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INDUSTRIAL AGRICULTURE: COMPLICATION TO SOLUTION

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Contents

1. INTRODUCTION

Industrial crops are crops grown specifically for non-food purposes, such as the production of raw materials for various industrial products. These crops include cotton for textile production, rubber for tire manufacturing, and sugarcane for biofuel production, among others. The growing demand for these crops is driven by the need for sustainable and renewable sources of raw materials for various industries. The cultivation and processing of industrial crops play a significant role in the global economy, providing employment and contributing to the growth of many countries. There are many other advantages of industrial crops including: social, economic and environmental factors, such as replacement of fossil fuels, carbon sequestration, increase profit margins for smallholder farmers and commercial farmers and improve the use of marginal and polluted lands. Additionally, industrial farming can help in the changeover to organic and sustainable agricultural practices. Sustainability with industrial agriculture can also be achieved by using industrial crops as substitutes for traditional petroleum-based goods, such as polymers and solvents etc. However, the focus now falls on how potential can industrial agriculture be in creating new markets., sustainable agriculture systems and business models that can create value for EU farmers without displacing food production.

Even though the benefits and huge potential of industrial agriculture are obvious, there are many numbers of obstacles that agriculture industry must overcome to integrate the industrial cops as standard practice. Lack of experience and knowledge in cultivating industrial crops is deemed as an impeding factor to the agricultural industry. The expansion of the industry will be aided by the dissemination of more information and the promotion of knowledge-sharing through the establishment of networks and the promotion of cooperatives. Demonstration projects that offer farmers and industry with clear business models are crucial to the progress of the sector.

The study focuses to extend the present knowledge base in the field and give future farmers/entrepreneurs with examples of value chains from which to draw inspiration. The potential environmental advantages offered by industrial crops, the valorisation of marginal or polluted areas and importance of hemp and miscanthus value chains are highlighted. Also, many other factors require more research and development other than the those focused in this study, which include fair pricing, development and awareness on the value chains, and research into the life cycle evaluation of crops, as well as more study into the potential of industrial crops on marginal and contaminated areas, is needed.

Farmers in Europe benefit from industrial crops because they give access to new markets and facilitate the growth of the bio-based economy in the European Union. Non-food products have their start with these products such as biochemicals, bio lubricants, bioplastics, bioenergy, bio-composites and medicine. Therefore, farmers that cultivate these crops can play a pivotal role in producing high value-added goods, which can increase the revenue for farmers. However, in many cases entering these new value chains necessitates substantial modifications to agricultural business models, contact with new economic players and investments. It is also crucial to provide professional assistance, access to information and innovation and collaboration to small and medium holder farmers for them to succeed in bio-based industrial agriculture. Therefore, operational groups and NGO's can bridge the gap to success.

Industrial crops can also produce a substitute for petroleum-based products with plant-based materials, that can help meet energy and climate goals. However, there exists concern that industrial crops might hinder food production, as they can occupy fertile land dedicated for food production due to high added value. But, this concern can be mitigated if the industrial crops are grown on marginal and polluted soils and by using multi and intercropping techniques. Sustainable production of industrial crops may also aid in land regeneration and provide many ecosystem benefits, including biodiversity intensification and enhancing soil structure and organic matter.

Providing a viable industry while utilizing marginal and polluted land is a fundamental aim for several companies in this sector. A sustainable business model which utilizes marginal and polluted lands are essential for farmers to obtain huge returns from novel crops. These novel crops grown on non-managed lands also diversifies the incomes obtained by farmers and is crucial for sustainable development of this region.

European Union needs a key area to focus in order to minimize dependence on CO2-intensive activities, which is bio-based circular economy. The bio-based economy can reduce the CO2-intensive dependency and can ensure to emerge a more sustainable localized economy. However, the bio-based economy to succeed and accomplish the set goals, it needs a substantial planning to guarantee non-conflict and sustainable markets for all stakeholders in the food industry.

In this study, industrial crops with great potential for the advancement of bio-based circular economy were selected. Fibres crops have the greatest potential for this advancement, due to their versatile usage in variety of industrial sectors including textiles, construction materials and paper manufacture. Not only do some industrial crops have the potential to benefit the market and the environment because of their biodegradability and ability to replace petroleum-based goods, but they also have a positive influence on the market and the environment in many other ways.

The vast diversity of applications of industrial crops can provide farmers with resiliency and protection against crop price changes, making this a crucial consideration. The better pricing for industrial crops and increased flexibility in the usage of harvested products are the greatest threats to food production caused by industrial agriculture crops.

The possible market prospects for industrial crops emphasizing their advantages, considering social, economic, and environmental factors are studied.

2. AIM AND OBJECTIVE

- Determine the effects of industrial agriculture on different environmental aspects.
- To provide examples and best practices for cultivation industrial crops without relying on other methods to generate food.
- Find major biobased material value chains in which farmers may have a key role through either long-term contracts or hands-on participation.
- Prospects of industrial farming and considerable improvements to enhance the sustainability value of industrial farming.
- Provide case studies.
- Identify further research requirements arising from practice and potential knowledge gaps.
- Provide unique solutions to several NGO Agri organizations and other innovative initiatives.

3. ADVANTAGES OF INDUSTRIAL CROPS TO ENVIRONMENT

In Europe, industrial crops covered only 4.7% of land as of the 2016, there are a variety of variables that contribute to Europe's limited adoption of industrial crops. Lack of a necessary market, reluctance to embrace new agronomic methods required for new crops, and high land prices are some of these problems.

At present, sustainability is no longer defined as an avoiding depletion of natural resources and is not primarily associated to a certain natural resource. The word sustainability is now become synonymous to society’s economic, social and environmentally sustainable growth.

Sustainable agriculture is the utilization and management of the agricultural ecosystem in a manner that maintains its productivity, vitality, biological diversity, regeneration capacity, and ability to function, so that it can fulfil – today and in the future – significant economic, social, and ecological functions at the local, national, and global levels, while causing no harm to other ecosystems. (Pulford et al., 2002)

Currently, the majority of energy and material supplies are derived from limited, non-renewable fossil fuels, whose usage generates grave environmental issues. The worldwide concern for preventing environmental destruction such as energy scarcity, climate change, soil degradation and depletion of non-renewable resources is to find an alternative energy and bioproducts supplies that are more sustainable (environmentally, economically, and socioeconomically).

Biomass energy is considered to be the most environmentally friendly source of energy due to its compatibility with the current systems, renewable, biodegradable and locally generated characteristics. However, due to the increasing demands for biomass energy there is heightened risk of competition for agricultural land. Therefore, this caused a situation leading to food vs fuel demand. (Tóth et al., 2016). Furthermore, due to increase in demand of environmentally sustainable biomass a question may arise, can this lead to agriculture intensive cultivation of bio-energy crops which raised the reliance on natural resources. As a result, various industrial crops are recognized as having low-input and high-yielding biomass generation to address this issue. Sustainable energy, biomaterials, phytomedicine (hemp), and protein-rich feed/food production can be attained via the cultivation of these plants.

Industrial crops have the potential to provide several advantages, such as improving habitats and boosting biodiversity by minimizing the fragmentation of ecosystems caused by conventional agricultural farming. Compared to conventional arable farming, the cultivation of industrial crops like willow, camelina, hemp, miscanthus and aromatic plants require less soil cultivation which results in reduced habitat loss and soil erosion. Apart from that these crops often require less use of insecticides and herbicides, and crops like hemp and willow have an off seasonal flowering which can complement the pollen supply where other crops are scarce. By providing nesting areas, dense canopy cover, insect-pollination plants, and healthy soil interaction while minimizing agricultural interference, the diversity and complexity of the canopies of many native industrial crops (flax, cardoon, lavender) can also benefit soil fauna, biodiversity, and native avian populations.

Conventional crop management practices and characteristics of plants can influence soil quality through soil organic matter (SOM), nutritional value, soil structure and acidity and erosion potential. Industrial crop influence on soil organic matter content, soil pH and structure have been assessed to be largely dependent on local circumstances.

Nevertheless, the literature details generic tendencies that provide a comparison between short rotation forests trees, long-term forest trees, perennial grasses, and annual crops. In terms of SOM content and structure, annual cropping systems are the most detrimental due to their fast soil turnover, short soil permanence, and litter clearance.

According to the research (Tuskan et al., 2001), herbaceous perennial crops and woody crops collect more soil organic matter and improve soil structure than annual crops due to their long-term duration in soil, rapid root growth and input residues. Additionally, majority of industrial crops need lo inputs (i.e., fertilizers and pesticides) resulting in less intensive use of amendments which improves overall soil health, reduce alteration in soil pH values.

In comparison to annuals, perennial herbaceous trees and plants are even less damaging to soil properties due to their reduced input requirements. However, concerning soil pH, a few woody crops enhance soil acidity, whereas herbaceous and annual crops do not increase soil acidity (Boardman et al., 2014). Herbaceous trees and perennials have lesser soil erosion potential because of the larger surface area covering foe a long time period, and continuous supply of subterranean biomass, and increased ability to capture and store rainwater.

In contrast, annual crops have a greater soil erosion potential, particularly those that cover the soil for shorter time periods, example like sweet sorghum and sunflower. A few oil crops such as Ethiopian mustard have a similar effect to that of perennial crops when they are grown in winter due to their prolonged presence in soil.

The crop inputs and outputs (i.e., Fertilizers and emissions/crop uptake) may be used to estimate the surplus or deficiency of soil nutrients N, P, and K, and the impacts of these can be modified or mitigated by employing different methods of crop management. According to the data collected on the cultivation of a variety of industrial crops in Europe, most of the crops have demonstrated a balance phosphorous treatment profile. Once soil stores are substantial, this is not a concern for K, but for N, it can lead to soil depletion. However, nutritional deficiencies can be compensated for by leaving agricultural wastes, such as sunflower stalks, on the field. (Boardman et al., 2014)

3.1 Soil Quality and Carbon Sequestration

In several texts and scientific works, the significance of soil and soil quality is stressed. Land and soil are crucial to all life-sustaining processed on earth according to EU mission. As they provide the base for food we cultivate and most important sources for many other things like timber, feed and textiles (Boardman, J et al., 2014). Therefore, the primary concern is the how we can augment soil quality, fertility to make it an ecological resource for biomass crops. Soil quality and carbon sequestration are both greatly aided by non-food crops. Perineal herbaceous crops are said to have a high capacity for carbon sequestration according to the policy of intergovernmental panel on climate change (Intergovernmental Panel on Climate Change, 2006).

Depending in the agriculture techniques employed the rate of carbon sequestration in the plantations of the non-food crops varies greatly. For instance, the biomass of autumn-harvested crops contains more nutrients than spring-harvested crops. Because improving the soil quality by increasing the amount of soil organic matter and mineralized nutrients typically depend on the number of leaves fall to the ground until spring harvest. Emphasis should be placed on how capacity of carbon sequestration is greatly affected by crop species, genotypes, growing circumstances and agriculture management. Also, most non-food crops supply a greater biomass energy production and higher potential for carbon sequestration in warmer climates. Therefore, if these crops are tended to cultivate in dry environmental conditions, that can negatively affect the potential of carbon storage (Samarappuli et al., 2018). Hence, the cultivation of the non-food crops should be selected based on considering several environmental conditions.

3.2 Water and Air Quality

Water Utilizing and water efficiency is an important part of many agricultural management strategies. Most crops that aren't used for food have a high water-use potential and may be grown in arid regions, but this allegedly isn't enough (Malesky et al., 2019). High-yielding non-food crops, especially perennials, can contribute to deep-soil water depletion because of their comparatively massive roots. According to research Cherrett et al., 2005).

Not only is it crucial to minimize water waste, but also to ensure that the water used is of high quality. Commonly, farmers grow high-yield crops in polluted soil in an effort to reduce the accumulation of heavy metals and other toxins and the seepage of these substances into the water supply. Thus, extra care must be taken when planting trees and other woody crops with a shorter rotation time. There is some speculation that allowing toxins to accumulate in biomass might help clean water.

Water Utilizing aquifers and rainfall may either be used to irrigate crops or to minimize the amount of water needed to grow them. Therefore, the amount of water given by rainfall may be used as a proxy for water needed by crops in order to assess the rate of groundwater depletion. Short-rotation forest trees, oil crops including Ethiopian mustard, sunflower, and rapeseed, and perennial herbaceous crops are less likely to degrade groundwater supplies than other industrial crops, according to research (Maurício et al., 2020). Nonetheless, in areas with little precipitation, like the Mediterranean, where the optimal conditions may be less prevalent, hemp, sweet sorghum, and sugar beet may contribute to the depletion of groundwater resources. Therefore, it is possible to reduce the burden on water supplies by deciding on water-friendly crops and suitable places.

Beyond the obvious water usage, the cultivation of energy crops can have far-reaching implications on hydrology, including the movement of ground water, stream water, and runoff. Although these variables are site-specific, they are linked to crop characteristics, nonetheless. In general, the findings suggest either no effect or a favourable one. Using perennials to cover the soil has a favourable effect on minimizing sediment, surface runoff, and nutrient losses because of the plants' greater longevity in the ground. Alternatively, crops that spend less time in the soil have a higher impact on hydrology. However, some crop species with transpiration roots, increase growth rates, high water demands, long seasonal growth and complex and deep rooting systems (e.g. perennials, hemp, sweet sorghum) can reduce the pace at which ground water is refilled by rainfall, leading to water deficiency. (Fernando et al., 2010, 2015).

In 2005, according to the ecological footprints compared between to hemp, cotton and fibre crops performed by Stockholm environmental institute. The result indicated that hemp is more ecologically sustainable compared cotton and other fibres in terms of water usage. Hemp is shown to need between 2,401 and 3,401 kg of water per kilogram, whereas cotton requires 9,758 kg water per kilogram. This represents a water savings of 75%. Hemp textile production utilizes substantially less water and chemicals than cotton textile production.

Air quality is of paramount importance to human health. In recent years, the concentration of greenhouse gases in the atmosphere has increased, necessitating the development of additional strategies for air purification.

In 2005, Schmidt found that the use of perennial grasses for stationary heat and electricity generation can reduce greenhouse gas emissions by up to 13 t CO2 equivalent per hectare per year, this is a huge success considering these crops were produced on poor soil. Thus, it may be argued that using certain industrial crops for non-food purposes could be beneficial for lowering emissions of greenhouse gases.

Few industrial crops like lavender, hemp, Rosmarinus, Camilla, and willow etc, require low inputs for cultivation and are associated with very low emissions of greenhouse gases, low-fertilizer demands are typical of perennials because their rhizomes and subterranean roots can store and recycle nutrients during the winter.

In addition, except for herbicides during the initial years of establishment, most industrial crops require fewer chemical applications, if any, for good development (Rusenski et al., 2019). As perennial herbaceous non-food crops are low-maintenance and use less energy inputs (fertilizers, insecticides, etc.), these crops are more significant than annual crops as they also have more impact on decrease in greenhouse gas emissions and climate change mitigation. (Rosinsky et al., 2019).

3.3 Biodiversity and land use

The European Commission has often stated its aim to prevent the development of non-food crops, particularly energy crops, on productive agricultural land in order to minimize negative impacts on the food market Therefore, it is acceptable to encourage agricultural land utilization, and efforts have been made to reconcile these conflicts by increasing planning for and interest in the cultivation of non-food crops in marginal regions. This strategy is a viable alternative for sustaining and enhancing rural development, particularly in regions at risk of abandonment, as it helps to regenerate landscapes while generating additional income for landowners (Altieri et al., 2004). For crops like perennial grasses like miscanthus short rotation forest trees like poplar trees and annual crops like flax and hemp have a high tolerance against marginal and degraded soils. Cultivation of marginal soils may improve soil quality and biological and landscape diversity, but it may reduce yields and biomass quality, putting economic exploitation at risk (Barbosa et al., 2018).

The conservation of biodiversity and the improvement of landscape management practices by industrial crops like reducing fertilizer use and increasing plant diversity are anticipated to result in long-term increases in ecosystem services. Another important predictor of the ecological services provided by industrial crops is the topography of the areas in which they are grown.

These plants are able to thrive on low-quality soils without compromising food production or soil fertility. Changing the composition of agricultural landscapes' ecosystem services may be an unintended consequence of adopting industrial crop systems to supply feedstocks for the bioenergy and bioproducts industries, in turn increasing the biodiversity of grasslands, which can be beneficial to insect and avian habitat. (Berg A, 2002).

A study emphasizes the importance of perennial and woody crop species on their benefits, particularly on maintaining biodiversity and improving habitats for many organisms. Management strategies focusing on crop diversification using crop rotations, cover crops, agroforestry and polyculture have been proven to lower pests' population targeted on specific crops and providing shelter and alternate prey for natural enemies (Christian et al., 1998). Similar methods, such using less pesticides, no-till systems, and agricultural rotations that include crops with many blooms, may benefit native pollinators. Hemp flowers during the months of July and September, a time when few other crops are producing pollen. As a dioecious and staminate plant that is pollinated by the wind, cannabis produces large amounts of pollen that honeybees rely on during flowerless periods.

Natural vegetation types, as opposed to monocultures, are superior in terms of ecosystem services and, by extension, biodiversity. This is because the greater the complexity and variety of a plant system, the greater the cover value it provides for animals. Consequently, colourful flower crops (e.g., oil crops, lavender, flax, cardoon) and native species (e.g., cardoon, reed canary grass, rapeseed) and perennial grass and tree plantations contribute to increase biodiversity value, as they provide shelter to soil fauna, microfauna, and avian species. However, it has also been noted few crops such as sugar beet contribute to biodiversity loss, as it disrupts the soil structure and harvesting require removal of complete plan it is deemed to be very hostile to soil fauna (Clifton-Brown et al., 2017). Also, gigantic reed and reed canary grass are highly aggressive and invasive plant species leading to loss in diversity. Additionally, eucalyptus is not favoured due to it inhibiting grow of local flora because of its allopathic traits. Ground-hugging crops, like sugar beet, are detrimental to landscape diversity, whereas those that add structure (perennials, trees) and/or colour are seen favourably (Fernando et al., 2010).

3.4 Inputs and Resources

Industrial crops are unique in that each variety may require different environmental and logistical considerations at its designated place. Industrial crops with high transpiration rates, such as willow, are more suitable to humid environments than crops like hemp or cardoon, which have been reported to use less water. Planting the proper industrial crop in the proper place may have enormously favourable effects on the water and resources required to cultivate the crop. Camelina, cardoon, and castor bean are drought-tolerant industrial crops that do not require irrigation and may be produced in places where land abandonment is a problem.

Due to their agronomy, several industrial crops require fewer chemical inputs, such as fertilizers and fuels. Due to their longer cycle and the recycling of nutrients through leaf fall, perennial crops such as willow, poplar, miscanthus, switchgrass, etc. require less inputs yearly. This improves the environmental profile of certain perennial industrial crops, such as willow. Reducing emission-intensive processes, such as yearly ploughing, fertilizer application, and herbicide usage, increases efficiency.

Robust agriculture systems are required to impact climate change with reduced fossil fuels inputs. (Lin et al. 2008). One of the powerful agricultural systems, sustainable intensification may increase food production while reducing the impact of agriculture on climate change, biodiversity, and ecosystem services. In 2009, a group of researchers led by Baulcombe found an additional method of agriculture, "low-input farming" that aims to minimize the application of external production inputs like fertilizers and pesticides in favour of better management of the farm's internal resources. Practicing low-input farming can achieve lower production costs, reduce pesticide residues in food, avoid pollution of surface and groundwater, increase short term and long-term farm profitability and to reduce farmer's overall risk.

Most of agriculture systems rely on the supply of synthetic fertilizers, mineral resources, and pesticides for increased production, which in turn pollute water, air and soil and can cause adverse effects to human health, contaminate soil and ground water, damage flora and fauna, and promote the development of pests and diseases. However, industrial crops require very small dosed of pesticides due to their low vulnerability to pests and diseases. Also, the selection of insecticides with a smaller impact on soil and water might be an alternative for reducing environmental impact. Perennials are noted to require less nitrogen, phosphorus, and potassium from fertilizers than annuals, resulting in a smaller impact on inputs and mineral resources.

