Strengthening Key Competences in Agriculture for Value Chain Knowledge "SKILLS"

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DIGITAL COURSE
IN CIRCULAR AGRICULTURE

Coordinator:
University of the Aegean, Department of Food Science and Nutrition, Greece

Partners:
- Association for Internationalisation of Education and Science, North Macedonia
- Distretto Agroalimentare Regionale Scrl, Italy
- Vytautas Magnus University, Lithuania
- Asociația de Dezvoltare Intercomunitară Harghita, Romania

UNIVERSITY OF THE AEGEAN
DEPARTMENT OF FOOD SCIENCE AND NUTRITION

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TEXTBOOK

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CHAPTER 1

INTRODUCTION IN CIRCULAR AGRICULTURE

Chapter 1: Introduction in Circular Agriculture

The goal of this module is to explore an introduction to Circular agriculture (CA) at a HEI level. This digital course delves into the exciting and transformative world of Circular agriculture. As we navigate the challenges of our time, CA emerges as a powerful approach to build a more sustainable and resilient food system. This introductory chapter focuses on a comprehensive literature review, laying the foundation for your exploration of CA. SKILLS course in CA inspires students and teachers to learn not only circular agro-economy principles but also a policy-making tool to help achieve sustainability. Below we will explore our core points in CA and resources. It is important to familiarize yourself with each of these tools to better understand the thematic you will be working with.

1.1. Learning outcomes

By the end of this course, you will be able to:

- **Explain** why students and teachers should be educated about CA.
- **Describe** CA values for HEI.
- **Describe** CA core points and resources.
- **Identify** the key features of the CA.

Education about circular agriculture and food can present opportunities to students. Students bring their questions about food and circular agriculture to the classroom. However, circular agriculture is not recognized as a distinct subject in the SKILLS project HEI partner's curriculum, so few teachers have the expertise needed to share well-informed answers. If teachers or students search online sources for answers, they are likely to find conflicting, and possibly misleading, information. Circular agriculture is complex, so an informed consumer needs a thorough understanding of the perspectives and tradeoffs of agri-food practices. The education system, the circular agriculture and the agri-food industry owe students information about food and agriculture to fill a gap in food knowledge. When this gap is filled by myths about food and farming, those myths continually challenge the growth and progress of the agri-food industry. Educating students about food and circular agriculture can help dispel myths, create a deeper interest and connection to food, and promote local food. But education might do even more. The food and circular agriculture sector have real-world applications for university level subjects. For example, biology could lead to a specific application like plant or animal agriculture, followed by many career opportunities. We need to teach – because students are waiting to hear about the corresponding opportunities.

1.2. Target Audience

Our target audience is educators and their students, with an added focus on higher university level. We reach them using online resources, and we strive to have a meaningful and measurable impact. With this introductory course we remain committed to serving university educators by offering a carefully selected collection of state-of-the-art resources. Our goal is to have every teacher in at least the SKILLS partnership, but preferably beyond, to use one of our resources with this course. With the course in CA, SKILLS project needed to address the gap at the university outreach to attract the interest of our future generation of customers and workforce. Our approach to higher education encourages critical thinking about food – where it comes from, how it is produced, and the facts about hot topics.

The CA course and its resources are available digitally. Educators are turning to technology for teaching and learning, so the education system has changed a lot in the last few decades. Students have changed their expectations too, as they are surrounded by technology in their home lives. Digital and online resources compete with blackboards and handouts. The course will be available from our project website but also via the partner's websites. The digital age has allowed us to track resource downloads and helps us monitor our impact on teachers and students.

1.3. Resource Library

Here, we will embark on a journey through research papers, articles, and reports about Circular economy, circular economy society and circular agriculture. The purpose for this review is to prove, that higher education students, academics, as well as agricultural producers and practitioners need green skills, which are relevant for circular economy society members and are represented in this learning material of digital course. The circular economy is defined as an economic system based on business models that replace the concept of "end-of-life" by reducing, alternatively reusing, recycling and recovering materials in production and/or distribution and consumption processes, thereby affecting the micro (products, companies, consumers), meso (eco-industrial parks) and macro (city, region, country, etc.) sectors of the economy. Levels to achieve sustainable development, which means creating environmental quality, economic prosperity and social justice for the benefit of present and future generations (Kirchherr, Reike, Hekkert, 2017). The circular economy is a socio-economic model that aims to minimise waste and resource depletion while maximising the durability and value of products, materials and resources. This concept contrasts with the traditional linear economy, where resources are extracted, converted into products, used and discarded as waste. In a circular economy, resources are continuously reused, renewed and recycled, creating a closed-loop system (Padilla-Rivera, A., Russo-Garrido, S., Merveille, N., 2020).

However, Padilla-Rivera, A., Russo-Garrido, S., Merveille, N. (2020) noted that while sustainability is highlighted as a key objective of the circular economy - to provide benefits to the environment, the economy and society at large - it currently appears that the main beneficiaries of the circular economy are the political and economic actors implementing the system.

In order to ensure that the benefits of the circular economy go beyond the political and economic actors that shape its principles, according to Jaeger-Erben M., Jensen C., Hofmann F., Zwiers, J. (2021), the circular economy paradigm needs to be complemented by the concept of 'society' in order to create an alternative paradigm that goes beyond growth, technology and market solutions. The addition of a societal component to the circular economy paradigm is linked to the idea that the transition to a circular economy is not possible without the commitment and participation of all members of society. The concept of a circular economy society frames the transition to circularity as a profound socio-ecological-economic transformation to which society must not only contribute but also benefit.

1.4. Concepts and state of the art

Circular agriculture represents a transformative shift from the traditional linear agricultural model of 'take-produce-consume-discard' to a more sustainable and regenerative system. This approach prioritizes the avoidance of waste and losses, the reuse and recycling of by-products, and the efficient utilization of nutrients and biomass to feed humans (Hoogstra et al., 2024). By adopting circular practices, agriculture becomes more robust and sustainable, benefiting both farmers and the environment. This enhances household food security, reduces dependency on external inputs, and fosters a self-sustaining and productive farming approach (Kansah-Dwamena, 2023). To keep resources in use for longer, extract maximum value from them whilst in use, and recover and regenerate products or components when they reach their end of life help Circular business models. Piscicelli, L., & Ludden, G. (2016) determined product-service systems, hiring and leasing schemes, collaborative consumption, incentivised return and reuse and 4 business models by grouping them under the broad categories of 'product-based', 'service-based', 'sharingbased' and 'supply chain-based' circular business models. Product-based circular business models are built around high quality products designed to last. Service-based circular business models the manufacturer or retailer retains the ownership of the product and acts as a service provider. Sharing-based circular business models enable an increased utilisation rate of products by making possible their shared use, access or ownership. Supply chain-based circular business models reduce the quantity of raw materials required to meet the market demand by recovering useful resources or energy out of disposed products and byproducts. Circular agriculture, also known as closed-loop agriculture, promotes farming in harmony with nature, ensuring that nothing is wasted (Schouten, 2020; Toop et al., 2017).

Circular agriculture offers a compelling framework for transforming modern farming into a more sustainable and environmentally friendly practice. By moving away from the exploitative 'take-produce-consume-discard' model, circular agriculture promotes the efficient use of resources, minimizes waste, and fosters a regenerative approach to farming. This system not only enhances food security and reduces reliance on external inputs but also contributes significantly to the preservation of ecosystems and the mitigation of climate change. As scientific advances and new technologies continue to evolve, the implementation of circular agriculture will be crucial in ensuring that agricultural practices meet the needs of the present without compromising the ability of future generations to meet their own needs. The integration of circular economy principles into agriculture thus represents a vital step towards achieving a sustainable and resilient food system.

Farmers have a key role to play in the transition to a circular economy society, as according to Nordin et al. (2022), global agricultural production needs to increase by 70% in 2050 to meet food demand. But it is the challenges we face. The food supply system, on which we all rely, is threatened by climate change and biodiversity loss. Changing our food system to one based on the principles of the circular economy is one of the most powerful things we can do to tackle climate change and build biodiversity, provide healthy nutritious food for all. When implementing the principles of circular agriculture, it is very important to look for business models and strategies that meet the concept of sustainable development, as well as new ways of farming. Due to its various advantages, the circular economy is still the most revolutionary concept in modern agriculture, with the potential to make agricultural practices more accessible and practical.

In circular agriculture, all steps of the food system from growing, harvesting, packing, processing, transporting, marketing, consuming and disposing food are designed with a view to promoting sustainable development. Primary agriculture and processing, agro services circular agriculture considerations in organizing the production and adaptation of the value chains. Farmers are rational business people. They farm according to the principles of the market, the dynamics of the market, which are created through the food system. Green competences, circular economy leadership could play a key role in this system, it could be achieved that more farmers can and want to farm more sustainably. Farmers help to regenerate nature by choosing regenerative farming's strategy. The chosen farming strategy helps create not only benefits for the farmer but also for society: climate; soil health; resource use efficiency; biodiversity; prosperity. Regenerative agriculture improves long-term farmer livelihood through reduced costs, improved crop yield and crop quality, and greater resilience to market volatility and extreme climate events. It also opens new green revenue streams for farmers, such as rewarding them for carbon capture and storage in the soil (World Economic Forum, 2023).

Table 1. Different definitions of circular agriculture

Definitions of circular agriculture	Key objects
Circular agriculture is a closed-loop system in which nothing is wasted (Toop et al., 2017).	a closed-loop system, nothing is wasted
Circular agriculture is known as closed-loop agriculture, a method of farming with nature, rather than against it (Schouten, 2020).	closed-loop agriculture, a method of farming with nature
Circular agriculture is defined as a facet of the circular economy that targets the challenges of the farm-based rural economy and environmental issues (Atinkut et al., 2020).	aspect of the circular economy, to solve economic and environmental problems
Circular agriculture is a shift away from the current exploitative ways of growing food that destroy soil fertility, contribute largely to greenhouse gas emissions and leave little space for wilderness to a model that regenerates and cares for nature (Marinova, Bugaeva 2020).	a model that regenerates and cares for nature
Circular agriculture is an effective approach for the management of soil organic inputs that improves soil fertility and cropping system sustainability (El Janati et al., 2021).	an effective approach, improves soil fertility and cropping system sustainability
Circular agriculture is a way to farm sustainably, while making use of scientific advances, innovations, and new technologies (Helgason, Iversen, Julca, 2021).	a way to farm sustainably, scientific advances, innovations, and new technologies
Circular agriculture contributes to a more robust and sustainable food system, benefiting both farmers and the environment. The adoption of circular practices enhances household food security, diminishes external input dependency, and fosters a self-sustaining and productive farming approach (Kansah-Dwamena, 2023).	more robust and sustainable food system, a self-sustaining and productive farming approach
Circular agriculture is to move from the current ‘take-produce-consume-discard’ model to one in which waste and losses are avoided, where by-products are reused and recycled and nutrients and biomass are used more efficiently to feed humans (Hoogstra et.al., 2024).	waste and losses are avoided, products are reused and recycled, more efficiently

1.4. The need for CA in HEI

This Digital Course in Circular Agriculture equips higher education students, academics, as well as agricultural producers and practitioners with the green skills needed to thrive in a circular economy society. This course is for circular society members who are passionate about circular agriculture – and provides the knowledge to transition towards a more sustainable future. Using innovative content and tailored materials, learners will explore ways to enhance resource efficiency, profitability, and environmental responsibility in agricultural production, how to implement the principles of circular agriculture. Also, this course empowers stakeholders within the agricultural sector to embrace circularity and become drivers of positive change. By equipping the green skills needed to implement circular agriculture practices effectively, society can significantly reduce their environmental impact, improve the economic viability of farms, other business organizations, institutions and even create new jobs. Furthermore, the course will catalyze innovation and collaboration across agricultural value chains, paving the way for a widespread adoption of circular economy principles in our food system. The survey conducted in the partner countries of the project showed that their universities have curricula or at least separate courses that teach the basics of circular agriculture, and the educational materials and tasks created in this course can be easily integrated into existing courses.

For example, in the Faculty of Bioeconomy Development in Agriculture Academy of Vytautas Magnus University in Lithuania organize and implement several study programs related to the circular economy and circular agriculture. There are first cycle study program "Sustainable Bio-Business Management", the second cycle (master) study program "Agricultural economics", the broader master's degree program "Rural Development Administration". These study programs aim to provide knowledge, skills about circular economy and circular agriculture, sustainability and related decisions. In the study program descriptions note that in order to develop the bioeconomy as a separate sector of the economy, sustainable bio-business management specialists are needed who are able to perform management functions, who have the knowledge and abilities necessary to manage and develop organizations, who are familiar with management processes, technologies for the production, sustainably processing and conversion of biological resources, who understand the economic, political, legal and social context in global society, able to evaluate it and make management decisions in business and public organizations operating in the bioeconomy sector and government institutions responsible for the sustainable development of the bioeconomy sector striving to implement circular economy. Are study subjects taught at the University, which are closely related to the development of circular agriculture. For example, "Fundamentals of Circular Economy", "Sustainable food systems", "Sustainable project management", "Strategic management of rural development", "Analysis of Agriculture and Rural Development Policy" and others.

The Romania state-of-art of current ag-programs offered at the faculties of agriculture in moving towards circular agriculture. Outstanding study programmes and faculties in Romania: "Agroalimentary Economics" Sapientia Hungarian University of Transilvania. Faculty of Technical and Human Science study programme "Agricultural Engineering". In Agricultural Economics students' study "Sustainable Economic Development", "Circular Economy". There students can learn about the history of the circular economy, local good practices and the sharing economy. The master study program of "Management and Organisation". Students in the first year, first semester, in the subject "Sustainable and Regional", have a lecture on the circular economy and the indicators of the circular economy, more specifically, how to measure the circular economy.

The curricula of Greek Agricultural Universities have (plus University of the Aegean, School of the Environment, Department of Food Science and Nutrition) many courses, related with Circular economy. Agricultural University of Athens, Department of Plant Production Science "Environmental management and protection", Department of Forestry and Natural Environment "Climate Change & Forest Ecosystems" and "Citizen education for the natural environment", Department of Animal Production Science, "Environmental Management and Protection option", Department of Natural Resources Utilization & Agricultural Engineering" Soil environmental Physics – Reuse of Treated Liquid Waste" and "Waste Treatment and Management".

Although there are university and other study programmes in the partner countries that focus on circular agriculture, the research carried out in the first and subsequent phases of this project shows that there is still a lack of in-depth knowledge and green skills in circular agriculture among the public. So, this digital course material is not only intended for self-learning by those interested, but also as a complement to formal study programs.

1.5. Personal Benefits

The need for professional circular economy specialists is based on the provisions of the 2030 Agenda for Sustainable Development (2015), adopted by the United Nations (UN), the European Union (EU) Growth Strategy "European Green Deal" and other strategies require a fair transition to national, regional and local public administration systems, focusing on the integrated/inclusive development of the territory, bringing together local resources without leaving anyone behind. The overarching aim of the European Green Deal is for the European Union to become the world's first "climate-neutral bloc" by 2050. The European Green Deal of the EU's strategy for sustainable and inclusive growth is at the heart of the link between healthy people, healthy societies and a healthy planet's sustainable food system. The green course in the transition to circular agriculture is intended to stimulate the economy, improve people's health and quality of life, and nurture nature. The management of these processes and activities requires professional, proactive circular agriculture development specialists who assume leadership based on evidence, experience, and knowledge. In order to participate effectively in and benefit from the circular economy, its members need to have a high level of green skills (knowledge, values, behavior and abilities that enable them to integrate into green jobs. Thus, promoting the inclusion of society in the circular economy requires action not only by business organizations but also by government and educational institutions, to ensure that members of society receive the necessary training and acquire the knowledge and skills to perform the jobs that are relevant to the needs of the circular economy (Padilla-Rivera, A., Russo-Garrido, S., Merveille, N., 2020).

a) Develop skills

You will be able to develop your own CA literacy skills which will allow you to carry the subject matter expertise in agriculture throughout your career. You are also now equip to answer important questions that students are curious about.

b) Network

The SKILLS CA course allows you to build a network with teachers and teacher candidates from SKILLS partner countries. Through participating in discussion boards located within the modules, you will be able to build your teaching and agricultural tool kit by sharing and learning from their colleagues.

c) Become informed

There are benefits to your personal life too. What you learn about circular agriculture can help you become an informed consumer. If you have ever struggled with terms like sustainability of food security, value chain for minimizing waste resources, megatrends, concepts and factors of CA you will have the chance to learn the facts. You might develop an informed opinion that can give you confidence in your teaching decisions.

1.7. Activity: Develop an elevator pitch

SCENARIO: You are leading a lesson with your students around circular agriculture. You start to speak, remember key terms, and then pause. Where do you start?

MAKING A PITCH: An elevator pitch is a 20-30 second, compelling speech. You will use it to describe how you will hook students into understanding the importance of circular agriculture. It should be interesting and sound natural in conversation. The speech should be prepared in advance, so it is a clear and succinct explanation. In this activity, you will develop your own elevator pitch.

To do so, follow these steps:

a) *Identify your goal*

Describe the goal of circular agriculture – with a focus on how it relates to your students.

b) *Be engaging*

Communicate what you want your audience to remember most about you. A great pitch shows your enthusiasm and attracts your listener's attention.

c) *Communicate uniqueness*

Identify what makes circular agriculture a unique sector that is filled with potential.

Consider the messages from this list:

Every 1 in 8 jobs in Europe is in the agriculture sector.

Over 2.1 million people directly or indirectly interact with your food from farm to table.

By 2050, there will be over 9 billion people on planet Earth.

Food travels on average 4500 km to reach our plates.

Every 1 in 8 households in Europe are experiencing food insecurity.

1.8. Conclusion

In conclusion, the advancement of circular agriculture is intrinsically linked to the broader goals of a circular economy society and the cultivation of green skills among its members. This integrated approach not only ensures the sustainability and resilience of agricultural systems but also contributes to the overall sustainability of our economy and environment. Through the adoption of circular practices and the development of green skills, circular economy society members, were farmers and other stakeholders of the agricultural sector, have a key role and can play a pivotal role in creating a sustainable future for all. This digital course analyses and introduces learners to topics relevant to the transition to circular farming:

1. Objectives and potentials of CA
2. Sustainability of food security in CA
3. Value chain for minimizing waste resources in CA
4. Megatrends, concepts and factors of CA
5. Case studies of CA and Best practices implied in CA

The topics analyzed and presented in this digital course will provide learners with the necessary knowledge and green skills to successfully transition their operations and farms to the topic of circular farming. Each topic is given its own chapter with a detailed overview of the concepts, explanation, practical examples and, where possible, related exercises.

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CHAPTER 2

OBJECTIVES AND POTENTIALS OF CIRCULAR AGRICULTURE

Chapter 2: Objectives and potentials of Circular Agriculture

This chapter explores the objectives and potentials of CA, focusing on its role in improving the profitability of agricultural production, creating new job opportunities and fostering economic development. It examines how the principles of circularity can enhance resource efficiency, reduce production costs, and increase yields, thereby improving the overall profitability of agricultural operations. Additionally, it explores the potential for CA to stimulate economic growth by creating new job opportunities and supporting the development of sustainable agricultural value chains. Through an analysis of the economic benefits and opportunities associated with CA, this chapter aims to empower stakeholders to embrace circularity as a pathway to prosperity.

2.1. Exploration of the objectives of Circular Agriculture

The traditional linear model of agriculture – extracting resources, production, consumption, and waste disposal – is increasingly unsustainable. It depletes natural resources, pollutes ecosystems, and contributes to climate change. Circular agriculture (CA) offers a paradigm shift, mimicking a closed-loop system found in nature. It emphasizes resource efficiency, waste minimization, and the creation of byproducts that become inputs for other processes.

According to Shebanin (2024), shifting towards a circular economy offers advantages for enterprises. Through reassessing business models, production methods, and product design, companies embracing circularity can notably diminish expenses associated with materials, energy, and waste management. Consequently, this can result in heightened profitability and a strengthened competitive edge. This approach is reflected in the new Circular Economy Action Plan adopted by the European Union, which is a key element of the European Green Deal and a new strategic direction for Europe's sustainable development, New circular economy action plan for the European Union. The sustainability principles identified in the plan include improving durability, reusability, renewability and maintainability, addressing the presence of hazardous chemicals in products and increasing the content of recycled products. These new rules and initiatives have been developed with the participation of businesses and stakeholders and will be implemented by the European Commission to support sustainable development.

Circular agriculture (CA) emerges as a promising solution, aiming to create a closed-loop system that minimizes waste and maximizes resource efficiency. This review identifies and defines the key objectives of CA. We review the last 4 years of the EU and researchers' views on CE and discuss how these objectives interlink and serve as guiding principles for developing and implementing CA practices.

2.1.1. Key objectives of circular agriculture based on United Nations Department of Economic and Social Affairs (2021):

1. **Minimize external inputs:** This means reducing reliance on fertilizers, pesticides, and other resources brought in from outside the farm system.
2. **Close nutrient loops:** Nutrients are cycled within the farm instead of being lost to the environment. Manure and compost are used to replenish soil fertility, reducing the need for chemical fertilizers.
3. **Regenerate soils:** Practices that improve soil health and fertility are prioritized. This can involve techniques like cover cropping, crop rotation, and reduced tillage.
4. **Minimize environmental impact:** Circular agriculture aims to reduce pollution, conserve water, and protect biodiversity.
5. **Reduce resource requirements:** By minimizing waste and maximizing resource efficiency, circular agriculture lowers the overall ecological footprint of farming.
6. **Reduce land use:** Efficient practices can potentially decrease the amount of land needed for food production.
7. **Reduce chemical fertilizer and waste:** This objective can significantly improve environmental health and reduce greenhouse gas emissions.
8. **Promote smallholder farming:** Circular practices are often more suited to smaller farms that can integrate diverse crops and livestock.
9. **Improve food security and nutrition:** Diverse production systems lead to a wider variety of nutritious food.
10. **Create rural jobs:** Circular agriculture's labor-intensive nature can revitalize rural economies, especially for women.
11. **Reduce barriers to entry for women in agriculture:** Lower input needs in circular agriculture can empower women to participate more actively in farming.
12. **Promote sustainable development:** All aspects of the food system, from production to consumption, are designed to minimize environmental impact and ensure long-term sustainability.

Overall, according to United Nations Department of Economic and Social Affairs (2021) circular agriculture strives for a closed-loop system that minimizes waste, maximizes resource efficiency, and promotes environmental and economic well-being.

2.1.2. Key CE objectives for a circular agriculture based on Velasco-Munoz (2021):

1. Eliminate Waste and Pollution:

- Reduce soil contamination by minimizing the use of chemical fertilizers, herbicides, and pesticides.
- Develop and implement alternative pest control methods like biological control systems.
- Promote integrated crop-livestock systems where animals can reduce the need for herbicides and provide organic fertilizer.
- Conserve water resources by minimizing agricultural water use and preventing water body degradation.

2. Maximize Resource Use:

- Extend the value of products, co-products, and by-products throughout the supply chain.
- Utilize technological advancements to find new uses for agricultural waste:
- Bioenergy production
- Soil amendment and bio-fertilizers
- Livestock feed

3. Regenerate Natural Systems:

- Implement regenerative agriculture practices that:
- Improve soil health and fertility
- Reduce greenhouse gas emissions
- Increase carbon sequestration in soil and plants
- Minimize soil disturbance
- Enhance water storage capacity

By focusing on these CE objectives, according to Velasco-Munoz, etc. (2021), circular agriculture can create a more sustainable and resource-efficient agricultural system and achieve system-wide efficiency in resource use within agriculture.

