land Area: Phase 1: 177 ha</td>
<td>Total Land Area: 300 ha (Phase one 140 ha and phase 2 160 ha)</td>
<td>Total Land Area: 75 ha</td>
<td>Total Land Area: 102 ha</td>
<td>Total Land Area: 100 ha</td>
<td>Total Land Area: 75 ha</td>
</tr>
<tr>
<td></td>
<td>Employees: ~18,000 workers</td>
<td>Total Factory sheds: 52</td>
<td>Total Factory sheds: 15</td>
<td>Total Factory sheds: 15</td>
<td>Total Factory sheds: 9</td>
<td>Total Factory sheds: 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Government-Owned Industrial Parks

<table>
<thead>
<tr>
<th>Park</th>
<th>Location</th>
<th>Sector</th>
<th>Total Land Area</th>
<th>Total Factory sheds</th>
<th>Expected Employees</th>
<th>Export Value (2019)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahir Dar IP</td>
<td>Amhara Regional State</td>
<td>Textile &amp; Apparel</td>
<td>100 ha</td>
<td>9</td>
<td>~10,000 workers</td>
<td>Has not started exporting yet</td>
</tr>
<tr>
<td>Debre Berhan IP</td>
<td>Amhara Regional State</td>
<td>Textile &amp; Apparel, Agro processing</td>
<td>100 ha</td>
<td>8</td>
<td>~10,000 workers</td>
<td>Has not started exporting yet</td>
</tr>
</tbody>
</table>

### Under Construction

<table>
<thead>
<tr>
<th>Park</th>
<th>Location</th>
<th>Sector</th>
<th>Total Land Area</th>
<th>Total Factory sheds</th>
<th>Employees</th>
<th>Export Value (2019)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilinto IP</td>
<td>Addis Ababa – capital of Ethiopia</td>
<td>Pharmaceutical</td>
<td>279 ha</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Bole Lemi II IP</td>
<td>Addis Ababa – capital of Ethiopia</td>
<td>Textile &amp; Apparel, Leather &amp; Leather Products</td>
<td>176 ha</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Dire Dawa IP</td>
<td>North-Eastern part of the Country</td>
<td>Multiple Sectors (Textile &amp; Apparel, Machinery, Chemical, Equipment, etc)</td>
<td>150 ha</td>
<td>15</td>
<td>~10,000 workers</td>
<td>None</td>
</tr>
</tbody>
</table>

### Privately-Owned Industrial Parks

<table>
<thead>
<tr>
<th>Park</th>
<th>Location</th>
<th>Sector</th>
<th>Total Land Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huajian IP</td>
<td>Addis Ababa</td>
<td>Textile &amp; Apparel and Leather &amp; Leather Products</td>
<td>138 ha</td>
</tr>
</tbody>
</table>
## Government-Owned Industrial Parks

<table>
<thead>
<tr>
<th>Park</th>
<th>Location</th>
<th>Sector</th>
<th>Total Land Area</th>
<th>Total Factory sheds</th>
<th>Export Value (2019 – Feb 2020)</th>
</tr>
</thead>
<tbody>
<tr>
<td>George Show IP</td>
<td>Addis Ababa</td>
<td>Leather and Leather Products</td>
<td>86 ha</td>
<td>33</td>
<td>~1.7 Mill USD</td>
</tr>
<tr>
<td>Eastern IP</td>
<td>Addis Ababa</td>
<td>Mixed</td>
<td>400 ha (phase one 233 ha and phase 2 167 ha)</td>
<td></td>
<td>~6 Mill USD</td>
</tr>
<tr>
<td>Vogue IP</td>
<td>Tigray Regional State</td>
<td>Textile &amp; Apparel</td>
<td>177.5 ha</td>
<td>2 (each 100,000 sqm)</td>
<td>~1.4 Mill USD</td>
</tr>
<tr>
<td>DBL IP</td>
<td>Tigray Regional State</td>
<td>Textile &amp; Apparel</td>
<td>78.05 ha</td>
<td>5</td>
<td>~1.6 Mill USD</td>
</tr>
<tr>
<td>CCCC Arerti IP</td>
<td>Amhara Regional State</td>
<td>Construction materials &amp; home appliances</td>
<td>100 ha</td>
<td>5</td>
<td>Has not started exporting yet</td>
</tr>
<tr>
<td>CCECC Dire Dawa IP</td>
<td>North-Eastern part of Ethiopia</td>
<td>Mixed</td>
<td>1000 ha</td>
<td>None</td>
<td>Has not started exporting yet</td>
</tr>
</tbody>
</table>