3.5 Case studies

3.5.1 Hemp

Hemp is a fast-growing plant with a rapid leaf turnover rate that, when cultivated under optimal circumstances, will completely cover the soil three weeks after germination. The thick leaves quickly produce a natural soil cover that prevents soil erosion and water loss. Furthermore, falling leaves contribute essential nutrients to the soil. During retting, hemp stalks destined for fibre are a significant source of nutrient-rich organic matter for the soil (decomposition of the outer layer of the stalk allowing fibres to be accessible for manufacturing). Hemp effectively removes weeds due to its height and ability to provide shade, leaving the soil in pristine conditions. The early harvest date of hemp grown in the summer, according to experiments conducted by the Rodale Institute in the United States, suggests that weeds were professionally managed throughout the growing season. This allowed for more time to be spent on the development of winter crops. Hemp's inclusion in crop rotations has this additional advantage as well. Hemp may also be utilized very well in land restoration, and it is regarded as an ideal pioneer crop, particularly due to its phytoremediation potential, or ability to remove heavy metals from the soil. The plant is cadmium-tolerant and resistant to prolonged exposure to heavy metals.

Industrial hemp, in contrast to other crops, may be used to make a diverse assortment of goods, such as food, animal feed, cosmetics, bio composites, paper, textiles, construction materials, power, and phytomedicine. Both the flowers and the leaves contain beneficial phytochemicals, including as cannabinoids, terpenes, and polyphenols.

Because of their excellent thermal efficiency, buildings made from hemp can save money on utilities while accumulating carbon dioxide. Hempcrete, hemp wool, and hemp fibreboard are all examples of this material used for thermal insulation (a hemp-lime composite walling and insulation material). Hempcrete is a highly effective building material since it is resistant to flames, mould, germs, insulation, sound, and it can control humidity on its own. Hemp-based materials are being used by many major European automakers for vehicle interiors. For the reasons that hemp is both strong and lightweight. Hemp also has the potential to be utilized in the production of biodegradable packaging, which would greatly aid in the elimination of plastic trash. (Hoodeh, 2017).

In addition to flax, hemp was one of the oldest natural fibres used by humans and has been used in textiles for ages. Hemp fabric was commonly used for the sails and rigging of ships for centuries due to its resistance to salt. Because of its durability, breathability, natural antibacterial properties, and resistance to UV light, mould, and mildew, hemp textiles are quickly gaining in popularity. Tobacco paper accounts for the primary usage of hemp paper nowadays. However, it is also useful for filtration and absorption purposes, as well as for packing food, heavy-duty cardboard, sanitary sheets, and other similar uses. Hemp was used in the past for a wide variety of everyday products. This includes currency, postage stamps, and even bank bonds. Hemp paper may be recycled between seven and eight times, while paper made from wood pulp can be recycled just three to five times. Bleaching hemp paper using hydrogen peroxide is possible, although oxygen, ozone, peracids, and polyoxometalates are better options. (Kramer, 2017).

In other words, hemp with a high biomass rate has a larger ability to sequester carbon. Hemp is a great crop for carbon sequestration because it grows quickly (in 4–5 months), is tall (up to 5 meters), and has deep roots (up to 3 meters).

A ton of dried hemp stalk contains 0.75 tons of cellulose (45% carbon), 0.22 tons of hemicellulose (48%), and 0.06 tons of lignin (40%). Therefore, industrial hemp stems absorb 0.4445 tonnes of carbon from the atmosphere for every tonne produced (44.46% of stem dry weight). Using the formula 12 tons of carbon = 44 tons of carbon dioxide, this equates to hemp absorbing 1.6 tons of CO2 per ton.

With an average yield of 5.5–8 t/ha, this equals 9–13 metric tons of CO2 absorbed every cultivated hectare (Hayo et al., 2008). This helps to mitigate the CO2 emissions contribution to environmental advantage.

3.5.2 Poplar

Poplar plantations provide various positive environmental advantages in comparison to annual crops, while the possibility of negative environmental repercussions is frequently modest. Dimitriou in his study outlined the positive effects of growing short rotation forest crops (SRC) like poplars on farmland rather than food crops, specifically with regard to the soil's chemical and physical qualities. When compared to two of the most prevalent conventional agricultural crops—cereals and intensively managed grasslands—soil organic matter storage is greater under SRC. SRC has greater C sequestration than traditional agriculture because soil organic matter is more persistent in SRC. When compared to traditional agricultural methods, the SRC approach has been shown to be more effective in halting soil erosion. Soil organic matter under SRC has a higher carbon to nitrogen (C/N) ratio than soil organic matter under traditional agricultural crops, leading to a higher total soil N content and a lower relative nitrogen (N) availability for plant growth. Plants in SRC have a harder time absorbing phosphorus (P) than they would in conventional farm produce. SRC crops are somewhat denser in volume than conventional farm produce. Soil pH may drop somewhat with SRC compared to conventional farming. (Dimitriou et al., 2015)

The pace at which new biomass is being created in the soil is only just above the rate at which microbes are active (leaves, roots). This improves soil organic matter compared to conventional farming. Compared to typical agricultural practices, SRC reduces cadmium (Cd) in soil. Soil carbon levels can increase by as much as 62% in sandy soils and by as little as 9% in regions with annual cropping when hybrid poplar trees are present. Carbon content in soils varied from 4 to 15 Mg hectare, with the least abundant form being found in sand (Andr´e, 1991).

Poplars are often hailed as a beneficial crop for improving water quality. Thus far, research on poplar's effect on water quality has focused mostly on the leaching of nutrients; however, due to bans on the use of pesticides on poplar plantations, it has been unable to identify individual chemical compounds in the aquifer. Nitrate(NO3-N) concentrations in the groundwater were found to be higher near grasslands and cereal crops than near poplar plantings, per study conducted in Sweden (Dimitriou et al., 2017). The average concentration of NO3-N in grain crops in detain was five times higher than that in poplar fields. Similarly, as compared to grasslands, poplar fields had much lower quantities of PO4-P.Poplars have been used to treat and utilize N-rich wastewaters such as municipal effluent or landfill leachate, as well as solid wastes such as sewage sludge, since their large fine root systems rapidly absorb N and N leakage to the groundwater is minimal (combined with the ability to take up heavy metals). When extremely high N quantities have been applied (e.g., up to 300 kg N/ha per year), in attempt to improve the systems, with minimal leaching from SRC, therefore, to examine the leaching of nitrogen and phosphorous an extensive study has been conducted which showed optimal results.

The results also suggest to minimise nutrient leaching, cultivating poplars in intensively managed agriculture regions, either by replacing current crops, or by using poplars as buffer zones between water bodies and intensively manged arable lands to reduce the soil surface runoff and groundwater leaching.

Poplar plantations which are produced on agriculture lands, when grown instead of wheat or in uncultivated lands in a homogenous agriculture environment, can increase the biodiversity at a landscape scale. By way of illustration, it has been shown that young poplar plantings, especially if not too broad in area, boost vascular-plant diversity when compared to farms in northern Sweden and manged coniferous woods. Studies of fauna have found the same thing to be true as those of flora; more species of birds and animals may be found in poplar plantations than in agricultural croplands. Therefore, a more broad management of poplar plantations can improve habitat quality for a variety of organisms, including plants and birds, in comparison to highly managed grain crops. Several concerns have been voiced about the aesthetic effects of poplar reforestation. However, when used imaginatively as part of deliberate landscape research and design, poplar plantings have the ability to dramatically improve visual and recreational qualities of a landscape, while also adding variety and structure to the aesthetic impression of monotonous agricultural landscapes (Van Ginneken et al., 2007).

Poplar plantations can be certified for their sustainable usage to guarantee that they are developed and managed in a way that protects important conservation values, intact landscapes, the elimination of pesticide use, and essential ecosystem services. According to current trends in the wood processing industry and the energy sector, wood clients in industrial and energy sectors are increasingly looking for particular evidence of sustainability (certifications) for bought raw materials (required by the new Renewable energy law). There is an impact on both traditional forest resources and SRC. Plantation standard was developed by the Forest Stewardship Council (FSC), one of the most popular sustainability certification methods for wood resources. First attempts have been made in the European Union, while the United States and other countries have already certified vast swaths of poplar plantations as FSC-compliant.

4. INDUSTRIAL AGRICULTURE ON MARGINAL AND POLLUTED LANDS

Population growth, increased food consumption, and the need for biomass feedstock for bioenergy and biomaterials have all contributed to a rise in the value placed on reclaiming marginal and contaminated areas during the past two decades. Third of the world's population lives off marginal land, which accounts for around a third of all farmlands (1,3 billion hectares)

In addition, it is projected that there are more than 10 million large, polluted sites globally, with up to 650,000 contaminated sites recognized in the European Economic Area (EEA) comprising 39 nations. Even though they are frequently seen as a nuisance, polluted places have the potential to become valuable assets.

On marginal and polluted areas, the production of industrial crops is often encouraged and supported for non-food uses. The majority of these crops are utilized to create a variety of bioproducts with added value and bioenergy, therefore contributing to the biobased economy. Food security and land usage for bioenergy/industrial non-food crops have been the subject of controversy in recent years.

Consistently, cultivating industrial crops on marginal and polluted lands which are unfit for food production, is described as a feasible option to reduce it negative implications on food security and competition for food production, biodiversity loss and land based GHG emissions. Extensive research on the viability of energy crop farming in trace element-contaminated soils already exists. Today, biomass energy production focuses on low-input perennial energy crops of the second generation, such as Salix, Panicum virgatum, Spartina pectinata, and Miscanthus (Guo et al. 2015). These plants have substantially lower input needs, provide more energy per hectare, and emit less greenhouse gas per hectare than first-generation annual food crop species that have been utilized in the past (Dohleman et al. 2012). Several commercially marketed energy crop species have also been investigated for their phytoremediation effects on arable land with positive results. However, further study is required to establish its resilience for large-scale applications in heavy metal clean-up. (Clifton-Brown et al. 2017)

Industrial crops such as miscanthus, willow, and hemp have enormous potential for use on land deemed unsuitable for food production or containing excessive quantities of toxic substances or elements (either contaminated or naturally occurring). The potential land area that may be used for industrial crops has been mapped, and appropriate crops have been assigned to each place, through a number of systems. By mapping out where industrial crops like camelina, lavender, poplar/willow, and sweet sorghum may be grown without interfering with food production, the MAGIC (Marginal

Lands for Growing Industrial Crops) effort continues to make progress. The MAGIC study estimates that over 29% of Europe's land is underused yet suitable for industrial agricultural production.

Some industrial crops, like miscanthus, willow, and camelina, do well even on less rich soils. The crops may still need inputs like fertilizer to maintain yields, but marginal lands offer enormous yield potential, especially if high-value end uses can be developed for all fractions of the crops.

Since the dry, arid soils of Guadalajara, Spain, could not sustain significant yields of tillage crops, the region was abandoned, and the land was reallocated for the cultivation of industrial crops. High profits were obtained by the farmers from the experiment of lavender at the site.

In Porto Torres, Sardinia, Italy, Cynara cardunculus (Cardoon) is grown on unused, marginal land. The crop's resilience in poor, unirrigated soil guarantees a consistent supply of inputs for the nearby bio-processing plant. The crop generates enough infrastructure to produce bioplastics and other biobased goods within a regional economy. Cardoon can be used to create compounds with therapeutic properties, paper pulp, green feed, seed oil, biodiesel, and solid biofuel.

It is widely established that some types of industrial crops, like as poplar, may help boost biodiversity in areas with poor soil. Some of the detrimental consequences of exploiting marginal land for monocultures of industrial crops on flora and fauna may be lessened by hedge maintenance and biodiversity bridges.

Mining waste, petrochemical accidents, and naturally occurring high concentrations of heavy metals are just a few examples of the types of activities that can lead to soil pollution. These areas are typically kept uncultivated because the soil is unsuitable for plant development or to minimize bioaccumulation of pollutants in food crops. Miscanthus and willow are just two examples of industrial crops that have been found to not only prosper in contaminated environments, but also bioaccumulate pollutants like heavy metals, rendering them harmless or stabilizing them in soil. In spite of the fact that the harvested crop may have a measurable amount of these chemicals in its biomass, it is common practice to remove or eradicate them during the processing of industrial crops. Miscanthus is unique in that its above-ground biomass may be made easily accessible for processing by stabilizing inorganic compounds in its root system. Phyto mining is a brilliant method for extracting metals from plants for use in other industries, like nickel and copper. This feature of industrial crops gives farmers an economic boost in areas where the soil has a high metal content.

Growing two or more crops in succession on the same plot of land is known as intercropping or multiple cropping. Off-season crops, also known as intermediate crops, are those that are planted in the intervening time between the planting of cash crops and their subsequent harvest. Therefore, when selecting intermediate crops or intercropping systems, it is crucial to think about not only the objective (such as provide weed control or nitrogen) but also the identification of the best time and place and simulation of the use of crops that can help to address current societal challenges like carbon sequestration, water and soil conservation, food security, mitigation of greenhouse gas emissions, and sustainable intensification of cropping practice.

4.1 Europe's marginal and polluted soils

Typically, marginal land is characterized by poor productivity and low economic return, resulting in severe agricultural limitations. They often require additional inputs to sustain output, but permanent degeneration is always a possibility.

Low fertility, stoniness, poor drainage, salinity, unfavourable texture, excess soil wetness, shallowness, and toxicity are examples of biophysical soil characteristics; adverse climatic circumstances and/or a steep landscape are examples of socioeconomic soil conditions.

Around 13.2 million hectares are available for cultivation of non-food crops in the European Union, as reported by European Commission, 2013. This research suggests that most of this area belongs to nations in Eastern Europe. When harmful compounds that are either already known to have or have the potential to have extremely negative impacts on the ecosystem are found on land, it is called "polluted" (including human health). Three-fifths of European soils are impacted by soil metalloids, making them the most prevalent soil pollutants in the region. Many human activities, like as mining, manufacturing, smelting, agriculture, transportation, waste disposal, and the combustion of fossil fuels, contribute to the release of these substances into the environment. Due to contamination, the area is unfit for food cultivation and might instead be used to grow biomaterials and bioenergy feedstock crops. Putting contaminated soil to use might open new avenues of rural economic development. The Forum of European Geological Surveys (FOREGS) compiles comprehensive data on soil cover throughout Europe, including heavy metals and metalloids content, in conjunction with the European Union's Land Use/Land Cover Area Frame Survey (LUCAS). (Krasuska et al. (2010).

4.2 Advantages of exploiting marginal and polluted soils

Marginal and polluted areas are vast underused resources that might and should be used to cultivate plants for a variety of lucrative applications in a sustainable manner. Supporting the rehabilitation of marginal and polluted soils is among the most significant advantages of using these land regions for industrial crop production.

- Freeing up conventional agricultural land for food and feed production will reduce exposure to pollutants, hence improving human health.
- Generating more revenue for local farmers and residents
- Boosting employment and encouraging creative enterprise
- Boosting domestic raw material availability for usage in new growing markets
- Enhancing plant cover to reduce soil erosion and desertification.
- Facilitating long-term carbon sequestration by minimizing the transmission of pollutants to other non-contaminated areas (through the air, surface runoff, and/or leaching to subsurface aquifers).

4.3 Phyto management of polluted soils

Phytoremediation is the non-invasive, cost-effective, and socially acceptable practice of removing or neutralizing environmental toxins with green plants. This method is used to remediate inorganic (metal, metalloids, etc.) and/or organic (aromatic hydrocarbons, pesticides, etc.) pollutants. The two most important phytoremediation sub technologies are: Phytoextraction and Phytoremediation. Phytoextraction is the process by which plants collect metals from the soil and concentrate them within their harvestable biomass. By immobilizing or preventing movement, plants restrict the mobility and bioavailability of pollutants in the environment, hence promoting Phyto stabilization.

A more recent and innovative aspect of phytoremediation is phytomanagement, in which high-biomass-yielding non-food crops are used to manage and reduce risks associated with soil contamination, all while ensuring the sustainable and profitable use of contaminated sites by producing biomass energy in high demand on the market.

Recent studies have also concentrated on high-yielding (Dimitriou et al., 2005), fast-growing, high-value non-food crops that could be used as products for a wide range of industrial-scale applications (including biochar, biofuels, biochemicals, biopolymers, bioplastics, bio-lubricants, pulp of paper, construction biomaterials, etc.).

By boosting the availability of domestic raw materials for use in new developing markets, the exploitation of polluted soil might create new economic prospects for local farmers and rural communities in the future. Such prospects might drive creative entrepreneurship and employment development and sustain a rural renaissance within a biobased economy over the long term.

4.4 Utilizing plants for wastewater and harmful effluents management

Some sections of the European Union have recognized the potential of forest crop trees as a low-carbon natural treatment option for wastewater management and environmental preservation. For instance, due to climate change, Northern Ireland and the Republic of Ireland will continue to face competing economic and environmental pressures. Factors including rising agricultural production, a growing human population, insufficient wastewater treatment systems, and a wider variety of environmental toxins all have a detrimental effect on water quality. In willow plantations, wastewater from municipal treatment plants, farmyards, agri-food processors, and other sources is used to irrigate the plants and manage the waste nutrient in compliance with environmental and waste regulations. This means that natural treatment methods may be utilized to deal with society's wastes, which would be good for the environment and would also serve to feed a bioresource supply chain.

Poplars thrive in contaminated soil because their longer rotations filter out more of the harmful substances. Continuously harvested and discarded grasses must be cultivated on contaminated land to lessen soil pollution. However, poplars may only be cut down every 15–20 years due to the accumulation of contaminants in the wood over time.

Additional research has shown that landfill leachate may be recycled and treated with Short Rotation Coppice (SRC) systems and bio-filters. Similar leachate treatment systems are already in use in Sweden (Tuskan et al., 2001). It's possible that the weather in Ireland and the UK is even better for willow growth, and using such systems there would be an innovative approach to managing effluent from unregulated trash sites. In fact, willow can be used for leachate control according to a license granted by the United Kingdom's Environmental Agency (EA).

4.5 Industrial crops ideal for growing on marginal lands

There are four major types of industrial crops are: annual herbaceous, perennial herbaceous, oilseed, and woody. A few industrial crops that are ideal to be grown on marginal lands are:

- Jatropha: a drought-resistant plant that can grow on poor soil and produce oil for use in biofuels.
- Camelina: an oilseed crop that can grow on marginal lands and is used for biofuels and other industrial purposes.
- Agave: a succulent plant that can be grown on poor soils and is used for the production of tequila and other spirits.

- Sweet sorghum: a drought-resistant crop that can grow on marginal lands and is used for biofuels, animal feed, and human food.
- Hemp: a versatile plant that can be grown on a variety of soils, including those that are marginal, and is used for industrial purposes such as textiles, bioplastics, and building materials.
- Kenaf: a fast-growing crop that can grow on marginal lands and is used for industrial purposes such as paper production and animal feed.

These crops can be used for various purposes and biofuel is one of the major uses of these crops. Renewable biomass fuel for bioenergy and the creation of high-value bio-based commodities may be obtained in large quantities from the industrial crops (i.e., Pharmaceuticals, bio-composites, bio-lubricants, bioplastics, bio-chemicals, etc.). The versatility of these plants provides an opportunity to develop cascade bio refineries and broaden the basis for the bio-based economy. However, its use in European farming is still quite uncommon.

Although just a handful of European businesses focus on bio-based products, several large chemical conglomerates are investigating the potential of bio-based applications. Between 2008 and 2010, the European chemical industry made use of between 8% and 10% renewable resources while producing various chemical compounds and polymers.

Biomass is in high demand as a means to help the European Union meet its renewable energy goals. Conflicts over land usage are becoming more likely as competition for food and feed becomes more obvious (Van Liedekerke et al., 2014). Producing specialized industrial crops on underutilized land is a simple way out of this predicament (Clifton-Brown et al., 2017). Studies of industrial crop production in marginal soils, however, reveal that productivity is a crucial factor in economic sustainability. A decrease in productivity will affect the energy balance, the reduction of greenhouse gas emissions, and the economic return since outputs will be lowered while inputs will remain the same or increase (for example, the need for additional fertilizer to deal with the soil's marginality) (Fernando et al., 2018). Industrial use of aerial biomass may be hindered by the increased concentration of ash, minerals (such as potassium), and nitrogen that may result from lower yields (Costa et al., 2020). However, biomass production might not change if certain types of marginalities are ignored. In this scenario, the yields of conventional food or feed crops may be affected by the soil type or physical condition (such as water availability), while the yields of a particular chosen industrial crop may not be affected by these same factors due to the different tolerance qualities.