2.1.3. Objectives of circular agriculture based on Marinova & Bugaeva (2022):

1. **Minimize waste:** A core principle is to create a closed-loop system where everything is reused or recycled, eliminating waste.
2. **Mimic natural processes:** Circular agriculture aims to emulate nature's regenerative cycles, promoting sustainability.
3. **Maintain soil health:** By returning nutrients to the soil through organic fertilizers, circular agriculture promotes soil fertility and productivity.
4. **Reduce reliance on external inputs:** The system should minimize dependence on external resources like fertilizers and focus on closed-loop nutrient cycles within the farm.
5. **Decouple food production from environmental harm:** Circular agriculture strives to achieve food production that minimizes negative impacts on the environment, such as water pollution and greenhouse gas emissions.
6. **Implement localized solutions:** While some general principles apply, circular agriculture acknowledges the need for adaptable and context-specific approaches based on local conditions.

These objectives paint a comprehensive picture of circular agriculture's potential to create a sustainable food system. By focusing on closed-loop cycles, resource efficiency, and environmental protection, circular agriculture offers a promising path towards a more resilient and future-proof agricultural landscape, adaptable to diverse local conditions.

2.1.4. CE objectives for circular agriculture based on the five principles outlined in Hoogstra and etc. (2024):

1. Safeguard the Health of Agro-ecosystems:

- **Protect and regenerate biodiversity:** Maintain healthy populations of plants and animals within agricultural systems.
- **Minimize environmental pollution:** Avoid or reduce pollution from agriculture, such as nutrient runoff and greenhouse gas emissions.
- **Maintain regenerative capacity:** Use natural resources at a rate that allows them to replenish themselves.

2. Minimize Waste:

- **Avoid unnecessary production:** Focus on producing only what is essential for human needs.
- **Prevent food waste:** Implement strategies to minimize food loss and waste throughout the supply chain.

3. Prioritize Human Needs:

- **Direct biomass towards human consumption:** Use agricultural resources primarily to feed people rather than animals.
- **Feed animals with inedible biomass:** Utilize food scraps or other human-inconsumable materials for animal feed.

4. Maximize Resource Use:

- **Recycle by-products and residuals:** Repurpose agricultural waste streams like crop residues and manure back into the food system for productive use.
- **Prioritize highest-value use:** When recycling by-products, prioritize uses that extract the most value from the material.

5. Minimize Energy Use:

- **Reduce overall energy consumption:** Optimize processes to minimize the energy required for agricultural production.
- **Utilize renewable energy sources:** Prioritize renewable energy sources like solar or wind power to reduce reliance on fossil fuels.

These five CE objectives provide a framework for developing and evaluating circular agriculture initiatives. They emphasize resource efficiency, environmental protection, and prioritizing human needs within the agricultural system.

Common CA Objectives:

In conclusion, the UN prioritizes minimizing external inputs and closing nutrient loops within the farm system. Velasco-Munoz et al. (2021) broaden the scope by including waste reduction throughout the supply chain. Marinova & Bugaeva (2022) and Hoogstra et al. (2024) both emphasize prioritizing human needs. This includes directing biomass towards human consumption and utilizing inedible biomass for animal feed. Hoogstra et al. (2024) provides a more detailed framework with five CE objectives, encompassing safeguarding ecosystems, minimizing waste, prioritizing human needs, maximizing resource use, and minimizing energy use. **Overall, these convergent objectives paint a clear picture of what CA strives to achieve: a closed-loop system that minimizes waste, maximizes resource efficiency, protects the environment, and prioritizes human needs.**

Circular agriculture (CA) is gaining traction as a promising approach to achieving a more sustainable and resource-efficient food system. This conclusion analyzes key objectives highlighted by various sources, revealing both commonalities and points of divergence. So Common CA Objectives are:

1. **Minimize Waste and Pollution:** All sources emphasize reducing waste generation and minimizing environmental pollution from agriculture. This includes reducing reliance on chemical inputs, promoting integrated crop-livestock systems, and conserving water resources.
2. **Maximize Resource Use:** Extending the value of agricultural products, co-products, and by-products is crucial. This involves utilizing technological advancements for bioenergy production, soil amendments, and animal feed.
3. **Maintain/Regenerate Natural Systems:** Improving soil health and fertility, reducing greenhouse gas emissions, and enhancing water storage capacity are all highlighted as vital for long-term sustainability.

2.4. Showcase examples of economic development

The current food system doesn't work for everyone, and it certainly doesn't work for the environment. Industrial farming has turned agriculture into a leading source of greenhouse gas emissions and pollution, and is driving the extinction of species, farms are moving very slowly to resource-efficient farming. The Circular Economy is gaining traction in academia, industry, and policy making as an alternative model that minimises resource depletion, waste, and emissions. To implement the concept on the organisational level, business models are an important leverage (Geissdoerfer, Pieroni, Pigosso & Soufani, 2020).

A circular economy in which products have multiple lifecycles requires business models articulates the logic of how an organization creates, delivers, and captures value to its broader range of stakeholders while minimizing ecological and social costs.

Business models can be understood as a structured management tool used to present the company's organisational structure and value creation processes. Circular business models are key levers for the implementation of a circular economy.

Circular business models contribute to a circular economy by adhering to the circular economy's three fundamental principles:

- Design out waste and pollution;
- Keep products and materials in use;
- Regenerate natural systems.

Circular business models are fundamentally different ways of producing and consuming goods and services. They can drive the transition to a more efficient use of resources and a circular economy, thereby significantly reducing the negative environmental impact of economic activity.

"A circular business model is how a company creates, captures, and delivers value with the value creation logic designed to improve resource efficiency through contributing to extending useful life of products and parts (e.g., through long-life design, repair and remanufacturing) and closing material loops" (Nußholz, 2017, p.12).

A circular economy business models based on longevity, reuse, repair, upgrade, refurbishment, renewability, capacity sharing and dematerialisation (Accenture 2014; Wallace, et al. 2015; Piscicelli, L., & Ludden, G., 2016).

Different authors have proposed various lists of '*circular business models'* (also referred to as '*innovative*' or '*resource efficient*' business models). Piscicelli, L., & Ludden, G. (2016) compares the classifications and adopted by Accenture (2014), Bakker et al. (2014), Kiørboe et al. (2015) and REBUS (2015) in Table 1. The authors grouped them under the broad categories of 'product-based', 'service-based', 'sharingbased' and 'supply chain-based' circular business models (OECD, 2018).

Table 2. Circular business models (Piscicelli, L., & Ludden, G., 2016; OECD, 2018)

Categories of circular business models	Authors and source				
	Accenture, 2014	Bakker, et al., 2014	Kiørboe, et al. 2015	REBUS, 2015	OECD, 2018
PRODUCT-BASED	Product life extension a. Resell b. Repair/Upgrade c. Remanufacture	Classic long life	Product design model	Long life	Product life extension
		-	Reuse	Incentivised return & re-use	-
		-	Repair	-	-
	-	Hybrid model	-	-	-
SERVICE-BASED	Product as a service	Performance model	Service- and function based models	Product Service System	Product Service System

			-	Dematerialised services	-
		Access model	-	Hire & Leasing	-
	-	-	-	Made to order	
SHARINGBASED	Sharing platforms	-	Collaborative consumption	Collaborative consumption	Sharing models
SUPPLY CHAIN - BASED	-	-	-	Made to order	-
	Circular supplies	-	Recycling and waste management	-	Circular supply
	Resource recovery a. Re-/upcycle b. Waste as a resource c. Returning byproducts	-	-	Asset management	Resource recovery
	-	Gap exploiter model	-	Collection of used products	-

Five Business Models for the Circular Economy from a Policy (OECD, 2018) perspective was headline:

- Circular supply models, by replacing traditional material inputs derived from virgin resources with bio-based, renewable, or recovered materials, reduce demand for virgin resource extraction in the long run.

- Resource recovery models recycle waste into secondary raw materials, thereby diverting waste from final disposal while also displacing the extraction and processing of virgin natural resources.
- Product life extension models extend the use period of existing products, slow the flow of constituent materials through the economy, and reduce the rate of resource extraction and waste generation.
- Sharing models facilitate the sharing of under-utilised products and can therefore reduce demand for new products and their embedded raw materials.
- Product service system models, where services rather than products are marketed, improve incentives for green product design and more efficient product use, thereby promoting a more sparing use of natural resources (OECD, 2018, p.4).

Circular business models operate in different parts of the value chain (Figure 1) and not all circular business models are necessarily new. Recycling, reuse, and repair have existed for millennia. The sharing of under-utilised household possessions also has a long history, and the provision of access to products, rather than ownership of them, is not so different from traditional product leasing. What is new is the growing diversity and sophistication of these business models, as well as the range of sectors they are adopted in.

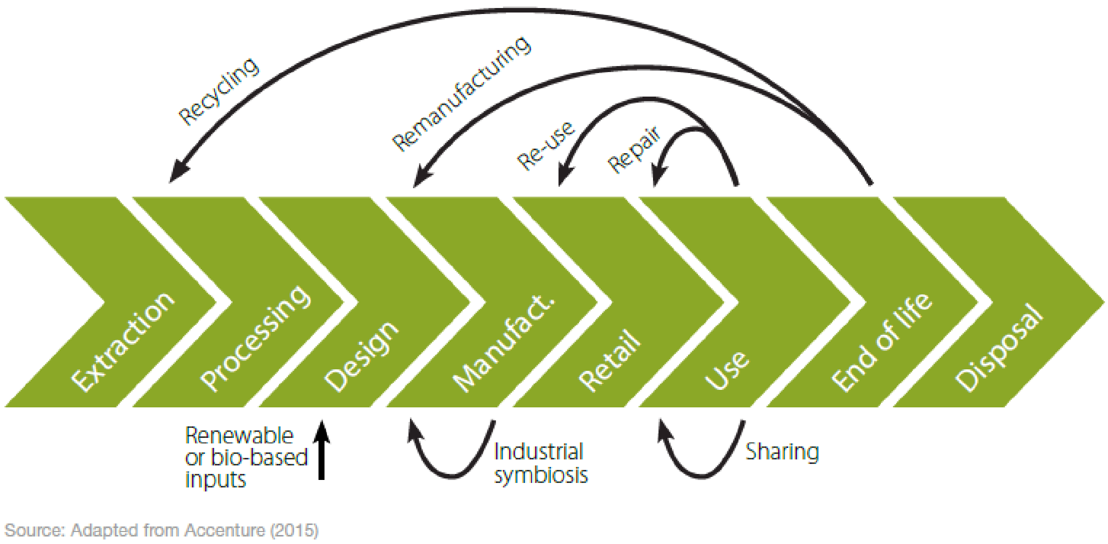

Figure 1. Circular business models operate in different parts of the value chain (Accenture (2015); OECD, 2018)

Circular business models, by closing resource loops and by slowing and narrowing resource flows, can reduce the environmental footprint of economic production and consumption. But the environmental potential of circular business models is clear, but risks remain.

The distinction between different circular business models is clear in theory, but may be less so in reality.

A framework for conceptualising business models that has been acknowledged for its practical relevance is the "*business model canvas*" by Osterwalder and Pigneur (2010). The authors distinguish between nine business model elements: key resources, key partners, customer segments, customer relationships, channels, value proposition, revenue streams, cost structure, and key activities (Figure 2).

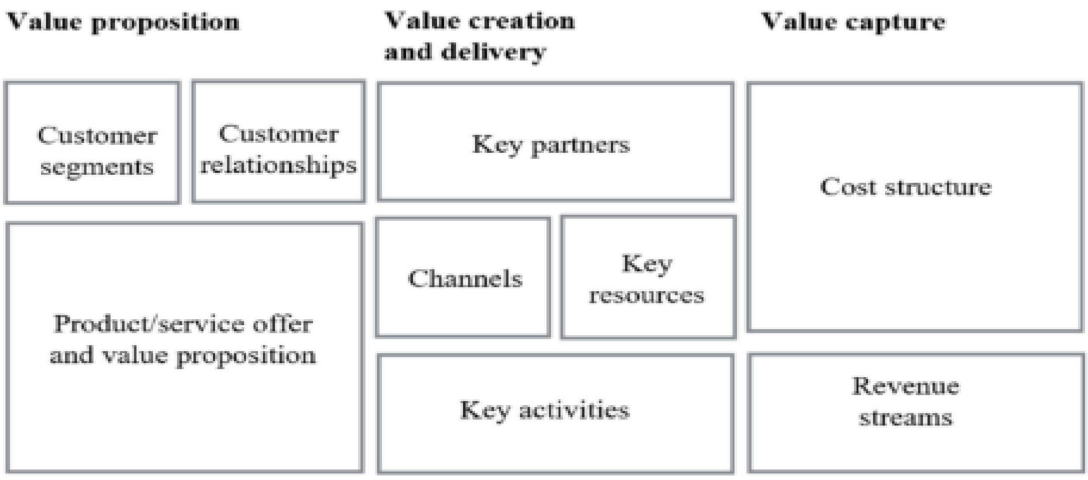

Figure 2. Business model conceptualisation, adapted from Osterwalder and Pigneur (2010).

By rethinking the three value dimensions, i.e., *what value is proposed, how value is created and delivered, and how value is captured* (Nußholz, 2017), business model innovation provides a more systemic approach for aligning the value creation logic of the company with circular principles. As Figure 3 illustrates, a circular strategy and the associated changes in material flows can be embedded into the value creation logic to aid its implementation. Aligning the three value dimensions and adjusting the configuration of business model elements can facilitate its operation.

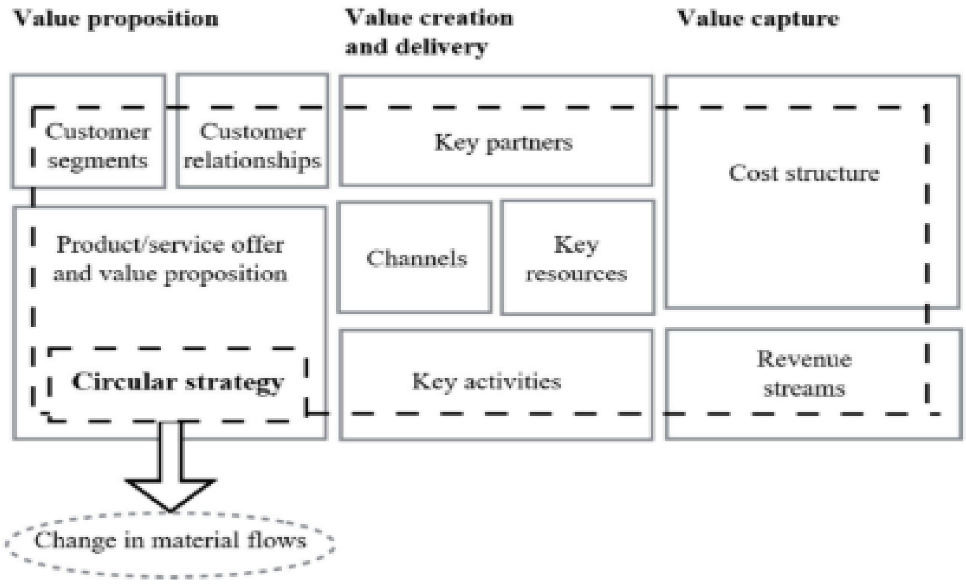

Figure 3. Illustration of embeddedness of a circular strategy in a business model (Nußholz, 2017)

Examples of economic development related to circular agriculture

Farmers on their way to circularity (Dagevos & Lauwere, 2021). to explore how Dutch farmers perceive circularity and what kind of implications ca has for their production practices Dagevos & Lauwere (2021) selected thirteen types of farms in Netherlands were the Dutch government has expressed the ambition to establish circular economics in the Netherlands in 2050. the types of farms included varying from a conventional pig farmer with a small plus for animal welfare and production of sustainable energy to biodynamic (bd) multifunctional farms with livestock, crops, nature conservation, a farm shop and/or webshop and care. in between scientists found a conventional pig farmer who made use of residuals flows of the food industry, a conventional broiler farm with high-tech solutions to reduce ammonia emissions, smart cooperation between livestock and conventional arable farmers, a bd dairy farm and an organic mixed farm with dairy cattle and arable crops, a farm with special livestock, an outdoor pig farm and a bd pig farm and a nature-inclusive mixed farm with dairy cattle and arable crops, and a community farm. in addition, three of the farmers who were not certified organic or bd (the outdoor pig farm, the farm with special livestock and the community farm) claim to go beyond the organic standard but did not want to certify to avoid administrative burden and additional costs (Dagevos & Lauwere, 2021).

Table 3. The motives of farmers to choose for a particular (transition) path link circular agriculture and prefer to rely on technological solutions (Dagevos & Lauwere, 2021)

Excerpts from the interviews	Type of farm
Because of a car accident and problems with my immune system and all kinds of allergies, I started to gain more in-depth knowledge about food. As a result I lost trust in food from retailers and decided to start producing my own food and keeping my own animals. My father owned some parcels of forest and there I could start.	BD outdoor pig farmer
My farmer's heart was violated very much... As an agricultural contractor I once worked on the tractor for 48 h. Nobody had their own labour anymore and because of the use of pesticides and artificial fertiliser, the farms became larger and larger. I realised that these developments are not future proof, and that I did not want to be part of it as a farmer if it has to be like this.	BD multifunctional farmer 1
I wondered whether they needed a producing farmer here who produces as efficiently as possible for the world market, or a farmer aligned to the society who also asks society 'What do you want from me?' And I decided to turn to the side of society.	BD multifunctional farmer 2
I am a dedicated newcomer in agriculture. If you do not want to become the largest food producer, you should become the most sympathetic one. Expansion in livestock farming will go on, but if you do not want to join that tendency, you have to invent something special.	Farmer with special livestock
I have always liked short food supply chains because in that way there will be some money left for the farmer. The ignorance of the consumer struck me. I wanted to do something about that. My wish is that finally 100% of the consumers become more aware of how their food is produced.	Community farmer
I am a bit of a developer. Someone who thinks about new systems. How can we better use the land and protect nature? I just like to think about these things. And how it can be put into a business model. But some things cannot be expressed in money. It is also about the fun of being a farmer.	Cooperating farmer
We have 500 sows at the new location and we have a permit to build a new stable for meat pigs. But we do not want to build a conventional stable because we need to install an air washer then and we do not want that. Therefore, we talked about joining a project about separating manure into a thick and a fluid fraction, which aims to reduce ammonia	Conventional pig farmer 1

emission, and making manure more suitable for fermentation and production of gas.	
I noticed little understanding for food producers. I wanted to show the role of pigs in the food system. In that way, I hoped to receive more societal approval. I started feeding the pigs with residual flows from the food industry within a 100 km radius, instead of feeding them soy from abroad.	Conventional pig farmer 2
We opted for writing a business plan that aimed at “and-and” solutions directed towards cost price, environment, animals and people. We also looked specifically for a solution for the vans that drive back and forth between our farms.	Conventional broiler farmer

The researchers also aimed to determine how circular are farms in practice. All farmers with (more or less) alternative methods have taken several measures to contribute to CA. However, some farmers express their inadequacy in realizing production processes and a business model that was completely circular. None of the interviewed farmers believed that it was possible to become 100% circular, and there were clear differences in intentions and opinions regarding the goal of becoming as circular as possible. Various quotes could be provided to illustrate the different opinions of the interviewees.

Table 4. Circularity of farms in practice (Dagevos & Lauwere, 2021)

Excerpts from the interviews	Type of farm
The farm is not completely circular yet, and I hardly know how to make further improvements. The inputs come from the region, that is, from the Netherlands and Germany. The farm is neither climate neutral nor energy neutral, and I do not know how to change that either. I use “blue diesel” for my tractor that is made out of food waste and labelled CO_2 neutral. I do realise though that using this type of diesel is possible because not many farmers use it. When more farmers would use blue diesel, there would not be enough of it.	BD dairy farmer
The farm is not completely circular: Feed is imported and, by selling meat, nutrients are taken away from the farm which do not come back. I am idealist but it is good as it is.	BD outdoor pig farmer
Our credo is to decrease the cycle as much as possible, preferably at the own farm. We try to be as local as possible, both with respect to external inputs and our supply of meat. How circular can you be? Although we	Outdoor pig farmer

realise that an electric van needs batteries, we like to buy an electric van, but at this moment we are still using diesel.	
The farm has more outputs than inputs, much more, and that does not bother me. Concentrate (grain and maize flower) is bought for the dairy cattle, because it is not possible to grow grain and maize on peaty soil and recreants do not like grain and maize because you cannot walk through it and you cannot look across the maize, and the recreants are my clients.	BD multifunctional farmer 2
Sustainability and circularity do not bother me much in daily practice. I try to be as sustainable as possible, but I realise and accept that not everything I do is "green".	Farm with special livestock
It also is possible to produce milk without concentrate but then the cows will produce about 5000 L of milk per year. That does not fit in our business model yet. However, farms which do not use concentrate inspire me. Maybe we will stop using it one day. To me, sustainable farming is a process, a way of life.	Organic mixed farmer
Well, every pig farmer will say that they contribute to CA because residual flows from the food industry are used already as pig feed, for example, citrus and soy pulp. Because of that, the cycle is already closed for quite a big part. In addition, we buy straw from an arable farmer and the manure goes back to the land.	Conventional pig farmer 1
An air washer is expensive and it does not produce anything but clean air, and you cannot sell clean air. So we asked ourselves: Is it possible to regain heat with the air washer? Now we not only regain heat but minerals as well. So now we have developed a system in which heat is available unrestrictedly, without using fossil fuels.	Conventional broiler farmer
We never use antibiotics, the broilers are never sick, there is enough heat, also during the winter and the farming system is better for animal welfare than at the most other farms with slower growing broilers. Slower growing broilers cost 40% more raw materials and the need for energy is much bigger (in that case gas is still needed). The consequences of that choice are; thus, far-reaching.	Conventional broiler farmer

Table 4 provides an overview, and we add information to it by combining it with the ten critical performance indicators for CA as identified by Erisman and Verhoeven (2020):

1. soil preservation;
2. closing nutrient cycles;
3. reduction of greenhouse gasses and ammonia;
4. sustainable energy;
5. maintenance of biodiversity;
6. nature conservation;
7. animal welfare;
8. animal health;
9. using residual flows from the food industry; and
10. contribution to regional economy and vitality of the rural area.

After analyzing the interview data and the available farmer websites, it was found that 13 farmers met the following criteria: Biodynamic or organic farming (5 farms); proper soil maintenance, preservation of organic matter (7 farms); closing nutrient cycles (7 farms); reduction of greenhouse gas (CO2, CH4, N2O) and ammonia emissions (6 farms); sustainable energy (8 farms); support of biological diversity (8 farms); nature conservation (5 farms); improving animal welfare (ranging from a small plus to keeping animals according to their natural needs) (12 farms); antibiotics are used less (10 farms); using residual flows from the food industry (four farms); and contribution to the regional economy and rural vitality through a farm shop or online shop (9 farms).