List and details of operational Industrial Parks in Ethiopia

---

*Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final*
ANNEX 4: Ethiopian export trend of Brassica carinata for the last ten years

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Volume (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011/12</td>
<td>413.712</td>
</tr>
<tr>
<td>2012/13</td>
<td>2,373.693</td>
</tr>
<tr>
<td>2013/14</td>
<td>10,089.3</td>
</tr>
<tr>
<td>2014/15</td>
<td>6.614</td>
</tr>
<tr>
<td>2015/16</td>
<td>29,251</td>
</tr>
<tr>
<td>2016/17</td>
<td>8,787.7885</td>
</tr>
<tr>
<td>2017/18</td>
<td>3,939.522</td>
</tr>
<tr>
<td>2018/19</td>
<td>1.58</td>
</tr>
<tr>
<td>2019/20</td>
<td>2,407.48</td>
</tr>
<tr>
<td>2020/21</td>
<td>5.541</td>
</tr>
</tbody>
</table>

Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final
ANNEX 5: Required data for analysing greenhouse gas emissions for Brassica carinata crop production using RSB GHG tool

<table>
<thead>
<tr>
<th>General information</th>
<th>Climate region</th>
<th>Tropical, moist</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil type</td>
<td>High activity clay soil (Oxisols)</td>
</tr>
<tr>
<td></td>
<td>Farm/Production Unit/dataset name</td>
<td>Brassica carinata</td>
</tr>
<tr>
<td></td>
<td>Specify the region of the cropping (if many, indicate the main producing region)</td>
<td>Oromia and Amhara, Arsi, Bale, West Shewa, East Wellega, East Gojiam, West Gojam and South Gondor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crop information</th>
<th>Agricultural feedstock (crop)</th>
<th>Brassica carinata</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agricultural feedstock (crop) yield</td>
<td>1800 kg wet mass / ha</td>
</tr>
<tr>
<td></td>
<td>Agricultural feedstock moisture content</td>
<td>4% %</td>
</tr>
<tr>
<td></td>
<td>Agricultural feedstock price</td>
<td>0.8 $ / kg wet mass</td>
</tr>
<tr>
<td></td>
<td>Feedstock lower heating value (LHV)</td>
<td>37.6 MJ/kg dry mass</td>
</tr>
<tr>
<td></td>
<td>Number of seeds planted</td>
<td>6.00 kg / ha</td>
</tr>
<tr>
<td></td>
<td>Relevant feedstock characteristics</td>
<td>glucosinolat for fumigation and animal feed</td>
</tr>
</tbody>
</table>
### Mineral fertilisation during growth period