Soil quality (fertility, structure, organic matter), erosion rates (the more complex the framework and heterogeneity of a vegetation system, the greater the value of the cover for wildlife and landscape values), and biological and landscape diversity (the more complex the framework and heterogeneity of a vegetation system, the greater the value of the cover for wildlife and landscape values) all improve when vegetation cover and agricultural wastes are incorporated into soils (Fernando et al., 2010). As a result, the cultivation of industrial crops can restore ecological services and soil functioning in marginal locations. Cultivation of industrial crops on marginal soils has the potential to both aid in soil rehabilitation and provide commercially viable biomass for industrial purposes.

4.6 Industrial Crops effects on contaminated soils

4.6.1 Phyto management of heavy metal- and metalloid-contaminated soils

Many people are interested in the Phyto management potential of non-food industrial crops including miscanthus, industrial hemp, castor bean, cardoon, giant reed, kenaf, switchgrass, sorghum, poplar, and willow since they produce copious amounts of biomass. These plants may be equally as effective in absorbing metals in the long term, despite their inability to bioconcentrate them as efficiently as hyperaccumulator plants. These plants may be used as a raw material to create a wide variety of goods, including bioenergy. Both the production process and the final product of chemicals like landfill leachate and sewage sludge mean that they include elements that, in big enough doses, might be harmful to both land and water. Protecting the environment from the release of potentially harmful heavy metals during land application is the goal of the EU Sludge Regulations (1989), as amended by the Sludge Regulations (1990), SI 1990/880.

Recent years have seen a flurry of research into the uptake of heavy metals by willow to both determine the extent to which willows could remediate heavy metal-contaminated land and develop sustainable methods for recycling organic wastes by using non-food crops to safely utilize the nutrient (Barbosa et al., 2018). In many investigations, researchers found that willows were able to absorb far more heavy metals than other woody species or agricultural crops. For example, willows may take up more Cd (Cadmium) in the stem biomass than is generally provided to the crop through sewage sludge. Willow is also excellent at bioaccumulating Zn (Zinc), with the capacity to take in 1,000 to 1,500 g/ha/year from conventional agricultural land. Wheat (grain and straw) normally absorbs over 200 g of zinc per hectare per year, whereas Cd absorption is often around 1 g per hectare. Willow has an absorption rate for copper and nickel that is on par with or slightly greater than that of wheat. (Riddell-Black and Ferguson 2002).

This is mostly owing to the occurrence of Nitrogen leaching, according to the present research (Dohleman et al., 2012), however it is not unanimous. There are beneficial impacts and advantages, and there are several programs now in operation that provide solid grounds to examine the potentials in various EU climates, soils, and leachates, etc. It is strongly suggested that nitrogen should be administered at the crop absorption rate, thus avoiding leaching. This is because the beneficial effect of the nutrient on plant development (NH4 being used and not released to the environment) firmly suggests that nitrogen should be administered at the crop absorption rate. These soil/plant systems have a high tolerance for leachate-induced stress and are able to retain nitrogen, phosphorus, and total organic carbon It is clear that the highly significant are leachate loading rates and timings, as is the establishment of a healthy plant together with the evapotranspiration rate that goes along with it. It is abundantly clear that short rotation coppicing is a potentially effective approach for leachate management. (Aronsson et al., 2010),

Northern Ireland a region in EU, have a rigorous grass-based system from which departure is challenging due to the topography and climate. As a result, ruminants are dominant in the agriculture industry. The receiving land bank is under a lot of nutritional stress as a result of this, therefore there is a rising need to implement sustainable measures to environmental protection and wastewater treatment to avoid point and diffuse sources of pollution from degrading environmental water quality. SRC willow grows rapidly, absorbs great quantities of water, and can utilize the nutrients, especially nitrogen and phosphorus. These measures have the potential to protect the environment from diffuse pollution by reducing the number of pollutants carried by surface run-off into water bodies like lakes, streams, and ditches, while also providing a steady supply of biomass. Northern Ireland is home to several agri-food processors and farmers, all of which have taken steps to reduce their carbon footprints and production costs by proactively addressing these twin concerns (energy and pollution management). (Dimitrou, Aronsson 2011).

4.7 Overall advantages of industrial crops on Marginal and Polluted Lands

As direct or indirect land use changes, mostly driven by renewable energy projects, have regularly impacted the food market in many regions, it is appropriate to promote the growing of industrial crops on marginal soil types, such as polluted land. Despite the reduced land rent cost, polluted land cultivation is often more expensive per tonne of generated biomass (Hasselgren, 2003). However, the introduction of an industrial crop into a polluted soil may also aid in the soil's repair, which is far less expensive (both economically and ecologically) than physical and chemical soil remediation procedures. Utilizing polluted soil for industrial crop production can have a beneficial socioeconomic impact while creating area employment. By diversifying agricultural operations and increasing infrastructure for harvesting, storage, transport, and logistics, this supports the rural economy.

Several concerns with environmental sustainability can be helped by a shift in agriculture's focus toward biomass crops. It is possible that by increasing the vegetative cover and so reducing erosion and surface runoff, industrial crops grown in marginal and polluted areas might help to avert desertification and even floods. This will have a profound effect on a wide range of outcomes that are crucial to achieving the EU Sustainable Development Goals, such as decreasing the amount of contaminants leached into groundwater, increasing the amount of organic matter and carbon sequestered in the soil, decreasing the amount of contaminants transported to previously clean areas, fostering soil biodiversity, and safeguarding the soil's structural integrity. (McDonald et al. 2008).

As an example, short rotation coppice willow has been established on 35,000 hectares across the EU and has shown to be a profitable crop. Sweden, Poland, Germany, Denmark, France, and the United Kingdom all have high rates of this, as do the less developed parts of Italy, Ireland, and Austria. This biomass is solely burned for heat or heat and electricity by direct combustion or co-combustion. The benefits of short rotation coppice crops, such as improved soil health and stability, are not immediate but rather cumulative. Soil bulk density is reduced via root penetration, water infiltration is improved, and organic matter content is increased. This rhizosphere activity, in conjunction with leaf mulch, contributes to soil fertility by maximizing nutrient uptake, retention, and cycling. It also includes creating new avenues for economic growth and employment, diversifying and expanding natural habitats for plants and animals, and decreasing the likelihood of erosion. These benefits are essential features of willow biomass crops, but they are difficult to quantify through life cycle assessment.

Economic projections indicate that the many advantages of renewable energy fuel sources will not materialize in the absence of appropriate regulatory or legislative incentives. Energy production from biomass has the added benefit of improving air quality at existing fossil fuel power plants, reducing greenhouse gas emissions, and reducing dependency on non-renewable energy sources. Although biomass energy is more expensive than other options, it has the potential to reduce our dependency on fossil fuels and therefore our emissions of dangerous gases.

However, risks are most frequently related with market and supply chain confidence. There have been a variety of assistance initiatives and proposals in the United Kingdom and Ireland to encourage the planting of willow and Miscanthus. There are renewable requirements, renewable heat incentives, and renewable heat assistance programs, as well as set apart and energy crop programs. Unfortunately, the amount of land used for growing willows and Miscanthus has not risen nearly as much as was hoped for despite these steps. Renewable energy goals are being fulfilled in this part of the EU, but renewable heat and transportation fuel goals are not.

4.8 Case studies of industrial crops effects on marginal and polluted lands

4.8.1 Perennial herbaceous crops

For marginal terrain, miscanthus is an acceptable plant. Quality, quantity, and soil interactions of Miscanthus biomass as a potential option for contaminated and marginal areas.

The primary objective of this case study was to generate novel approaches to biomass production on marginal land that might be implemented in a variety of European countries. In three European locations (Poland, Germany, and the United Kingdom), researchers are testing a variety of cutting-edge Miscanthus seed-based hybrids on marginal and polluted soils. Research shows that the selected field test sites had low soil quality based on initial baseline assessments (Cosentino et al., 2015). High clay and stone content distinguish the German site; depleted nutrient levels in the British site; excessive amounts of cadmium, lead, and zinc render the Polish site in the Upper Industrial Region in Silesia unsuitable for agricultural use. Depending on how the biomass will be utilized, miscanthus can be harvested at different periods of the year. In this case study, the material was obtained in March for brown harvest for direct burning and in October for green harvest for anaerobic digestion. Especially during brown harvest, the producing potential of new seed-based hybrids was on par with that of Miscanthus x giganteus. It appears that next-generation hybrids are well-suited for cultivation, especially in the climate and soil conditions of Germany and Poland, suggesting that these unique hybrids may lead to cheaper plantation growth. (Douglas et al., 2018)

Growing miscanthus for biofuel is a non-food alternative to conventional farming. Miscanthus crops have been shown to boost soil fertility through the addition of organic matter and the stimulation of soil life, and the plant's root and rhizome mass have been shown to aid in the storage of carbon in the soil. Increases in heavy metal concentrations in biomass grown on polluted Polish farmland showed no appreciable impact on ash melting behaviour. The anaerobic digestion process benefits from a harvest prior to winter because higher substrate-specific methane outputs are possible. Results demonstrate that the presence of heavy metals in biomass has no adverse effect on anaerobic digestion. In spite of its surprising low concentration of heavy metals in its biomass, Miscanthus is not suitable for phytoextraction. However, research indicates that farming Miscanthus might provide a safe and profitable alternative for marginal and contaminated land (Fernando et al., 2010). However, the same three showcase sites will be used to test out innovative methods. Interventions in agronomy will be used to increase the longevity of Miscanthus plants, long-term yield persistence will be tracked, and the effects on biomass quality and soil health indicators will be measured. This will allow for analysis of the environmental and socioeconomic impacts of cultivating crops on these degraded soils, and it will aid in the optimization and development of sustainable, environmentally friendly, and economically viable valorisation options for biomass from contaminated and marginal lands.

4.8.2 Oilseed crops

Oil crops, which are abundant in fatty acids, can replace fossil-based feedstocks in the production of a variety of products, such as surfactants, detergents, lubricants, and plasticizers. Production of energy oil crops for biofuels, bioenergy, biomaterials, or bioenergy, however, directly competes with production of food oil crops with land utilization; this conflict can be avoided if these oil crops are able to be produced on contaminated soils. The MAGIC (Marginal Lands for Growing Industrial Crops) program is conducting experiments in many climatic zones across Europe to determine how heavy metal-contaminated soils affect crop production (Pb, Zn, Cd, Ni). At the amounts tested, heavy metal pollution had no effect on the growth of these oilseed crops (B. carinata and C. sativa) (Zn: 450/900 mg/kg; Pb: 450/900 mg/kg; Cd: 4/8 mg/kg; and Ni: 110/220 mg/kg). Heavy metal pollution, especially Ni and Cd contamination, was demonstrated to significantly lower the number of siliquae, which is expected to diminish the economic viability of oil crop production in heavily metal contaminated soils. However, preliminary studies showed that the increased deposition of metals in the siliquae percentage of all examined oil crops was negligible in comparison to that of crops produced in unpolluted soils (Costa et al. 2019). Comparable results were seen with sunflower seeds collected from river basins in southern Spain's Guadiamar rivers after a spill there in 1998 due to the failure of a tailing dam for pyrite mining. As a result of this disaster, almost 2,000 acres of farmland were contaminated. The spilt sunflower plants absorbed more As, Cd, Cu, and Zn than the controls, although these concentrations were still well below acceptable limits (Murillo et al., 1999). Multiple studies show that when sunflowers are subjected to high levels of heavy metal stress, their proteasome activity decreases, resulting in an accumulation of oxidized proteins (Petkova et al., 2018). It has also been suggested that the organic acidic salt potassium tartrate, a popular ingredient in the food sector, might be used to reduce the quantities of heavy metals to below the permissible threshold, as multiple studies have demonstrated that the metals are preserved in the seed meal rather than the oil. (Yang et al., 2017).

4.8.3 Woody species

The Department of Agriculture in Northern Ireland funded studies in 2007 to investigate the potential of willow plants as a bio/Phyto-filter for wastewater from agricultural operations. The findings show that there were no harmful impacts on the environment, a significant amount of water cleaning, and a substantial amount of nutrients consumed (Tuskan et al., 2001). Thanks to the foundation laid by this initiative, the EU-Interreg lV ANSWER project was able to plant almost 100 acres of SRC willows for wastewater treatment and the simultaneous generation of bioresources for bioenergy. Even if bioenergy is the most obvious and current use of this bioresource, other, more profitable applications are possible. Due to infrastructure age and population increase, certain wastewater treatment works (WWTW) were changed so that their somewhat non-compliant outputs could be used to irrigate treated effluent to willow plantations. Once discharged into the nearby river, treated wastewater is now utilized mostly to irrigate 14 ha of willows. In 2014, the plant reduced its river discharge by 85%, and in 2018, it reduced it by a 93%, due to the sensitivity of the river's chemical and ecological makeup during the growing season. Two harvests have occurred as a direct result of planting willows. (Forbes et al 2017).

More than 80% of the treated wastewater has been returned to the willows yearly over the previous five years, and this percentage rises during the summer months. There is less precipitation, less water flowing into the receiving body, and lighter and heat available in the summer, making the water body more vulnerable to pollution, eutrophication, and ecological deterioration. Willow's high evapotranspiration rate, capacity to preserve soil and groundwater, and ability to absorb nitrogen and phosphorus during this time period all contribute to increased crop yields. Willows can help plants absorb macronutrients and remove and bioaccumulate heavy metals such as copper, cadmium, nickel, and zinc that would otherwise be retained in the combustion ash if used for bioenergy, making them a useful tool for greening and cleaning up contaminated sites, waste management, and bioremediation.

In Northern Ireland, it is well-known that it leaves an unsustainable mark on the soil foundation for nutrient cycling. The climate and geography of Northern Ireland make it difficult to transition to a grain-based agricultural economy, therefore the majority of the country's livestock population consists of ruminants. As part of the EU WaterPro project and the more recent EU CatchmentCARE project, SRC willow biofiltration blocks and buffer strips are being investigated as a viable strategy for absorbing some of the overland runoff of nutrients from pastureland and therefore protecting the receiving water bodies.

5.CO-CULTIVATION OF FOOD AND INDUSTRIAL CROPS (INTERCROPPING, INTERMEDIATE CROPPING)

5.1 Industrial crops appropriate for intermediate crops and intercropping techniques.

Intermediate crops are considered often as an off-season crop that are grown after the harvest of the cash crop to replace the fallow time. Typically, these crops are grown to cover the soil rather than for harvest, which contributes to system diversity and environmental performance. In addition to managing soil erosion, soil fertility, weeds, pests, soil quality, water, biodiversity, diseases, and wildlife in an agroecosystem, year-round ground cover and root activity provide farmers with additional revenue whether planted for seed, feed, or energy. In addition, diversity of crop rotations is seen as a strategy for enhancing the resilience of agricultural output to climate change (Kollas et al., 2015).

Intermediate crop should satisfy the producer’s principal purpose(s) for intermediate cropping which are; to be well suited to the local climate and farm environment; to be easy to establish and maintain with available equipment; to be able to withstand stresses that are likely to occur such as frost, drought etc; and not to compete with income-generated crops grown subsequently or concurrently.

Utilization efficiency of Europe's limited land resource is a major factor in the growth of the continent's agriculture. Industrial crops are in the first phases of creating technologies for symbiotically growing food and raw resources. It is becoming increasingly apparent how crops may operate in unison to boost productivity and agronomic methods. It is possible for food crops and industrial crops to coexist rather than compete with one another.

Several traditional food crops require lengthy crop cycles to prevent soil erosion, nutrient depletion, and disease accumulation for following harvests. Certain industrial crops, such as lupins, can function as a break crop that can benefit food-growing soils to improve their structure and dynamics and can boost soil nitrogen fixing capacity. Utilizing industrial crops in this manner can not only increase the yields and sustainability of the following crop production but can also provide a cyclic source of raw-materials for non-food market. (Sharma et al., 2018).

Growing both edible and non-edible crops at the same time is possible using the double cropping technique. Sorghum and sunflower, for example, may be grown in tandem with arable crops in a very short growth cycle, allowing farmers to capitalize on the land's traditional fallow season. Camelina, with its 80–90-day growth cycle, has also proven useful as an intermediate crop. Utilizing industrial crops, such as camelina, in conjunction with organic cultivation of legumes has resulted in several advantages, such as improved soil covering, less chemical inputs, and greater returns for landowners on the same piece of land.

Agroforestry is another method that may be utilized to cultivate both industrial crops such as poplar and willows, but also food crops. The agroforestry method has shown that it can improve soil structure, soil moisture retention, provide wind barrier capabilities, provide buffer zones that benefit and preserve water quality, and provide different habitats for animals and avifauna. A few examples of agroforestry include the cultivation of food crops such as sunflower, wheat, etc., with willow or poplar planted approximately at every 30 meters across the field and along the ditches to form a symbiotic system.

The employment of agroforestry techniques, such as growing willow or poplar on headlands, has the ability to aid with soil structure and buffer zones, as well as use the entire field. This strategy of growing industrial crops alongside food crops offers synergistic advantages for soil structure, biodiversity, environmental services, and the revenue diversification possibilities of farmers.

The practice of growing many crops in rotation on the same piece of land is known as intercropping. The primary objective of this cropping method is to improve yields by maximizing the efficiency with which various plant species utilise land, water, and nutrients (Lithourgidis et al., 2011). Some examples of crop rotation include row intercropping, in which different crops are planted in adjacent rows (like maize and soybeans), strip cropping, in which multiple rows of one crop are alternated with multiple rows of another crop (like woody crops and sorghum), and mixed or multiple cropping, in which the component crops are completely mixed in the available space (like aromatic species and coffee) (e.g. wheat and cotton).

Using intermediate crops has several positive economic and environmental outcomes. Most crops gain nutrients by mineralization of the leftovers of the preceding crop, and intermediate crops are commonly utilized as nutrient-adding crops, so the requirement for mineral fertilizer, and notably nitrogen, can be decreased. (Samarappuli and Berti, 2018),

It is possible that planting an intermediate crop between the seedling and the harvest might increase the quality of the soil by introducing organic matter and preventing runoff before it can wash away essential nutrients from the root zone of the primary crop. Intermediate crops will enhance the crop's potential water supply by increasing soil water storage capacity, and they will also preserve long-term soil fertility and habitat quality for soil organisms and avoid erosion. By choosing appropriate intermediate crops, pests and diseases can be reduced. These plants can also be used to decrease weeds by breaking the life cycle of pathogens (Kollas et al., 2015). However, there are a number of drawbacks that should be considered before deciding to integrate an intermediate crop. The use of an intermediate crop might add time and money to the production cycle, provide a new host for pests and diseases, or even be detrimental to the main crop itself.

Environmentally, intercropping has the potential to improve soil fertility by using crops that encourage biological nitrogen fixation (allowing for lower inputs by reducing fertilizer), improve soil conservation by providing more ground cover than single cropping, decrease slope erosion, and maximize land use. Companion cropping can also give structural support, which can help prevent lodging in crops that are otherwise vulnerable when compared to monoculture. (Astegaard and Eriksen, 2008). By creating a home for a variety of insects and soil organisms that would not thrive in a single crop setting, intercropping also improves biological and environmental diversity. By minimizing the need for pesticides and other agricultural chemicals, intercropping helps to lessen agriculture's negative impact on the natural world. According to (Lithourgidis et al., 2011), the environmental effect of sorghum-maize intercropping is lower than that of maize in all of the categories that were assessed. The main reason for this is because forage sorghum has several useful agronomic properties that maize lack. The use of water and nitrogen fertilizer may be minimized in intercropping, and the efficiency with which P and K utilized can be improved. In places prone to adverse weather events like frost, drought, and flood, intercropping provides a farm family with two or more unique crops in a single growing season, affording security against crop failure or variable market prices for a given commodity. Because of the increased financial security, it provides compared to growing a single crop, intercropping may be especially useful for small farms that rely significantly on human labour. When two crops are cultivated together and their mutual interactions improve one or both of their fitness levels, the result is often greater overall output and greater farm profitability than would be the case if the same crops were produced in isolation (and therefore yield). There are, however, additional difficulties connected with intercropping, such as selecting appropriate crop species and planting densities. Intercropping increases labour needs throughout the whole growing cycle, from preparation to planting to care to harvest. (Kirkegaard et al., 2008).