Table 5. Farms included and meeting critical performance indicators for circular agriculture: 1 = soil preservation, 2 = closing nutrient cycles, 3 = reduction of greenhouse gasses and ammonia, 4 = producing sustainable energy, 5 = maintenance of biodiversity; 6 = nature conservation, 7 = animal welfare, 8 = animal health, 9 = using residual flows from the food industry, 10 = contribution to regional economy and vitality of the rural area (Dagevos & Lauwere, 2021)

Type of Farm		Critical Performance Indicators for Circular Agriculture									
	Adaptive or Alternative?	1	2	3	4	5	6	7	8	9	10
Community farm	Alternative	+	+			+		+	+	+	+
Biodynamic multifunctional farm 1	Alternative	+	+	+	+	+	+	+	+		+
Biodynamic multifunctional farm 2	Alternative	+	+	+	+	+	+	+	+		+
Conventional mixed nature inclusive farm	Alternative	+	+	+		+	+	+	+		+
Biodynamic outdoor pig farm	Alternative	+				+	+/−	+	+		+
Outdoor pig farm	Alternative		+		+	+	+/−	+	+	+	+
Farm with special livestock	Alternative						+	+	+	+	+
Organic mixed farm	In between	+	+	+	+	+	+/−	+	+		+
Biodynamic dairy farm	In between	+	+	+		+	+/−	+	+		
Cooperation between conventional arable and livestock farms	In between		+		+	+	+	+/−	+/−	+	+
Conventional broiler farm	Adaptive			+	+				+		
Conventional pig farm 1	Adaptive				+			+/−			
Conventional pig farm 2	Adaptive				+/−			+/−	+	+	

2.5. Insights for stakeholders

In order to create conditions for the wider application of circular business models, policy programs and measures are needed at various levels of the economy. In order to move faster to a significantly more circular and more efficient resource-using economy, where the negative impact on the environment related to economic production and consumption is significantly reduced, stakeholders will have to apply circular business models more widely.

It is important to be able to recognize the initiatives with true ransformative potential and prevent that the implementation of circular agriculture remains focused on merely optimization within the current system while more fundamental changes are needed to address the sustainability challenges. The concept of circular agriculture, as a guiding mission for food system innovations, lacks clarity and risks being used superficially without real transformative impact (Hoogstra, Silvius, de Olde, Candel, Termeer, van Ittersum & de Boer, 2024).

To prevent this, policymakers need to make clear decisions about the future of food systems and further operationalize the term of circular agriculture. Hereby, instead of fixating on the label "circular agriculture," it's recommended to focus on the practices that align with the desired food system direction. Different initiatives may use different terms, but they can all contribute to the broader mission of creating a more sustainable food system.

Measuring the circularity of the food production systems is the first step in the process of moving towards a circular food production system (Velasco-Muñoz et al., 2021). For this, it is necessary to know the level and the possibilities of circularity of each of the phases that make up the complete food production cycle.

Jauernig et al. (2020) argued for trying to find the common ground of different visions—more specifically here the "agrarian" and "industrial" visions of agriculture - and looking for compatibility rather than accentuating distinction, controversy and incongruence between perspectives. "We should not simply stick the label 'transformation' on any amendment to the status quo, or call each technological efficiency gain an 'innovation.' If the benchmark for the changes to which we aspire is not radically different to the one that has guided development solutions so far, humanity will not escape those strong path dependencies. At the same time, dismissing the role that incremental steps play in getting there means ignoring the insights that complex system research offers about patterns of change. So juxtaposing the two approaches as entirely separate strategies - a practice often used to discredit someone else's proposals—does not help. What helps is to keep each other challenged with respect to both the radicalness of the imagined outcomes (what do we deem possible) and the amount of change in this direction that the next, often little, steps could bring (what do we do to make it happen)"(Jauernig et al., 2020).

Policy can play an important role in addressing the market failures, policy incoherence, and status quo biases that currently hinder the competitiveness of these business models.

According to OECD (2018, p.4) policy can help to:

- Ensure that the full environmental costs of production and consumption activities are reflected in market prices.
- Improve collaboration within and across sectoral value chains. Fostering industrial symbiosis clusters, promoting online material marketplaces, establishing secondary raw material certification schemes, and, more generally, facilitation of cooperation within and across value chains may be worthwhile initial steps.
- Ensure that existing regulatory frameworks are coherent and fit for purpose, and not serving to preserve an existing status quo.
- Improve existing educational and information programs to provide individuals with a better understanding of the unintended consequences of their consumption choices. The use of behavioral insights and nudges, such as through labelling requirements, may be a promising way forward.
- Promote the supply of circular products ("supply-push measures") or demand for them ("demand-pull measures"). For the former this includes eco-design standards, strengthened extended producer responsibility (EPR) schemes, and the provision of

targeted R&D funding. Examples of the latter include differentiated VAT rates, recycled content mandates, product labelling standards, and green public procurement.

Circular agriculture (CA) presents a paradigm shift in agricultural practices, advocating for closed-loop systems that minimize waste and maximize resource efficiency. Beyond its environmental benefits, CA offers compelling economic advantages for stakeholders across the agricultural value chain. This chapter outlines practical insights and recommendations for stakeholders interested in maximizing the economic potential of CA.

Policy Development: Fostering an Enabling Environment

Government subsidies and tax breaks: Incentivize on-farm resource recovery practices like composting facilities and cover cropping through targeted subsidies and tax breaks. (Wallace, 2019; Badu-Nkansah, Opoku-Agyemang, Adu-Dapaah & Asare-Kumah, 2018).

Knowledge dissemination and extension services: Invest in farmer education programs and extension services to promote knowledge transfer and adoption of CA practices (Sumberg, & Hoffecker, 2017; Titton, Perretti, Bonneau & Münnich, 2012).

Research and development funding: Allocate public research and development funding towards CA innovations like nutrient recycling technologies and decision-support tools for farmers.

Investment Strategies: Seeding Economic Growth

Private sector investment: Encourage private sector investment in CA infrastructure, such as biorefineries for processing agricultural waste into valuable products.

Impact investing: Attract impact investors seeking opportunities that align financial returns with environmental and social benefits associated with CA.

Risk mitigation instruments: Develop risk mitigation instruments, such as crop insurance programs tailored to CA practices, to encourage broader adoption.

Collaboration Opportunities: Building a Circular Economy Ecosystem

Farmer cooperatives: Facilitate the formation of farmer cooperatives to share resources, knowledge, and best practices in implementing CA.

Supply chain partnerships: Encourage collaboration between farmers and food processors to develop and promote CA-produced products with premium pricing.

Public-private partnerships: Foster public-private partnerships to develop and implement comprehensive CA strategies across the agricultural sector.

Conclusion

By implementing these recommendations, stakeholders can create an enabling environment for CA adoption and unlock its full economic potential. Policymakers can establish supportive frameworks, while investors can channel resources towards innovative solutions. Collaboration among diverse stakeholders, including farmers, researchers, industry players, and policymakers, will be crucial in building a robust circular agricultural economy. As CA gains momentum, stakeholders who embrace this transformative approach are poised to reap the economic benefits alongside environmental and social rewards.

Key Takeaways from Showcase examples of economic development

Importance of Circular Economy:

The circular economy is emerging as a vital alternative to traditional industrial farming, aiming to minimize resource depletion, waste, and emissions. This model emphasizes designing out waste, keeping products and materials in use, and regenerating natural systems to reduce the environmental impact of economic activities.

Diverse Circular Business Models:

Circular business models are categorized into product-based, service-based, sharing-based, and supply chain-based models. Each model supports the circular economy by promoting practices such as product life extension, resource recovery, sharing platforms, and product-as-a-service approaches, all aimed at improving resource efficiency and sustainability.

Implementation in Agriculture:

The transition to circular agriculture is being explored by various types of farms in the Netherlands. These farms implement practices such as using residual flows from the food industry, reducing ammonia emissions, and integrating livestock and crop production to move towards more sustainable and circular farming methods.

Challenges and Realities:

While many farms are adopting circular practices, achieving 100% circularity remains challenging. Farmers face difficulties in fully realizing circular production processes due to factors like reliance on external inputs, limitations in technology, and the balance between economic viability and environmental goals. Despite these challenges, continuous efforts and innovative solutions are essential for progressing towards a circular agricultural system.

Ideas to Consider from Showcase examples of economic development

Adopting Circular Business Models Across Industries:

Businesses in various sectors can significantly benefit from adopting circular business models. These models focus on resource efficiency by extending the life of products through design, repair, remanufacturing, and reuse. Organizations should explore how to integrate circular principles into their operations to reduce waste and environmental impact.

Leveraging Technology for Sustainable Farming:

Technological innovations play a crucial role in advancing circular agriculture. Farms can utilize high-tech solutions to reduce emissions, such as ammonia, and improve resource efficiency. Investing in technologies for better waste management, sustainable energy production, and efficient resource use can drive the transition towards circular farming practices.

Promoting Collaboration Among Farmers:

Collaboration among farmers can enhance the implementation of circular agriculture. By sharing resources, knowledge, and best practices, farmers can collectively address challenges related to sustainability and resource management. Cooperative efforts can also lead to more efficient use of inputs and better integration of livestock and crop production systems.

Consumer Awareness and Involvement:

Increasing consumer awareness about the benefits of circular economy practices is essential. Consumers play a critical role in driving demand for sustainably produced goods. Educational initiatives and transparent communication about the environmental impacts of products can encourage more responsible consumption patterns and support circular business models.

Policy Support for Circular Initiatives:

Governments and policymakers should provide robust support for circular economy initiatives. This can include incentives for businesses adopting circular practices, funding for research and development in sustainable technologies, and creating regulatory frameworks that facilitate the transition to a circular economy. Policy support can accelerate the adoption of circular principles across industries and contribute to broader environmental sustainability goals.

Video material from Showcase examples of economic development

What is Economic Development?
https://www.youtube.com/watch?v=DRPioDFGWRQ
Differences between Economic Growth and Economic Development.
https://www.youtube.com/watch?v=fJ25w66DJCk

Key Takeaways from Insights for stakeholders

Policy and Economic Levels:

To facilitate the broader adoption of circular business models, it is crucial to implement policy programs and measures across different levels of the economy. Effective policies can significantly reduce the negative environmental impacts associated with economic production and consumption.

Clarity and Transformative Potential:

Circular agriculture (CA) must go beyond superficial implementation to achieve real transformative impact. It is essential for policymakers to define clear objectives and operationalize CA in a way that addresses sustainability challenges and drives fundamental changes in the food system.

Measuring Circularity:

The first step towards a circular food production system is to measure the circularity of each phase of the food production cycle. Understanding the current level and possibilities for circularity is necessary to identify areas for improvement and implement effective circular practices.

Collaboration and Investment:

Collaboration across the agricultural value chain and investment in circular agriculture infrastructure are critical for maximizing CA's economic potential. Public-private partnerships, farmer cooperatives, and private sector investments can drive innovation and promote sustainable practices, leading to economic, environmental, and social benefits.

Ideas to Consider from Insights for stakeholders

Policy Alignment and Support:

Governments should align regulatory frameworks to support circular agriculture (CA) and remove barriers that hinder its adoption. This can include subsidies, tax breaks, and targeted R&D funding to promote resource recovery, nutrient recycling, and sustainable farming practices.

Educational Programs and Knowledge Dissemination:

Investing in education and extension services for farmers is crucial. Comprehensive programs that disseminate knowledge about CA practices can accelerate their adoption and ensure that farmers are equipped with the necessary skills and information to implement these practices effectively.

Economic Incentives and Risk Mitigation:

Developing economic incentives such as impact investing, crop insurance tailored to CA practices, and premium pricing for CA-produced products can attract investment and reduce the financial risks associated with transitioning to circular agriculture.

Collaboration Across Sectors:

Building a robust CA ecosystem requires collaboration among diverse stakeholders, including farmers, food processors, researchers, industry players, and policymakers. Initiatives like farmer cooperatives and public-private partnerships can facilitate resource sharing, innovation, and the development of comprehensive CA strategies.

Practical Implementation and Measuring Progress:

Focus on practical implementation of CA by measuring circularity in food production systems. Stakeholders should prioritize identifying and scaling practices that contribute to sustainability goals, ensuring that circular agriculture initiatives have a tangible and measurable impact on reducing waste and improving resource efficiency.

Video material from Insights for stakeholders
How does circular agriculture contribute to biodiversity?
https://www.youtube.com/watch?v=RV77QBFFb-w
Explaining the Circular Economy and How Society Can Re-think Progress
https://www.youtube.com/watch?v=zCRKvDyyHmI

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CHAPTER 3

SUSTAINABILITY OF FOOD SECURITY IN CIRCULAR AGRICULTURE

Chapter 3: Sustainability of Food Security in Circular Agriculture

This chapter delves into the sustainability aspect of food security within the context of CA. It explores how embracing circularity in agricultural practices can contribute to long-term food security by ensuring reliable access to safe and nutritious food while minimizing environmental impact. It emphasizes the interconnectedness between sustainable food production, economic stability, and community resilience. Through an exploration of key concepts, learners gain a deeper understanding of how circular agriculture promotes sustainable food systems that support food security for present and future generations.

3.1. Definition of Food Security in the Context of CA

Understanding Food Security in Circular Agriculture

Food security, within the framework of circular agriculture, encompasses the availability, access, utilization, and stability of food resources. This chapter aims to provide a comprehensive understanding of food security, emphasizing its multidimensional nature and the importance of sustainable practices in achieving a secure food system.

The objective of this chapter is to define food security in the context of circular agriculture, highlight its significance, and examine the factors that contribute to a secure and sustainable food system. By the end, students and educators will have a nuanced understanding of food security and the critical role circular agriculture plays in enhancing it.

Food security is essential for human well-being, ensuring access to sufficient, safe, and nutritious food. In circular agriculture, the importance of food security is amplified as it promotes sustainable practices that minimize waste and optimize resource use. Envisioning agricultural systems as regenerative, where waste is transformed into resources and food production processes are sustainable and resilient, underscores the relevance of food security in achieving a sustainable future.

Learning Objectives

Food security refers to a state where all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences for an active and healthy life. This concept involves four key dimensions:

- Availability: Ensuring an adequate and stable food supply through sufficient production, distribution, and exchange at global, national, and local levels.
- Access: Ensuring economic and physical access to food for individuals and communities, considering factors such as income, infrastructure, and social resources.
- Utilization: Effective use of food by the body, involving safe and nutritious preparation, access to clean water, sanitation, and healthcare.
- Stability: Maintaining the other three dimensions over time, even in the face of shocks or disruptions like natural disasters, economic downturns, or conflicts.

Factors Influencing Food Security

Several interconnected factors contribute to food security, ensuring access to sufficient, safe, and nutritious food:

- Sustainable Agriculture: Practices promoting sustainable and efficient agricultural methods, such as crop rotation, conservation tillage, and agroforestry, increase productivity and long-term food security.
- Infrastructure: Adequate transportation, storage facilities, and distribution networks are essential for efficient food movement from production areas to consumers, preventing food loss and waste.
- Economic Stability: A robust economy ensures that individuals and households have the financial means to purchase food, reducing poverty and improving food access.
- Access to Markets: Local and global market access allows farmers to sell produce, ensuring fair returns and contributing to economic growth and food security.
- Technological Advancements: Innovations in agricultural technology, such as improved crop varieties and precision farming techniques, enhance productivity and contribute to a secure food supply.
- Education and Knowledge: Educating farmers and communities about modern agricultural practices, nutrition, and food safety improves farming methods, dietary choices, and overall food security.
- Social Safety Nets: Programs like food assistance, subsidies, and targeted support for vulnerable populations ensure access to food during crises.
- Political Stability: Effective governance and political stability create an environment conducive to sustainable agriculture, economic development, and social well-being.
- Climate Resilience: Building resilience to climate change through strategies like drought-resistant crops and climate-smart agricultural practices ensures the stability of food production.
- Biodiversity: Maintaining agricultural biodiversity protects against crop diseases and pests, ensuring a reliable and diverse food supply.

Personal Responsibility in Food Security

Individuals and families play a crucial role in ensuring food security through responsible choices, sustainable practices, and awareness:

- Diversified Diets: Maintaining a balanced diet with various foods ensures a broader range of nutrients and reduces nutritional deficiencies.
- Sustainable Food Choices: Purchasing locally produced and seasonal foods supports local farmers and reduces the environmental impact of food production.
- Home Gardening: Growing fruits, vegetables, and herbs at home provides a direct source of fresh produce and fosters a connection to food production.
- Reducing Food Waste: Planning meals, proper storage, and creative use of leftovers help maximize food resources and minimize waste.
- Financial Planning: Effective budgeting ensures that families allocate resources wisely, including funds for nutritious food, preventing economic challenges from leading to food insecurity.

- Food Preservation: Methods like canning, freezing, and drying extend the shelf life of perishable foods and reduce reliance on constant access to fresh produce.
- Cooking Skills: Developing cooking skills enables individuals to make the most of available ingredients and create nutritious meals.
- Community Engagement: Engaging with local communities, farmers' markets, and food-related initiatives strengthens local food systems and contributes to overall food security.
- Educational Initiatives: Staying informed about nutrition, agricultural practices, and food-related issues empowers informed decisions about food choices.
- Water Conservation: Adopting water conservation practices at home contributes to broader efforts to sustain agriculture and ensure food security.
- Supporting Local Agriculture: Purchasing locally produced food supports farmers and strengthens regional food systems, reducing dependence on distant supply chains.
- Emergency Preparedness: Planning for emergencies ensures effective responses to disruptions in food access and maintains food security during crises.

<u>Community and Global Perspectives</u>

Global food security is a complex challenge requiring recognition of the interconnectedness of communities and nations:

- Supply Chains and Trade: Global food supply chains involve production, processing, and distribution across countries, influencing food availability.
- Climate Change Impact: Climate change affects global agricultural productivity, leading to shifts in food production and availability.
- Economic Interdependence: Fluctuations in one part of the world can influence global food prices and economic stability.
- Conflict and Migration: Political instability and conflict disrupt food systems and displace populations, affecting food security.
- Technological Transfer: Agricultural technology and knowledge shared globally influence farming practices and productivity.
- Knowledge Exchange: International collaboration on agricultural expertise and research improves farming practices and resilience.
- Global Cooperation: International initiatives and agreements, like the United Nations' Sustainable Development Goals (SDGs), emphasize collaborative efforts for global food security.
- Environmental Conservation: Conservation efforts contribute to maintaining biodiversity, essential for global food security.
- Pandemic Preparedness: Collaborative efforts ensure the resilience of food systems in the face of future crises.
- Cultural Exchange: Appreciating cultural diversity in food preferences enhances global food security efforts.

<u>Nurturing a Sustainable Future through Food Security Education</u>

Exploring food security within the context of circular agriculture reveals its profound significance in shaping a sustainable and equitable future. This chapter aimed to provide a comprehensive understanding of food security, emphasizing its multifaceted dimensions, global importance, and the pivotal role of circular agriculture.

Understanding the dimensions of availability, access, utilization, and stability highlights the interconnected factors contributing to or hindering food security. Recognizing the diverse challenges leading to food insecurity is crucial for developing comprehensive strategies for a secure and sustainable global food system.

Individual and community roles are vital in shaping food security. Sustainable practices, responsible choices, and awareness at the personal level resonate through communities, contributing to a resilient food future.

Global awareness and cooperation are essential, recognizing the interconnectedness of communities and nations. Addressing global food security requires a collective commitment to sustainable practices, equitable access, and the well-being of all people, transcending geographical boundaries.

Concluding, the exploration of food security within the context of circular agriculture, it becomes evident that the principles of circularity are fundamental to achieving a resilient and sustainable food system. Circular agriculture not only addresses immediate food security challenges but also aligns with broader global trends and innovative concepts shaping the future of agriculture.

In Chapter 5, "Megatrends, Concepts, and Factors of Circular Agriculture," the larger forces at play that are driving the adoption of circular agricultural practices will be presented. Megatrends, concepts and factors will be explored in detail, understanding their implications and applications within circular agriculture. This comprehensive examination will provide a deeper insight into how global trends and innovative concepts are shaping the future of sustainable agriculture and enhancing food security.

Takeaways about Food Security

- Food security involves more than just having enough food; it's about access to safe and nutritious options.
- Sustainable agriculture and responsible consumption contribute to long-term food security.
- Everyone has a role in promoting food security at the personal, community, and global levels.

Ideas to Consider about Food Security

- Why is it important for everyone to have access to safe and nutritious food?
- How can individuals reduce their environmental impact to contribute to global food security?
- What challenges do communities face in ensuring food security, and how can these challenges be addressed?
- How can knowledge about food security help make better choices in daily life?
- How can global cooperation improve food security around the world?

3.2. Exploration of the interplay between circular agriculture and sustainable food systems

Circular agriculture is a key approach to developing sustainable food systems, focusing on closing nutrient loops, minimizing waste, and optimizing resource use. This approach is built on core principles that significantly contribute to sustainability. First, closing nutrient loops aims to recycle nutrients, maintaining soil fertility and reducing reliance on synthetic fertilizers. Techniques like composting convert organic waste, such as food scraps, crop residues, and manure, into compost that enriches the soil. Effective manure management involves using livestock manure as a natural fertilizer, returning vital nutrients to the soil. Additionally, planting cover crops helps fix nitrogen, reduce erosion, and improve overall soil health. Through these practices, circular agriculture promotes a more resilient and sustainable agricultural system.

Waste minimization is a crucial objective in developing sustainable food systems, aiming to reduce food waste at all stages. This can be achieved through various methods. Efficient harvesting employs precision agriculture techniques to ensure crops are harvested at optimal times, thereby reducing loss. Food preservation methods, such as canning, freezing, and drying, extend the shelf life of food, preventing spoilage and waste. Additionally, food redistribution programs redirect surplus food to those in need through food banks and similar initiatives. By incorporating these strategies, waste minimization contributes significantly to a more sustainable and efficient food system.

Resource efficiency is a fundamental objective in sustainable food systems, focusing on optimizing the use of essential resources such as water, energy, and land. Precision farming plays a key role by utilizing technology to apply water, fertilizers, and pesticides more efficiently, thus reducing waste and enhancing productivity. Intercropping, the practice of growing multiple crops together, maximizes space and resource use, leading to higher yields and improved soil health. Agroforestry, which integrates trees and shrubs into farming systems, enhances biodiversity and resource use efficiency, contributing to more resilient and sustainable agricultural practices. Through these strategies, resource efficiency helps build a more sustainable and productive food system.

Renewable energy use is essential for reducing reliance on non-renewable energy sources in sustainable agriculture. By installing solar panels and wind turbines on farms, renewable energy such as solar and wind power can be harnessed, providing a clean and sustainable energy supply. Additionally, bioenergy production from agricultural residues and manure offers another renewable energy source in the form of biogas or biofuels. Implementing energy-efficient practices in farming operations further enhances sustainability by reducing overall energy consumption. These approaches collectively contribute to a more sustainable and energy-efficient agricultural system.

Maintaining soil health and promoting biodiversity are critical objectives in sustainable agriculture. Crop rotation is another effective practice, as rotating different crops breaks pest cycles and enhances soil fertility. Polyculture, the cultivation of diverse crops together, fosters resilience and biodiversity within the ecosystem. These practices collectively support robust soil health and a rich, diverse agricultural environment, essential for long-term sustainability and productivity.

Water conservation is a crucial objective in sustainable agriculture, focusing on efficient and sustainable use of water resources. Implementing drip irrigation systems helps minimize water waste by delivering water directly to the roots of plants, reducing evaporation and runoff. Rainwater harvesting offers another sustainable solution, allowing farms to collect and store rainwater for irrigation and other agricultural needs, thus reducing reliance on freshwater sources. Furthermore, cultivating drought-resistant crops that require less water and are resilient to dry conditions contributes significantly to water conservation efforts, ensuring agricultural productivity even in water-stressed environments.

Circular supply chains play a vital role in enhancing sustainability by minimizing waste and maximizing resource use throughout the production and distribution process. Local sourcing of inputs reduces transportation emissions and supports local economies, fostering a more resilient agricultural system. Adopting reusable packaging options reduces waste by allowing packaging materials to be reused or recycled, thereby reducing environmental impact. Additionally, utilizing byproducts such as crop residues for animal feed or bioenergy ensures that resources are utilized efficiently throughout the supply chain. These practices collectively contribute to the creation of circular supply chains that are more sustainable, resilient, and environmentally friendly.