<table>
<thead>
<tr>
<th>Residues information</th>
<th>Agricultural residue 1</th>
<th>Agricultural residue 1 yield</th>
<th>Agricultural residue 1 price</th>
<th>Agricultural residue 2</th>
<th>Agricultural residue 2 yield</th>
<th>Agricultural residue 2 price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Carinata leaves</td>
<td>3500.00 kg wet mass / ha</td>
<td>0.31 $ / kg wet mass</td>
<td>Straw</td>
<td>4000.00 kg wet mass / ha</td>
<td>0.13 $ / kg wet mass</td>
</tr>
<tr>
<td>Nitrogen application, as N</td>
<td>urea, as N</td>
<td>23.33 kg N/ha/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>`</td>
<td>1100 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>monoammonium phosphate, as N</td>
<td>22.8 kg N/ha/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Truck</td>
<td>1100 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorus application, as P2O5</td>
<td>monoammonium phosphate, as P2O5</td>
<td>45.60 kg P₂O₅/ha/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Truck</td>
<td>1100 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium application, as K₂O</td>
<td>No Potassium Fertiliser application</td>
<td>0 kg K₂O/ha/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime application (CaO)</td>
<td>No lime application</td>
<td>0 kg/ha/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other fertilisers</td>
<td>Sulfur</td>
<td>8.40 kg/ha/year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and micronutrients application</td>
<td>Truck (40 tonne) for dry product (Diesel)</td>
<td>1100</td>
<td>km</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------------------------------------</td>
<td>------</td>
<td>----</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Organic fertilisation during growth period</strong></td>
<td><strong>Solid organic fertiliser application</strong></td>
<td>Cattle - solid manure from loose housing</td>
<td>5</td>
<td>t solid org fert/ha/year</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Truck (40 tonne) for manure (Diesel)</td>
<td>15</td>
<td>km</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Plant protection during growth period</strong></td>
<td><strong>Pesticide application</strong></td>
<td>Karate 5% EC</td>
<td>0.05</td>
<td>kg active component/ha/year</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Other plant protection products applied</strong></td>
<td>Herbicide (Gallant™ Super)</td>
<td>0.52</td>
<td>kg active component/ha/year</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Herbicide (Dual Gold)</td>
<td>0.96</td>
<td>kg active component/ha/year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Energy consumption during feedstock production, excluding transportation</strong></td>
<td><strong>Diesel</strong></td>
<td>Land Preparation and Cultivation</td>
<td>8.5</td>
<td>L/ha/year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Effluent emissions</strong></td>
<td><strong>Annual rainfall</strong></td>
<td>750</td>
<td>mm/year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Annual irrigation applied to feedstock</strong></td>
<td>No irrigation</td>
<td>m3 water / ha / year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Climate region</strong></td>
<td>Tropical, wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Soil pH</strong></td>
<td>6 - 7.5</td>
<td>pH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Soil type</strong></td>
<td>High activity clay soil (Oxisols)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>USDA Soil Order</strong></td>
<td>Oxisols</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final
ANNEX 6: GHG emissions for Carinata production in Ethiopia

Considering Annex 5 data and utilising the RSB GHG Tool, results of Life-cycle GHG emissions for Carinata seed production in Ethiopia have shown promising opportunities to mitigate CO₂ emissions. The baseline result, which considers only the agriculture stages of cultivating and harvesting the Carinata seed, is 270 gCO₂eq/kg of Carinata seed. Residues from this cropping system include Carinata leaves, which have been used as food in some regions of Ethiopia, and straw. Despite the applicability of the leaves for food, this study considered that both leaves and straw are residues and, therefore, no GHG emissions were allocated to them. The main driver of the Carinata seed carbon footprint is the direct N₂O emissions from managed soil, which is responsible for 73% of the total LCA GHG emissions. These emissions are related to direct N₂O emissions from synthetic and organic N fertiliser applied to soil and the amount of nitrogen in crop residues (above-ground and below-ground) returned to soil.

![Breakdown LCA GHG emissions for Carinata seed production in Ethiopia.](image)
LCA GHG emissions related to nitrogen production and phosphorus production account for 14% and 7% of the overall carbon footprint, respectively (Figure 1). Parameters assumed in this analysis are indicated in the table below.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Application</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monoammonium phosphate, as N</td>
<td>22.8</td>
<td>kg N/ha.yr</td>
</tr>
<tr>
<td>Urea, as N</td>
<td>23.3</td>
<td>kg N/ha.yr</td>
</tr>
<tr>
<td>Monoammonium phosphate, as P₂O₅</td>
<td>45.6</td>
<td>kg P₂O₅/ha.yr</td>
</tr>
<tr>
<td>Sulphur</td>
<td>8.4</td>
<td>kg/ha.yr</td>
</tr>
<tr>
<td>Cattle - solid manure from loose housing</td>
<td>5</td>
<td>t solid organic fertiliser/ha.yr</td>
</tr>
<tr>
<td>Pesticides</td>
<td>1.53</td>
<td>kg (active component)/ha.yr</td>
</tr>
<tr>
<td>Diesel</td>
<td>9.5</td>
<td>L/ha.yr</td>
</tr>
</tbody>
</table>

* The study considered Carinata seed yield at 1,800 kg/ha.

Parameters used in the Carinata LCA GHG emissions study.