5.2 Case Study of Intermediate and intercropping Crops

5.2.1 Camelina as intermediate crops and intercropping.

Camelina is a hardy oilseed crop, characterized by great environmental flexibility and low input demand, which makes it suited for diverse pedoclimatic situations in Europe. One of the most distinguishing aspects of camelina as an oilseed crop is its early maturity. In addition, camelina possesses a number of properties that make it a good cover crop such as: rapid germination even when sown at a shallow depth (less than 1 cm); rapid soil cover with allelopathic influence; high weed competition; good water efficiency, especially in low rainfall settings (less than 250 mm)

In order to prepare for the subsequent sowing of the winter crop, camelina is typically planted in the summer as a catch crop following a proteaginous crop (peas) or a winter cereal (barley, wheat, rye). In place of a summertime fallow, farmers may plant camelina instead, reaping the economic and ecological benefits of a cover crop. Depending on climatic conditions, the harvest potential of camelina under these sustainable catch crop settings exceeds 2,000 kg/ha, in addition to reaching 80% reductions in greenhouse gas emissions. As land availability in Europe reaches 10 million hectares, camelina catch crop is a sustainable feedstock with significant volume potential for the manufacture of advanced biofuels.

Intercropping of camelina with legumes is most common, since the symbiotic N-fixation and residue incorporation adds to further improving soil fertility. While intercropping with camelina is uncommon in conventional farming systems, it is more prevalent in organic farming, particularly in France and Germany, in order to effectively manage weeds and diseases, two of the most significant problems associated with organic farming.

Camelina is typically intercropped with lentils or peas because it serves as a mentor during the development of legumes. This enables a win-win solution that provides the following benefits: enhancement of the efficient use of natural resources (such as water), early soil coverage, particularly in the winter, and prevention of nitrogen leaching and soil erosion. Furthermore, due to reduced pesticide usage in crop rotations because of camelina's rapid soil cover and its allelopathic properties it proves a competitive advantage over weeds (not just in camelina and legumes), also there is a reduced demand for fungicides because of the camelina effect of reducing legume interaction with soil moisture. New market opportunities also arise, especially for the animal feed industry, as camelina seed contains a high protein content (above 25% on a dry matter basis) and a high-quality amino acid profile; increased economic performance of European farming systems as a result of "eco-friendly agronomic management" (savings in nutritional needs, irrigation, pest/weed control, etc.).

6.VALUE CHAINS OF BIO-BASED INDUSTRIAL CROPS

Industrial crops can supply ample renewable biomass feedstocks for the development of high-added-value bio-based products (e.g., bioplastics, bio-lubricants, bio-chemicals, medicines, bio-composites, etc.) and bioenergy.

The structure of their value chains is crucial to the effective incorporation of industrial crops into the agriculture of the European Union. Only selected value chains of eight industrial crops are selected: two perennial grasses(switchgrass and miscanthus), two oilseeds(castor bean and camelina), two fibre crops(industrial hemp and cotton), one speciality crop(lavender), and one woody species (poplar). Some of these industrial crops, like cotton and industrial hemp, are already grown in Europe on large or small plots of land; others, like camelina, miscanthus, poplar, and lavender, are considered ready for practice and can increase farmers' profits and sustainability; and finally, practitioners need specific information to become familiar with and successfully cultivate these crops. However, this is merely the first step; further research, development, and dissemination of knowledge are required to meet the needs of farmers for commercially viable industrial crops. These actions and activities may take the form of specialized programs that include major participation from farmers, such as EIP operational groups, which are places where demonstrations and supporting materials, such as videos and growing instructions, should be supplied.

6.1 Oilseeds (camelina & castor bean)

6.1.1Camelina value chain

Camelina is a rare Brassicaceae oilseed crop that normally requires low inputs, including moderate nitrogen fertilization1, little herbicides, and often no pesticide or fungicide treatments. Camelina is characterized by its durability, particularly under situations of drought stress: camelina has a higher water-use efficiency than other oilseeds, particularly under low rainfall conditions (250 mm) (Fernando AL et al.,2010) Camelina has additional agronomic benefits when incorporated into a farmer's rotation, including a strong allelopathic effect that allows for weed competition and a higher pest tolerance than other crucifers, such as rapeseed. Environmentally speaking, camelina's root system aids in the improvement of soil structure, and being a melliferous plant, it provides nectar and pollen to bees during a crucial time of year.

Although camelina oil has the potential for various applications, the majority of patents issued in the previous 30 years have been for the biofuel and cosmetic sectors. Currently, camelina oil is utilized in a variety of cosmetic formulations, but its demand is limited to a tiny niche market. On the contrary, camelina oil produced responsibly for the biofuel business would have a phenomenal demand on the market. (Angelova, V et al., 2004)

One of the most distinguishing aspects of camelina as an oilseed crop is its early maturity, since European cultivars have been produced for cultivation in 80 to 90 days from seeding to harvest. Due to its adaptability, camelina may be introduced responsibly as a catch crop (growing between repeated plantings of primary crops) to generate camelina oil for advanced biofuels.

In arid parts of the EU with a high risk of desertification and low levels of organic matter, camelina can be grown as a fall crop, replacing fallow land periods in cereal monocultures. This is particularly important in Southern and Mediterranean Europe, where studies have shown that desertification would have long-lasting effects. These are economically depressed areas, characterized by monocultural grain crop rotations and extensive bareness. To improve soil structure, nitrogen cycling, fertilizer efficiency, weed control, and soil degradation prevention, farmers require an alternative oilseed crop. (Fernando AL et al.,2010)

To combat nitrogen leaching, a major issue in agricultural parts of Central Europe, short cycle camelina variants can be cultivated as a summer cover crop. In 2020, the Camelina Company of Spain will launch a commercial trial project covering over 2,000 acres in central Europe. There is a possibility for cultivation on more than 10 million hectares in the European Union (EU), where camelina is being cultivated as a catch crop following the harvest of winter cereals and legumes.

From planting to gathering, camelina may be grown using standard cereal farming machinery with just a few tweaks for small seeds. Due to its higher fibre and lignin concentration and lower ash content than cereal straw, camelina harvest may be fully processed using existing farming and crushing infrastructure for major oilseeds, such as rapeseed, or feedstock for energy uses, most notably in boilers.

Typical camelina grain consists of 38-42% oil and 22-24% protein. Camelina meal, which is generated in the crushing plant as a solid by-product of the oil extraction process, is a very intriguing animal feed raw materialTo put it in perspective, rapeseed meal (33%) and soybean meal (47%) both have about 33% protein, but camelina meal (40%) can exceed 40% protein while containing about 2% fat. Because of its high protein content and comparably high digestibility to rapeseed meal with regards to limiting amino acids like lysine and methionine, it makes for an excellent feed ingredient. Research into the feeding of animals has shown that 10% camelina meal may be added to the diets of broilers, laying hens, swine, and cattle without posing any health risks. (Costa, J et al., 2019)

The key to raising the market value of camelina oil while unleashing a considerable biofuel volume lies in its increased sustainability potential. Camelina oil is a catch crop that may be harvested in order to take advantage of the higher prices paid for industrial uses. Greenhouse gas (GHG) emissions might be reduced by as much as 80% when using camelina biofuel instead of their petroleum counterpart (Foster, M. et al., 2014). Camelina oil cultivated in a way that significantly reduces greenhouse gas emissions might command a price premium.

Value for the farmer comes from growing camelina as a catch crop, rather than as a replacement for another crop, so that he may realize the agronomic and environmental benefits of the crop and have the option to market his sustainable camelina harvest as an advanced biofuel. As a result, a grower's CO2 emissions policy will determine the value of his camelina harvest. In addition, this method is in line with the Green Deal's A Farm to Fork Strategy (May 2020), which aims to financially compensate farmers for adopting practices that reduce greenhouse gas emissions.

6.1.2 Castor bean value chain

In the tropical area, Castor is a valuable annual spring oilseed crop (about 80 cm tall) with a growth cycle of 120 to 150 days. Each of its up to 40 cm long and its racemes produces 80 to 120 capsules.

There are claims that castor can withstand a wide range of environmental stresses, including those caused by nematodes, extreme temperatures, high and low pH, poor soil, and sloping terrain. India, China, and Brazil are the primary commercial producers. More than 3 million acres of land is devoted to growing castor across the world right now. Only in demonstration and test plots is the plant found in the Mediterranean region (Melo et al., 2009).

The crop may be cultivated in low-rainfall and low-fertility environments, making it suitable for dry farming. Castor is a resilient crop that may be produced in a variety of temperatures in warm regions with 250-750 mm of precipitation. Throughout the crop season, it operates best in conditions of moderate temperature (20-26oC), low relative humidity, and clear, sunny days. Temperatures greater than 40^{o}C or lower than 15^{o}C are incompatible with castor growth. A environment free of frost is required for the crop. Due to its tap root and light-reflecting stems and leaves, which reduce heat load and promote survival under moisture stress, this plant is drought tolerant. The crop may be cultivated effectively on the majority of soil types, with the exception of hard clay and poorly drained soils. Furthermore, soils with a limited water retention capacity, such as sandy soils, are unsuitable for castor production. Avoid soils with pH values of > 9.0 or 4.0. High fertility promotes excessive vegetative growth, prolongs blooming, and delays maturation, resulting in low yields.

Improved seed yields (up to 5 t/ha seeds, normally 2 to 5 t/ha seeds and oil content 48 to 50%), uniform seed maturity, pest and disease resistance, and mechanical harvest performance are only some of the benefits of the many short hybrids developed in recent years. (Melo et al., 2009).

Weed suppression and water retention are both enhanced by thoroughly ploughing and afterwards harrowing the soil. The suggested seeding rate per hectare is 15 kg, with 1 meter between rows and 25 centimetres inside rows. The distance between rows can range from 15 to 60 centimetres, while the distance between rows as a whole can range from 60 to 100 centimetres (12-15 kg seeds per ha). Depending on the kind of soil, the ideal planting depth might be anywhere from 6 centimetres to 10 centimetres. Heavy soils benefit most from a modest sowing depth of 6 to 8 centimetres.

Finally the key to improve castor bean value chain: Improving seed quality through breeding programs that produce high-yielding and disease-resistant castor bean varieties; enhancing agronomic practices like training farmers on best practices for growing castor beans, such as proper planting and maintenance, pest and disease management, and efficient use of inputs; increasing processing efficiency by improving the efficiency of castor bean processing facilities can help to reduce costs and increase profitability for processors and farmers. This can be done through the adoption of modern processing techniques and the use of appropriate technology; Diversifying end-use applications; and improving building market linkages by connecting farmers with processors, manufacturers, buyers to facilitate the flow of goods and services along the value chain. This can be done through the development of marketing and distribution networks and the promotion of the benefits of castor beans to potential customers (Melo et al., 2009).

6.1.3 Perennial grasses

Switchgrass is a warm-season perennial grass belonging to the Poaceae family (Kingdom: Plantae, Order: Poales) with a lifespan ranging from 10 to 20 years, depending on its cultivated region. It is grown from seeds. The plant's stems might range in height from 0.5 to 2.7 meters. The root system of switchgrass plants can extend as deep as three meters.

Initial consideration was given to switchgrass as a viable feed crop. In the early 1980s, switchgrass was identified as a prospective energy crop for the United States (for lignocellulosic feedstock production (combustion, conversion to liquid or gaseous forms)), and a decade later, "Switchgrass for Energy" research was initiated in Europe (Rusinowski, et al., 2019).

Two primary ecotypes of switchgrass, known as upland and lowland, have been distinguished based on the physical characteristics and ecological settings of their respective wild populations. As opposed to its upland counterparts, lowland ecotypes are higher and have longer bluish-green leaves and ligules. Lowland ecotypes thrive in warmer and wetter conditions, while upland ecotypes prefer cooler and drier weather.

Although it may be grown in a wide range of soils, from sand to clay loam, switchgrass does best in moist, nutrient-dense environments with good drainage. Whereas cool-season grasses can't handle soils that are acidic and nutrient-deficient, switchgrass does. It has been found in certain research that the plant can grow in soils with a pH of 4.9 to 7, as well as in alkaline soils, however it does best in neutral soil (pH 8.9 to 9.1) (Schmidt et al., 2015).

Since switchgrass is planted at a relatively shallow depth, it is essential to have a solid seedbed in order to position the seeds precisely. Standard practice calls for utilizing conventional tillage techniques while planting switchgrass for best results. Reducing residue from previous cropping systems and managing populations of cold season weeds are also possible outcomes of conventional tilling. Due to the risk of soil erosion, traditional tilling should be avoided on regions with steep slopes. If bioenergy is to be produced using no-till techniques, then weed populations must be controlled or reduced using both pre-emergence and post-emergence herbicides in the establishing year.

Proper preparation is essential to a successful crop planting. Crop establishment is aided by paying attention to seed-to-soil depth, soil texture, soil moisture, and soil temperature. Switchgrass can be planted anywhere from 0.2 to 2 centimetres deep, while several studies agree that the depth should be no more than 13 millimetres at most. Soil temperatures over 200 degrees Celsius might promote rapid germination when planting seeds. Switchgrass should be planted at a rate of 200-400 PLS m-2, where PLS stands for pure live seed. Row spacings ranging from 15 to 70 centimetres were studied.

Switchgrass displays a broad tolerance to soil moisture availability by germinating, establishing, and reproducing in both arid and wet environments. According to reports, a large portion of eastern North America is ideally suited for switchgrass cultivation, but regions with a Mediterranean climate are unsuited without irrigation (Rusinowski, et al., 2019).

Annual reports indicate yields of 20-24 t/ha with 20-30% moisture content. Typically, yields peak in the second or third growing season. The average yields of switchgrass grown on marginal terrain ranged from 10 to 12 t/ha. In the Mediterranean area, lowland varieties were fruitful.

Switchgrass's final use has a significant impact on the methods chosen for harvesting and storing the crop. Even though switchgrass management as an energy crop is still in its infancy, commercially available haying equipment may be adapted to harvest and bale switchgrass. Switchgrass is best cut at a height of over 10 centimetres, which keeps the windrows off the ground and promotes faster drying to a moisture content of less than 20% before baling. The collected material can be rolled into enormous, round or rectangular bales for storage and transport. Switchgrass stored outside is best preserved in round bales rather than rectangular bales because of the lower storage losses experienced by the former. The rectangular bales can be more easily moved about and loaded onto a truck because of the lack of width restrictions (Rusinowski, et al., 2019).

A grazing or hay crop, switchgrass was originally chosen in the 1940s. Back in the 1980s, when lignocellulosic energy first began to take off, switchgrass was widely regarded as the best feedstock crop (combustion, conversion to liquid or gaseous forms). Switchgrass is also being researched as a potential paper fiber or pulp source, as well as a phytoremediation tool, a biomaterial, a bioproduct, etc. Perennial grasses like switchgrass have the potential to provide lignocellulosic feedstock, which is inexpensive compared to oil, sugar, and starch-rich crops and fits well with the current bio-based economic model to stimulate biorefineries. Because of its projected energy potential, which is double that of first-generation biofuels, switchgrass has been included in the current EU directive for the development of advanced biofuels. Bioethanol produced from lignocellulosic feedstock holds tremendous potential as a clean, renewable energy source.

6.1.4 Miscanthus market value

Miscanthus is a rhizomatous perennial grass native to East Asia that has the capacity to produce a lot of biomasses. The hybrid of Miscanthus sinensis and Miscanthus sacchariflorus, known as Miscanthus x giganteus, is the only miscanthus genotype grown commercially today. The invasive species of Miscanthus x giganteus is spreading through the soil via rhizomes and/or plantlets. Its biomass is highly valuable for many applications, including but not limited to power generation.

It's possible it might do well in a European garden. About 25% of Europe's arable land is devoted to its cultivation, with the majority of that space in the United Kingdom, Germany, Switzerland, Poland, and France. It does well in a broad variety of soil types but thrives in those with a pH between 5.5 and 7.5.

Growing to a maximum height of 3 meters, miscanthus is an excellent feedstock for energy (heat, electricity, and bioethanol) and non-energy (animal bedding, paper, and bioplastics) uses due to its low mineral content and high biomass yield (Deferne, J.L et al., 1996).

It has been shown to be very useful for reducing soil erosion and storing carbon in soil because to the high amount of above- and below-ground plant remnants. It is a perennial plant that regrows each spring for 10 to 20 years. Miscanthus, a sterile crop, is planted in the spring with rhizomes or plantlets at a density of 1-2 plants per square meter. Because rhizomes are frost-sensitive, they must be planted before the frost season. In the first year of the cycle, the soil is prepared, 19,000 rhizomes per hectare are planted, and chemical weeding is performed (if necessary). The second year, an additional chemical weeding is used to guarantee a successful crop establishment.

In the majority of situations, weed management is only required during the early phases of development during the establishing year. Efforts are being made to scale up the seed-based establishment since it will be cost-effective and assist in meeting the rising market demand (Barbosa B et al., 2015).

Miscanthus requires extremely little chemical intervention for insect, disease, and weed control. According to reports, under European circumstances, pest and disease concerns are minor, with blight being the most significant recorded disease (mildew). Miscanthus can successfully compete with weeds after it has established itself.

Once a year, in the shape of 3- to 4-meter-tall canes, the plant can be harvested. The harvest occurs between December and March, depending on the climate of the location. Using typical agricultural equipment (e.g., self-propelled forage harvesters, etc.), harvesting can produce either bales or chipped material.

Miscanthus chips can be kept effectively in closed containers, however they have a low bulk density (150 kg/m3), low fuel mass in combustion chambers, and the possibility for bridging and clogging in automated feed systems. Miscanthus may be pelletized, and the greatest pellet bulk density of 810 g/L is achievable.

Miscanthus biomass may produce up to 16.3 tons of dry matter per hectare per year. The crop output for 3-4 m tall, well grown miscanthus ranges from 10 to 25 tons of dry matter per hectare. Due to its strong photosynthetic activity and biomass output, it is a good biomass crop.

6.2 Woody species

6.2.1 Poplar value chain

The poplar (Populus spp.), a tree in the family Salicaceae, is useful for many reasons due to its useful characteristics. Poplar trees are grown on roughly 500,000 acres of planted and natural woodlands across the European Union, mostly in France, Italy, Spain, Hungary, and Romania. Poplars are also cultivated as an industrial crop throughout a total area of 50,000 hectares in Poland, Germany, Italy, France, Spain, Romania, Hungary, Slovakia, Lithuania, Sweden, and other EU states.

Choosing the right poplar clones, establishing them successfully, having adequate acreage, water, and favourable market conditions are all crucial to the bottom line of a poplar producing business. The initial plantation installation is crucial to the plantation's long-term quality. The key success factors for plantation establishment are the availability of rainfall, the quality of the soil, and the effectiveness of weed management. Significant new dangers to the development and growth of poplar plantations have emerged as a result of recent substantial climate change consequences, such as frequent severe droughts (Laureysens et al., 2004).

The breeding of climate-adapted poplar hybrids with high biomass yields is the first step in the poplar value chain, since these characteristics are necessary for the commercial sustainability of poplar agriculture. Populus nigra and Populus deltoids hybrids predominate in southern Europe, whereas Populus maximowiczii and Populus trichocarpa hybrids, which can withstand colder temperatures, are grown in northern Europe. EU breeding studies initially concentrated on hybrid poplars for energy generation; however, recent efforts have shifted toward improving the species' industrial quality, which might find utility in a variety of biorefinery settings.