Circular agriculture principles play a crucial role in the development of sustainable food systems by promoting resource efficiency, reducing waste, enhancing biodiversity, and improving soil health. By implementing these principles, farmers can create more resilient, productive, and environmentally friendly agricultural systems that support both local communities and global sustainability goals.

Takeaways

1. **Closing Nutrient Loops**: Recycling nutrients through composting and effective manure management maintains soil fertility and reduces dependency on synthetic fertilizers, promoting sustainable agriculture.
2. **Waste Minimization**: Strategies like efficient harvesting, food preservation, and food redistribution minimize food waste at all stages, contributing significantly to a sustainable and efficient food system.
3. **Resource Efficiency**: Utilizing precision farming, intercropping, and agroforestry optimizes water, energy, and land use, enhancing productivity and resilience in agricultural practices.
4. **Renewable Energy Use**: Adopting solar panels, wind turbines, and bioenergy from agricultural residues reduces reliance on non-renewable energy sources, promoting a cleaner and sustainable energy supply.
5. **Maintaining Soil Health and Biodiversity**: Practices such as no-till farming, crop rotation, and polyculture preserve soil structure, enhance fertility, and foster biodiversity, crucial for long-term sustainability and productivity.
6. **Water Conservation**: Implementing drip irrigation, rainwater harvesting, and cultivating drought-resistant crops minimizes water waste and ensures agricultural productivity in water-stressed environments.

7. **Circular Supply Chains**: Minimizing waste and maximizing resource use through local sourcing, reusable packaging, and byproduct utilization creates more sustainable, resilient, and environmentally friendly supply chains.
8. **Promoting Sustainable Food Systems**: Circular agriculture principles contribute to resource efficiency, waste reduction, biodiversity enhancement, and soil health improvement, fostering resilient, productive, and environmentally friendly agricultural systems

<u>Ideas to consider</u>

1. **Education and Training**: Educate farmers and agricultural workers about the principles and benefits of circular agriculture. Provide training on techniques such as composting, precision farming, and water-efficient irrigation methods to ensure effective implementation.
2. **Policy Support**: Advocate for policies that incentivize and support circular agriculture practices, such as tax incentives for renewable energy installations, subsidies for adopting sustainable farming practices, and regulations that promote waste reduction and resource efficiency.
3. **Research and Innovation**: Invest in research and development of innovative technologies and practices that enhance circular agriculture. Support collaborations between academia, research institutions, and farmers to develop new solutions for nutrient recycling, waste minimization, and resource optimization.
4. **Financial Support**: Provide financial support through grants, loans, or funding programs specifically designed to help farmers transition to circular agriculture practices. This could include funding for infrastructure improvements like drip irrigation systems, renewable energy installations, or composting facilities.
5. **Collaboration and Networking**: Foster collaboration and knowledge sharing among farmers, agricultural organizations, and stakeholders in the food supply chain. Facilitate networking opportunities to exchange best practices, experiences, and challenges related to circular agriculture.
6. **Consumer Awareness**: Raise consumer awareness about the benefits of supporting farms that practice circular agriculture. Promote labels and certifications that indicate sustainable farming practices, encouraging consumers to make environmentally responsible choices in their food purchases.
7. **Monitoring and Evaluation**: Establish monitoring and evaluation mechanisms to assess the environmental, economic, and social impacts of circular agriculture practices. Use data and metrics to track progress towards sustainability goals and identify areas for improvement.
8. **Scaling Up Success Stories**: Highlight successful case studies and demonstrations of circular agriculture practices. Showcase farms that have effectively implemented nutrient recycling, waste minimization, and resource efficiency to inspire and motivate other farmers to adopt similar practices.
9. **Community Engagement**: Engage local communities in supporting circular agriculture initiatives. Encourage participation in community-supported agriculture (CSA) programs, farmer's markets, and initiatives that promote local sourcing and sustainable food consumption.

10. **Adaptation to Local Conditions**: Recognize the diversity of agricultural landscapes and climates. Tailor circular agriculture practices to local conditions, considering factors such as soil type, climate resilience, water availability, and biodiversity conservation priorities.

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CHAPTER 4

VALUE CHAIN FOR MINIMIZING WASTE RESOURCES

IN CIRCULAR AGRICULTURE

Chapter 4: Value chain for minimizing waste resources in circular agriculture

This chapter delves into the intricacies of the value chain for minimizing waste resources. It explores the interconnected steps involved in reducing waste generation and maximizing resource efficiency throughout the lifecycle of products and services. Drawing upon insights from sustainable practices and circular economy principles, it examines each stage of the value chain, from resource procurement to end-of-life management, to uncover strategies for minimizing waste and promoting sustainability.Throughout this chapter, the importance of adopting sustainable practices at each stage of the value chain, from responsible sourcing of raw materials to efficient manufacturing processes, eco-friendly packaging solutions and consumer education initiatives, will be highlighted. By understanding the key principles and practices associated with waste reduction, learners will gain valuable insights into how businesses and organizations can contribute to a more sustainable and CA.

4.1 Resource procurement

Resource sourcing is the initial step in the value chain and plays a crucial role in reducing waste and increasing sustainability. Choosing raw materials and inputs from suppliers that prioritize sustainability and environmental responsibility is key to minimizing the overall environmental impact. Companies can opt for renewable, recycled, or responsibly sourced materials, which not only reduce environmental impact but also promote the circular economy.

4.1.1 Renewable and recycled materials

Bioplastics: Produced from renewable sources such as cornstarch, sugarcane and algae, bioplastics are biodegradable and reduce dependence on fossil fuels. Using bioplastics in products or packaging can significantly reduce plastic waste and carbon emissions.

Recycled paper and cardboard: Using recycled paper and cardboard for packaging and other industrial uses reduces demand for new forest resources and waste levels. Recycled paper requires less energy and water than new paper production, contributing to a more sustainable product life cycle.

Recycled metals: Recycled aluminum and steel can be reused in various industries. Recycling these metals requires less energy than extracting and processing new metals.

4.1.2 Responsibly Sourced Materials

FSC Certified Wood: Wood from sustainably managed forests certified by the Forest Stewardship Council (FSC) ensures that forestry practices meet high environmental and social standards. The use of certified wood can mitigate deforestation and protect biodiversity.

Organic Cotton: Cotton grown without the use of pesticides and chemical fertilizers reduces soil and water pollution. In addition, organic certification ensures sustainable farming practices and decent working conditions for workers.

Sustainable Raw Materials for Technology: Minerals such as lithium and cobalt, when mined and processed according to ethical and sustainable practices, can reduce environmental impacts and improve social responsibility in the supply chain of electronic devices.

Adopting these sustainable practices in resource sourcing not only minimizes waste, but also encourages a product life cycle that is regenerative by nature. This contributes to the circular economy, where materials are continuously reused and recycled, minimizing the extraction of new resources and the accumulation of waste.

4.2 Product Design

A crucial aspect of sustainable development is the product design focusing on waste product minimization. This parameter covers the entire lifecycle of the product, from raw material extraction to manufacturing, usage, and end-of-life disposal. A basic aspect is the product design for higher durability and longevity, the ease of disassembly so as products to fulfill the requirements of 3R (reuse, recycling, repair) and the clear labeling to facilitate sorting and recycling. Moreover, the material efficiency is also very important covering the need for optimized use of the materials often using a computer-aided design program (CAD), a lightweighting product resulting to the reduction of energy and transport cost and the incorporation, if possible, of waste materials from other processes into the specific product design. Moreover, the sort of materials is also vital. Sustainable materials may be separated to recycled materials from post-consumer or post-industrial sources, biodegradable or photodegradable materials or edible films, which are friendly to the environment and finally the use of materials from renewable resources, i.e. materials from natural sources. Other factors such as the work with suppliers who follow sustainable practices and can provide certification for materials and the reduction in the number of different materials (minimizing product variety) used to simplify recycling processes are also crucial for product design eco-friendly strategies.

Product design should also cover the aspects of life-cycling thinking. More specifically, the lifecycle assessment and the end-of-life planning are two parameters that influence the product final design. It is necessary to understand and minimize the environmental impact of a product throughout its lifecycle and to design a product having in mind the end-of-life image of it. Moreover, the product design shall consider energy and water efficiency. The production process from the first to the last step should follow the rules of circular economy reducing the loss of water using it for other applications such as crop irrigation and the minimization of energy loss through the development of eco-friendly industrial processes. Moreover, space efficiency of the products is also an important factor covering the design of products and reducing simultaneously the transportation and storage issues.

Companies should also invest in educating consumers to become more environmentally conscious. Measures in this direction can be the creation of incentives for the return of used products and their recycling as well as clear instructions in the manuals regarding the repair, upgrade and recycling of the products. Companies that are active in the creation of electronic and electrical devices (modular products) that are easily repaired and by extension have a longer life as well as companies that through electronic means, e.g. internet, resell recycled or low-use products are the best examples of sustainability and circular economy

Waste minimization in product design is not only beneficial for the environment but can also be economically advantageous. It reduces costs associated with material waste, enhances brand reputation, and meets increasing consumer demand for sustainable products. By integrating these principles and strategies into the design process, companies can create products that are more sustainable, efficient, and appealing to environmentally conscious consumers. Minimizing waste throughout the entire lifecycle of a product requires a holistic approach, from the initial design phase through to end-of-life disposal.

Takeaways

1.Minimization of Waste: Sustainable product design focuses on minimizing waste throughout the entire lifecycle, from raw material extraction to end-of-life disposal.
2. 3R Concept: The 3R concept (Reuse, Recycling, Repair) is integral to sustainable design, aiming to maximize product longevity and facilitate circular economy practices.
3. Material Efficiency: Optimizing material use through tools like AutoCAD and lightweighting reduces energy and transport costs, promoting efficiency.
4. Material Types: Sustainable materials include recycled materials, biodegradable or photodegradable materials, and those sourced from renewable resources.
5. Lifecycle Thinking: Lifecycle assessment and end-of-life planning are crucial in understanding and reducing environmental impacts across a product's lifecycle.
6. Circular Economy: Principles of the circular economy minimize waste, enhance energy and water efficiency, and optimize space efficiency in product design.
7. Consumer Education: Educating consumers fosters environmentally conscious behaviors, such as product return incentives and clear repair and recycling instructions.
8. Economic Benefits: Waste minimization not only benefits the environment but also reduces costs associated with material waste and enhances brand reputation.

Ideas to consider

1. **Design for Durability and Longevity**:
Focus on creating products that are robust and durable to extend their lifespan and reduce the frequency of replacement.
2. **Ease of Disassembly and Repair**:

Design products that are easy to disassemble for repair, upgrade, or recycling, supporting the principles of the circular economy.

3. **Optimized Material Use**:
Utilize computer-aided design (CAD) software to optimize material use, ensuring products are efficient in both material consumption and performance.
4. **Lightweighting**:
Reduce material weight where possible to decrease energy consumption during manufacturing and transportation, while maintaining product integrity.
5. **Incorporation of Recycled Materials**:
Integrate recycled materials from post-consumer or post-industrial sources into product designs, promoting resource conservation and waste reduction.
6. **Use of Sustainable Materials**:
Explore materials that are biodegradable, photodegradable, or sourced from renewable resources to minimize environmental impact.
7. **Lifecycle Thinking**:
Conduct lifecycle assessments to understand and minimize the environmental footprint of products across their entire lifecycle, from production to disposal.
8. **Efficient Use of Energy and Water**:
Optimize production processes to reduce water usage and energy consumption, utilizing resources more efficiently and minimizing environmental impact.
9. **Space Efficiency in Design**:
Design products that optimize space during transportation and storage, reducing packaging needs and logistical costs.
10. **Collaboration with Sustainable Suppliers**:
Partner with suppliers who adhere to sustainable practices and provide certified materials, ensuring transparency and environmental responsibility throughout the supply chain.
11. **Consumer Education and Engagement**:
Educate consumers about the environmental benefits of products and empower them with information on proper disposal, recycling, and reuse options.
12. **Circular Economy Initiatives**:
Implement circular economy principles such as product take-back programs, remanufacturing, and recycling initiatives to close the loop on product lifecycles.

4.3 Manufacturing Processes

The demand for sustainable development of cities and the use of environmentally friendly manufacturing techniques are necessities these days. The introduction of environmentally friendly processes will significantly reduce waste outputs and the use of energy and water resources by ensuring the creation of products that meet environmentally friendly specifications.

A basic technique for achieving efficient manufacturing processes with a focus on waste reduction is the lean manufacturing which leads to the elimination of waste and the improvement of industrial efficiency. Lean manufacturing is based on specific principles which covers the aspect of the identity value from the consumer's perspective, the mapping of the value stream, the creation of a harmonized and integrated set of processes in which activities move in a constant stream, a continuous choice of perfection and finally the establishment of a system, where the creation of a new activity is based on the customer's demand as a result of flexibility and communication.

A new circular strategy applied in manufacturing operations to achieve the goals of circular economy is the green-lean-six sigma (GLSS). This strategy is recognized as an emerging way to minimize resource waste flows, to remove systematically the non-added value (NVA) activities, to streamline processes, to control processes through variation reduction and produce products without defects. Other aspects that influence GLSS are the need for material and resource circulation and the environmental conservation in the production and management operations.

Moreover, sustainability and smart automation technologies can be combined and are crucial factors for the manufacturing processes. Smart technologies can increase productivity and simultaneously reduce the environmental impacts so as to follow the Industry 4.0 technology adoption. The implementation of robotic process automation (RPA) is vital for the increase in precision in manufactures and the reduction of human errors and material wastes. Moreover, the utilisation of computer-aided design (CAD) and computer-aided manufacturing (CAM) optimizes designs and manufacturing processes, ensuring efficient use of materials. Finally, the implementation of IoT devices to monitor equipment performance and predict maintenance needs, reduces downtime and waste.

The manufacturing industry has been evolving to reduce its environmental impact by product-oriented and process-oriented optimization. This area focuses on the optimization of the material use and the reduction of waste. Key parameters are the replacement of materials and the use of new ones that produce less waste and are easier to recycle. It is necessary to implement systems to collect, recycle, reuse scrap materials within the production process and to use inventory management systems to reduce material overstocking and waste. Other waste reduction techniques are the closed loop systems where waste materials are captured and reused in the production process. For instance, a sustainable or green manufacturing practice can replace plastics with bioplastics derived from natural sources incorporated in manufacturing cycle as direct raw material substitution.

Manufacturing consumes both renewable and non-renewable materials (e.g. metals, fossil oil-derived materials, and water) as well as significant amounts of energy, resulting in environmental degradation. Manufacturing activities dominate industrial energy consumption. The investment in energy-efficient equipment as a result to more stringent regulations (e.g. emission standards, worker exposure standards, and banned materials) will reduce CO_2 emissions waste treatment, disposal costs and conserve energy, water, and materials.

The adoption of new technologies in manufacturing must be followed by the employee training and engagement. A unique training offer to achieve a multidisciplinary expertise in smart manufacturing is a crucial and inevitable target. Building on novel educational paradigms and recent developments in the area of manufacturing, the main goal of the program is to provide the European industry with outstanding experts willing, able, and trained to bring novel solutions that address relevant societal challenges.

Implementing efficient manufacturing processes is essential for reducing waste generation. By leveraging lean manufacturing, green-lean-six sigma, automation, sustainable materials management, energy efficiency, waste reduction techniques, and employee engagement, companies can significantly minimize waste while enhancing productivity and profitability. This comprehensive approach not only benefits the environment but also leads to a more sustainable and resilient manufacturing operation.

Takeaways

1. **Importance of Sustainable Development**: Sustainable manufacturing is crucial for reducing waste outputs, conserving energy and water resources, and meeting environmentally friendly specifications.
2. **Lean Manufacturing Principles**: Lean manufacturing focuses on eliminating waste and creating efficient processes through principles like value stream mapping, continuous flow, and continuous improvement.
3. **Green-Lean-Six Sigma (GLSS)**: GLSS integrates green practices with lean and Six Sigma methodologies to minimize resource waste, remove non-value-added activities, and control processes for defect-free production.
4. **Smart Automation Technologies**: Adoption of Industry 4.0 technologies, such as robotic process automation (RPA), computer-aided design (CAD), and Internet of Things (IoT), enhances productivity while reducing environmental impacts.
5. **Material Efficiency and Waste Reduction**: Techniques like just-in-time (JIT) inventory management, closed-loop systems, and direct substitution of sustainable materials contribute to minimizing material overstocking and waste.
6. **Energy Efficiency**: Investment in energy-efficient equipment helps in reducing CO_2 emissions, waste treatment costs, and conserving energy, water, and materials.
7. **Employee Training and Engagement**: Successful adoption of new technologies requires multidisciplinary expertise and continuous training to engage employees in sustainable manufacturing practices.

Ideas to consider

1. **Design for Sustainability**: Focus on designing products and processes that prioritize durability, recyclability, and the use of sustainable materials.
2. **Lean Manufacturing Implementation**: Implement lean principles to streamline operations, eliminate waste, and improve efficiency throughout the manufacturing process.
3. **Integration of Green Practices**: Integrate green practices such as GLSS to systematically reduce resource waste and enhance process control.
4. **Adoption of Smart Technologies**: Embrace Industry 4.0 technologies like RPA, CAD, CAM, and IoT to optimize manufacturing processes and reduce environmental impacts.
5. **Waste Management Systems**: Implement closed-loop systems and JIT inventory management to minimize material waste and improve resource efficiency.
6. **Energy and Resource Conservation**: Invest in energy-efficient equipment and practices to reduce energy consumption, CO2 emissions, and waste treatment costs.

7. **Employee Training and Development**: Provide continuous training and foster a culture of sustainability to empower employees with the skills and knowledge to support sustainable manufacturing practices.
8. **Regulatory Compliance and Certification**: Ensure compliance with environmental regulations and seek certifications that validate sustainable manufacturing practices.
9. **Collaboration and Supplier Engagement**: Collaborate with suppliers who follow sustainable practices and prioritize environmental conservation in their operations.
10. **Continuous Improvement**: Foster a culture of continuous improvement to regularly assess and optimize manufacturing processes for sustainability and efficiency.

4.4 Packaging

Packaging plays an important function in the food industry to facilitate products handling, transport, stacking, storage, and distribution. Packaging main role is the protection of foods from the environmental conditions, the avoidance of the transfer of organic or inorganic chemical substances to the product during their contact and the microbiological stabilization of the product.

The design of packaging should follow specific standards, i.e., simplicity, integrated design and right sizing. Packaging should be tailored to fit the product precisely, minimizing excess material. Additionally, it must fulfill multiple roles, such as providing protection, facilitating marketing, and enabling storage. Unnecessary layers should be avoided, and designs should prioritize using the minimal amount of material needed for protection and presentation.

In the pursuit of sustainable packaging solutions, it is essential to use recycled content, biodegradable materials, and renewable resources. Utilizing materials that have been recycled reduces the need for virgin resources, conserving natural materials and lowering the carbon footprint. Selecting biodegradable materials such as paper, cardboard, or bioplastics ensures that packaging will naturally decompose, reducing landfill waste and environmental pollution. Additionally, incorporating renewable resources like bamboo or plant-based plastics promotes sustainability by relying on materials that can be replenished over time.

Reusable packaging is an essential strategy for sustainability, aiming to design packaging that can be reused multiple times. This approach includes creating refillable containers that consumers can refill and reuse, using durable materials and designs that withstand multiple uses, such as glass bottles or sturdy plastic containers. Additionally, implementing systems where customers can return packaging for reuse, like beer kegs or milk bottles, further enhances the reusability of packaging.

Lightweighting is a critical strategy in packaging design aimed at reducing material usage and lowering transportation emissions. This approach involves using thinner materials that maintain strength and protection, thereby minimizing the overall weight of the packaging. Innovative structural design techniques are employed to ensure integrity while using less material, optimizing efficiency without sacrificing performance. Additionally, leveraging advanced materials with high strength-to-weight ratios further enhances the effectiveness of lightweight packaging solutions. By prioritizing lightweighting strategies, businesses can significantly reduce environmental impact throughout the packaging lifecycle, from production to disposal.

Recyclable packaging aims to facilitate easy recycling processes throughout its lifecycle. This is achieved by designing packaging using a single type of material to simplify recycling efforts, ensuring clear labeling with recycling instructions directly on the packaging, and selecting materials that are widely accepted by local recycling programs. By adhering to these principles, recyclable packaging minimizes waste and promotes the efficient reuse of materials, contributing to environmental sustainability.

Compostable packaging focuses on designing materials that can naturally decompose at the end of their lifecycle. This involves using certified compostable materials that meet industrial or home composting standards, enabling consumers to dispose of packaging in composting facilities. Designs often include features for home compostability, making it accessible for consumers to participate in sustainable waste management practices. Education about proper composting techniques further supports the widespread adoption of compostable packaging solutions, reducing landfill waste and supporting soil health

Innovative packaging solutions explore cutting-edge technologies and materials to enhance sustainability and functionality. These include edible packaging options made from biodegradable materials like seaweed or rice, which offer safe consumption and minimal environmental impact. Water-soluble packaging is utilized for specific applications such as single-use laundry pods, dissolving safely in water to reduce waste. Plantable packaging integrates seeds into biodegradable materials, allowing consumers to plant packaging waste to grow plants, promoting ecological benefits and circularity in packaging practices.

Supply chain optimization strategies aim to reduce packaging waste across the entire supply chain. Bulk shipping practices minimize individual packaging needs by shipping products in larger quantities. Reusable shipping containers are employed for logistics, reducing the demand for single-use packaging materials. Optimized shipping and storage practices enhance efficiency, decreasing the reliance on excessive protective packaging and lowering environmental impact. These approaches collectively improve resource management and contribute to a more sustainable supply chain ecosystem.

Takeaways

1. **Packaging Functions**: Facilitates handling, transport, stacking, storage, and protects food from environmental conditions and chemical transfer.
2. **Design Principles**: Follows simplicity, integrated design, and right sizing to minimize material use and fulfill multiple roles.
3. **Sustainable Materials**: Uses recycled content, biodegradable materials, and renewable resources to reduce environmental impact.
4. **Reusable Packaging**: Focuses on durability and multiple-use containers to minimize waste and support sustainability.
5. **Lightweighting**: Reduces material usage and transportation emissions while maintaining packaging integrity.
6. **Recyclable Packaging**: Simplifies recycling processes with clear labeling and single-material designs to enhance recyclability.

7. **Compostable Packaging**: Designed to decompose naturally in industrial or home composting systems, reducing landfill waste.
8. **Innovative Solutions**: Integrates advanced technologies like edible, water-soluble, and plantable materials to enhance sustainability and functionality.
9. **Supply Chain Optimization**: Reduces packaging waste through bulk shipping, reusable containers, and optimized logistics practices.
10. **Environmental Impact**: Emphasizes waste reduction, resource efficiency, and sustainable practices throughout the packaging lifecycle.