To better understand how the level of carbon input and soil management can affect GHG results, a scenario was modelled. Considering an improved scenario using better soil and residues management, the carbon footprint might reach negative values up to -1570 gCO₂eq/kg Carinata seed. The carbon input to soil is affected by the type of farming practices and by the return of crop residues to the field. Intensively farmed areas, for instance, might lead to carbon losses due to the drainage conditions of the soil. Grassland, however, tends to accumulate carbon.

Considering the assumptions used in this study, Carinata might contribute to carbon reduction targets and carbon storage. However, deeper analysis and verification procedures, following robust certification schemes such as the Roundtable on Sustainable Biomaterials, would be required to confirm the potential.
Sensitivity analysis of the LCA GHG emissions for Carinata seed production in Ethiopia.

-1570 gCO2eq/kg carinata: with soil improvement practices (no-till), residues left in the field, and additional practice of addition of animal manure.

269 gCO2eq/kg carinata: without soil improvement practices (full-tillage, removal of residues, and no mineral fertilisation or nitrogen-fixing crops.)
ANNEX 7: Validation Workshop

On October 25, 2022, RSB organised a half day validation workshop to discuss the results of the current pre-feasibility study on Carinata brassica crop for biofuels in Ethiopia with selected stakeholders. The agenda of the workshop is presented in the figure below.

![Agenda of the validation workshop](image-url)
Photos taken during the duration of the workshop are shown below.

Photos from the workshop

During the workshop, the Consultant delivered a detailed presentation of study; the relevant file accompanies the present document.

The participation of stakeholders in the event was deemed satisfactory and a vivid discussion took place during the Q&A session. The main topics discussed are summarised below:

- Attracting the necessary investment becomes the major priority to launch the “BC-to-SAF” project. Initial state interventions should concentrate on inviting investors to develop agricultural and industrial parts and on establishing a strong project management governance reflecting and the interest of an international company
- Agricultural part of the value chain:
  - Competition with other crops, personal preferences of farmers, feedstock market volatility, long-term perspective of business, cultivation risks, etc., are factors hindering scale-up of sustainable biofuels production
  - Interventions needed to overcome identified barriers include:
  - Institutional development and awareness campaigns, capacity building
  - Establishment of strong linkages among the farmers’ associations and the agro-industry institutions.
  - The scale up of the few existing pilot projects

Pre-Feasibility Study for the Production and processing of the Brassica carinata (Ethiopian Mustard) crop for Biofuels in Ethiopia – November 2022 – Final
Sustainability certification is a prerequisite to provide access to the international market.

Industrial part of the value chain: technologies are 'international', but a detailed feasibility study should be undertaken to optimise infrastructure location (Ethiopia or aboard) and production profile (fuels, quantities).

The comparative analysis of the costs from other parts of the world (USA, Italy, Canada) should not be considered as a detailed benchmark exercise. The reason is that very different underlying assumptions were considered in each work and additional necessary assumptions were made by the authors of this work to overcome the lack of unified information. However, the analysis has revealed that the estimated costs in Ethiopia are, at least, competitive to other reported similar costs internationally. This observation can provide confidence on the potential of the cultivation of BC in Ethiopia at an industrial scale for the production of SAF.

It is important to resolve issues related to land management for the cultivation of food and feed, as well as the cultivation of energy crops. The potential to follow advanced agronomic practices to cultivate BC as a rotation or cover crop constitute a positive measure.

A conservative approach with respect to the revenues from the markets of BC by-products (i.e. leaves for food and seeds for greasing) should be considered; as the cultivation of BC will be scaling up, quantities will become larger and therefore prices will go down.

A detailed feasibility study should consider:
  - A complete analysis of the industrial part of the value chain considering all technological cost aspects based on the international market
  - A dedicated strategy for seeds collection
  - Detailed characterisation of the oil produced
  - Detailed quantification of the oil production per hectare of BC cultivated
ABOUT RSB

RSB (The Roundtable on Sustainable Biomaterials) is a global membership organisation that drives the sustainable transition to a circular bioeconomy. RSB’s sustainability framework has been developed by its multi-stakeholder membership, and is a uniquely robust and credible foundation for supporting innovative solutions to the climate crisis. RSB uses this foundation to develop projects, new knowledge and solutions that equip key decision-makers to deliver positive impacts for people and the planet.
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