Most poplars are grown on unfavourable soil, so they require careful attention and a lot of fertilizer to provide a good crop (especially compensating lack of nitrogen on marginal lands). Poplars are great for recycling nutrient-rich waste such as sludge from municipal water treatment plants, ashes from biomass burning, and digestate from biogas production because they prevent nitrogen and other pollutants from leaching. The EU LIFE project NutriBiomass4LIFE conducted in Lithuania showed that even all municipal water treatment sludge from big cities can be utilised successfully and without creating serious environmental difficulties, while also significantly improving biomass yields on marginal and contaminated soils. The fact that the project could be completed is evidence of this. (Laureysens et al., 2004).

In order to provide chips for the development of renewable energy (heat and/or electricity), energy or high density (10,000-15,000 short cuttings/ha) poplar plantations are being established for up to a three-year cycle. Since the majority of energy chip costs come from harvesting/chipping and transporting, these poplar plantations are frequently built within a reasonable distance of biomass boilers/CHPs. Chips need specialist poplar harvesting/chipping equipment, therefore investing in this kind of technology necessitates the participation of smaller poplar farmers. In regions where traditional forest resources are few and where bioenergy for heating and power generation is still in its infancy, poplar plantings are being developed as an alternative energy source. Energy chip-producing poplar plantations are created mostly in France, Spain, Germany, Italy, Poland, Hungary, and other nations. Energy chip market is very susceptible to oil price variations; hence, this business loses its appeal during periods of low oil prices.

Pulp logs for paper, pulp and wood-based board (particleboard, MDF) manufacturing may be sourced from industrial or medium density (1600 long poles/ha) poplar plantations that are established for a 5–8-year cycle. Medium-density poplar plantations may offer comparably increased biomass yields over a longer rotation time, even if maintained at a much lower density than energy plants. To stimulate development, long (150-180 cm) poles/rods are used to construct medium-density poplar plantations. These plants are harvested manually or with little forestry equipment. As medium density poplar plantations provide money over longer rotations (which is not very attractive to farmers), industrial corporations and financial investors are the usual investors in such plantations. Farmers construct industrial poplar plantings with long-term contracts with companies and even some industry pre-financing of plantation expenditures. The European countries of Poland, Romania, Hungary, Slovakia, Italy, France, and Lithuania have all recently constructed large-scale medium-density poplar plantings. In the past ten years, medium-density poplar plantings have grown increasingly widespread.

In order to meet the demands of the veneer industry, low-density poplar plantations (270 long pokes/ha) are being replanted every 15 years. Veneer plantations are created by planting trees two meters deep within a 6 by 6 grid made out of poles or rods. Poplar trees grown specifically for the production of veneer logs need to be pruned meticulously in order to provide logs of a high enough grade for use in veneer. Farmers that produce poplars exclusively for veneer under long-term contracts and industry pre-financing can expect to get the bulk of their funding from veneer firms. Since poplars are an important resource for the European woodworking industry, veneer farms are set up in countries like Italy, Spain, and France.

To put it simply, poplars are a crucial part of the production process at forward-thinking bio-based companies. Extracting sugars and lignin from poplars might be employed in the manufacturing of liquid biofuels, chemicals, and other polymers. Industrial medium density (1600 long poles/ha) poplar plantings may be employed in sugar platform bio refineries because of the increased cellulose and hemicellulose content that can be extracted from poplar stem as opposed to bark.

6.3 Exceptional crops

6.3.1 Lavender Value Chain

Lavender (Lavandula) is grown for its oil as well as its fresh flowers, dried products, and other applications. Lavandula latifolia, Lavandula angustifolia, and Lavandula intermedia are the most common commercial varieties of lavender.

Since lavender is resistant to most insect pests and fungal diseases, growing it has social and ecological significance beyond just the economic advantage it provides to growers. Since neither pesticides nor fertilizers are needed to cultivate it, it is regarded as a sustainable crop, however it may occasionally benefit from irrigation. Finding an appropriate marketing approach is the biggest obstacle. In spite of the fact that certain lavender plants may live for up to 20 years, on average they only produce flowers for around ten, and the best way to propagate them is by softwood cuttings of standard kinds. Not all seeds are true to type, and lavandin seeds are infertile. The reason for growing lavender greatly determines the selection of cultivars (Kara, N et al., 2012).

The most important ingredient derived from L. angustifolia is essential oil, which is collected from the flowers using steam distillation. Lavender oil is comprised of almost one hundred components. Two significant ingredients are linalool and linalyl acetate, and camphor level is very low since it gives lavender oil its unpleasant odour. Linalyl acetate is abundant in lavender oil, but linalool is abundant in lavandin oil. Lavender oil is mostly employed in the perfume, cosmetic, and medicinal sectors. According to the European Pharmacopoeia's standard values, lavender oil must contain between 20 and 45 percent linalool, 25 to 46 percent linalyl acetate, and less than 1.2% camphor. (Singh, S et al., 2007)

The essential oil of L.angustifolia is more costly than that of other lavender species on the market due to its superior quality and low production. The qualitative and quantitative content of L. angustifolia's essential oil varies according to genotype, environmental circumstances, reproduction, and morphological traits. L. latifolia produces approximately three times as much oil as L. angustifolia. Due to its increased output and capacity to grow at lower elevations, the price of its essential oil is lower, but the oil's camphor-dominated aroma lowers its quality (Stanev, S et al.,2016).

Bulgaria, France (combined, these two nations produce two-thirds of the world's lavender), the United Kingdom, Spain, China, and Russia are the leading producers. Grebenicharski, S. (2016) In 2017, Bulgaria exported more than two hundred tons of lavender oil, making it the world's largest exporter and produces of lavender oil. Despite the persistent threats presented by Stolbur phytoplasma, France is the world's largest lavender oil producer, with Spain a close second. Spain is the second-biggest lavender oil producer in the world, with 2,000 acres yielding around 80 tonnes of oil. The greatest producer is France. Less than 10 metric tons per year of spike lavender (L. latifolia) essential oil is produced in this country. Recently New Zealand is a relatively new player in the worldwide market for lavender oil, which has traditionally been exported by Bulgaria, China, France, Russia, and a few other countries in Eastern Europe (Yilmaz, D. et al., 2014).

Essential oils like lavender and lavandin are distributed through two main distribution channels: 1) smaller producers sell to regional and specialty markets like aromatherapy shops, and 2) larger manufacturers sell to global markets directly or in conjunction with multinational conglomerates.

Increasing numbers of distribution channels, especially digital marketing and online sales, have also contributed to the growth of this industry. Consistent quality is required for a market participant to be viable.

Commercial lavender essential oils are extracted using steam distillation, as was explained earlier. Oil is vaporized and then extracted using steam distillation. Despite its many advantages, growing lavender need a highly automated system and a distillation structure close to productive areas (weed management and harvesting). Numerous opportunities exist for farmers and agricultural businesses to boost their profits through the production of lavender oil. Production of lavender oil has several by-products, including the essential oil itself, fresh flowers and plants, dried goods, food, and agrotourism.

6.4 Fibre plants

6.4.1Cotton's supply chain

Approximately 30 million acres are dedicated to growing cotton, making it the world's largest fibre crop. Most of the world's cotton is produced in Asia. Cotton is the major raw material for the textile industry and has been used for more than 8000 years, making it the most significant natural fibre on a global scale. Cotton is a very high-maintenance crop since it consumes a lot of water, needs a lot of fertilizer, and attracts a lot of pests. Cotton only accounts for 2.4% of all farmed area, but it receives 11% of all pesticides and 24% of all insecticides.

The cotton value chain is the backbone of the global textile industry since cotton is one of the most sought-after crops for its usage in textiles and garment manufacture. Since the cotton business is a global one, many nations are involved in the value chain. In addition to high-quality fibre, this value chain also produces useful by-products including oil and seed cake that may be used in animal feed.

The tremendous increase in demand for synthetic fibres in recent years has caused the global cotton industry to stagnate. Rapid industrialization and widespread use of synthetic fibres have led to serious environmental problems, most notably the release of microplastics into the environment. Microplastics may now be found in every ocean on Earth, elevating the importance of this problem. Because of this preference for natural fibres, the synthetic fibre market share is expected to decrease, which will increase demand for this product. Consumers, particularly in Europe, are becoming more hesitant to purchase clothing manufactured from chemical-intensive crops like cotton due to growing environmental concerns (Fernando et al.,2015).

Despite contributing less than 1% of the world's total crop output, this crop is nonetheless one of Europe's most widely farmed industrial crops. It's larger than 300,000 acres and is held equally by Spain, Greece, and (to a lesser extent) Bulgaria.

Since Greece's accession to the EU in 1981, this crop has had a special CAP aid program due to agro-ecological, historical, and political concerns. While the substantial fluctuation of this commodity's international price, cultivated area has been maintained thanks to CAP aid, despite being tied to stringent environmental laws that have reduced its global competitiveness.

This crop has a considerable social significance in the aforementioned nations; in Spain and Greece, it is one of the primary sources of income in regions with high unemployment. It is typically grown on tiny farms, which explains its political significance as the primary source of income for many households in these region. Despite this social added value, cotton producers are unable to differentiate their product because the majority of it is sold straight to other nations at global commodity pricing. This also explains why this particular crop is so dependent on CAP assistance. (Fernando et al.,2015).

The organic value chain represents a thriving market for cotton farmers. The growing awareness of environmental issues associated with fibre production and the textile industry has contributed to the increase in demand for organic cotton.

Given the increasing demand for organic products, EU cotton producers have the opportunity to improve their product's sustainability and add value by placing it on rapidly expanding marketplaces. Even with modest yields, the cotton grower's perception of the organic premium might provide a compelling incentive to shift production methods.

ECOFIBRA is the name given to a Spanish program that aims to improve the cotton supply chain. Textile producers in the European Union are involved in this initiative to identify local, environmentally friendly cotton suppliers. Spain cultivates 74,000 acres (22% of the EU total) of the plant. Despite a large amount of land being dedicated to this old industrial crop in Spain, farmers there are unable to distinguish their produce, and the vast bulk of it is exported to Pakistan at global commodity prices. (Fernando et al.,2015).

Supporting sustainable practices among Andalusia's cotton farmers and increasing the supply of local cotton for the textile industry are the goals of this project, which was formed by a consortium of enterprises that specialize in organic and sustainable cotton. This study indicates the potential for sustainable practices to spread among Spanish cotton growers as a result of the growing demand for sustainable and organic cotton.

6.4.2 Hemp industrial value chain

Grown traditionally for its fibre stems, hemp is a spring annual crop. It's a fast-growing crop that can potentially reach 4 meters in height in just 100 days. The stems are divided into three distinct parts: the bark (which houses the fibre bundles), the woody core body, and a hollow area in the centre. Its deep tap roots can go as far as 2 meters underground. Between 20 and 40 centimetres is where the bulk of the root system is. Shells of hemp seeds feature a marbled pattern and a spherical-oval shape that is slightly flattened on both sides.

It originated in the Middle East and then expanded throughout the rest of the continent, including Eastern and Southern Asia. Five thousand years ago, in ancient China, it was first cultivated, and from there it spread to the rest of the world. Hemp is one of the oldest cultivated plants ever. Industrial hemp has seen a rise in popularity all around the world in recent years. Specifically in Europe, the cultivated area went from 14,000 hectares in 2012 to 42,500 hectares in 2017. The country with the highest output in Europe is France, but there are other rapidly developing regions in other European countries including Italy, the Netherlands, Lithuania, Estonia, Ukraine, Romania, and Germany. There have been a number of European Union (EU) research projects focused on industrial hemp.

Hemp plants are naturally dioecious, including both male and female flowers. Male plants are shorter, have a greater fibre content and mature quicker than female plants, which are taller and produce more seeds. A variety of monoecious varieties have been chosen in order to eliminate the agronomic issues associated with the sexual vegetative dimorphism found in dioecious cultivars. The monoecious cultivars generate consistent plantations and plants with equal maturation, height, fibre content, and seed yield, allowing for an effective mechanical harvest. Currently, sixty-eight varieties are recognized in the European database and grown for fibres, seeds, or both (Deferne, J.L et al., 1996).

Hemp thrives in soils with a pH of 7.1 to 7.6. It should not be cultivated on soils with a pH below 6. 0. It grows well after manure- and legume-grown root crops. It may even be cultivated on the same field for many years. It enhances the soil's structure thanks to its taproot. Heavy metals such as Cd, Pb, Zn, and Cu are absorbed by hemp, contributing to the cultivation of polluted soils. It requires a warm, temperate environment and at least 500 to 700 mm of yearly precipitation or irrigation. The hemp plant is sensitive to short day duration, causing it to blossom prematurely. Flowering period is a crucial aspect in determining both the amount and quality of hemp production. During its vegetative period, it requires lengthy days (14-16 hours).

Hemp may also be affected by fungus; diseases such as Fusarium wilt, septoriosis, and grey mildew are prevalent in climates that favor their development. Occasionally, especially if hemp is cultivated several times on the same plot, it may be plagued by a parasite plant called branching broomrape (Orobranche ramosa L.). Virus infections can occasionally harm hemp as well (Hoodeh et al., 2017).

When the average temperature hits 10 degrees Celsius, it may be sown. The eventual use for the crop is a major factor in determining the sowing density. Seeds at a rate of 10-15 kg/ha should be used for seed production, whereas 60-70 kg/ha should be utilized for fibre production. Space each row either

12.5-25 cm (50-70 in.) apart. Plant the seeds between 3 and 4 centimetres deep. Extreme caution must be exercised while suppressing weeds, especially Elymus repens (L.) Gould, in seed cultivation. High-density planting with close row spacing is optimal for fibre production and eliminates the need for chemical weed suppressants. The groundwork should be done in the same way as for spring grain planting (Hoodeh et al., 2017).

Rates of 90–120 kg/ha of nitrogen, 70–100 kg/ha of phosphorus, and 150–180 kg/ha of potassium are suggested. While potassium and calcium (required for plant cell synthesis) are more vital in fibre crop production, phosphorus availability is crucial for seed development in crops grown for seeds. An NPK ratio of 1:0.7:1.5 is optimal for producing fibre, whereas an NPK ratio of 1:0.8:1 is ideal for growing seeds. Following legumes with hemp reduces the need for nitrogen fertilizer. Extending the growth season and promoting lodging may be possible with the use of nitrogen-rich fertilizer. For the first six weeks of its existence, and for the rest of the growing season, it does best in humid environments. To reach their full potential, plants require between 250 and 300 mm of precipitation throughout the vegetative growth stage. Drought is most harmful to crop development and productivity during the germination and blooming phases. A typical harvest in Europe would produce about 7.5 t/ha of dry stems and 2.5 t/ha of fibres. The oil in the seeds is mostly made up of polyunsaturated fatty acids (around 70%) (Hoodeh et al., 2017).

The timing of hemp harvest depends on the reason for its growing. When cultivated for fibre, it should be harvested toward the commencement of blooming. At that time, the fibres are delicate yet relatively robust, making them suitable for textile manufacture. Due to the increased lignification that occurs when harvesting is postponed, the increased fibre yields cannot be utilized to make textiles but are useful in making pulp. The crop should be harvested at full maturity, when the seeds at the centre of the panicle are mature, in order to maximize the quality of the seeds or fibres that may be extracted from them. Following this, the fibres might be put to use in industries apart from the textile industry (insulation mats, etc) (Hayo et al., 2008).

Even though industrial hemp is technically a fibre crop, it is also a biorefinery since high-value bioproducts can be derived from every part of the plant (stems, leaves, seeds, and flowers). The shivs, which are the woody part of the plant's stem, have several use. Oil derived from the seeds can be used in foods, cosmetics, and medicines. The cannabinoids found in the flowers, like as THC, CBD, and others, have a number of therapeutic uses. The plant's leaves are also utilized in the production of pharmaceuticals, tea bags, and other related products.

Hemp has a long history of therapeutic use. Different civilizations have long used it to treat asthma, cystitis, diarrhoea, dysentery, gonorrhoea, gout, epilepsy, malaria, and fevers, among others. The whole plant has anti-inflammatory, antispasmodic, analgesic, cholagogic, hypotensive, emollient, hypnotic, diuretic, laxative, ophthalmic, narcotic, and sedative properties. Cannabidiol (CBD) from hemp is used to reduce nausea and vomiting caused by cancer treatment. It is also used to treat anorexia since it enhances the appetite. It has a number of industrial applications, including as a food additive and in the production of technical products including Varnishes, lamp fuel, detergents, paints, and emulsifying agents in the pharmaceutical sector. Hempseed oil is a sought-after base material for making "greasy soap" (grey soap). Because of the chlorophyll it contains, this soap is also often referred to as "green soap" in various parts of the world. Notably, hemp essential oil, a separate chemical produced from hemp, is used to resist parasites found, for example, on horse skin. Similar to several other essential oils, it is bacteriostatic and repellent to insects (Hayo et al., 2008).

7. SUCCESS FACTORS FOR INDUSTRIAL AGRICULTURE AND THEIR USES IN DIFFERENT SECTORS

Success in industrial agriculture requires a combination of factors, including efficient production techniques, effective resource management, and a strong market strategy. With the right approach, industrial agriculture can provide a consistent and reliable supply of food, fibre, and fuel to meet the growing demands of a growing population. Key success factors include the adoption of advanced technology, the development of sustainable practices, and the cultivation of strong relationships with suppliers, customers, and other stakeholders.

Due to their eco-friendlier qualities, there is a rising demand for raw materials derived from industrial crops. Biobased goods are intrinsically simpler to sell, and the recent growth in the usage of biobased and biodegradable components has enhanced the market share potential. Industrial crops are essential to a completely circular biobased economy in which all resources are supplied locally, sustainable and recycled throughout their entire life cycle. Most stakeholders now see protecting arable land for food production as more important than growing fuel crops in light of the food vs fuel debate.

Compared to fossil fuel-based supply chains, biobased circular economies have a significantly lower carbon footprint, as the carbon emitted during processing (harvest, transport, and manufacture) is reabsorbed during crop growth. Because of their ability to secure a raw material supply from local farmers, create jobs, and reduce reliance on expensive petrochemical-based commodities, industrial crops may prove to be the essentials of local, sustainable economies.

Some cash crops, such as camelina, lavender, etc., can tolerate more abrasive soils than others and are therefore more adaptable. Farmers can increase their income by using marginal soils. As an added bonus, they may revive degraded soils so they can be used again for agricultural purposes. Industrial crops like camelina, when used as a break crop in tillage rotations, have been shown to increase the efficiency of the nitrogen cycle in some soils, enhance soil structure, and decrease fungicide loads.

Several infrastructural technologies are readily available to farmers, lowering the initial investment needed to cultivate and harvest a variety of industrial crops. With the installation of a specialized header, machines designed for collecting feed crops may also be used to gather poplar, willow, and miscanthus. Despite their common usage for drying grains, drying floors may also be put to use for drying other types of industrial crops. By synchronizing the harvest of arable crops (early autumn), fodder crops (early summer), and willow crops (late winter/early spring every two or three years), issues with the usage of agricultural infrastructure can be reduced.

Building a market for all components of industrial crops can increase profits, decrease trash, and free up more resources suited to long-term use. Industrial crop farming has a lot of promise, and so does the development of effective mechanisms to educate landowners and farmers. Farmers have always been innovative, but with the new possibilities presented by industrial crops, they may be able to expand their activities into other areas of the value chain. As these online venues continue to expand, they may bring together cooperatives that are innovative, long-lasting, and highly profitable for their members (farmers) and communities. The prosperity of an economic sector is predicated on the quality of its interpersonal connections.

A collection of best practices and potential solutions are offered with the goal of closing the information gap between farmers, the manufacturing sector, and consumers. The inputs of the many diverse specialists that participated in "Sustainable Industrial Crops in Europe" were used as reference. In an effort to bridge the information gap between farmers, the manufacturing industry, and consumers, a set of best practices and potential solutions are provided.