Ideas to consider

1. **Design for Minimal Environmental Impact:** Focus on designing packaging that minimizes environmental impact throughout its lifecycle, from production to disposal. Incorporate principles of simplicity, integrated design, and right sizing to reduce material usage and waste generation.
2. **Utilization of Sustainable Materials:** Emphasize the use of recycled content, biodegradable materials, and renewable resources in packaging design. Opt for materials that have minimal environmental footprint and can be easily recycled or composted at the end of their life.
3. **Promotion of Reusable Packaging:** Implement strategies to promote reusable packaging solutions that can be refilled and reused multiple times. Design durable packaging using materials like glass or sturdy plastics, and establish systems for customers to return packaging for reuse.
4. **Adoption of Lightweighting Strategies:** Prioritize lightweight packaging designs to reduce material consumption and transportation emissions. Utilize advanced materials and innovative structural design techniques to maintain packaging integrity while minimizing weight.
5. **Facilitation of Recycling Processes:** Design packaging that is easily recyclable by using a single type of material and providing clear recycling instructions. Ensure compatibility with local recycling programs to promote efficient material reuse and waste reduction.
6. **Development of Compostable Packaging:** Explore materials certified for industrial or home composting to enable environmentally friendly disposal options. Educate consumers on proper composting techniques to encourage widespread adoption of compostable packaging solutions.
7. **Innovation in Packaging Technologies:** Invest in research and development of innovative packaging technologies, such as edible packaging and water-soluble materials, to enhance sustainability and functionality. Integrate seeds into biodegradable materials for plantable packaging options that promote circularity.
8. **Optimization of Supply Chain Practices:** Implement supply chain optimization strategies like bulk shipping and reusable shipping containers to minimize packaging waste and reduce environmental impact. Optimize shipping and storage practices to enhance efficiency and sustainability across the supply chain.
9. **Compliance with Regulatory Standards:** Stay informed about local and international regulations concerning packaging materials, recycling standards, and environmental impact

assessments. Ensure compliance to mitigate legal risks and uphold responsible packaging practices.

10. **Continuous Improvement and Industry Collaboration:** Foster a culture of continuous improvement within the organization to innovate and refine sustainable packaging solutions. Collaborate with industry peers, research institutions, and organizations to share best practices and drive advancements in sustainable packaging practices

4.5. Distribution and Logistics

Distribution and logistics are crucial steps in the value chain, directly affecting energy consumption and carbon emissions associated with the movement of goods. Optimizing transportation and distribution networks can contribute significantly to reducing waste and improving overall efficiency.

4.5.1 Shipping Consolidation Strategies

Route Planning: Implementing advanced route optimization software can reduce the distance vehicles travel, thereby decreasing fuel consumption and greenhouse gas emissions. Companies can use algorithms to calculate the most efficient routes, considering variables such as traffic and road conditions.
Load Consolidation: Grouping shipments to maximize the use of space in vehicles reduces the number of trips required. This approach not only decreases CO_2 emissions but also lowers transportation costs.
Regional Logistics Hubs: Establishing regional distribution centers can reduce transportation distances between final origin and destination points, thereby optimizing last-mile logistics. This is especially important in urban areas, where traffic congestion can be significant.

4.5.2 Efficient Modes of Transportation

Intermodal Transportation: The combined use of different modes of transportation, such as trains and trucks, can optimize transportation time and costs while reducing carbon emissions. Trains, for example, are more energy efficient for transporting goods over long distances than trucks.
Low Environmental Impact Vehicles: The adoption of electric or hybrid vehicles for distribution can significantly reduce CO_2 emissions. In addition, the use of technologies such as hydrogen engines can be a long-term solution for sustainable logistics.
Sea and River Transport: For international or high volume shipments, sea transport may be a more sustainable option than air transport due to the greater energy efficiency of ships. The use of barges for transport along rivers can also reduce the load on road networks.

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4.6 Consumer Use

Sustainable consumption has become an increasingly important topic of debate in the world over the last decade. Sustainable production and consumption of goods and services is a major focus of both the public and private sectors. Sustainable consumption is defined as conscious and sustainable consumption behaviour that aims to meet individual needs by acquiring, using or disposing of relevant goods or services without harming the environment and social well-being (Geiger Fischer and Schrader, 2018).

While the EU is making great efforts to become a more sustainable union, this is not enough to be achieved by government initiatives alone but must be accompanied by a change in consumption patterns. Societies are not homogeneous across countries, with social (different cultures, values, goals) and economic environments influencing consumers in different ways, so the relevance of sustainable consumption is not the same across countries (Pacita Project). For this reason, governments and businesses are undertaking a variety of citizen awareness, information projects and initiatives on sustainability.

Consumption is increasing due to the availability of sustainability information to support purchasing decisions. 87% of consumers are concerned about the social and environmental impacts of the goods they purchase (Shao, 2016). In addition, consumers are becoming more demanding, requiring more and more information not only about the composition of the product, but also about the supply chain and production processes. The authors argue that both government and organisations must take responsibility for providing consumers with information on the sustainability of a product (Shao, Taisch, & Mier, 2017).

This suggests that consumers are concerned about sustainable consumption and that the role of the company in this context is linked to the purchase of the product. Recognising the importance of a sustainability strategy and the importance of increasing the availability of information to consumers, a strong emphasis must be placed on educating and informing consumers about the sustainability of goods and services.

Consumer awareness has a significant impact on the promotion of environmentally friendly goods on the market. According to Urbaitytė K., (2020), eco-labelling is one of the methods by which consumers are made aware of the environmental impact of products. The

European Union's labelling provides credible information that the products in question have been certified as more environmentally friendly than most other similar products throughout their life cycle. According to Chen, Lin and Weng (2015), environmentally friendly consumer behaviour includes purchasing behaviour that includes reading labels, buying reusable materials, and recycling goods.

Informing consumers about the sustainability, durability, consumption, maintenance and disposal options of products not only raises their awareness but also increases their responsible consumption habits. **According to (CosumerPro, 2022), the most common ways in which consumers are informed about a product's level of sustainability are:**

- **Eco-design**
- **Energy labelling**

A detailed discussion of the three forms of consumer information on the sustainability of products is given below Eco-labelling:

<u>Eco-design</u>

Eco-design encourages manufacturers to improve products through more efficient use of resources throughout their life cycle - for example, through repair requirements. Product quality and usability must also be taken into account. Consumers are required to be given more information on the sustainable use of the product. The EU Ecodesign Directive76 not only protects the environment but also helps consumers save money. According to a 2016 survey77 commissioned by BEUC, the average EU household can save up to €330 per year through eco-design and by making products more energy efficient over time.

According Wojnarowska (2021), Eco-design also plays an important role in the implementation of a company's environmental policy, which includes adapting to the criteria established for specific eco-labelling. According to Directive 2009/125/ CE [Directive 2009], eco-design involves the regular incorporation of the environment life cycle perspective into the design of products, services, and processes. Eco-design entails embedding environmental aspects in the product design with the aim of improving its eco- effectiveness throughout its life cycle. The eco-design process results in an environmental profile describing outlays and products related to a given product throughout its life cycle that are significant from the point of view of its environmental impact and are expressed in measurable physical terms. Continual modifications can be observed in the extent to which a company perceives its role in economic development and its importance in satisfying comprehensive social needs and requirements. New phenomena in the domain of consumption, production, and cooperation between respective market participants have given rise to some very dynamic and interdisciplinary issues.

Energy labelling

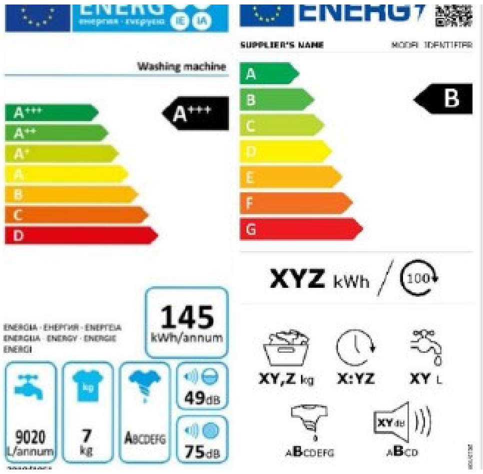
The Energy Labelling Regulation 78 empowers the European Commission to adopt mandatory labelling measures for specific energy-related product groups such as washing machines and televisions. This ensures that consumers can make an informed choice about the energy consumption of products during use.

According to 24take (2024), as climate change is intensifying, intensive efforts are being made to reduce electricity consumption in a wide range of activities, and residential households are no exception. The Energy Labelling Directive adopted by the European Union not only contributes to a more sustainable use of household appliances, but also has financial benefits for consumers. With electricity prices rising, many consumers are choosing to buy more economical, resource-efficient appliances that will save them money in the long term.

Energy efficiency classes are a way of determining the amount of electricity consumed and an efficiency index. The old system, which ran on a scale from A++ to D (lowest efficiency), was replaced in 2021 to encourage manufacturers to improve appliances and develop new, more efficient and sustainable technologies. The new categorisation of A, B, C, D, E, F and G is not only clearer for consumers, but also allows for uniform labelling between different manufacturers and increases common standards for appliances. The system applies to fridges and freezers, washing machines, tumble dryers, ovens, hoods and dishwashers.

The highest energy class, A, is the most efficient and wastes the least electricity. These appliances are the friendliest to the environment and to your wallet, as they consume the most resources. The second B category appliances, although they consume slightly more energy, are also efficient and economical. Class C and D appliances are classified as medium energy savers. Appliances in the low energy efficiency category (E, F and G) will use significantly more resources, so you need to consider both environmental and financial aspects when choosing such appliances. It is also important to remember that even an old appliance with the highest energy rating will consume more energy than a new appliance with a medium rating, so investing in a periodic renewal of your appliances will also be worthwhile.

When we buy home appliances or electronics, we are used to seeing an energy efficiency label with all the relevant information about the product's consumption. Sellers are obliged to provide this label in both physical and online shops.



EcolabelLING

According Wojnarowska (2021), Eco-labels are a way to tell consumers how much a product impacts the environment throughout its life. These labels look a specific way and show that a product meets certain environmental standards. This means producers can't just put an eco-label on anything they want. While not mandatory, eco-labels can only be used if they follow strict rules. Essentially, eco-labels set products apart by highlighting their lower environmental impact compared to similar ones. They often focus on comparing how easy a product is to use while considering its environmental footprint. Some labels even consider social factors beyond the environment.

The EU Ecolabel was established in 1992 as a Europe-wide optional label to help consumers make greener and healthier purchasing decisions. The Ecolabel now covers more than 77,000 products and services in 24 different categories. This number has almost doubled since 2016.

To qualify for the 'flower' logo, a product or service must meet a list of environmental and health-related criteria, from the durability of the product to the exposure to harmful chemicals.

There are other eco-labels officially recognised at national or regional level in the EU which are equivalent to the EU Ecolabel. Examples of such labels include, for example, the "Nordic Swan" in the Nordic countries, the "Blue Angel" in Germany or the Austrian ecolabel.

By providing sustainable information, eco-labels help consumers trust products that are better for the environment. However, for them to be effective, consumers need to understand and trust the labels themselves. Unfortunately, there can be issues with how these labels are monitored, which can make them less reliable.

One of the main goals of eco-labels is to encourage consumers to be more environmentally conscious and choose sustainable products (Wojnarowska, 2021). This, in turn, pushes businesses and governments to offer and make products that meet higher environmental standards. Ultimately, eco-labels aim to create a market for more environmentally friendly goods.

According to Wojnarowska (2021), **there are several benefits to eco-labels**:

- including promoting environmentally friendly products,
- informing consumers,
- encouraging businesses to be more sustainable,
- and educating the public.

The most important role, however, is **helping consumers identify products that are better for the environment**. Eco-labels are a powerful tool for influencing consumer choices and promoting sustainable products.

Sustainable consumption is becoming increasingly important for both consumers and businesses. In order to reduce environmental impacts and promote social responsibility, it is important not only to produce sustainable products, but also to encourage consumers to choose them. Consumers are increasingly interested in the environmental and social impact of the products they buy, which is why eco-labelling is becoming increasingly important. The EU Ecolabel and other nationally or regionally recognised labels guarantee that products meet strict environmental and health criteria. In addition to eco-labelling, other measures such as consumer education, the production of durable products, the use of recycled materials and the responsible management of waste can also help promote sustainable consumption. Sustainable consumption is vital for a more sustainable future and all stakeholders - governments, businesses and consumers - need to work together to make it happen.

Takeaways

Importance of Consumer Awareness:

- Sustainable consumption relies heavily on informed consumers. Governments and businesses play a crucial role in providing accurate and comprehensive information about the environmental and social impacts of products. Eco-labelling, energy labelling, and eco-design are essential tools for raising consumer awareness and promoting environmentally friendly purchasing decisions.

Role of Eco-Design:

- Eco-design focuses on improving products by making them more resource-efficient throughout their life cycle. This not only benefits the environment but also helps consumers save money in the long run. The EU Ecodesign Directive, for example, ensures that products are designed with both environmental protection and cost savings in mind.

Significance of Energy Labelling:

- Energy labelling is a critical component in guiding consumers towards energy-efficient products. The updated EU Energy Labelling Regulation provides clear and uniform labels that help consumers make informed choices, leading to reduced energy consumption and financial savings. The categorization from A (most efficient) to G (least efficient) allows for easy comparison between products.

Impact of Eco-Labelling:

- Eco-labelling helps consumers identify products that have a lower environmental impact throughout their life cycle. Labels like the EU Ecolabel provide assurance that products meet stringent environmental and health criteria. This encourages sustainable consumer behavior and pushes businesses to adopt higher environmental standards, fostering a market for greener products.

Ideas to consider

Enhanced Consumer Education Programs:

- Governments and businesses should invest more in consumer education programs that emphasize the importance of sustainable consumption. Educating consumers on the benefits of eco-design, energy efficiency, and eco-labelling can significantly influence purchasing behaviors and promote a more sustainable market.

Incentivizing Sustainable Choices:

- Implementing incentives for purchasing environmentally friendly products, such as tax breaks or rebates, can encourage more consumers to choose sustainable options. Additionally, providing subsidies for manufacturers to produce eco-friendly products can help drive the market towards sustainability.

Strengthening Eco-Labelling Standards:

- To ensure the reliability and effectiveness of eco-labels, it is crucial to develop and enforce stringent standards. Regular monitoring and certification processes can maintain the integrity of eco-labels, making them a trusted source of information for consumers.

Promoting Sustainable Product Design:

- Encouraging manufacturers to integrate sustainability into the design process can lead to products that are not only environmentally friendly but also durable and cost-effective. Policies that support the development and adoption of eco-design principles can drive innovation in product design.

Collaborative Efforts for a Sustainable Future:

- Achieving sustainable consumption requires collaboration between various stakeholders, including governments, businesses, and consumers. Public-private partnerships, industry collaborations, and community initiatives can collectively work towards creating a more sustainable economy and society. By pooling resources and expertise, these collaborative efforts can have a more significant impact on promoting sustainable consumption practices.

Audiovisual Material

Sustainable Consumption
https://www.youtube.com/watch?v=RYFEL7RJTmU
How to make sustainable consumption possible?
https://www.youtube.com/watch?v=XeoCfBg9eSY
What are Eco-Labels or Sustainability Labels? Different types of Eco Labeling.
https://www.youtube.com/watch?v=XbgbGE_fqe0
Measures to support energy-efficient products and services: Ecodesign, eco-labels and green...
https://www.youtube.com/watch?v=EOQpOzAtpFQ

4.7 End-of-Life Management

According to Wray& Veer (2024), the circular economy as "a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution" based on three principles driven by design:

- eliminate waste and pollution;
- circulate products and materials (at their highest value);
- regenerate nature.

Transitioning to a circular economy will place significant demands on manufacturers and designers. Two trends characterize current consumption patterns: consumers have more products than before, but at the same time most of them are being used for a much shorter period. Shorter life spans and more frequent replacement are leading to an increased need to use resources for production. Research on product lifetimes has recently shown a trend towards decreasing lifetimes. However, the motivation of consumers to change products more frequently than in the past is not yet fully clear. This can be attributed to changing consumer attitudes, early product deterioration and marketing pressures that encourage consumerism. Surprisingly, although some products are replaced after a short period of use, some studies show that consumers want products to last much longer and that information on product durability is important to them.

Moreover, according to ConsumerPro (2022), many consumers are disappointed if the products they buy do not meet their expectations. Very often, products that are essential for a comfortable lifestyle, such as washing machines, electric toothbrushes, televisions, printers and smartphones, break down shortly after the end of the warranty period and cannot be repaired.

Obsolescence and lack of repairability is a multifaceted problem; it can include intentional and unintentional product failure due to faulty design, failure to maintain, repair or install updated software. Sometimes there is also consumer dissatisfaction with the current performance of a product, which leads to product replacement - i.e. although the product purchased works, it no longer meets the consumer's expectations and is replaced.

In order to minimise waste at the end of the product life cycle, it is essential to implement effective recycling, reuse and disposal strategies. Designing products for easy disassembly and recycling, implementing take-back programmes and promoting the re-use of products or components can help to close the loop and reduce waste

The Circular Economy Action Plan specifically mentions the fight against programmed obsolescence. The EU Circular Economy Action Plan (2020) also provides an outline of such future measures:

- **Making more products sustainable.** The future Sustainable Product Policy Framework (*SPPF*) is expected to make many more consumer products, such as smartphones and computers, more durable, reusable, renewable, repairable and recyclable.
- **Highly polluting sectors** such as textiles and buildings are expected to use raw materials more efficiently. The high-profile ban on single-use plastics, which the EU institutions pushed through in record time, is now seen as a good model and a source of inspiration for sector-specific rules.
- **Consumers' "right to repair" will gain new momentum.** More consumer products will need to be easily repaired and updated. Smartphones, coffee machines and printers should be at the top of the priority list, as they are the ones that receive the most consumer complaints in Europe.

Consumers will get more reliable information on **durability and reparability**. For example, in future, companies may have to disclose at the point of sale how long their products will last or how long the supply of spare parts will be guaranteed. Consumers will be better protected against "green brainwashing" and premature obsolescence. This means that the European Union will seek to prevent unsubstantiated advertising claims of green products and stop fraudulent ageing.

The European Commission is committed to creating a culture of product repair, and recent measures to implement the Ecodesign Directive show that providing the opportunity to repair is a very concrete way to extend product life. It is important to maintain access to spare parts over time, and information on repair and maintenance options must be easily accessible.

Building on existing instruments, the European "Right to Repair" can be implemented, in particular for ICT products:

- Availability of spare parts - at least for the expected lifetime of the products. This can also be extended to software parts, as is already the case for servers.
- Accessible instructions for use and repair.
- A design that provides for easy repairability - i.e. there must be easy access to the parts that need to be repaired or replaced.
- Information at the point of sale on the 'repairability' of the product - possibly using a repairability rating system.

Our consumption habits are becoming increasingly disposable, with shorter product lifespans driven by various factors. However, consumers still desire durable goods and are frustrated by early product failure. To combat this trend, the EU's Circular Economy Action Plan promotes product sustainability through increased durability, resource efficiency, and the "Right to Repair" initiative. This plan includes mandatory spare parts availability, accessible repair information, repairable product design, and potential repairability rating systems. These measures aim to extend product lifespans, reduce waste, and transition towards a more circular economy.

Takeaways

Importance of Design and Policy:

The text emphasizes the critical role of product design and policy in promoting sustainability. Designing products for easy disassembly, recycling, and repair, coupled with policies like the EU's Circular Economy Action Plan, can significantly reduce waste and enhance resource efficiency.

Challenges of Consumer Behavior:

Consumer attitudes and behaviors play a significant role in the lifecycle of products. While consumers desire durable goods and are concerned about early product failure, they are also influenced by marketing pressures and the perception of product obsolescence, leading to shorter product lifespans and increased waste.

Initiatives to Combat Obsolescence:

The EU's initiatives, such as the "Right to Repair" and Sustainable Product Policy Framework, aim to combat programmed obsolescence. These initiatives promote longer-lasting products, access to spare parts, and clearer information on product durability and repairability, empowering consumers to make informed choices.

Benefits of Transitioning to a Circular Economy:

Transitioning to a circular economy offers numerous benefits, including extended product lifespans, reduced waste generation, and enhanced resource efficiency. By implementing strategies like effective recycling, reuse, and disposal, we can close the loop on product lifecycles and minimize environmental impact.

Ideas to consider

Design for Durability and Repairability:

Manufacturers should prioritize designing products that are durable, easy to repair, and upgradeable. This includes ensuring access to spare parts and providing clear instructions for maintenance and repair.

Promote Consumer Awareness:

Educating consumers about product durability, repair options, and the environmental impacts of their purchasing decisions can empower them to make more sustainable choices. Transparent information at the point of sale about a product's lifespan and repairability can influence consumer behavior positively.

Support Policy Initiatives:

Advocating for and supporting policies that promote the circular economy, such as the EU's Circular Economy Action Plan and the "Right to Repair" initiatives, can create a regulatory framework that incentivizes manufacturers to produce longer-lasting and more sustainable products.

Encourage Recycling and Reuse Programs:

Implementing effective recycling programs, promoting the reuse of products or components, and establishing take-back schemes can help close the loop in product lifecycles. These initiatives reduce waste and conserve resources by reintroducing materials into the production cycle.

Innovate Sustainable Farming Practices:

Farmers can contribute to sustainability efforts by adopting practices that minimize agricultural waste, improve soil health, and reduce the environmental footprint of farming operations. Embracing sustainable agricultural techniques aligns with the broader goals of the circular economy by promoting resource efficiency and environmental stewardship.

These ideas underscore the importance of collaborative efforts among manufacturers, consumers, policymakers, and agricultural stakeholders to advance sustainability and achieve the goals of a circular economy. By implementing these ideas, we can collectively work towards reducing waste, conserving resources, and mitigating environmental impacts.

Audiovisual Material

How to Develop an End of Life Policy:
https://www.youtube.com/watch?v=AucSlBLVTIU
Life Cycle Engineering — End-of-Life Management
https://www.youtube.com/watch?v=GKM42UU6lqM
EU Eco-innovation policies: Electronics product End-of-Life & waste management
https://www.youtube.com/watch?v=115MUWx6nDg

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CHAPTER 5

MEGATRENDS, CONCEPTS AND FACTORS OF CIRCULAR AGRICULTURE

Chapter 5: Megatrends, Concepts and factors of Circular Agriculture

This chapter provides an in-depth analysis of the driving forces and foundational principles of CA. It explores global megatrends such as sustainability, population growth, and technological advancements, elucidating how these trends shape the evolution of agricultural practices. By examining core concepts like closed-loop systems and resource efficiency, learners gain insights into the fundamental principles guiding CA practices. Additionally, the chapter explores the diverse factors influencing the adoption of CA, offering a comprehensive understanding of its potential and challenges in shaping a more sustainable future for agriculture.

5.1 Megatrends of Circular Agriculture

Agro-Industry and Circular Agriculture: A Case Study on Biomass Valorization

This section explores the significant global megatrends shaping the evolution of Circular Agriculture (CA). These megatrends include sustainability, population growth, resource scarcity, and technological advancements. Understanding these trends is crucial for comprehending the broader context in which CA operates and its potential for fostering a sustainable agricultural future.

Sustainability

Sustainability has become a central focus due to growing concerns about environmental degradation and climate change. Circular Agriculture aligns with this megatrend by promoting practices that reduce resource depletion, greenhouse gas emissions, and waste generation. Key aspects of sustainability in CA include:

- Environmental Impact: CA practices, such as closed-loop systems and biomimicry, aim to minimize environmental impact by recycling nutrients and reducing reliance on external inputs.
- Climate Change Mitigation: CA contributes to carbon sequestration, capturing carbon dioxide from the atmosphere and storing it in the soil, which helps mitigate climate change.
- Resource Efficiency: CA emphasizes the efficient use of resources, including water and nutrients, aligning with sustainability goals by reducing waste and optimizing input usage.

Population Growth

The global population is projected to reach 9.7 billion by 2050, increasing the demand for food production. CA offers sustainable solutions to enhance food production while minimizing environmental impacts. Important considerations related to population growth include:

- Food Security: CA practices can improve crop yields and resilience, contributing to food security in the face of a growing population.
- Urbanization: The shift of populations to urban areas places additional pressure on agricultural systems to produce more food with fewer resources, making CA an attractive approach.

- Intensification of Agriculture: CA promotes sustainable intensification, which aims to increase productivity on existing agricultural land while preserving natural resources.

Resource Scarcity

The depletion of natural resources such as water and arable land poses significant challenges to agriculture. CA aims to optimize resource use and promote sustainable practices to mitigate the effects of resource scarcity. Key points include:

- Water Management: CA techniques like no-till farming and cover cropping improve soil structure and water infiltration, enhancing water use efficiency.
- Soil Health: Maintaining and improving soil health is crucial in CA. Practices like crop rotation and organic amendments help preserve soil fertility and structure.
- Land Use: CA encourages the efficient use of arable land, reducing the need for deforestation and the conversion of natural ecosystems into agricultural areas.

Technological Advancements

Technological innovations play a crucial role in driving advancements in agriculture. CA leverages technologies such as precision farming, the Internet of Things (IoT), and biotechnology to enhance efficiency and sustainability. Key technological advancements include:

- Precision Farming: The use of GPS and sensors allows for precise application of inputs like water, fertilizers, and pesticides, reducing waste and enhancing efficiency.
- IoT in Agriculture: IoT devices can monitor soil moisture, weather conditions, and crop health in real-time, providing data that helps farmers make informed decisions.
- Biotechnology: Advances in biotechnology, such as genetically modified crops and microbial inoculants, can improve crop resilience and yield while reducing the need for chemical inputs.
- Automation and Robotics: The development of automated machinery and robotic systems can increase the efficiency and precision of agricultural operations, further supporting the principles of CA.

Understanding these megatrends is essential for grasping the broader context in which Circular Agriculture operates. Sustainability, population growth, resource scarcity, and technological advancements are driving forces that shape the evolution of agricultural practices. By aligning with these trends, CA has the potential to address the challenges and opportunities of modern agriculture, contributing to a more sustainable and resilient agricultural future.

Takeways

1. **Embrace Sustainability**: Circular Agriculture (CA) aligns with global sustainability goals by promoting practices that reduce waste, conserve resources, and mitigate environmental impacts.
2. **Address Population Growth**: CA offers sustainable solutions to enhance food production while minimizing the ecological footprint, crucial for feeding a growing global population.

3. **Optimize Resource Use**: Efficient management of water, nutrients, and land is at the core of CA, contributing to resilience against resource scarcity and climate change.
4. **Leverage Technology**: Integration of precision farming, IoT, and biotechnology enhances productivity and sustainability in CA practices.

Ideas to consider

1. **Local Adaptation:** Explore how CA principles can be adapted to local environmental conditions and agricultural practices.
2. **Policy Support:** Consider the role of government policies in incentivizing and promoting CA adoption among farmers.
3. **Educational Outreach:** Develop educational programs to raise awareness and train farmers in CA techniques and benefits.
4. **Research and Innovation:** Support research initiatives focused on improving CA practices and technologies.

5.2 Concepts of Circular Agriculture

The idea of Circular Agriculture (CA) is based on the circular economy, in which decisions about how to produce and utilize products include reusing and recycling materials as an essential component rather than just as an additional step to close cycles. Its focus is minimizing external inputs, such as using wastewater for irrigation and manure as an organic fertilizer. Agroforestry, organic farming, mixed crop-livestock production, and other related activities are sometimes linked to CA (OECD, 2023). The main concepts regarding CA mentioned below are closed-loop systems, resource efficiency, biomimicry, and product-service systems.

5.2.1 Closed-loop systems

In contradiction with the linear economy where waste disposal is the last phase and this frequently means that goods are burned, dumped in landfills, or left to pollute the environment, the "reduce-reuse-recycle" concept is used in the circular economy. As shown in Figure 4, by designing closed-loop systems, where trash is recycled or repurposed, it seeks to maximize resource utilization and minimize waste (Sreekumar et al., 2024). Under the same notion, CA is differentiated from the linear form of conventional agriculture, which results in hazardous waste outflows and deteriorated soil quality inside the farm system, applies a heavy dose of pesticides and fertilizers (OECD, 2023).

Closed-loop systems have become a focus for agricultural innovation in recent times. The concept of reducing, reusing, and recirculating is at the core of a closed-loop system. Regarding CA, the main goal of a closed-loop system is to minimize the inputs needed throughout a growing cycle in all aspects, including water, nutrients, and soil, among others. Due to their ability to conserve resources, closed-loop systems within greenhouse infrastructure show promise in advancing the food and agriculture industry (Ragany et al., 2023).

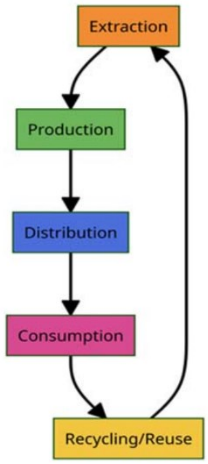

Figure 4. Circular model of economy creating a closed – loop (Sreekumar et al., 2024).

An example of a closed-loop water reuse agriculture system is presented in Figure 5. In this example, future farms in remote areas can be operated in a way that minimizes water demand and reduces waste generation by integrating biochar into existing units and processes. This will follow a properly designed circular material (and energy) flow and has great potential to create additional economic and environmental profits (Li et al., 2020).

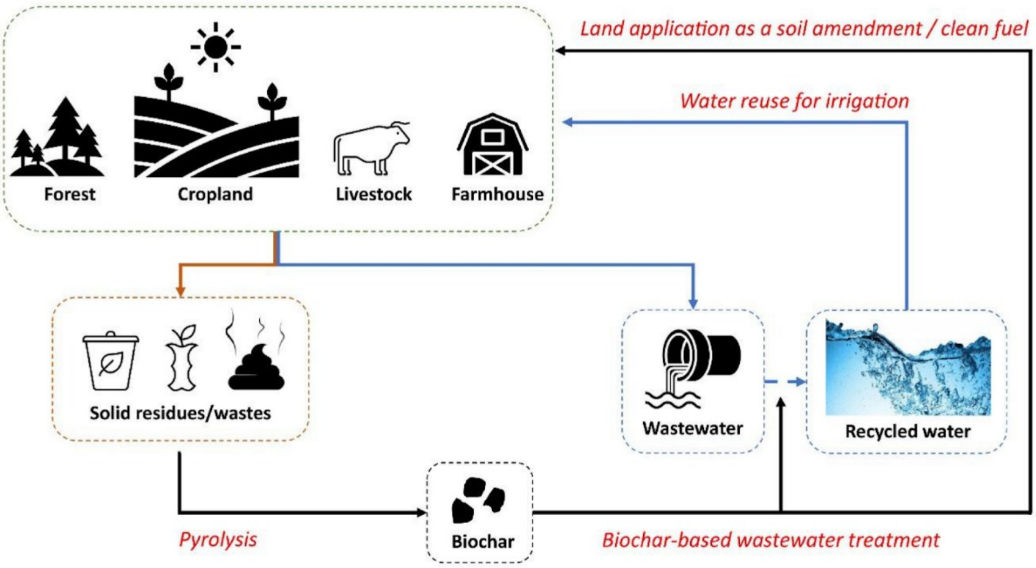

Figure 5. A closed-loop, water-reuse agricultural system using biochar (Li et al., 2020).

5.2.2 Resource Efficiency

Optimizing the life cycle of resources is the main goal of circular economies. This may entail creating items that are durable, recyclable, and reusable to lessen the need to extract resources. It is unsustainable to assume an infinite supply of resources in the linear model of consumption. In order to conserve these limited resources, a circular economy encourages resource efficiency, reduces waste, and aims to prolong the useful life of materials (Sreekumar et al., 2024).

In CA some practices are incorporated that ensure resource efficiency. Organic farming is one of the practices that contributes to resource efficiency as it is considered as the most cost-efficient way to cope with climate change (Akter et al., 2023). Furthermore, CA along with precision farming and suitable crop management tools, may also promote the efficiency of resources (Tagarakis et al., 2021). Livestock manure and agricultural straw waste are examples of wasted resources. The environment is under a great deal of strain as a result of planting and breeding being done separately. In order to increase resource efficiency, there is a growing need for a system that can combine crop and livestock farming (Yang et al., 2022).

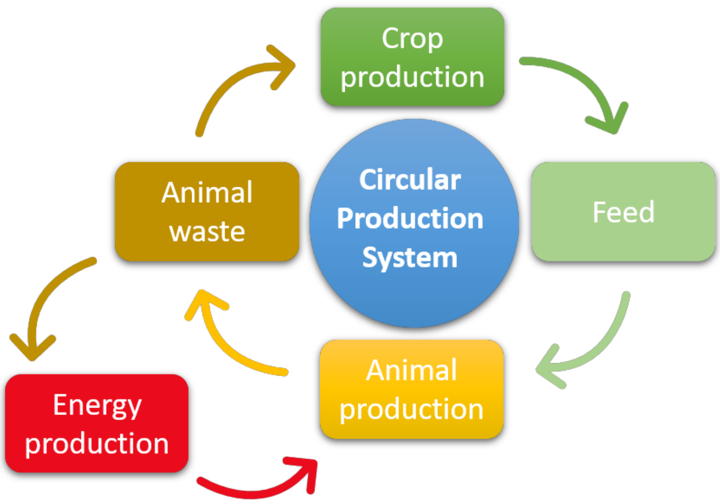

Figure 6. A circular production system of where crop and livestock farming are combined (Tagarakis et al., 2021).

5.2.3 Biomimicry

The English term biomimicry is derived from the two Greek words 'βίος' (life) and 'μιμέομαι' (imitation), in fact meaning "life imitation" and refers to the creation of more sustainable designs, by studying and imitating natural ecosystems and their functions in a creative way (Eid & Al-Abdallah, 2024). This definition of biomimicry includes both the imitation of natural processes and structures as well as the search for inspiration in nature to create engineering solutions to problems that humanity is facing (Burgess et al., 2018). Biomimicry brings together different fields of study having an interdisciplinary approach, involving applied sciences (agriculture, engineering, architecture etc.), natural sciences (biology, chemistry, earth sciences, etc.), social science (economics, etc.), and humanities (philosophy, etc.) (Dicks, 2016; Gejdoš et al., 2018).

In CA, biomimicry is applied to produce food in a sustainable way learning from nature. Any ecosystem, like a prairie has a resilient, effective, self-sustaining production system. The short-term benefits of modern agricultural practices such as irrigation, fertilizer, and pesticide applications are outweighed by the fact that food crops are currently using up increasingly limited water and soil resources. Using natural grasslands as a model, some researchers have successfully revolutionized the conceptual underpinnings of contemporary agriculture (Othmani et al., 2021). An example of biomimicry in agricultural production that faces the shortage of fresh water was inspired by Namibian fog-basking beetle. A greenhouse that included a saltwater-cooled system, concentrated solar power and technologies for desert vegetation, aiming to provide fresh water for agriculture was designed emulating this beetle (Othmani et al., 2022).

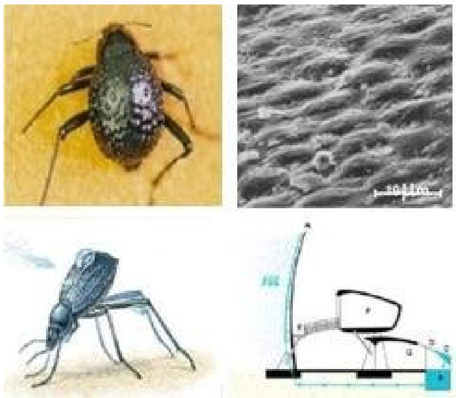

Figure 7. Illustration of Namib Beetle harvesting water vapor (Othmani et al., 2021).

5.2.4 Product Service Systems

A business model known as Product-Service Systems (PSS) is regarded as a strategy of circular economy and combines goods and services created to satisfy customers in an environmentally friendly manner while minimizing resource usage and negative effects on the environment (Kolling et al., 2022). PSS as a business model, could be categorised in (a) product-oriented PSS, (b) use-oriented PSS, and (c) result oriented, with each one of the above categories representing a distinct set of strategies that companies could use (Annarelli et al., 2016). In recent years, eco-designs and sustainable production and consumption methods have become essential. Businesses adopting PSS, can increase sustainability by shifting from goods to services and focusing on mitigating environmental impact through efficient services or product consumption (Nasiri et al., 2018).

As shown in Figure 8, in the agri-food sector PSS alongside with Second Raw Materials (SRM) can play a distinct role in value optimization from the scope of production. On the other hand, there is the scenario from consumption's point of view, the Consumption Model (CM). As the triple bottom line approach explains below, adopting the circular economy's guiding principles and components can aid in analysing how value is created and optimized in relation to the economic, social, and environmental aspect (Poponi et al., 2023).

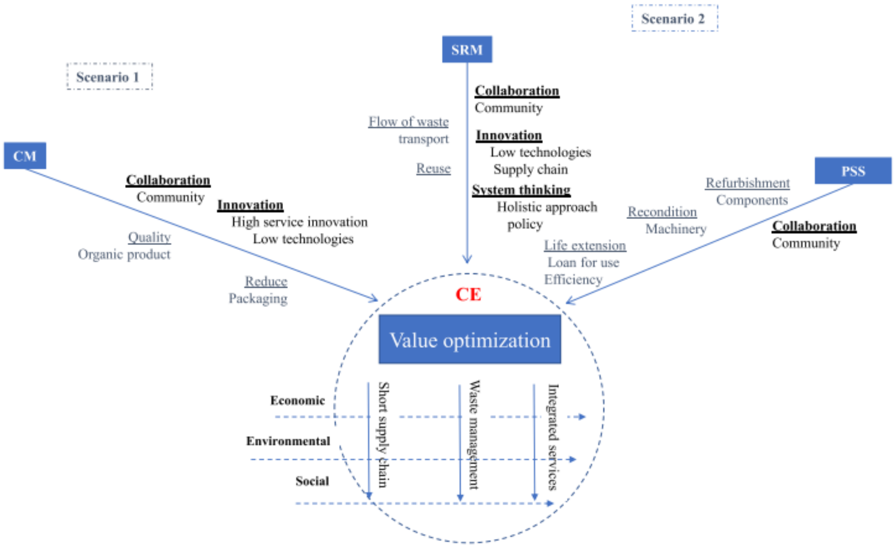

Figure 8. Value optimization conceptual model for Circular Agriculture (Poponi et al., 2023)**.**

Takeaways

1. Closed-Loop Systems

• CA uses the "reduce-reuse-recycle" concept to maximize resource utilization and minimize waste.

• Closed-loop systems aim to minimize inputs needed throughout a growing cycle in all aspects, including water, nutrients, and soil.

• Examples include a water reuse agriculture system using biochar, which can minimize water demand and waste generation.

2. Resource Efficiency

• CA aims to optimize the life cycle of resources, creating durable, recyclable, and reusable items.

• Practices such as organic farming and precision farming can contribute to resource efficiency.

• Livestock manure and agricultural straw waste are examples of wasted resources.

• A growing need for a system that can combine crop and livestock farming could increase resource efficiency.

3. Biomimicry

• Biomimicry is the creation of more sustainable designs by studying and imitating natural ecosystems.

• In CA, biomimicry is applied to produce food in a sustainable way, learning from nature.

• Biomimicry can revolutionize the conceptual underpinnings of contemporary agriculture by using natural grasslands as a model.

4. Product-Service Systems

• Businesses adopting PSS can increase sustainability by shifting from goods to services and focusing on mitigating environmental impact through efficient services or product consumption.

• PSS can play a distinct role in value optimization from the scope of production.

5.3 Factors of Circular Agriculture

5.3.1 Intergrated Farming systems

Climate change is emerging as a major threat to farming, food security and the livelihoods of millions of people across the world. Agriculture is strongly affected by climate change due to increasing temperatures, water shortage, heavy rainfall and variations in the frequency and intensity of excessive climatic events such as floods and droughts. Farmers need to adapt to climate change by developing advanced and sophisticated farming systems instead of simply farming at lower intensity and occupying more land. Integrated agricultural systems constitute a promising solution, as they can lower reliance on external inputs, enhance nutrient cycling and increase natural resource use efficiency (Kakamoukas, 2021). In this context, the concept of Integrated farming systems (IFS) represent a holistic approach to agricultural production that emphasizes resource optimization and minimal waste generation. This strategy achieves synergy by incorporating various components within a single farming operation. These components can encompass crop production, livestock rearing, agroforestry (integration of trees and shrubs with crops), and aquaculture (fish farming).

Examples of IFS:

Crop-Livestock Integration: Manure from livestock can be composted and used as a natural fertilizer for crops. Crop residues can be used as feed for animals, reducing reliance on external feed sources (Martin, 2016).

Aquaponics: This innovative technique combines aquaculture (fish farming) with hydroponics (soilless plant cultivation) in a closed-loop system. Fish waste provides natural nutrients for plants grown in water-based mediums. The plants filter the water, removing harmful ammonia and returning clean water to the fish. This reduces water usage and eliminates the need for chemical fertilizers, promoting a sustainable and efficient food production system (Goddek, 2019).

Aquaculture-Agriculture Integration (excluding Aquaponics): Fishpond effluent, rich in nutrients, can be used to irrigate crops. In turn, aquatic plants grown in the fishpond can provide additional food for fish or livestock (Mugwanya and etc., 2023).

Agroforestry: Nitrogen-fixing trees planted alongside crops can enrich the soil, while also providing shade and wind protection. Fruits or nuts from the trees can generate additional income (Bastos and etc., 2023).

By strategically combining these elements, IFS fosters a closed-loop system where outputs from one component serve as inputs for another. This cyclical approach reduces reliance on external resources such as fertilizers and pesticides, promoting environmental sustainability. Additionally, IFS aims to enhance overall farm productivity and profitability, particularly for small-scale farmers with limited resources.

Below is a good example of how aquaponics has been applied to strawberries on a Lithuanian farm.

Growing strawberries and vegetables using the principles of circular agriculture on the "Ateities lysvės" (Molėtai district, Lithuania)

Growing strawberries in a bed is common knowledge, but now that raised beds have become popular, it is possible to grow strawberries in bags, baskets and water. A family living in Vilnius and farming in the Molėtai district has stubbornly embraced NASA technology and set up an aquaponics farm.

Aquaponics is the technology and process of growing fish and plants together. It is a symbiotic relationship between the two systems: the plants live and grow thanks to the fish and the fish live and grow partly thanks to the plants. Bacteria play an important role in this process, breaking down the ammonium produced by fish into nitrite and nitrate, which is available to plants. The aquaponics system guarantees the production of two valuable and high-quality foodstuffs (certain fish and vegetables) in a single, space-saving location.

The family set up the "Ateities lysvės" on their homestead in Molėtai and set out to replicate in practice the agricultural technology used by the National Aeronautics and Space Administration (NASA). They are among the pioneers in Lithuania. Such farming is well known in Australia, America and Japan. Farms are even being set up in big cities, because it is said that if you have a goldfish, you can have a mini-Aquaponics farm. Family-run aquaponics farming is sustainable and deliberate ecosystem-based farming

Figure 9. Equipment for the aquaponics farm

The family grows strawberries using an aquaponics system, where all the fertiliser is natural, coming from fish farmed right in the pool. They grow about 5000 strawberry plants in a greenhouse and use about 1 tonne of water per week for irrigation. Just imagine how much water resources are used by conventional growers.

METHODS OF GROWING STRAWBERRIES:

Strawberries can be grown in different ways, and the timing of the first harvest of the year depends largely on this. And the care in each case has its own particularities.

- **Growing outdoors in beds:** the advantage is that the technology is easy to understand and no special tools are needed. Disadvantages: the yield is weather-dependent, frequent weeding is necessary, pests attack;
- **Outdoor cultivation in raised beds:** Advantages: very convenient, aesthetically pleasing, can be covered with an agro-canopy underneath to protect against moles. Disadvantages: strawberries need to be watered more heavily and more often as water evaporates faster;
- **Growing in a greenhouse in the ground:** advantage: early harvest. Disadvantages: requires space in the greenhouse, frequent weeding, constant watering.
- **Growing in bags in the greenhouse:** advantages: very early harvest, clean berries, no need for weeding, no moles. Disadvantages: not environmentally friendly as the bags are peat substrate and the bags are plastic; after a while the nutrients will be depleted and constant fertilization is necessary.

Slightly unconventional, based on circular economy principles:

- **Hydroponics** - feeding the strawberries through water saturated with fertiliser. This is a comprehensive water control that makes it easy to regulate the supply of nutrients needed by the strawberry. Disadvantage: the system requires a large investment.
- **Aquaponics** is a form of hydroponics where all the fertilisers are natural and come from fish grown right in the pool. Strawberries are more resistant to disease and water consumption is extremely low.

Figure 9. Strawberries grown aquaponically (Photo. A. Burneikienė).

In strawberry aquaponic greenhouse, strawberries grow in vertical tubes filled with expanded clay. It is also equipped with automatic irrigation, so that every couple of hours the plants receive a set amount of water with the nutrients they need. The water for irrigation comes from a large pool where the fish live.

So how does it all work? Aquaponics is like a small ecosystem:

- The fish in the pool excrete nitrates;
- Bacteria break them down to macro and micro elements;
- The water saturated with these nutrients travels to the plants;
- The plants take up the nutrients and filter the water;
- The filtered water goes back to the fish tank.

This system allows the use of up to 90% less water compared to conventional ground watering of strawberries.

Figure 9. Strawberries

Aquaponic advantages:

- **Natural Ecosystem:** Aquaponic systems create a closed ecosystem where fish waste provides nutrients for strawberries. This reduces the need for chemical fertilizers and pesticides, and helps maintain natural balance in the environment.
- **Disease Resistance:** Strawberries grown in aquaponic systems are more resistant to diseases and pests because they do not have direct contact with soil. This reduces the need for chemical controls and improves product safety.
- **Low Water Usage:** Aquaponic systems use 90% less water than traditional strawberry cultivation. Water circulates in a closed system, is constantly filtered, and reused. This is especially important in regions with limited water resources.
- **Early Harvest:** Due to the controlled environment and balanced nutrition, strawberries grown in aquaponic systems ripen earlier than traditionally grown ones. This allows farmers to get an early harvest and take advantage of higher market prices.
- **Higher Yields:** Strawberries grown in aquaponic systems can produce higher yields than traditionally grown ones. Due to the controlled environment and balanced nutrition, plants grow faster and are more stress-resistant.

Aquaponic challenges:

- **Balancing:** Aquaponic systems require careful balancing of nutrient levels in the water to ensure that both fish and strawberries receive all the nutrients they need. This can be a complex process that requires specialized knowledge and experience.
- **Diseases and Pests:** While aquaponic systems are generally more resistant to diseases and pests, some problems can still arise. It is important to regularly monitor plants and fish and take preventive measures to avoid the spread of diseases and pests.
- **High Initial Costs:** Setting up aquaponic systems can be expensive as they require specialized equipment and materials. This can be a limiting factor for smaller farms or new farmers.
- **Technical Knowledge:** Operating and maintaining aquaponic systems requires some technical knowledge and skills. It is important to properly care for the system to ensure optimal plant and fish growth.

Figures 11, 12, 13. Strawberries, strawberries grow in vertical tubes filled with expanded clay (Photo. A. Burneikienė).

5.3.2 Collaborative Networks

Importance of Collaboration: Collaboration among stakeholders—including farmers, researchers, policymakers, and consumers—is essential for advancing CA. Building collaborative networks facilitates knowledge sharing, innovation, and the adoption of sustainable practices.

Knowledge Sharing: Collaborative networks enable the exchange of best practices, research findings, and technological innovations. Farmers can learn from each other and from experts about new techniques for improving soil health, reducing chemical use, and enhancing biodiversity.