7.1 Policy sector

To address contemporary policy challenges and make sense of the myriad accidental links across seemingly unrelated domains, a broader perspective is required. Farmers should be viewed as more than just producers of food and raw materials for the decarbonization of manufacturing; they should also be considered providers of ecosystem services (such as biodiversity conservation, material and natural resource conservation, soil fertility enhancement, carbon sequestration, promotion of closed production cycles, etc.). Farmers can be greatly aided by growing multi-use crops in order to meet this challenge (Ahlgren et al., 2014).

Plants and trees classified as multipurpose can be used for more than one purpose, such as for human consumption, animal husbandry, and environmental upkeep. By increasing land usage and crop income, multipurpose crops help farmers increase revenue and distinguish their product offers. Farmers may have better stability in the value chain and fair recompense if the exploitation of multifunctional crops is combined with subsidies or other market measures designed to promote sustainable practices (Ahlgren et al., 2014).

The global economy is getting ready to make a transition to more environmentally friendly products and services, which means that compensatory measures like carbon farming for credits might help fuel additional demand expansion. With an accurate evaluation of market potential, a thorough investigation of barriers and bottlenecks, and the dissemination of best practices and policy advice, we can speed up the transformation of our economies.

7.1.1 The economic and environmental value of cultivating crops with many uses

Optimizing the use of land and other resources is becoming increasingly important as the world's population rises and its ecosystems decline. In order to restore the health of our natural environment and to decrease the consequences of extreme weather events, this rationalization must be carried out in accordance with natural constraints. Multipurpose industrial crops, which can produce several goods from a single plot of land while also having a positive effect on the environment, may be a huge help in achieving the goals (Dauber et al., 2012).

When used as an alternative raw material for manufactured goods, multipurpose industrial crops are seen as an ideal resource with the potential to decarbonize industry and give green impetus to the growth of rural areas through the development of novel value chains (new materials, graphene, etc.), the relocation of crucial manufacturing sectors (feed, textile, bio-based composites, and pharmaceuticals, etc.), and the valorisation/conversion of existing resources (food, downstream industries, packaging, etc).

After years of declining real commodity prices, shrinking government subsidies, and tightening environmental regulations, the EU's agriculture is less competitive than ever. This makes it all the more urgent to create new economic prospects in rural regions. Alternative applications for existing crops and/or the introduction of new crops with additional value may be proposed to diversify EU agriculture and bolster rural economies (Dauber et al., 2012).

Careful mapping of the demands of national and regional economies is essential for the construction of a fully functional and efficient chain of production for industrial crops at a sustainable size and with a high degree of integration at the EU level.

Complete circularity is essential to efficient value chain management. Because of this, it's crucial to give extra thought to the product's eco-friendly design and recycling practices. This is a smart financial move as well as a necessity for the planet. The medicinal and aromatic plants sector, for instance, has contributed significantly to economic development, environmental sustainability, and social benefits through its efficient exploitation and recycling of waste biomass. Aromatic plant growers may get financial benefits from the efficient recycling of these discarded biomasses (viz., biochar, compost, enzyme, biogas, bio pesticides, etc.). Therefore, distillation biomass's dual use not only reduces end product costs but also solves the problem of what to do with the vast quantities of biomass that result from the process (Dauber et al., 2012).

7.2 Sustainable agriculture practices

Industrial crops with several applications seem to be a good fit for new, more sustainable agriculture practices. Organic farming and agroecology are two of these methods; their market value has more than doubled from 2009 to 2018 yet they are still relatively small compared to conventional farming because of how popular they are with consumers (IFOAM) (Paladino and Baggiere, 2008).

Analysis of commodity price changes indicates the allure of sustainable agriculture practices. European farmers confront a variety of challenges as they try to participate in the free and competitive global market economy. The significant price volatility in many of the traditional markets and distribution channels through which farmers sold their goods has led to seasonal crises when agricultural prices do not cover production expenditures. Agricultural products having secondary markets, such as biomass for energy and fiber for textiles, are similarly impacted by the current market trend. Therefore, many markets throughout the world are susceptible to increased volatility.

The organic industry is one of the few exceptions to the downward trend in agricultural markets throughout the world. The sector only uses 7.7 percent of EU cropland and contributes a little amount to the EU's agricultural GDP (Willer et al., 2020). On the contrary, this is not a niche market, but rather a sector that is expanding fast throughout the majority of EU countries. After 20 years of steady development, including double-digit growth rates in the preceding several years, the organic retail market is swiftly becoming one of the most important drivers in EU agriculture. As a result of this rising pattern of interest, the demand for organic agricultural goods is exceeding the supply. Furthermore, the influx of new businesses into the sector has affected product demand. Many new markets have opened up for industrial crops because to the growing interest from major corporations in organic items like clothing and cosmetics.

Not only that, but the European Union (EU) has just unveiled the "Farm to Fork" strategy, which sets lofty environmental standards for EU farmers to meet by 2030. Despite the plan's emphasis on food production and consumption, its aims are relevant to agriculture throughout the European Union. Industrial agricultural land usage does not negate the European Union's (EU) goal of converting 25% of its farms to organic by 2030. Furthermore, this political structure paves the way for a future shift in which industrial crops play a crucial role.

Multipurpose crops have the potential to play a crucial role in the transformation of EU agriculture into better sustainable agricultural practice. Because of the expanding bioeconomy, hitherto untapped markets have opened up for agricultural goods and associated by-products. Many types of agricultural waste, formerly considered useless, may now be put to good use by the right people as anything from animal feed to fibre. Also applicable to organic farms, as growing demand may increase premium money paid by organic farmers.

7.3 Biofuels and Bioenergy

The use of industrial crops to create biofuels and bioenergy has been shown to have positive effects on the environment and climate. A renewable energy source, these plants may be used to generate heat, gas, and fuel for other processes. Biofuels and bioenergy may be created by a wide range of processes, such as combustion, gasification, pyrolysis, fermentation, and torrefaction. Biomethane, district heating networks, biomass for power production, and a variety of first-generation transport fuels (ethanol, biodiesel), are only a few examples of these technologies that are already available to the public (ethanol, gasification and pyrolysis from the lignocellulosic raw material). Nonetheless, many specialists and politicians recommend a hierarchical sequence in which the highest value uses come first and energy consumption comes last in the "cascading utilization" of biomass.

Value and benefits from carbon sequestration are maximized in this way (Schmidt et al., 2015). Producing bioenergy and biofuels using various methods can yield products with variable commercial viability. In order to generate heat, lignocellulosic biomass is frequently burnt in furnaces, boilers, and stoves. Heating homes and household water with wood pellets, wood logs, and wood chips is a common practice in the residential sector. District heating, whose principal clients are buildings and businesses, receives its heat supply from wood chip-fueled medium- and large-scale devices like combined heat and power (CHP). There is an existing market and the technology is ready for commercialization. And burning solid biomass, gaseous biomass, or liquid biomass can produce either electricity or combined heat and power (CHP) from industrial crops. Biogas from digestion or gas from biomass gasification, as well as biodiesel, are examples of common liquid and gaseous fuels. However, only power/CHP generated by combustion and digestion is cost-competitive at commercial scale. As a result of market pressure, the conversion of industrial crops into liquid or gaseous biofuels is becoming increasingly feasible. Biodiesel and bioethanol are two biofuels that are competitive and abundantly accessible for potential usage in cars.

Existing rules limit the use of first-generation biofuels produced from food crops while encouraging the use of second-generation biofuels produced from waste or lignocellulosic biomass and third-generation biofuels produced from algae. Some methods, including gasification using Fischer-Tropsch synthesis, are now at the demonstration or commercial stage, such as biomethane, and further research is being done to produce advanced liquid biofuels like methane, solid biochar, hydrogen, and torrefied biomass (von Cossel et al., 2019). Future innovations should be held to a level of high technological reliability at low cost, with the added aim of lowering CO2 emissions.

7.4 Chemical sustainability

The fossil fuel hydrocarbons now used as the basis of organic chemistry can be phased out in favor of biologically produced compounds. Chemicals made from biogenic carbon, which can come from a variety of sources including various industrial crops, play a crucial role in the bioeconomy. Oilseeds, rich in fatty acids, might provide the European chemical industry with a source of raw materials for the production of a wide variety of products. By using a fully integrated and cost-effective cascade biorefinery system, sugar beet pulp may be processed into high-value products for use in applications such as detergents, personal care items, paints & coatings, and composites. To make bio-polyethylene terephthalate (bPET), monoethylene glycol created from sugar fermentation is combined with other components. Eventually, bPET might replace PET manufactured from fossil fuels. Resin acids found in tree resins are preferable to synthetic acids like 2-ethylhexanoic acid or naphthenic acid made from petroleum for use in paints, soaps, lacquers, and varnishes (Maurício et al., 2020).

Lignin may also be obtained from lignocellulosic crops and other industrial crops. While its primary use now is in the generation of energy, lignin's great chemical potential means it may also contribute to the expansion of the forest products industry as part of the expanding bioeconomy. As one of the most common polymers in nature, lignin is rich in aromatic compounds that may be used to make a variety of chemicals. From this perspective, lignin might be a great resource for the manufacture of potentially game-changing bio-based products. Lignin has great potential for the manufacture of aromatic monomers and polymers, but it is underused due to the challenges involved in producing pure aromatic chemicals. Benzene, toluene, xylene, phenols, hydroxybenzoic acids, coniferyl compounds, sinapyl, and p-coumaryl are only some of the basic chemical products that may be extracted from lignin with the use of newly developed technologies. Lignin may also be processed into carbon fibers with a lower environmental effect than traditional carbon fibers and other goods.

7.5 Pharmaceuticals, Food Supplements and Cosmetics

In the past decade, public interest in the use of phytocompounds as dietary supplements, in pharmaceutical, and in cosmetic products has increased. The future market potential will likely continue to expand as an increasing number of consumers opt for natural products over synthetic ones (Barbosa et al., 2020).

Several businesses in the healthcare industry may be able to benefit from the chemicals derived from industrial crops like oilseed crops, which are particularly rich in phytocompounds. Naturally occurring lipids, fatty acids, terpenes, terpenoids, flavonoids, isoflavones, cannabinoids, and phenolic chemicals have many potential use in the industry (Pascoal et al., 2015).

There is an increasing need for medicinal and aromatic plants (MAPs). The market for aromatic plants has traditionally been stable, with significant usage in the food industry (seasonings, drinks, etc.). In the case of medicinal plants, the herbalist business appears to expand due to a shift in consumer attitudes toward natural products and shifting therapeutic preferences driven by scientific research.

On the other hand, the EOs market is supported by the variety of goods, the large number of consumers (raised as a result of the aromatization of food with natural flavours), and the international trade element. The interest in growing cultivations is strengthened by the fact that many enterprises face quality and quantity raw material import issues (Moré et al., 2005).

7.6 Natural Pesticides

Natural pesticides are in high demand in the organic agricultural industry, and this business is developing and promising in developed nations. In the past decade, the entire demand for biopesticides has increased by a factor of two, indicating a strong upward trend for all eco-friendly products. Concerns about the possible influence of pesticides on the environment have grown, and stricter pesticide registration processes (EU Green Deal) have been implemented. The purpose of these new restrictions is to limit the number of synthetic pesticides used in agriculture. Some essential oils have demonstrated some herbicidal activity. They function as non-selective, contact herbicides (burn down) that offer effective but temporary weed control. Lemongrass, pine, citronella, and oregano are examples of effective herbicide essential oils. (Maurcio et al., 2020). Recent data suggest that the usage of natural product and natural product-derived insecticides continues to rise, while organophosphate sales continue to decline. Likewise with fungicides. Neem-based goods and the essential oils of Rosemary and thyme have anti-insect and anti-fungal properties, making them viable ingredients for a variety of products (Isman, 2006).

7.7 Colorants and dyes

Because of their low environmental impact and long history of use, natural dyes made from plants, insects/animals, and minerals have been put to use for many purposes beyond only textile colouring, such as cosmetics (Dweck, 2002) and culinary components (Kadolph, 2008). Some bio mordants are from plants that are known to have a high tannin content or from plants that are known to be hyperaccumulators of metals (Cunningham et al., 2011). Chlorophyll extracted from a variety of plants has also proven useful as a bio mordant in recent years. Vegetable tannins are polyphenolic compounds that are found in many parts of plants (roots, plant stems, bark, leaves, wood, fruit and fruit pods.), which can be used as colorants/dyes for many commodities.

7.8 Agromaterials

7.8.1 Natural rubber and bio-based polymers

In the beginning, plastics were made from bio-based polymers. Cellulose polymer was the first synthetic polymer and found usage as a film for cameras and an adhesive for aviation wings. Since the discovery of petroleum, their use has diminished (less expensive and easier to process).

As a result of their physical properties and vast variety of uses, bio-based polymers, often known as "bio-based plastics," have tremendous potential to replace fossil resources. Biopolymers have features that facilitate their fast decomposition. Starch, PLA (polylactic acid), and PHB are all examples of biopolymers (polyhydroxybutyrate). Bacteria that use a carbon source for synthesis, such maize, potato, and sugar cane wastes, have the potential to produce PLA and PHB. Biopolymers can soon be produced from agro-industrial byproducts thanks to the ongoing investigation into this area (Guesmi et al., 2012).

Since a few years ago, biomaterials have increased annually. Even while they currently constitute a small portion of the market (less than 1% of plastic is biobased), their market share grows annually.

Other chemicals of biological origin, such as pectin, are also being explored to produce biopolymers. Opuntia spp. is an increasing crop in the Mediterranean region and a significant source of pectin. Currently, these materials are mostly used for niche markets and specialized applications, such as bio-based polymers with an emphasis on durability, resilience, and degradability. The distinction of this sort of material through proper labelling is vital for consumers to understand the environmental benefits of these items and put them in the correct container, therefore preventing contamination of rubbish made of plastic that prevents recycling (Prabhu and Teli, 2011).

The elastomeric polymers included in natural rubber have a wide range of potential industrial applications. With regards to the bioeconomy, natural rubber is a cutting-edge and innovative bioproduct. When it comes to mechanical and physical qualities, the natural elastomer just can't be beat by synthetic alternatives. The need to discover environmentally friendly alternatives to petroleum-based products has contributed to natural rubber's rise to prominence as one of Europe's most significant raw resources in recent years. Therefore, researchers are exploring the guayule and the Russian dandelion as possible alternatives to rubber plants. Latex from the guayule tree has been studied because of its hypoallergenic properties. Surgical gloves are currently being made using guayule latex. In 2015, the Bridgestone Group manufactured the first tire made from guayule natural rubber. Throughout the whole process of creating tires, from cultivating guayule to extracting, purifying, and analyzing natural rubber to making and testing tires, the Bridgestone Group's own technologies were put to good use. Bridgestone Americas, the world's biggest tire manufacturer, and Versalis, the world's leading maker of polymers and elastomers, have entered into a strategic partnership to commercialize guayule in agriculture, sustainable rubber, and chemicals derived from renewable sources.

7.9 Bio-based composites

Materials such as biopolymers reinforced with biofibres (the most eco-friendly of which are called "green composites"), biopolymers reinforced with synthetic fibres like glass or carbon, and inorganic materials incorporating natural fibres are all included under the umbrella term "bio-composites."

Traditional plant fibres like hemp, flax as well as wood, are crucial in the framework of the bioeconomy. Composites made from these fibres find use in a wide variety of industries, including those related to transportation, food packaging, and building and construction (Fernando et al., 2015).

Nanocellulose, an engineered form of cellulose with exceptional surface area, bonding potential, and water bonding capacity, is a major development in the field. Hydrogels, aerogels, and other novel composites may be created by combining nanocellulose with organic polymeric matrices, carbon or graphene nanotubes, and inorganic components, and these combinations are the most outstanding products based on nanocellulose. Flexible electronic devices, packaging, energy recovery systems, sensors, biomedicine, catalysis, liquid crystals, filtration, cosmetics, adsorption, separation, decontamination, and even flame retardants are just some of the many places these materials may be put to use. This substance shows considerable promise as a biodegradable reinforcement for bioplastics and a potential biological substitute to carbon fiber in high-tech materials (Pires et al., 2019).

7.10 Building materials

The building manufacturing industries effects on environment accounts for around 40% of the EU's energy consumption and 36% of its CO2 emissions. The building industry accounts for over fifty percent of all extracted materials and over thirty-five percent of the EU's total trash production. Approximately 35 percent of EU buildings are over 50 years old, and nearly 75 percent of the building stock is inefficient. To fulfil the EU's energy efficiency goals, the yearly pace of building stock refurbishment must at least double. Similarly, 50 million people struggle to effectively heat or cool their houses (European Commission, 2020).

In order to reduce the carbon footprint of buildings and increase their energy efficiency, the EU must prioritize the use of bio-based materials with low embodied carbon. Potentially, industrial crops might provide a wide variety of raw materials that can be utilized in conjunction with or in instead of traditional construction components.

Common insulating and structural materials include wood and cork. Insulating matting made from flax or hemp fibre, bear-loading hemp bricks, in-situ hempcrete casting, prefabricated straw walls, etc. While certain materials do need further research and development, others are already in broad use and have shown to be more effective at controlling temperature and humidity than traditional products.

7.11 Fibres used in textiles

Increasingly, natural fibres are regarded as a superior option to synthetic fibres, which utilize non-renewable inputs (fossil or mineral resources), have a shorter lifespan, and contribute to microplastics pollution. A partial decarbonization of the textile industry is feasible, despite the fact that it would be impossible to totally abandon synthetic materials with the available technologies. Increasingly severe environmental regulations and a heightened consumer consciousness are the two elements driving the transformation that presents promising prospects for natural fibre.

However, the selection of natural fibre is not solely motivated by environmental concerns. Most, if not all, natural fibres offer special properties that are frequently superior to their synthetic counterparts, with price being the sole factor impacting demand and supply thus far.

As an example, long hemp fibres have desirable properties that make them useful in a wide variety of contexts. They can withstand a lot of wear and tear, are antistatic, move moisture quickly, absorb heat well, offer protection from the sun's rays, and fight mildew and bacteria (Fernando et al., 2018b).

Today, synthetic fibres made from fossil fuels (65%) outnumber cotton (26%) and other fibres (11%). In fact, just 2% of all feedstocks is made up of recycled materials. Considering the social difficulties in developing nations and the high input levels in conventional agriculture that plague the global cotton value chain, it's clear that alternative natural fibres have tremendous unexploited potential.

7.12 Existing best practices and potential resolutions

7.12.1 Biorefineries

Since the inception of the EU Research Framework Programme, the European Union has financed research into industrial crops. Several research initiatives have been carried out to investigate the potential of numerous new crops for the manufacture of bio-based products and bio energy. Investments in research have led to the establishment of biorefineries and the mass production of fibre, biofuel, electricity and heating fuel in Italy.

CREA studied the Matrica Biorefinery in Porto Torres (Sardinia) to develop the integrated supply chain for the cardoon (Cynara Cardunculus) growing in arid regions for use in the biorefinery's production of biofuel. A leading producer and distributor of petrochemical products and a forerunner in the bio-plastics business have joined forces to form Matrica Biorefinery as a 50/50 joint venture. The joint venture's objective is to transform the Porto Torres petrochemical facility into a green chemistry complex that will produce a wide range of cutting-edge products made from vegetable raw materials through the use of a streamlined agricultural production chain (Fernando et al., 2010).

Matrca creates a wide variety of novel intermediates used in many different industries, such as bio-based plastics, bio-lubricants, plant protection, home and personal care products, additives for the rubber and plastics industries, and food fragrances. To accommodate the many bio-based products on the market, a logistics system was developed with a primary focus on the separation of seed collection, pappus collection, and lignocellulosic biomass collection in the field. In the wake of prototype harvester development, commercial harvesting equipment based on the prototypes has been used to cultivate 400 ha of cardoon (Fernando et al., 2010).

Industrial uses for various oleaginous dryland crops grown on Sardinia's marginal land are considered. Considering the fields' precarious setting, creating sustainable agricultural practices and supplying networks that minimize costs without sacrificing environmental standards are applied.

Multiple bio-based goods are produced in Porto Torres, Sardinia, Italy. All sorts of bio-based products, with uses in a number of different fields, are made using vegetable-based feedstock. The rubber business is just one of several that makes use of biopolymers, plasticizers, biolubricants, biofibres, cosmetics, personal care, plant protection and cleaning additives.