Innovation: By bringing together diverse perspectives and expertise, collaborative networks foster innovation. Joint research initiatives and pilot projects can explore new approaches to circular farming, such as the integration of renewable energy sources or the development of new crop varieties that are more resilient and resource-efficient.

Adoption of Sustainable Practices: Collaborative networks also play a crucial role in the broader adoption of sustainable practices. Peer-to-peer learning, demonstration farms, and extension services can help farmers transition to circular methods by providing practical guidance and support.

Takeaways

Resource Optimization and Minimal Waste:

Integrated Farming Systems (IFS) emphasize optimizing resource use and minimizing waste by creating synergies between different farming components, such as crops, livestock, agroforestry, and aquaculture.

Sustainable Agriculture:

Aquaponics, as a form of circular agriculture, significantly reduces water usage (up to 90% less than traditional methods), eliminates the need for chemical fertilizers, and creates a sustainable closed-loop system where fish waste provides nutrients for plants.

Economic and Environmental Benefits:

IFS and aquaponics can enhance farm productivity and profitability, particularly for small-scale farmers, by reducing reliance on external inputs like fertilizers and pesticides and promoting environmental sustainability.

Ideas to consider

Adapting to Climate Change:

With climate change posing significant threats to agriculture, the adoption of advanced farming systems like IFS and aquaponics can help farmers mitigate these impacts through increased resilience and resource efficiency.

Initial Investment and Knowledge:

While aquaponics and other integrated systems offer numerous benefits, they require significant initial investment and specialized knowledge to balance nutrient levels and maintain the system, which can be a barrier for some farmers.

Local Adaptation and Innovation:

The successful implementation of integrated farming practices, such as the aquaponics system used for growing strawberries in Lithuania, demonstrates the importance of adapting innovative agricultural technologies to local conditions and needs.

Audiovisual Material

What is Integrated Farming System (IFS) | Benefits of Integrated Farming System
https://www.youtube.com/watch?v=tIqvxD7ao74
Economics of Integrated Crop-Livestock Systems
https://www.youtube.com/watch?v=m_QG0OjBqcc
Integrated Farming Aquaponics System | Commercial Aquaponic Farming Fresh Fish and Vegetables
https://www.youtube.com/watch?v=xtUXlXulrrM
https://www.youtube.com/watch?v=Lb4V7hwmSS8
https://www.youtube.com/watch?v=2uGOi52dW3I
Agroforestry Systems and Sustainable Agriculture
https://www.youtube.com/watch?v=rzImtlqjdxo
https://www.youtube.com/watch?v=LmsVj7f8bsE
https://www.youtube.com/watch?v=UTwtFVv8wkQ

5.3.3 Policy Support

Role of Policy Frameworks: Policy frameworks and incentives are critical for promoting CA. Governments can support circularity through subsidies for sustainable practices, regulations on waste management, and market incentives for circular products.

Subsidies for Sustainable Practices: Financial incentives can encourage farmers to adopt circular practices. Subsidies for organic farming, cover cropping, and integrated pest management can offset the initial costs of transitioning to more sustainable methods.

Regulations on Waste Management: Effective regulations on waste management are essential for closing the loop in agricultural systems. Policies that promote the recycling of agricultural waste, the reduction of single-use plastics, and the proper disposal of hazardous materials can help minimize environmental impact and enhance resource efficiency.

Market Incentives: Creating market incentives for circular products can drive demand for sustainably produced food. Certification schemes, eco-labels, and public procurement policies that prioritize circular products can help build consumer trust and encourage sustainable consumption.

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CHAPTER 6

CASE STUDIES AND BEST PRACTISES IMPLIED IN CIRCULAR AGRICULTURE

Chapter 6: Case Studies of Circular Agriculture and Best Practices implied in Circular Agriculture

This chapter explores diverse case studies that illustrate the practical application of CA principles. These case studies showcase innovative approaches to resource optimization, waste reduction, and sustainable production within various agricultural sectors. By examining real-world examples, learners gain valuable insights into how circular principles can be implemented effectively to promote environmental sustainability and economic viability in agriculture.

Moreover, this chapter delves into the best practices implied in CA, showcasing innovative approaches. Through an exploration of successful case studies and projects from diverse geographical regions and agricultural sectors, this chapter provides valuable insights into implementing circularity within agricultural systems. Additionally, the chapter integrates friendly innovative teaching methods artful thinking and experiential learning. These interactive approaches facilitate the presentation and analysis of good-practice examples of innovation towards circular agriculture, engaging learners in critical thinking and problem-solving.

6.1 Case Studies of Circular Agriculture

6.1.1 Agro-Industry and Circular Agriculture

Case Study: "Synergies Between Agro-Industry and CA: A Case of Biomass Valorization"

This case study explores the correlation between agro-industry and CA, focusing on biomass valorization as a means of resource optimization. It examines the integration of crop residues, along with other agro-industrial byproducts such as fruit pomace, sugar cane bagasse, and rice husks, into biofuel production processes to enhance circularity in agriculture. By valorizing these biomass residues through processes like bioconversion, pyrolysis, or fermentation, farmers and companies can reduce waste generation, lower environmental impacts, and create new revenue streams. The biofuels and value-added products produced can be utilized to power farm machinery, vehicles and even contribute to decentralized energy production, illustrating the potential of circular principles in transforming agro-industrial processes.

The integration of circular agriculture (CA) with the agro-industry presents a compelling opportunity to enhance resource optimization and sustainability. This case study focuses on biomass valorization, demonstrating how agro-industrial byproducts, such as crop residues, fruit pomace, sugar cane bagasse, and rice husks, can be converted into valuable biofuels and other products. By leveraging processes like bioconversion, pyrolysis, and fermentation, farmers and companies can reduce waste, lower environmental impacts, and create new revenue streams.

Synergies Between Agro-Industry and Circular Agriculture

Agro-industrial byproducts often represent a significant waste management challenge. However, within the CA framework, these byproducts are seen as valuable resources. Biomass valorization involves converting agricultural residues into biofuels and other high-value products, illustrating the circular principle of turning waste into wealth.

Key Biomass Valorization Processes:

- Bioconversion: Utilizing microorganisms to convert organic materials into biofuels, such as ethanol or biogas.
- Pyrolysis: Decomposing organic materials at high temperatures in the absence of oxygen to produce bio-oil, syngas, and biochar.
- Fermentation: Microbial fermentation processes to produce biofuels like ethanol from sugars present in biomass.

Case Study: Biomass Valorization in Practice

Example 1: Ethanol Production from Fruit Pomace

Fruit pomace, a byproduct of juice production, can be converted into ethanol through fermentation. This process not only reduces waste but also produces a valuable biofuel that can power farm machinery and vehicles. Ethanol production from fruit pomace is a practical example of how agro-industrial byproducts can be integrated into the circular economy.

Steps Involved:

1. Collection and Pre-treatment: Fruit pomace is collected from juice production facilities and pre-treated to release fermentable sugars.
2. Fermentation: The pre-treated pomace is inoculated with yeast strains, such as Saccharomyces cerevisiae, to ferment the sugars into ethanol.
3. Distillation: The ethanol is distilled and purified for use as biofuel.

Benefits:

- Waste Reduction: Significant reduction in waste generated by juice production.
- Economic Viability: Creation of a new revenue stream for juice producers.
- Energy Independence: Local production of biofuels reduces dependence on fossil fuels.

Example 2: Biochar from Rice Husks

Rice husks, typically discarded after rice milling, can be transformed into biochar via pyrolysis. Biochar serves as a soil amendment, improving soil health and fertility. It also sequesters carbon, contributing to climate change mitigation. This application demonstrates the environmental benefits of utilizing agricultural residues.

Steps Involved:

1. Collection and Drying: Rice husks are collected and dried to reduce moisture content.
2. Pyrolysis: The dried husks are subjected to high temperatures in an oxygen-limited environment, resulting in the production of biochar.
3. Application: Biochar is applied to agricultural fields to enhance soil quality.

Benefits:

- Soil Health: Improved soil fertility and structure.
- Carbon Sequestration: Long-term storage of carbon in the soil.
- Waste Utilization: Effective use of rice milling byproducts.

Example 3: Biogas from Sugar Cane Bagasse

Sugar cane bagasse, the fibrous residue left after juice extraction, can be anaerobically digested to produce biogas. This biogas can be used for heating, electricity generation, or as a vehicle fuel. The digestion process also produces nutrient-rich digestate, which can be used as a fertilizer, closing the nutrient loop.

Steps Involved:

1. Collection and Preparation: Sugar cane bagasse is collected and prepared for anaerobic digestion.
2. Anaerobic Digestion: The bagasse is placed in anaerobic digesters where microorganisms break down the organic material, producing biogas.
3. Biogas Utilization: The biogas is captured and used for various energy applications.
4. Digestate Application: The remaining digestate is used as a fertilizer.

Benefits:

- Renewable Energy: Production of renewable biogas energy.
- Nutrient Recycling: Utilization of digestate as a nutrient-rich fertilizer.
- Waste Reduction: Effective management of sugar cane processing byproducts.

Benefits of Biomass Valorization:

- Waste Reduction: Transforming agricultural residues into valuable products reduces waste generation.
- Environmental Impact: Lowering greenhouse gas emissions and mitigating climate change through carbon sequestration.
- Economic Viability: Creating new revenue streams for farmers and agro-industries.
- Energy Independence: Producing biofuels locally reduces reliance on fossil fuels and enhances energy security.
- Soil Health: Improved soil fertility and structure through biochar application.
- Nutrient Recycling: Effective recycling of nutrients back into the agricultural system through digestate application.

The synergy between agro-industry and circular agriculture, exemplified through biomass valorization, highlights the potential for sustainable and economically viable agricultural practices. By integrating crop residues and other agro-industrial byproducts into biofuel production, we can foster a more resilient and circular agricultural system.

Takeaways

- Biomass valorization transforms agricultural residues into valuable biofuels and products.
- Circular agriculture principles enhance resource optimization and sustainability.
- Synergies between agro-industry and CA reduce waste and environmental impacts.
- Biomass valorization creates new revenue streams and promotes energy independence.

Ideas to Consider

- How can more agro-industrial byproducts be integrated into biomass valorization processes?
- What are the potential challenges in scaling up biomass valorization technologies?
- How can policy frameworks support the adoption of circular agriculture practices in the agro-industry?
- What role do technological advancements play in enhancing biomass valorization?
- How can biomass valorization contribute to achieving broader sustainability goals?

6.1.2 Nutrient Recycling and Circular Agriculture

Case Study: "Nutrient Cycling in Organic Farming Systems: A Case of Closed-Loop Agriculture".

This case study investigates nutrient cycling practices in organic farming systems, showcasing a closed-loop approach to nutrient management. Organic farms utilize on-farm resources, such as compost, cover crops, and crop residues, to maintain soil fertility and productivity. By recycling nutrients within the farm system, organic farmers minimize the need for external inputs like synthetic fertilizers, reducing costs and environmental impacts. The case study highlights the importance of nutrient cycling in promoting soil health, crop resilience, and sustainable agriculture.

This case study delves into the nutrient cycling practices employed in organic farming systems, emphasizing a closed-loop approach to nutrient management. It showcases how organic farms utilize on-farm resources, such as compost, cover crops, and crop residues, to maintain soil fertility and productivity.

A. Nutrient Cycling in Organic Farming

Compost Utilization: One of the primary strategies for nutrient cycling in organic farming is the use of compost. Composting involves the decomposition of organic matter such as crop residues, animal manure, and food waste into a nutrient-rich soil amendment. By returning compost to the soil, organic farmers replenish essential nutrients, improve soil structure, and enhance microbial activity. This process not only recycles nutrients but also reduces waste and greenhouse gas emissions associated with the decomposition of organic matter in landfills.

Cover Crops: Cover crops are planted during off-season periods to cover the soil rather than for the purpose of being harvested. These crops, such as clover, rye, and vetch, play a crucial role in nutrient cycling. They capture and store nutrients in their biomass, which are then released back into the soil when the cover crops decompose. This practice prevents nutrient leaching, enhances soil organic matter, and improves soil fertility and structure. Additionally, cover crops can fix atmospheric nitrogen, providing an essential nutrient for subsequent crops and reducing the need for synthetic nitrogen fertilizers.

Crop Residues: Crop residues, such as stems, leaves, and roots left in the field after harvest, are another vital component of nutrient cycling in organic farming. Instead of removing these residues, organic farmers incorporate them back into the soil through practices like mulching or tillage. As these residues decompose, they release nutrients that are taken up by the next crop, thus maintaining a continuous nutrient cycle. This method also contributes to soil organic matter, enhances soil moisture retention, and suppresses weed growth.

B. Benefits of Nutrient Cycling in Organic Farming

Soil Health: Nutrient cycling is fundamental to maintaining and improving soil health. By using organic matter to replenish nutrients, organic farming enhances soil fertility, promotes beneficial microbial activity, and improves soil structure. Healthy soil is better able to retain moisture, support plant growth, and resist erosion, leading to more sustainable and resilient agricultural systems.

Crop Resilience: Through effective nutrient cycling, organic farming systems can produce more resilient crops. Adequate and balanced nutrient availability ensures that plants are healthy and vigorous, making them more resistant to pests and diseases. This reduces the reliance on chemical pesticides and herbicides, aligning with the principles of organic agriculture and promoting environmental sustainability.

Reduced Environmental Impact: One of the significant advantages of nutrient cycling in organic farming is the reduction in environmental impact. By minimizing the need for synthetic fertilizers, organic farmers reduce the risk of nutrient runoff into water bodies, which can cause eutrophication and harm aquatic ecosystems. Additionally, nutrient cycling practices help sequester carbon in the soil, mitigating climate change by reducing greenhouse gas emissions.

Economic Efficiency: Nutrient cycling can also lead to economic benefits for organic farmers. Reducing dependence on external inputs like synthetic fertilizers and pesticides lowers production costs. Furthermore, improved soil health and fertility can enhance crop yields and quality, leading to higher market value and profitability.

6.2 Best practices implied in Circular Agriculture

6.2.1 Identification of exemplary case studies / Showcase of successful projects

Identification of exemplary case studies / Showcase of successful projects: from diverse geographical regions and agricultural sectors, providing valuable insights into successful implementations and outcomes.

I. Best practices in agritourism based on the principles of CA

Best practices in agritourism refer to the optimal methods and strategies implemented by agricultural enterprises that integrate tourism activities. These practices aim to ensure sustainable development, enhance visitor experiences, preserve cultural heritage, and foster economic growth within local communities. They encompass a range of approaches such as promoting organic farming techniques, conserving natural resources, offering educational programs, engaging in community partnerships, ensuring visitor safety, and maintaining high-quality standards. By adhering to these practices, agritourism seeks to balance economic viability with environmental stewardship and cultural preservation, while providing authentic and educational experiences for tourists.

II. The importance of best practices in agritourism

The agritourism is a vibrant sector that honours agricultural traditions, promotes sustainable practices and cultural heritage, and provides immersive experiences for visitors. It blends agriculture with tourism, relies heavily on best practices to ensure sustainable development and positive outcomes for both farmers and visitors. These practices encompass a range of guidelines and strategies aimed at maximizing benefits while minimizing negative impacts on the environment, local communities, and agricultural operations.
The benefits of implementing best practices in agritourism are:

- **Integration:**

Best practices enable the seamless integration of agricultural activities with tourism experiences, allowing visitors to directly participate in farming processes, taste local products, and learn about cultural traditions. This integration enhances the authenticity of visitor experiences and fosters a deeper appreciation for rural lifestyles.

- **Sustainability:**

Sustainability is fundamental for thriving agritourism ventures. This includes employing organic farming methods, conserving biodiversity, and minimizing environmental footprints, all crucial for responsible environmental stewardship. Implementing natural farming techniques, reducing waste, and sourcing local produce exemplify sustainable practices at the heart of agritourism best practices.

- **Cultural preservation:**

Agritourism actively contributes to the preservation of local cultural heritage by promoting culinary traditions, historical accommodations, and cultural events. This not only enriches visitor experiences but also helps preserve regional identities and traditions.

- **Enhanced visitor experiments:**

In agritourism, integrating agricultural activities with tourism offers visitors opportunities to engage in farm tours, hands-on activities, and educational programs. These experiences deepen their understanding of agricultural processes and forge stronger connections with rural environments. Educational programs, including workshops on olive oil production, cheese-making demonstrations, and local craft workshops, enhance visitor engagement by providing immersive experiences that highlight traditional methods and local culture. Prioritizing these engaging and educational activities not only enriches the visitor experience but also fosters appreciation for agriculture while promoting sustainable tourism practices in rural areas.

- **Community and economic benefits:**

Agritourism stimulates local economies by creating jobs, supporting small-scale producers, and fostering partnerships with local businesses. It enhances community cohesion and contributes to the socio-economic development of rural areas. Community engagement is integral to successful agritourism practices. Farmers frequently partner with local businesses, artisans, and tour operators to craft immersive visitor experiences highlighting the area's distinctive agricultural heritage and products. This involvement not only garners backing for agritourism initiatives but also bolsters local economies. Agritourism enterprises often catalyse community development by generating employment locally, aiding small-scale producers, and promoting collaboration among community stakeholders. Such ventures significantly enhance the socio-economic landscape of rural areas, fostering resilience and sustainable livelihoods.
Agritourism thrives on best practices that intertwine agriculture with tourism, emphasizing sustainability, cultural preservation, and community engagement. These practices not only enrich visitor experiences through educational programs and hands-on activities but also contribute to the preservation of local heritage and traditions. By fostering partnerships with local businesses and promoting sustainable farming methods, agritourism enterprises play a pivotal role in supporting rural economies and promoting environmental stewardship. Ultimately, agritourism emerges as a sustainable and impactful avenue for both economic growth and cultural appreciation in rural communities.

III. Best practice examples in agritourism

- **Best practice No. 1**

The Cretan Olive Oil Farms represent a beacon of traditional agricultural practices and culinary excellence, rooted deeply in the island's cultural heritage. Established in 1995, the farm's journey began with a collaborative effort to document Crete's rich culinary traditions in response to growing interest from Dr. Schleicher's best-selling book, "Der sensationelle Kreta

Diet." This success led to further exploration under the guidance of renowned chef Eckart Witzigmann, who sought to uncover the secrets of Cretan cuisine firsthand.

Over the years, the farm has expanded its mission beyond documentation, becoming a vibrant educational center and a pioneer in sustainable agritourism. Today, it offers a diverse array of activities designed to immerse visitors in the authentic flavors and practices of Cretan agriculture. E-Guided Tours provide a firsthand look at the farm's natural landscapes, showcasing the synergy between olive trees, local fauna like bees and sheep, and traditional farming methods that sustain the ecosystem.

Visitors can engage in hands-on experiences such as olive oil production demonstrations, where they learn the ancient techniques of pressing olives into Extra Virgin Olive Oil. These sessions emphasize sustainability and minimal intervention, reflecting the farm's commitment to preserving centuries-old practices while meeting modern demands. The farm also hosts interactive cooking lessons, guided by local chefs who share the art of preparing authentic Cretan dishes using organic ingredients sourced directly from their garden.

For those interested in dairy products, interactive cheese-making sessions provide a unique opportunity to participate in the entire cheese-making process, from milking goats to tasting freshly prepared varieties like "malaka" and "mizithra." Additionally, pottery workshops offer insights into the island's ancient craft traditions, allowing visitors to mold clay into unique pottery pieces while learning about Crete's historical contributions to pottery-making.

Culinary exploration extends further with Cretan Wine Tastings, where visitors can sample wines cultivated from vines that have thrived on Crete for millennia. These tastings delve into the island's viticultural history, tracing back to ancient times as evidenced by archaeological discoveries like the 3500-year-old wine-press found in Vathipetro. The farm also hosts cultural festivals, providing a festive backdrop to showcase local cuisine, olive oil, and other traditional products.

The overarching goal of the Cretan Olive Oil Farms is to offer a comprehensive experience that not only educates but also inspires a deeper appreciation for Cretan culture and sustainable agriculture. Through their diverse range of activities and immersive programs, the farm invites visitors to rediscover the authenticity of Cretan life, fostering connections between past traditions and contemporary practices that ensure the preservation of this rich cultural heritage for future generations.

The Cretan Olive Oil Farms exemplify sustainability through their commitment to preserving traditional agricultural practices and promoting biodiversity. They employ organic farming methods and minimal intervention in olive oil production, aiming to sustain the ecosystem and support natural cycles. Integration of local fauna like bees and sheep contributes to soil health and pollination, aligning with principles of circular agriculture. Furthermore, the farm's use of organic ingredients from their garden in cooking lessons and cheese-making sessions showcases a closed-loop system, minimizing waste and maximizing agricultural efficiency while fostering a deeper connection to Cretan cultural heritage.

Figure 14. Products of the Cretan Olive Oil Farm

Figure 15. Ceramic mug from the Cretan Olive Oil Farm

For more information visit the website of the farm: https://www.cretanoliveoilfarm.com/

- **Best practice No. 2**

Nemunas Delta Regional Park in Lithuania offers various excellent locations for different outdoor activities such as bird watching, kayaking, and nature photography. Here are some specific places within the park that are known for their natural beauty and opportunities for recreational activities.

Mingės kaimo turizmo sodyba (Mingė Village Tourism Farmstead) is more of an agro-tourism site, providing a blend of traditional farming and hospitality. Visitors can learn about local agricultural practices and enjoy the serene environment of Mingė, where the main street is a river. Often referred to as the "Lithuanian Venice," this village is ideal for kayaking and boating. The village is unique as the main street is a river, offering a picturesque and tranquil setting.

Minija Village is a perfect destination for nature enthusiasts, including fishermen, sailors, day-trippers, and water-skiing lovers. The trend of celebrating birthdays and workplace anniversaries in nature, rather than in stuffy restaurants, has made Minija Village increasingly popular. It now hosts small groups and scientific symposia in both summer and winter.

About a decade ago, the residents of Minija Village recognized the potential for tourism and began welcoming holidaymakers with great hospitality, turning it into a thriving business. Stasys Petrošius was among the first to organize leisure activities in the village. He built a beautiful homestead on the bank of the Minija River, following the traditional village style.

Stasys believes that living on-site is essential to properly arrange, prepare, and develop the business. His sons have continued his innovative work, ensuring everything is done meticulously and sustainably.

The homestead offers various amenities and activities, including a café, boating, rentals of boats and water bikes, water skiing, fishing, a Lithuanian sauna, guest houses, and cabins-campers. Minija Village combines natural beauty with well-developed facilities, making it a model location for sustainable and hospitable tourism.

Visitors to the Nemunas Delta often find themselves drawn to the offerings of the Minge Exotica Homestead. Renting one of their ships opens up a world of exploration, allowing guests to see the vast delta of the Nemunas River and admire the stunning views of the Curonian Lagoon. With the freedom to reach scenic destinations like Nida, Preila, Pervalka, Juodkrantė, and Klaipėda at any time, travelers are spoilt for choice.

Nestled in this picturesque setting is the cozy café "Mingės Exotica," a welcoming spot that can accommodate up to 80 guests. It's a perfect venue for various celebrations, from weddings and birthdays to christenings and parties. This year marked a significant milestone for the homestead with the opening of a new hotel. The hotel features eleven comfortably furnished rooms, capable of hosting up to 27 guests, and offers a mix of five triple rooms and six double rooms.

For those seeking adventure, the UAB "Mingės Exotica" entertainment complex provides exhilarating activities. Speedboat tours offer a quick way to orbit the Nemunas Delta, visit Neringa, and explore other unique places in the region. Thrill-seekers can also enjoy water skiing or swimming on an inflatable wheel, experiences that promise to be unforgettable and leave guests eager for more.

In the tranquil yet vibrant environment of the Minge Exotica Homestead, every visitor finds a blend of relaxation and excitement, creating memories that last a lifetime.

Minija Village and Minge Exotica Homestead exemplify principles of sustainability and circular agriculture through their integration of tourism with traditional farming, eco-friendly development, and commitment to local economic and environmental stewardship. The holistic approach to managing both agricultural and hospitality aspects ensures that resources are used efficiently and that the natural and cultural heritage of the area is preserved and appreciated by visitors.

Figure 16. Fishing in the village of Minge

Figure 17. Minge homestead

For more information visit the website: https://www.mingeskaimas.lt/

- **Best practice No. 3**

Wine Paths Italy is an online platform from Italy dedicated to luxury wine tourism experiences around the world. It connects travellers with prestigious wineries, vineyards, and estates offering wine tastings, tours, accommodations, and culinary experiences. Wine Paths showcases destinations in renowned wine regions, providing detailed information, virtual tours, and booking options for visitors seeking immersive and high-quality wine-related experiences.

Wine Paths offers curated and luxurious wine tourism experiences across Italy's diverse regions. It features exclusive wine tours and tastings in renowned destinations such as Chianti Classico, Barolo, Brunello di Montalcino, and Prosecco. Guests can stay in luxury accommodations nestled amidst vineyards, enjoy gourmet dining paired with local wines, and participate in cultural activities like cooking classes and visits to artisanal food producers. The platform emphasizes sustainability, promotes local cuisine and culture, and provides personalized itineraries tailored to travelers' preferences. Wine Paths Italy caters to those seeking authentic and immersive encounters with Italy's renowned wine regions.

On the Wine Paths website, **Castello di Radda** showcases its offerings located in the Chianti Classico region of Tuscany, Italy, where visitors can explore its amenities and experiences.

Located in the heart of the Chianti Classico region in Tuscany, Italy, offers a picturesque setting surrounded by vineyards and olive groves, providing panoramic views of the Tuscan countryside. In the Chianti Classico region of Tuscany epitomizes excellence in wine tourism through a holistic approach. It champions sustainable vineyard practices with organic and biodynamic farming, promoting soil health and grape quality naturally. Guided vineyard tours educate visitors on these practices and the art of winemaking, complemented by tastings of esteemed wines like Chianti Classico DOCG in scenic settings showcasing the estate's production.

Castello di Radda oversees approximately 40 hectares of vineyards situated in Radda in Chianti and Gaiole in Chianti, at the heart of the Chianti Classico region. The vineyards face varying exposures from South-East to South-West, and the soils are predominantly medium clay-limestone with significant gravel content. Radda and Gaiole in Chianti are renowned for producing exceptional wines, particularly Sangiovese, which thrives in these optimal conditions. The estate primarily produces Chianti Classico DOCG, Riserva, and Gran Selezione wines. Additionally, they offer a rosé, two Toscana IGT wines, a Vermouth, and, starting from 2016, Vin Santo.

The estate offers luxurious accommodations blending Tuscan architecture with modern comforts, each providing views of vineyards or the medieval town of Radda in Chianti, alongside gourmet dining featuring regional flavors paired with local wines. Cultural immersion includes hands-on cooking classes with seasonal ingredients and visits to historical sites and artisan workshops, enriching guests' understanding of the region's heritage. Environmental stewardship is prioritized with waste reduction and energy-efficient systems. Educational wine programs deepen appreciation for Chianti Classico's terroir, and interactive workshops with winemakers foster a deeper connection to the estate's wines. Utilizing platforms like Wine Paths for seamless online booking and active engagement on social media enhances visibility and interaction globally, underscoring Castello di Radda's commitment to enriching and unforgettable wine tourism experiences in Tuscany.

In the context of Castello di Radda's operations as described on the Wine Paths website, one of the most sustainable impacts connected with circular agriculture is its commitment to organic and biodynamic farming practices. By embracing these methods, the estate promotes soil health, biodiversity, and grape quality without relying on synthetic chemicals. This approach not only preserves the integrity of the land but also contributes to the long-term sustainability of the vineyards in the Chianti Classico region. Additionally, Castello di Radda's emphasis on waste reduction and energy-efficient systems further underscores its dedication to environmental stewardship, ensuring minimal ecological footprint while maintaining high standards of wine production and hospitality.

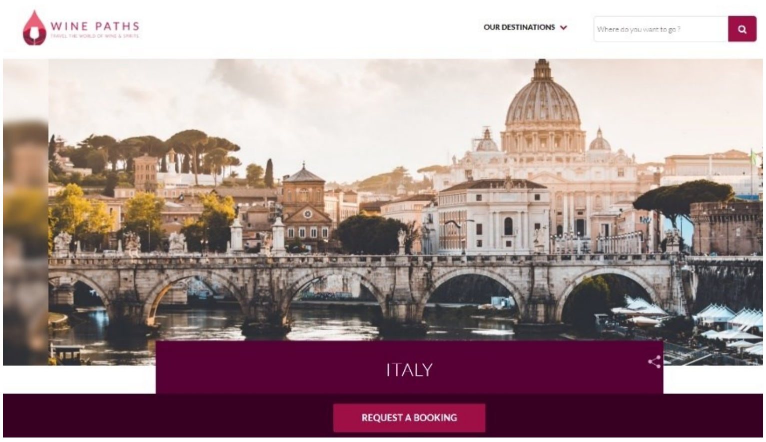

Figure 18. Website of the Wine Paths

Figure 19. Website of the Chianti Classico

For more information visit the websites:
https://www.winepaths.com/destination/italy
https://www.chianticlassico.com/aziende/castello-di-radda/

IV. General report on agritourism best practices

Agritourism has emerged as a dynamic sector that not only celebrates agricultural traditions but also promotes sustainable practices and cultural heritage, offering immersive experiences for visitors. Building upon prior research, this study compares best practices from five partner countries, including case studies from Olon Estate in Greece, Cascina Savino in Italy, Farmers Circle in Lithuania, and Eagle Craft Nest ("Sasfészek") Courtyard in Romania, highlighting their diverse approaches and common principles that define successful agritourism ventures across Europe. North Macedonia lacks a best practice study in agro-food tourism due to persistent traditional farming methods, insufficient educational outreach, low utilization of subsidies and EU-funded projects, and minimal collaboration between the agriculture and tourism sectors, all of which hinder the development of effective integrated initiatives.

Essential components of successful agritourism enterprises:

- **Integration of agriculture and tourism:**

Each case study seamlessly integrates agricultural activities with tourism experiences, allowing visitors to engage directly with farming practices, local products, and cultural traditions. This integration enhances the authenticity of visitor experiences and promotes a deeper appreciation for rural lifestyles. North Macedonia's integration of agriculture with tourism faces significant challenges due to traditional practices and limited collaboration, but efforts to modernize and follow EU recommendations offer hope for a more promising future.

- **Sustainability practices:**

Sustainability is a cornerstone across all ventures, evidenced by organic farming methods, biodiversity conservation, and efforts to minimize environmental impact. Practices such as natural farming techniques, waste reduction strategies, and local sourcing of produce underscore a commitment to environmental stewardship. North Macedonia's agriculture sector faces challenges in adopting sustainability practices due to traditional methods like field burning and limited educational outreach, but ongoing efforts to modernize farming and align with EU recommendations offer hope for a more sustainable future.

- **Cultural preservation:**

Agritourism ventures actively preserve and promote local cultural heritage through culinary traditions, historical accommodations, and cultural events. This emphasis on cultural preservation not only enriches visitor experiences but also contributes to the preservation of regional identity and traditions. North Macedonia faces challenges in integrating modern agriculture with tourism due to persisting traditional practices, limited educational efforts, and weak sectoral cooperation. Achieving a balance between cultural preservation and sustainable development is crucial for fostering effective agro-food tourism initiatives in the country.

- **Educational and experiential tourism:**

Educational programs play a crucial role in agritourism, offering visitors insights into agricultural processes, product origins, and traditional practices. Hands-on experiences such as olive oil production workshops, cheese-making demonstrations, and local craft workshops enrich visitor engagement and foster a deeper connection with the rural environment. North Macedonia's progress in educational and experiential tourism is constrained by traditional farming practices, inadequate educational programs, and minimal collaboration between agricultural and tourism sectors. Enhancing educational initiatives and fostering stronger sectoral partnerships are crucial for developing immersive tourism experiences that promote both cultural understanding and sustainable agricultural practices in the region.

- **Community engagement and economic impact:**

Agritourism ventures often serve as catalysts for community development by generating local employment opportunities, supporting small-scale producers, and fostering collaboration among local stakeholders. These ventures contribute positively to the socio-economic fabric of rural communities, enhancing resilience and promoting sustainable livelihoods. North Macedonia needs to improve community engagement and economic impact through better collaboration between agriculture and tourism, enhanced educational efforts, and reduced reliance on traditional practices. These steps are crucial for fostering sustainable development and maximizing economic benefits in the country.

Successful agritourism ventures across Europe represent a vibrant tapestry of geographical landscapes and cultural traditions. They offer unique experiences that cleverly combine agriculture with tourism. These businesses seamlessly integrate farming activities with visitor engagement, inviting guests to immerse themselves in local practices, savor regional products, and celebrate diverse cultural heritages. By combining agriculture and tourism in this way, these experiences not only enhance authenticity, but also foster a deeper appreciation of rural lifestyles and the rich cultural tapestry of each region.

Sustainability is fundamental to these ventures, characterized by organic farming methods, biodiversity conservation, and a commitment to minimizing environmental impact. Practices such as natural farming techniques, waste reduction strategies, and local sourcing of produce underscore their dedication to environmental stewardship. Sustainability lies at the heart of these endeavors, demonstrated through organic farming techniques and innovative strategies to reduce environmental impact. Whether situated in the sun-drenched olive groves of Olon Estate in Greece, where ancient olive oil production blends with Byzantine frescoes in local chapels, or amidst the rolling vineyards of Cascina Savino in Italy, where communal farming initiatives like Vazapp foster community and responsibility among farmers, each location champions sustainable practices tailored to its unique landscape.

Agritourism also plays a crucial role in cultural preservation by actively promoting local heritage through culinary traditions, historical accommodations, and cultural events. This emphasis not only enhances visitor experiences but also significantly contributes to the preservation of regional identity and traditions. Cultural preservation is a focal point, with agritourism ventures proudly showcasing culinary traditions, historical accommodations, and vibrant cultural events that underscore the unique identities of their respective regions.

Educational programs are important factors in agritourism, providing valuable insights into agricultural processes, product origins, and traditional practices. Hands-on experiences such as olive oil production workshops, cheese-making demonstrations, and local craft workshops are pivotal in deepening visitor engagement and fostering a meaningful connection with the rural environment. These programs are instrumental in enhancing visitor understanding and appreciation of rural life. For instance, cheese-making workshops at Lithuania's Farmers Circle and traditional chimney cake crafting at Romania's Eagle Craft Nest ("Sasfészek") Courtyard offer unique opportunities for guests to immerse themselves in local traditions, thereby strengthening their connection to the cultural heritage of the places they visit.

Furthermore, agritourism ventures frequently serve as catalysts for community development by generating local employment opportunities, supporting small-scale producers, and encouraging collaboration among stakeholders. These initiatives make a positive impact on the socio-economic landscape of rural communities, enhancing resilience and promoting sustainable livelihoods. Beyond their role in tourism, these ventures drive local economic growth by fostering employment, supporting small-scale producers, and cultivating partnerships within the community. This multifaceted approach not only strengthens the socio-economic fabric of rural areas but also enhances sustainability and resilience across diverse cultural landscapes.

North Macedonia faces significant challenges integrating agriculture with tourism, including traditional practices, limited collaboration, and sustainability issues. Efforts to modernize and align with EU recommendations provide hope for a more promising future. Enhanced educational efforts and stronger sectoral partnerships are crucial for fostering sustainable development and maximizing economic benefits through agro-food tourism and experiential initiatives in the region.

Successful agritourism ventures exemplify the integration of agriculture and tourism while prioritizing sustainability, cultural preservation, educational engagement, and community development. These elements collectively underscore the transformative potential of agritourism in promoting sustainable practices and fostering a deeper connection between visitors and rural environments.

Common themes and differentiators of successful agritourism enterprises:

These common themes and differentiators illustrate how successful agritourism ventures in Europe integrate agriculture with tourism while addressing sustainability, cultural preservation, educational engagement, and community development. Each location's unique characteristics contribute to a diverse agritourism landscape across the continent.

Common themes:

- Seamless integration of agricultural activities with tourism experiences.
- Direct engagement with farming practices, local products, and cultural traditions.
- Emphasis on organic farming methods, biodiversity conservation, and minimizing environmental impact.
- Practices such as natural farming techniques, waste reduction strategies, and local sourcing of produce.
- Active promotion and preservation of local cultural heritage.
- Highlighting culinary traditions, historical accommodations, and cultural events.
- Educational programs offering insights into agricultural processes and traditions.
- Hands-on experiences like workshops that deepen visitor engagement with rural environment.
- Catalysts for community development through local employment generation and support for small-scale producers.
- Contribution to socio-economic resilience and sustainable livelihoods in rural areas.

While these agritourism ventures share common themes such as sustainability, cultural preservation, and educational tourism, each location also offers unique elements that differentiate it.

Differentiators:

a. Geographical and cultural contexts:

Each location (Olon Estate, Cascina Savino, Farmers Circle, Eagle Craft Nest) offers unique landscapes and cultural traditions that shape their agritourism approach.

- ***Olon Estate from Greece*** stands out for its pioneering role in organic olive oil production on Lemnos, coupled with a cultural dimension through its chapel adorned with local frescoes.
- ***Cascina Savino from Italy*** prioritizes human connection and collaboration among farmers through initiatives like Vazapp, promoting a sense of community and shared responsibility in agricultural practices.
- ***Farmers Circle from Lithuania*** distinguishes itself with comprehensive event spaces and educational facilities, emphasizing a holistic approach to sustainable agriculture and community engagement in Lithuania.
- ***Eagle Craft Nest ("Sasfészek") Courtyard in Romania*** excels in showcasing local gastronomy and craft culture, offering authentic experiences like chimney cake crafting and seasonal workshops, while prioritizing sustainability through waste reduction initiatives.

b. Local initiatives:

Initiatives like Vazapp in Italy promote community responsibility, while specific cultural practices like chimney cake crafting in Romania highlight local gastronomy.

c. Challenges and opportunities:

North Macedonia faces specific challenges in integrating agriculture with tourism due to traditional practices and limited collaboration, but efforts towards modernization and EU alignment offer potential for growth.

Conclusion:

In agritourism, the convergence of agriculture, tourism, sustainability, and cultural preservation is evident. The achievements of Olon Estate, Cascina Savino, Farmers Circle, and Eagle Craft Nest ("Sasfészek") Courtyard highlight how agritourism can drive rural development, promote environmental stewardship, and safeguard cultural heritage. These ventures establish standards for sustainable tourism models that can be replicated globally.

Successful agritourism ventures seamlessly integrate agriculture and tourism while emphasizing sustainability, cultural preservation, educational engagement, and community development. They exemplify how these elements collectively advance sustainable practices and foster deeper connections between visitors and rural environments.

These initiatives showcase the synergy between agriculture and tourism, contributing to sustainability efforts, preserving cultural heritage, and enhancing visitor experiences. By prioritizing environmental responsibility, nurturing community ties, and celebrating local traditions, these ventures embody sustainable tourism practices that benefit both visitors and local communities, showcasing the diverse charm and authenticity of rural landscapes worldwide.

On the topic of the chapter, to find out more, we recommend you to watch the following interesting videos:

- **Tuscany, Italy: Farm to Table - Rick Steves' Europe Travel Guide - Travel Bite:** https://www.youtube.com/watch?v=vGjYqFYK8qE

This Travel Bite episode of Rick Steves promises to showcase the essence of Italian gastronomy as we delve into the region's farm-to-table traditions. From exploring local markets brimming with fresh produce to visiting picturesque vineyards and olive groves, viewers will witness firsthand how Tuscany's natural bounty shapes its world-renowned cuisine. Through Rick's expert guidance, you'll uncover the stories behind traditional Tuscan dishes and highlight the passion of local artisans dedicated to preserving centuries-old culinary techniques.

- **Farm Pioneering Organics in Croatia:** https://www.youtube.com/watch?v=aRxymTETvXk

Explore the innovative practices of a pioneering farm dedicated to organic agriculture against the backdrop of Croatia's breathtaking natural beauty. From lush fields to thriving orchards, discover how this farm harnesses sustainable methods to produce high-quality, organic produce. Meet the passionate farmers and hear their stories of dedication to preserving the environment while cultivating delicious crops. This video promises to showcase the harmony between agriculture and nature, offering viewers a glimpse into the future of sustainable farming in Croatia.

- **Three Friends Build Sustainable Farm in Europe's Wealthiest Country:** https://www.youtube.com/watch?v=TWYftfc9LJk&list=PLVQDfYEdBPj4Exe4DHm1BPRoJNT_egDR3&index=12_

Explore the remarkable story of three friends who have embarked on a mission to build a sustainable farm amidst stunning landscapes. Discover their innovative farming practices, from organic cultivation to eco-friendly livestock management, as they strive to create a model of sustainable agriculture. Gain insights into their challenges, triumphs, and the impact of their efforts on local communities and the environment. This video promises to showcase the dedication and passion behind sustainable farming practices in Europe, offering viewers a deeper understanding of how small-scale initiatives can lead to significant positive change.

- **Combining Agriculture with Tourism | A Common Farm Discovers a New Way of Bio-Economy - EU Science:** https://www.youtube.com/watch?v=etPfAYWh7-s

Discover how this farm applies environmentally friendly practices to crop and livestock production, while inviting visitors to share in the farm experience. From farm-to-table meals to educational tours on sustainable farming practices, see how this initiative promotes economic growth while also fostering environmental stewardship. This video highlights the intersection of agriculture, tourism and sustainability in the EU, giving viewers a glimpse into innovative strategies to achieve a harmonious balance between conservation and economic development.

Audiovisual Material

- Mingė Village Tourism Farmstead: https://www.mingeskaimas.lt/
- Ruraltour - European Federation of Rural Tourism: https://www.ruraltour.eu/
- The Cretan Olive Oil Farm: https://www.cretanoliveoilfarm.com/, https://www.instagram.com/cretanoliveoilfarm/
- Wine Paths Italy: https://www.winepaths.com/destination/italy
- Castello di Radda: https://www.chianticlassico.com/aziende/castello-di-radda/
- Tuscany, Italy: Farm to Table - Rick Steves' Europe Travel Guide - Travel Bite: https://www.youtube.com/watch?v=vGjYqFYK8qE
- Farm Pioneering Organics in Croatia: https://www.youtube.com/watch?v=aRxymTETvXk
- Three Friends Build Sustainable Farm in Europe's Wealthiest Country: https://www.youtube.com/watch?v=TWYftfc9LJk&list=PLVQDfYEdBPj4Exe4DHm1BPRoJNT_egDR3&index=12
- Combining Agriculture with Tourism | A Common Farm Discovers a New Way of Bio-Economy - EU Science: https://www.youtube.com/watch?v=etPfAYWh7-s

6.2.2 Integration of innovative teaching methods: Artful Thinking

Nowadays, teaching and learning have expanded rapidly covering many disciplines. Nevertheless, the crucial point for the educators in every subject area remains the cultivation of critical thinking skills and the creative learning. Many researchers (Corcoran, 2006; Eisner, 1999) support that critical thinking and creative learning could be enhanced through artwork material. The latter has been involved in everyday life in many aspects, the development of computer science and the internet and at the same time the huge growth of the social media gave free access in many museums, artworks, paintings, performances all over the world. This Erasmus project (SKILLS) suggests the usage of artworks in order to cultivate and enhance critical thinking skills and creative learning. Different disciplines could be involved through artworks to promote active learning and probably maintain a more permanent knowledge. The Erasmus project was based in the Artful Thinking educational method so as to combine art with sustainable agricultural waste streams management.

Artful Thinking is an educational method that was developed by Harvard Project Zero in collaboration with the Traverse City, Michigan Area Public Schools (TCAPS). The program was one component of a larger TCAPS grant from the US Department of Education that aimed at developing a model approach for integrating art into regular classroom instruction. The purpose of Artful Thinking is to help teachers regularly use works of visual art and music in their curriculum in ways that strengthen student thinking and learning (Barahal, 2008).

Artful thinking could enhance student’s critical thinking and learning using visual art and music. The zero project suggests six thinking dispositions through which students' intellectual behaviors could be enhanced. Artful thinking uses the artist's palette as a central metaphor for this six thinking dispositions. These dispositions are developed through Thinking Routines, which are easy to learn and can deepen students' thinking in the classroom. These routines are: *questioning & investigating, observing & describing, reasoning, exploring viewpoints, comparing & connecting, and finding complexity*. Thinking routines are designed to be used flexibly and frequently. Students can use these routines solo or in small or large group settings and they can be used across subject matters, as also with a wide range of topics and works of art. Above all, they are designed to deepen students’ thinking about the topic at hand, whether it is a painting, a historical event, or a mathematical operation (Barahal, 2008, Tishman & Palmer, 2007).

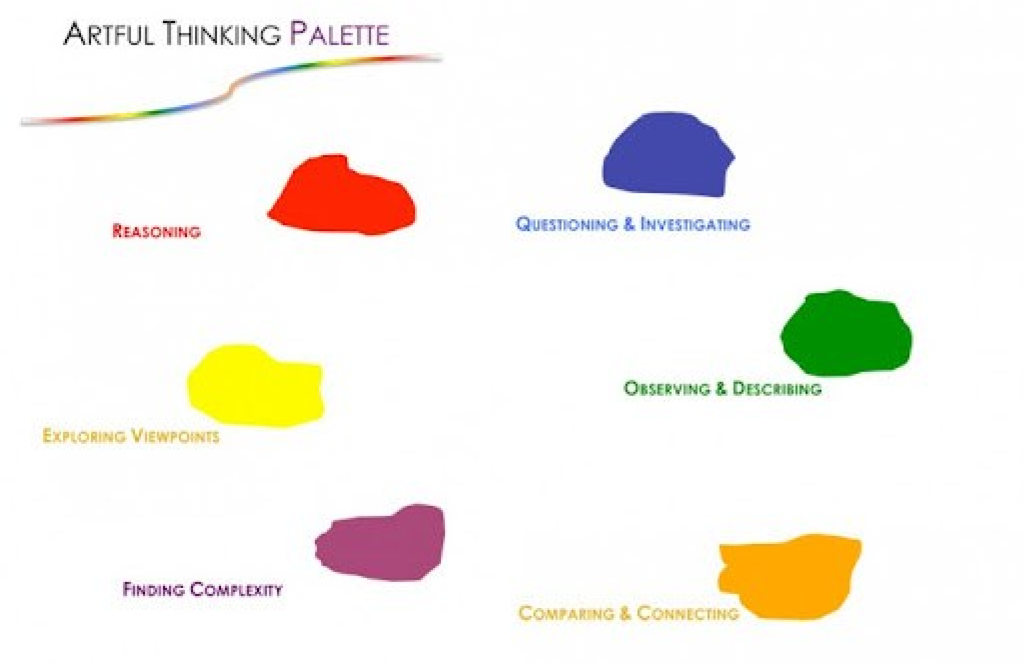

Figure 20. Artful Thinking Palette (http://pzartfulthinking.org/?page_id=5)

You may discover Artful thinking as an applied tool related to Circular Agriculture by pressing the following link:

Bioprocesses: the heart of circular economy

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