8. PROSPECTS OF FUTURE INDUSTRIAL FARMING

This section demonstrates a comprehensive review of the general knowledge requirements and potential techniques of information delivery to improve future potential of industrial farming. The recommendations are presented considering several European situations observed and the available resources. Industrial crop agronomy is relatively young compared to traditional agriculture. To accomplish the change, growers of industrial crops need clear information, particularly on how to diversify sustainably so that food crops are not displaced. An extensive collection and information is accessible for several crops, however there are still knowledge and delivery gaps.

8.1 Prior to sowing

A marketable crop that can be successfully grown in the farmer's soil is a priority at this point. It is crucial to evaluate the soil in order to determine the best fertilizer requirements, soil moisture profiles, etc., for a certain crop. Agronomists and experts can benefit much from guidance and examples at this stage. In this regard, a tool like the MAGIC database of crops suitable for marginal environments might prove very useful.

It is essential to know where plants come from. Advisors and scientists can now help farmers. It would be fantastic to have access to a database of disease-resistant, high-yield plant material. There have been several investigations into willow and other industrial crops. There is a large body of information on the features of various willow species and how they develop. Guidelines for soil preparation, planning, and planting dates are all crucial resources. Again, there are excellent crop planning recommendations available for a wide range of crops. Giving people the resources and information, they need to do things like grow food on polluted or marginal land, combine industrial crops with food crops, use agroforestry methods, etc. is a crucial aspect of this transfer of knowledge.

8.2 Planting and cultivating crops

New crop growers face a significant challenge in securing the essential equipment. Farmers need reliable data on the accessibility of crucial machinery. In addition, understanding the extent to which current agricultural machinery may be modified is essential to the sector's profitability. Instructions for preventing the spread of weeds and other pests while planting crops. Integrated pest management (IPM) in agricultural and forestry settings is the subject of a great deal of current study. This will be crucial for sustainable industrial crop development, together with understanding of organic crop growth (Pogrzeba et al., 2017). Some industrial crops have a physiology very different from that of more common crops. Information on how to adjust harvesting equipment for optimal performance across a wide range of crops is crucial for minimizing waste and maximizing efficiency. Advisors, business partners, and academics have accumulated a wealth of expertise in these areas, and they are willing to share it with newcomers.

There may be a wide range of ideal harvest times for different types of industrial crops. Variations in the concentration of vital plant components throughout the year necessitate selective harvesting to maximize harvests (e.g. salicylic acid in willow crops peaks at various times of the year). Hence, detailed awareness of crop physiology might increase the potential for growing sustainable industrial crops.

8.3 Selling and marketing

Knowledge of the market, market demands, and entry points is essential for every business. Access to information about emerging processing procedures and technologies is critical to ensuring continued productivity in the industrial agriculture sector. If farmers wish to enter the processing industry and sell a finished product, they require knowledge of the relevant laws, regulations, and business practices. Farmers have tremendous potential to increase their profits by diversifying into the processing industry. One of the most important ways to aid farmers is to make it easy for them to receive clear instructions and information on topics like market access, business establishment, legal and regulatory requirements, and more (Codex Alimentarius 2004).

Cooperation allows for economies of scale and a coordinated approach to marketing, logistics, and sales, all of which may be assisted by sharing information across institutions and countries. When it comes to exchanging information and goods related to forestry and bioenergy crops, biomass trade hubs across Europe have shown to be especially useful. They have served not just as centralized sales platforms, but also as technical demonstration pilots. Information about quality criteria and certification pertaining to sustainability, traceability, and standardization, amongst other things. The conveyance of information between European farmers/processors, advisers, and researchers has room for improvement. When it comes to new innovations, developing knowledge, or production chains that may be adjusting to unique operating circumstances, farmer advising services are less effective. (Galasso et al., 2016). It can be difficult to move knowledge from research to advisers and farmers/processors and vice versa. Scientific communication is a difficult process that requires both scientific expertise and communicative proficiency. Scientists often have basic standards for conveying their findings to the scientific community that may not apply to advisors or farmers. Therefore, a more widespread system with transparency is required to bridge the gap between scientists and farmers.

8.4 Innovation Requirements and Possible Operational Groups

As an overview of what is expected of Operational Groups and Innovation Needs, consider the following:

- It's not easy to persuade farmers to start growing new crops. To be successful, farmers need information and guidance on how to grow industrial crops. More people are willing to give a crop a try that has been more researched of its agronomic properties as it becomes more commonplace.

- The market must have confidence that it is getting a superior product. A supply chain breakdown awaits if farmers do not conform to a predetermined quality level.
- Because of their lack of expertise, advisory firms are cautious to give advice on new crops.
- Advice from agricultural experts is essential for unlocking the full potential of industrial crops.

Consultants regularly suggest farmers to groups or companies working with industrial crops like energy crops, providing advice on crop variety, harvesting, etc. This means they are rarely submitted to the country's Agricultural Knowledge and Innovation System (AKIS). The networking architecture might be improved by first referring farmers of industrial crops to their country's AKIS, and only then connecting them with cultivator groups and associations.

Training mechanisms for advisers are required. Advisory services must comprehend both the agronomy of crop production and the markets connected with a particular crop. If a consultant thinks and has faith in cultivating a crop, this will stimulate a farmer's confidence in that crop. Advisory services must be experienced working with unfamiliar plant species. Europe's research administrations should use the chance to devote more of their research resources toward achieving national goals within the EU framework, while simultaneously guaranteeing that knowledge may be adapted (where possible) for the mutual benefit of other European regions. Innovative techniques such as agroforestry, intercropping, unique crop rotations, utilization of marginal land, etc., can be used to successfully integrate industrial crops into the present agricultural infrastructure.

This information on the combination of intensive systems requires extra advisory help. The current source of best industrial crops practice guidelines is compiled, updated, and made universally understandable; missing crops are identified, and new guidelines are designed; farmers and advisors are surveyed to determine what information they would like to see included in guideline documents and how they would like to receive it; and the entire process is standardized (online, physical copies, webinars etc.). (Tomi et al., 2018) As a strategic technique for creating and disseminating data on bio-based industrial production, forming a "Bio-based Leadership Team" inside Advisory Services and Research may be quite useful. Tasks that the Team could handle include:

To determine the most pressing initiatives that can be implemented quickly and have a significant impact on expanding the production of renewable energy and other bio-based products derived from agriculture without displacing food production; Develop an overarching implementation strategy that increases the engagement of the value chain players by creating an inventory of internal and external persons and facilities that might be utilized to plan and execute projects, including other actors of the value chains and farmers (Struik et al., 2000). Establishing nodes in the industrial agriculture supply chain analogous to the well-established biomass trade centre. These hubs might learn from traditional farm cooperatives that have found success and use economies of scale. Moreover, cooperatives may play the role of knowledge transfer centers, providing easy access to all the rules and technical data needed to conduct industrial agriculture. Create a group of specialists comparable to the Focus Group with the continuous goal of disseminating research in the field and achieving the status of technical panel. The Agricultural Knowledge and Innovation System (AKIS) is a crucial instrument for advising farmers on optimal practices. They are specialized for the region in which they are located and are intimately aware with local characteristics.

The local advisory service can provide farmers with valuable technical assistance. However, AKIS staff members are generally more familiar with the region's traditional crops than they are with the cutting-edge industrial crops being created via various research efforts. They are also often uninformed of the vast untapped market potential in the agricultural industry, the companies investing in the bioeconomy, and the many partners involved in the countless research projects. Recruiting a team of AKIS with expertise in industrial crops would be useful for the region's many stakeholder groups (Struik et al., 2000).

Making educational resources that may be used wherever throughout Europe. Each region's acceptable crops can serve as examples for the fundamental modules that could be applied to any industrial crop. These modules include a decision matrix, logistics development, locating suitable land, figuring out how to avoid conflicts with food production, conducting a supply chain analysis, and so on. Earning a credential in industrial/innovative crops that is recognized throughout the world will help build the self-assurance and skills necessary to spread interest in the area across Europe.

Find out more about the pioneers who are making strides right now in that area. Find out what people who matter to your bio-based business say are the biggest challenges they face. Whether or not the study or advise service solves every issue facing the sector is unimportant. This work will lay the groundwork for future studies, business expansion, and legislative solutions involving the supply chain. Research aimed at fixing problems should be prioritized. You should include implementation in your strategy in a manner that not only defines the tasks that organizations will do (extension and research activities), but also how their accomplishments will contribute to increased output, increased profits, and better management of scarce resources (Struik et al., 2000).

Furthermore, it is critical to assess the potential role of research in informing the development of public policy. Strategic plans that include partners need the establishment of primary responsibilities and functions for each section of the supply chain. Principles must be established for the safekeeping, distribution, and acknowledgement of intellectual property and related works.

8.5 Dissemination and scientific communication

One of the responsibilities of researchers is to pick the most appropriate tools, tactics, and locations for directing the flow of information in the most efficient and effective manner. Audience is a crucial factor for researchers. In essence, two macro-types of information diffusion may be distinguished. Publishing in peer-reviewed journals with high impact factors (IF) is the standard method of making scientific findings public within the scientific community. This may also be achieved via the use of "uncensored research items," which are not included in the ISI database despite their significant scientific or cultural value. This kind of disclosure uses a particular terminology and adheres to well-defined, somewhat strict rules and regulations (Struik et al., 2000).

Although measuring the "social impact factor" might be challenging, much of the process of disseminating information requires adaptation to a much wider and more diverse audience. This suggests that the standards to follow and the setting in which it can function are fundamentally different, as it is possible that no "indexed research commodities" are employed under these conditions. To solve this problem, it is needed to employ scientific publications in scholarly journals, technical and popular publishing works, conferences, meetings with supply chain or agricultural organizations, seminars, training courses for sector workers, and even the mainstream media.

8.6 Guidelines for researchers

In order to speed up the process of bringing new discoveries or improved technologies and processes to wider commercial use, research institutions will need to construct research and development techniques. Rapid adoption of research and technology for producing bio-based products can be facilitated by creative public-private partnerships. When making decisions, make sure there are obvious routes to commercialization. For maximum impact and rapid recognition, set short-term goals (those with a deadline of less than five years).

Those working on technical advancements should collaborate with businesses that will invest in and benefit from their creations, and all innovations should have a clear commercial application. Establish relationships with groups that are dedicated to bringing technologies to market and growing enterprises. Agricultural research institutes may not have worked with some non-traditional stakeholders or consumers in the past, but they should consider commercialization an extension of extension and outreach. Taking this course of action would provide more recognition and financial benefit to research and consulting organizations who are dedicated to recycling agricultural waste into useful renewable energy and biomaterials.

8.7 The advantages of using an Integrated Crop Management System are

- Response to society and market demands for environmental preservation and the eradication of synthetic.
- There is a lot that can be learned from Italy's approach to sharing scientific discoveries for the bioeconomy.
- Around 150.000 hectares of cotton are farmed according to this protocol in Greece at present, thanks to the widespread adoption of the Integrated Crop Management System
- With the help of the Integrated Crop Management System in Cotton, the cotton ginning sector is now able to produce cotton wool that complies with the international STANDARD 100 by OEKO-TEX®, therefore increasing the value of the whole production chain.
- Reducing the negative effects of farming on the environment.

In response to the urgent need for research in Italy to support the shift from sugar beets to energy crops, The Scientific Support for Agricultural Conversion towards Industrial Crops project was started. By completing this work, it is hoped that:

- Assist interested parties by employing scientific methods to resolve the issues they have raised.
- To better pick energy crop species, variants, and growing techniques for the varied environmental circumstances, it is important to
- Share the most recent findings of scientific research among the stakeholders of the bio economy sector.
- Ensure that cutting-edge technological advances that are crucial to the functioning of supply networks are made available to farmers.
- Instruct farmers on how to put into practice the newly developed technologies, therefore spreading them far and wide.

8.8 Application of latest innovations

There has been a request for the latest innovations in technology to help with the growing of herbaceous and arboreal industrial crops and the creation of harvesting prototypes, without which it would be impossible to provide enough biomass to sustainably feed the processing plants. Fast-growing tree species (eucalyptus, poplar, robinia) and herbaceous oil plants (soya, sunflower, rapeseed, Brassica carinata) were also investigated (fibre, hemp, common reed, sorghum). Participating researchers were required to establish a communication plan to guarantee that the project's findings reached not just the scientific community, but also agricultural and mechanical business owners and the agro-bio economic industry.Scientific articles in peer-reviewed journals, technical publishing publications, conferences, meetings with industry or agricultural organizations, seminars, and most importantly a website where all the innovations developed were uploaded were the preferred methods of dissemination used by the Panacea Project's researchers.

The Agronomy section includes descriptions of successful cultivation methods, the findings of varietal testing on all Project species, the harvests from different planting strategies, and the results of any genetic enhancement efforts. The Mechanization subcategory contains descriptions of technical advances made and new mechanical systems developed, as well as the outcomes of the quality and performance of work of the prototypes generated. Harvested biomasses for energy crops, as well as agricultural and forest waste, are the subject of studies that publish their findings under the post-harvest subcategory (Struik et al., 2000).

Moreover, Italy has developed three Experimental Demo Centres for agro-energies, all with the same goals in mind: to facilitate the spread of technological innovations to end users and to bring together the many actors in the agro-bioeconomy value chain (industry, mechanical companies, agricultural entrepreneurs, contractors). The Centers collaborate with other organizations to perform scientific and experimental research as well as provide tours, training seminars, topic demonstration days, internships, degree theses, doctoral theses, and post-graduate specialization courses. Since it was developed in response to specific needs expressed by industry actors and with the purpose of providing scientific and technological aid for the creation of new bio-economy supply chains, the Italian experience can serve as a model for the dissemination of knowledge.

9. DISCUSSION

One of the main benefits of industrial agriculture is its ability to produce large quantities of food at a relatively low cost. This is achieved through the use of advanced technologies, such as genetically modified crops, mechanization, and the application of synthetic fertilizers and pesticides. This enables farmers to increase their yields and reduce their costs, thereby making their products more affordable and accessible to consumers.

Another advantage of industrial agriculture is its ability to improve the consistency and reliability of food production. By using standardized practices, farmers are able to produce crops that are uniform in size, quality, and maturity, which is essential for meeting the demands of the global food market. This is particularly important for crops that are used for industrial purposes, such as sunflower, soybeans, and cotton, which require consistent quality to meet the needs of food manufacturers and other end users. However, industrial agriculture also has its drawbacks. One of the most significant challenges is its impact on the environment.

The large-scale use of synthetic fertilizers and pesticides can have negative effects on soil and water quality, as well as on wildlife and other non-target species. Additionally, industrial agriculture often relies on monoculture crops, which can reduce the diversity of plant species and the resilience of the ecosystem. Another issue with industrial agriculture is its impact on local communities. In many cases, large-scale industrial operations can displace small-scale farmers and disrupt traditional agricultural practices, leading to social and economic consequences. This is particularly true in developing countries, where the expansion of industrial agriculture can lead to land grabs and the displacement of local communities. Despite these challenges, industrial agriculture remains an important component of global food production, and it is likely to continue to play a key role in meeting the food needs of a growing population. To ensure its long-term viability, however, it is important to address the environmental and social impacts of industrial agriculture and to explore alternative approaches that are more sustainable and equitable.

One approach to improving the sustainability of industrial agriculture is to promote agroecological practices. This involves integrating natural processes and systems into farming operations, such as using cover crops, crop rotation, and biological pest control methods. By adopting these practices, farmers can reduce their dependence on synthetic inputs, improve soil health and fertility, and increase their resilience to environmental and economic challenges. Another important factor in the sustainability of industrial agriculture is the development of new technologies and innovations. For example, advances in precision agriculture and digital technologies are enabling farmers to better manage their resources and increase their productivity.

These technologies can also help farmers to reduce their environmental impact, by providing more accurate and efficient methods for applying inputs, such as water and fertilizer. To achieve a well-functioning exploitation of industrial crops, state policies should also support the sector to structure itself at the local, national, and European levels and to build fair and well-functioning commercial relationships between the various corporate players. As a first step in this approach, the construction of collective or individual contractual agreements between primary processors and farmers may be facilitated by the development of Producers Organisations (POs) and Associations of POs (possible Operational Group idea).

Interbranch Organizations (IBOs) have the ability to play a pivotal role in facilitating fair market development and remuneration for all participants. In particular, they will look at the possibility of steering transnational IBO development and cross-border collaboration. Stakeholder organizations (including POs, APOs, and IBOs) should have a greater voice in policymaking at all levels and be better connected with one another throughout Europe. This might facilitate the interchange of market knowledge, new solutions, and best practices, as well as the monitoring of the market and the rapid response to market disruptions and opportunities, in close coordination with governmental authorities. Focus Group specialists believe that legislative and regulatory instruments are crucial for maximizing the potential of Europe's multi-purpose crops. The adoption and transformation of multifunctional crops are intrinsically connected to the development of a European market for bio-based goods. The establishment of product and production standards, together with hard and soft policy instruments capable of expanding the market, is necessary for its continued growth.

Product standards would facilitate the incorporation of novel raw materials into conventional production systems. They might be set by EU law or by private standards developed, controlled, and monitored inside the industry with the assistance of sector-specific organizations. The introduction of new product standards through particular legislation or the amendment of the Eco-design directive might be the result of rigorous policy initiatives. The establishment of uniform sustainability certification programs throughout the European Union to ensure that like goods can be easily compared and that the full effects of each stage of production are understood; Substantial monetary or tax benefits for the acquisition of ecologically sound bio-based goods; The Commission will incentivize carbon sequestration, multi-purpose crop growing, and land maximizing.

Investments, furthermore, are critical to the development of modern and efficient value chains. An accurate assessment of the potential of the various production areas and a map of the requirements of the territories would be helpful in increasing cross-border collaboration. To encourage investment in multifunctional industrial crops for decarbonizing the manufacturing sector, sustainable finance arrangements should be revised. For commercial projects to grow, public-private partnerships should be encouraged. Investments from both the public and private sectors should be made to bring previously missing processing lines to EU territory (such the spinning of hemp fiber or the processing of miscanthus/willow for electricity production).

More money is needed for things like introducing modern monitoring systems, making it easier to transfer intellectual property rights, and conducting research and development. It is likely important to undertake a mapping of extra particular requirements to better adapt the investment strategy to the unique realities of European land and the various value chains.

One of the main challenges to the development of multifunctional crops as a sustainable business model is the absence of market confidence, which slows down investment and innovation. There is a major impact on this position due to a lack of information across the value chain about the opportunities presented by these crops, the technology needed to optimize their potential, and the commercial partnerships essential to leverage these prospects.

Networking and matching are essential to removing roadblocks to innovative ideas and methods. Trade platforms may be the most convenient and time-saving approach to network with companies across Europe, including those that supply goods and services. The lack of facilities for processing energy crops like willow and miscanthus and for spinning hemp fibers would be alleviated. As an added bonus, it might facilitate communication amongst farmers who could mutually profit from collaborating on the acquisition of necessary equipment and services. Having an understanding of the market is also important for businesses, since this allows them to anticipate consumer demands and adjust production accordingly.

It is necessary to implement data gathering methods based on the idea of market transparency, as well as communication platforms that provide all market participants access to information, so ensuring opportunity equality. Data must be standardized, of high quality, and accessible to the public. Establishment of market analysis tools, maybe in the form of a European-level Market Observatory fed by contributions from farmers, processors, and merchants. Informally (conferences, networking, internet dating, etc.) or formally (meetings, etc.) contacts between business operators and institutions should be facilitated (civil dialogue groups, interinstitutional task forces, etc.). They should seek to foster a democratic discourse, efficient policymaking, and open communication with operators.

In the spirit of guaranteeing fairness, distribution efforts can be supplemented by advising services, with a focus on aiding farmers and small and medium-sized enterprises. In addition to assessing and addressing training requirements via specific programs (Erasmus and synergies), training needs should be evaluated. In order to establish consumer trust and further increase the sustainability of products, it is necessary to implement traceability systems that rely on cutting-edge technology and are able to translate trustworthy information regarding product quality and environmental impact to the market.

Specific considerations are required for the sustainability factors. Short supply chains should be favoured by organizing them in local/regional clusters and integrating them as much as feasible into existing economic systems, with a focus on complementarity and subsidiarity. In consultation with operators and scientists, sustainability guidelines should be established to produce raw materials and all subsequent transformation steps. To reach this purpose, the current private or national norms must be reviewed. The circularity of products requires special study. Implementing recycling and composability rules and pursuing a zero-waste plan are required.

Due to the importance of land utilization, particularly in light of the escalation of adverse weather conditions, industrial crop surfaces should not directly compete with food production. Complementarity of crops, soil-enriching agricultural methods, and adaptability to fluctuating market conditions might be utilized to maximize land and resources.

The ecosystem services supplied by the cultivation of multifunctional crops should be acknowledged, maybe remunerated, and facilitated through payment structures.

New economic models can only survive in the long run with the help of digital technology. Future opportunity enhancers and entrance requirements may include smart farming, blockchain technology, and artificial intelligence for mechanical processes. However, operator IT competence is often low, and widespread technological solutions inside the Union are uncommon. This is especially true in more remote areas that lack the basic information technology infrastructure needed to support a fast internet connection. Funding and advisory services will be essential to creating a level playing field for European businesses.

EU funds for research and development should be utilized to further investigate the possibilities of industrial crops with various applications, since they offer a long-term and sustainable economic recovery for the EU.

Financing is crucial at every stage of a project's lifecycle, from the research lab (high risk/poor money) through investment deployment (low risk/plentiful money), with scaling up being the most challenging. Ideally, project results will be tangible, replicable, or flexible.

It is essential that people talk to one another about what works and what doesn't. In order to raise awareness among retailers, stakeholders, industry leaders, and other retailers, national and EU public authorities should provide assistance and organise exchange opportunities at the level closest to development and production. Take use of these occasions to teach opinion leaders, merchants, and other interested parties about your field.

The chemical industry's adoption of essential oils, extracts, and oils as a substitute for products made with fossil fuels; The accumulation of knowledge concerning environmentally friendly options for extracting, recovering, and processing compounds with added value; Agriculturally appropriate drying methods for biomass.

- Drafting and ongoing revision of energy crop recommendations based on the most accurate information available from agricultural advisory and research networks.
- Developing best practices and instruments for facilitating cooperation among stakeholders in a particular value chain; Evaluating the condition of biomass harvesting, drying and storage research in the EU and providing recommendations for Member States.
- Diverse research with the aim of attaining higher yields, superior product quality, less input dependence, etc.
- Why EU funding should be utilised to further develop the potential of industrial crops with many applications, since they offer a sustainable and long-term economic recovery for the EU.

International deadlines for fulfilling renewable objectives for greenhouse gas emission reductions, as well as European Union programs such as the Farm to Fork Strategy, are a key motivation for the development of agriculture-based industrial cropping solutions. Farmers, processors, and consultants must have a lot of trust in the agronomy and markets of industrial crops to increase their adoption during times of limited or non-existent fresh supplies. The expansion of the bioeconomy relies heavily on the free flow of information among all stakeholders. Statistics were gathered by the boatload on sustainable industrial crops. The EU must do a better job of disseminating this data, together with the results of relevant industries' experiences and academic studies.

Finally, the success of industrial agriculture will also depend on the development of strong partnerships between farmers, government agencies, and other stakeholders. This includes the development of policies and programs that support sustainable agriculture, as well as the cultivation of partnerships between farmers and their communities, customers, and suppliers. By working together, these stakeholders can help to ensure the long-term viability of industrial agriculture and to promote sustainable and equitable food systems.

10. CONCLUSION

Industrial crops, also known as non-food crops, are grown for a variety of purposes including biofuels, textiles, and industrial materials. These crops have the potential to provide a sustainable source of energy and raw materials for various industries.

One of the most well-known industrial crops are corn and sunflower, which is used to produce ethanol for biofuels. This has the potential to reduce dependence on fossil fuels and decrease greenhouse gas emissions. Additionally, industrial hemp can be used to produce a variety of products including textiles, building materials, and biofuels.

However, there are also concerns about the impact of industrial crops on the environment. The large-scale cultivation of these crops can lead to deforestation, soil erosion, and loss of biodiversity. Additionally, the use of chemical fertilizers and pesticides can have negative effects on water and air quality.

In order to address these concerns, it is important to develop sustainable farming practices for industrial crops. This can include using cover crops to improve soil health, reducing the use of chemical inputs, and promoting crop rotation. Additionally, it is important to consider the potential impacts of industrial crop cultivation on local communities and to work with them to ensure that the benefits of these crops outweigh the potential negative consequences. This can be achieved by implementing and modifying industrial agricultural practises in a sustainable approach.

This approach recognizes that industrial agriculture can play a critical role in meeting the food needs of a growing population, but it also acknowledges the environmental and social impacts of this method of farming. As a result, sustainable industrial agriculture seeks to optimize the benefits of industrial agriculture while minimizing its negative consequences.

One of the key components of sustainable approach of industrial farming is the adoption of environmentally friendly practices. This includes the use of conservation tillage, cover crops, and reduced pesticide and fertilizer use. These practices help to protect soil and water quality, reduce the impact of industrial agriculture on wildlife, and conserve natural habitats. Additionally, this approach often incorporates the use of renewable energy sources, such as wind and solar power, to reduce the energy consumption of farming operations.

Another important factor is the promotion of biodiversity. This involves encouraging the use of crop rotations and intercropping, as well as the conservation of native habitats and wildlife. These practices help to maintain the resilience of the ecosystem and to reduce the impact of pests and diseases on crops. Additionally, the promotion of biodiversity can help to support the livelihoods of local communities by providing a more diverse and sustainable source of food, fibre, and fuel.

In addition to its environmental benefits, sustainable industrial agriculture also addresses the social and economic impacts of industrial agriculture. This includes the protection of small-scale farmers, the promotion of fair trade and equitable distribution of resources, and the support of local communities. By addressing these issues, sustainable industrial agriculture can help to ensure that the benefits of industrial agriculture are shared by all members of society, including those who are most vulnerable.

One promising area of innovation is precision agriculture, which uses digital technologies and data analytics to optimize crop production and reduce waste. For example, precision agriculture can help farmers to accurately target the application of inputs, such as water and fertilizer, reducing the number of resources used and improving the efficiency of farming operations. Additionally, precision agriculture can help farmers to better monitor their crops, detect pests and diseases early, and respond quickly to changing conditions.

Another important aspect of this sustainable industrial agriculture approach is the use of regenerative practices. This includes practices such as agroforestry, regenerative grazing, and conservation tillage, which can help to build soil health, improve water retention, and promote carbon sequestration. By adopting these practices, farmers can not only improve the sustainability of their operations, but also contribute to the health of the planet as a whole.

The next crucial part of sustainable development is transitioning to a bio-based economy. The depletion of fossil fuels can be slowed by relying on renewable resources as CO2-neutral raw materials for sustainable industrial production in the future. Each situation calls for a different chain integration method. Food safety, "green" energy production, and the production of sustainable non-food commodities for commerce must be addressed with waste management, recycling, and disposal. The public, government, and private sectors all need to work together on emerging initiatives for them to succeed.

It is the necessity to replace fossil fuels that drives the growth of industrial crops, bio-based economies, and bioenergy. The removal of harmful inputs and impurities is also driving research and development of bio-based solutions made from industrial crops. It is also necessary to import fossil fuels because there are no domestic sources of non-renewable fossil energy. Since agriculture is an energy user, the potential of creating an industrial crop supply from underutilized European land is appealing for farms and rural communities that rely heavily on non-renewable energy sources.

However, despite these advances, there are still many challenges that need to be addressed in order to achieve sustainable industrial agriculture. One of the most significant challenges is the need for greater investment in research and development, both to support the development of new technologies and to better understand the environmental and social impacts of industrial agriculture. Additionally, there is a need for greater public awareness and education about sustainable agriculture, as well as increased government support for sustainable agriculture initiatives.

In conclusion, sustainable industrial agriculture approach is an important step towards a more equitable and sustainable food system. By balancing the need for increased efficiency and productivity with the protection of natural resources and the welfare of communities, sustainable industrial agriculture can help to ensure the long-term viability of industrial agriculture and to promote a more sustainable and equitable food future.

11. FUTURE RESEARCH IN INDUSTRIAL AGRICULTURE

11.1 Identify options for intercropping MAPs according to regional circumstances.

To achieve high-quality, low-environmental-impact value chains, one operational group focuses on specialized industrial crops like hemp fibres and other natural fibres. Make a hub for the storage and processing of organic crops like hemp that may be used to demonstrate the success of organic agricultural methods to sceptical outsiders. The Operational Team is proving that contaminated soil may be used for large-scale agricultural purposes. Think about changing the land use designation to "non-food industrial crop land" to ensure its continued usage in the production of bioresources. The possibilities will range widely across the member nations of the European Union. It's important to take into account both the amount of pollution in a specific area and the types of crops grown there while deciding which Phyto control strategy to employ. Demonstrate that the region is secure and that contaminants have been contained.

Biomass crops (poplar, willow) might be grown on marginal land to make farming there more lucrative, and circular economy models (biomass ashes, wastewater treatment sludge, biogas digestate) could be implemented to make use of the water's nutritional richness. Measurement and utilization of poplar, willow, and other industrial crops as carbon capture and storage vehicles. Farmers, processors, academics, and financial experts may all be brought together in an Operational Group to assess the actual value of ecosystem services, carbon accounting, and the environmental advantages these crops could contribute in the battle against climate change.

11.2 Dissemination Recommendations Develop biomass trade coordination centres

Biomass trading centres can serve as a centralized site for the storage, marketing, and sale of energy crops, allowing for increased efficiency because of economies of scale and a steady supply to end users. In addition, they might be hubs for providing advisory and skill-building services to local communities and highlighting research shortages. Help get the word out and demonstrate the viability of new industrial crops in regions where there is a dearth of both scientific competence and market development. These organizations' primary goal would be to facilitate communication between key stakeholders (including agronomists, farmers, researchers, advisors, and processors) to ensure that information is shared effectively and that no unnecessary effort is wasted.

11.3 Practice-based research and innovation requirements

There is a need for further research into the following areas so that we can foster innovative, productive, and environmentally friendly industrial crops and markets.

11.3.1 General

Improving the network between farmers, processors, advisors, and research organizations is a problem for the industry. Focus Group 40 has begun to address this issue, but further effort is necessary. Several further proposals from Focus Group specialists include Plan for enhanced cooperation among all stakeholders.

Models for demonstrating and advancing research on crop use for several markets. Below are examples of two crops that might be utilized and the concerns that must be addressed: Multipurpose hemp use (whole plant method) as a real-world illustration of the area's expansion. Among the issues that must be addressed via study and practice are:

- Shortening supply chains.
- Creating cutting-edge technology (industrial scale).
- Supporting investments in new ventures, such as fibre processing, initial processing, and textile (technical + apparel) processing (yarn spinning, etc.)
- Supporting local procurement
- Developing facilities for fibre processing.
- Identifying seed types and cultivars for fibre & seed.
- Overcoming legal obstacles regarding flower/leaves (flowering-/fruiting tops). IP-based network and database transfer.
- Involving and winning the cooperation of policymakers, industry players, investors, and others.

Besides its use as a filler or reinforcement in the production of energy, miscanthus is also put to use in the construction industry, papermaking, and the creation of cellulose-based products like pulp and paper. Superior horse bedding and eco-friendly composite materials for uses like the production of biodegradable polymers and fibres for automobile parts are two other examples of these materials' versatility. The summarized the main challenges of cultivating miscanthus for different applications as follows.

- because certain areas lack adequate processing facilities and secure buying programs for farmers.
- variation in the price of products as a result of market conditions.
- Price fluctuations caused by the varying quality of crops.

Scaling up the requirements of the bio-based business, including the testing of large-scale crops (1,000 to 2,000 ha), can expose a number of difficulties that may be overlooked at lower research stages. The expansion of these study plots will identify the challenges and mitigation strategies required for the effective incorporation of industrial crops into present practices. Issues such as land mobilization, political and local community concerns, and (bad and positive) implications on biodiversity can be discovered prior to the release of crops. (Grebenicharski, 2016)

More study into the phytomanagement potential of industrial crops in field test demonstrations would be a valuable endeavour to better highlight the environmental and ecological advantages that industrial crops may deliver. Experiments on a larger range of contaminated soils in the field would generate an useful database for a wide range of European soils.

The impact of industrial crops on wildlife populations needs more in-depth research. How may biodiversity be enhanced through the planting and management of industrial crops? Agronomy standards for industrial crops should encourage biodiversity, but this cannot be assumed; further study is needed.

Life cycle analysis of industrial crops like hemp is needed to achieve full confidence in reported information. Collect data to be able to calculate the CO2 footprint of hemp, miscanthus, and willow production for industrial products from beginning to finish. To prove the feasibility of industrial crops from both an environmental and a financial aspect, an examination of life cycle costs would also be highly valuable.

Research is necessary to validate the quantity of carbon captured by industrial crops. Though some organizations are already engaged in this work, more must be done to build connections and ensure efficient collaboration across disciplines in order to properly account for a wide range of crops. When growing industrial crops, it's important to evaluate how different cultivation practices and crop rotations affect carbon sequestration and storage. For carbon instruments to be effective, farmers and landowners need to employ practical approaches. Carbon credits and counts might be a financially beneficial inducement for farmers to grow industrial crops if the terms are well stated.

11.3.2 Agronomics

There is a need for research into the measurement and enhancement of industrial crop earnings on marginal land. Break even costs, whole-plant strategies (double and triple use), and the identification of high-value end applications were analysed to determine whether low-yielding organic crops could be grown profitably on marginal land. Find out how much outside aid the market needs.

- Research on business models, such as the employment of different kinds of technologies, propagation tactics, and the usage of nutrient-rich garbage, etc.

- The study of contaminated areas' flora with the purpose of developing new types of industrial crop selection and breeding programs may gain from the identification and cataloguing of existing flora or indicator species that thrive on contaminated regions.
- It is important to study intercropping and catch cropping to increase the acreage available for industrial crops without displacing food crops.
- Create innovative, long-term methods of farming that can also benefit ecosystems, such catch-cropping, relay-cropping, and intercropping.
- Mechanization, the life cycles of main and catch crops, agronomics (such as species rotation and association), etc., may lead to innovations and optimizations in growing schemes.
- An evaluation of existing research on industrial crops to identify research gaps that must be filled. Work on new opportunities - with the appropriate modifications (varieties, agronomy/disease tolerances, training requirements, etc.) - is mostly concentrated on other EU nations.

The breeding programs of industrial crops, agricultural technology, and the introduction of novel crops require more study. ensuring that the appropriate plant is suggested for the appropriate temperature and soil. EU-wide adaptation of breeding programs for industrial crops to local circumstances. Initial resources are necessary to boost yields sufficiently to attract farmer and industrial interest (co-operatives, seed companies). (Perfecto et al., 2008)

Improved agronomic understanding of the production of aromatic and oil crops. Breeding program using populations of natural plants. Crop agronomy best practices are the subject of study.

11.3.3 Harvesting and processing

There must be more research done on environmentally friendly methods of obtaining and reusing valuable raw materials. More research is needed to determine whether the chemical industry can successfully transition to using essential oils, extracts, and oils in place of products made with fossil fuels.

The machinery used in harvesting and processing has to be continually improved via study and development. The improvement of harvesting techniques for crops with medium (5-8 year) rotations, such as poplar and willow, is a topic of particular interest. No specialized harvesting equipment for MAP crops exists at this time (rosemary, sage, thyme). Creating new prototypes to test and refine until we can find the best harvesting tools for MAP crops. Having a database of available equipment and its suitability for each crop, environment, budget, size, etc. would be useful in making sure that companies and farmers are aware of the costs and limits associated with processing and harvesting their products.

Investigating the properties and quality of biomass grown in marginal and polluted soils is crucial at the concept stage if industrial crops are to be accepted by various markets. The volume of raw materials produced from contaminated land and the proportion of raw materials mobilized from this source may both grow if research into techniques to "clean" crops before processing advances. Clean energy generation and precious metal recycling from polluted biomass: a possibility. To complete the pollutant extraction and purification technologies, you must: (high value Phyto-mining).

More research on the potential of using many biomass types in a single processing unit is required. Studying methods to ensure that processing equipment can handle several feedstocks. Improving processing efficiency requires more study of pre-treatment methods for industrial crops.

Additional research into processing options and methods to enhance biopolymer characteristics is required to increase the TRL (technology readiness level) to 7-8. There is a clear trend away from polymers generated from fossil fuels, making the conversion of cellulose from industrial crops to biopolymers an important topic right now. There should be more research done to find the most efficient ways to turn industrial crops into polymers. (Pires et al., 2019)

Incorporating industrial crops into bio composites requires more research. In spite of a lot of research, everything is still not known about the many uses for industrial crops. The potential for finding untapped markets for industrial crops is enormous. There should also be open discussion of the material advantages that industrial crops like miscanthus may bring about. For example, incorporating miscanthus fibres into bio composites improves the polymer's impact performance.

Find out how to mobilize the industry efficiently and jointly by researching the construction of Biomass Trade Centres. These research facilities may ensure the industry has access to high-quality, readily available biobased raw materials.

The best methods for drying biomass must be available for use by farmers. Much of this has already been studied. The regulations for growing energy crops must regularly include the most up-to-date findings from agricultural research and advice networks. Farmers value facilities like roads, markets, and storage facilities.

11.4 Policy implementation

Sustainable practices for mass-scale agricultural farming. Review of current sustainable standards, making connections with groups working on similar standards, and making sure standards include a wide variety of sustainability requirements for industrial crops such as:

1. Sustainability and Environmental Impact: The industrial agriculture sector has come under increased scrutiny in recent years for its impact on the environment, and in particular its

contribution to climate change. Further research is needed to determine the most effective ways to reduce the environmental impact of industrial agriculture, while still ensuring food security and economic viability. This will require a comprehensive examination of the entire agricultural value chain, including land use, crop selection, fertilizer use, and livestock production.

2. Agricultural Economics and Policy: Agricultural policy has a significant impact on the development of the industrial agriculture sector. Research is needed to determine the most effective policies that can support sustainable agriculture, while also promoting economic growth and food security. This will require a deeper understanding of the economic, social, and political factors that shape agricultural policy, as well as the interactions between different stakeholders in the sector.
3. Food Safety and Quality: Industrial agriculture has come under increasing scrutiny for the quality and safety of the food it produces. Research is needed to identify the most effective policy ways to improve food safety and quality, including measures to reduce the use of pesticides and other chemicals, as well as ways to improve the traceability of food products from farm to table.
4. Water Management: Water is a critical resource for industrial agriculture, and the sector has come under increasing pressure to reduce its water use. Further policy improvements are needed to determine the most effective ways to conserve water in the sector, including the use of innovative irrigation systems, drought-resistant crops, and alternative water sources.
5. Technology and Innovation: Technology and innovation are critical drivers of progress in the industrial agriculture sector. Research is needed to identify the most promising technologies and innovations that can support sustainable agriculture, including precision agriculture, digital agriculture, and alternative energy sources.
6. Social and Economic Equity: The industrial agriculture sector is often associated with economic and social inequality, with small-scale farmers and rural communities often being left behind. Policy improvement is needed to determine the most effective ways to promote social and economic equity in the sector, including the development of inclusive business models, the creation of local supply chains, and the promotion of fair-trade practices.
7. Climate Change Adaptation: Climate change is having a significant impact on the global agricultural sector, and further research is needed to determine the most effective ways to adapt to these changing conditions. This will require a comprehensive understanding of the

impacts of climate change on the sector, as well as the development of new technologies and management practices that can support sustainable agriculture in a changing climate.

To conclude, future research is needed to address the key challenges facing the sector, including sustainability and environmental impact, food safety and quality, water management, livestock production, technology and innovation, social and economic equity, and climate change adaptation to achieve a complete sustainable system.

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Keith Murray, Sustainability Reporting— Beyond TBL?, The Solutions Journal, Volume 10, Issue 2, June 2019

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