UNIVERSITY OF THE AEGEAN
DEPARTMENT OF FOOD SCIENCE AND NUTRITION

Co-funded by the European Union

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

https://www.euskills.info/home

DIGITAL COURSE IN CIRCULAR AGRICULTURE

eClass: https://eclass.aegean.gr/courses/FNS-OTHER164/

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).

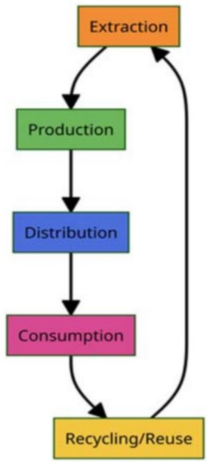

Figure 4. Circular model of economy creating a closed – loop (Sreekumar et al., 2024).

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).

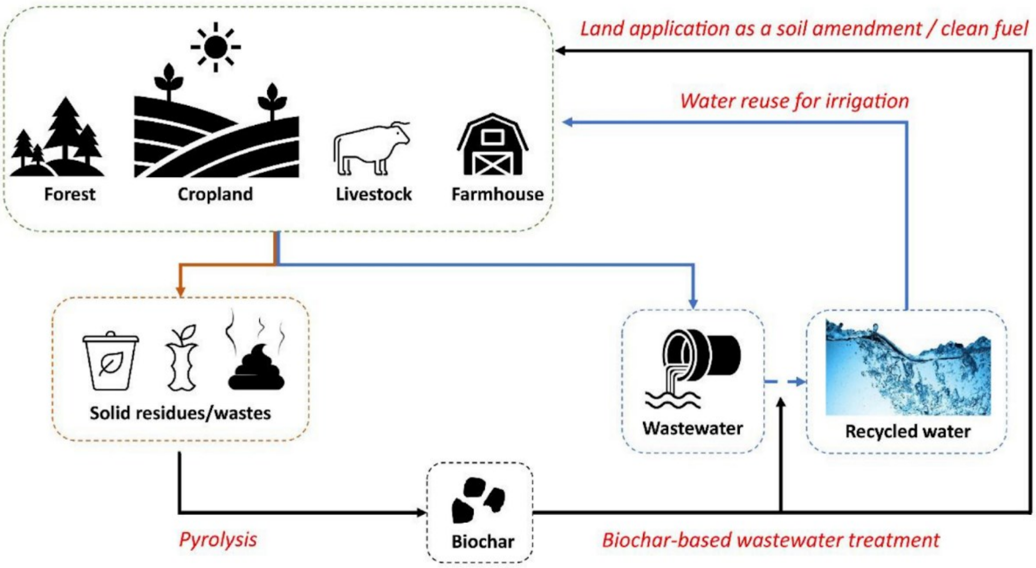

Figure 5. A closed-loop, water-reuse agricultural system using biochar (Li et al., 2020).

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).

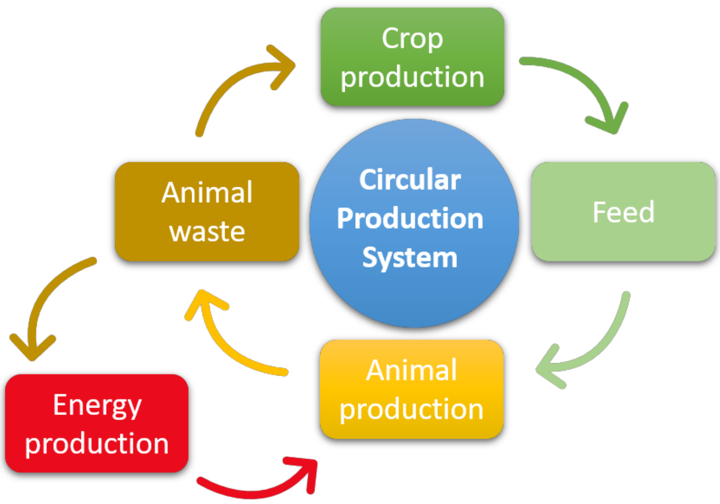

Figure 6. A circular production system of where crop and livestock farming are combined (Tagarakis et al., 2021).

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).

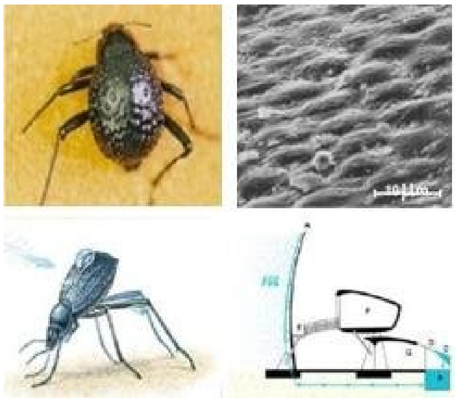

Figure 7. Illustration of Namib Beetle harvesting water vapor (Othmani et al., 2021).

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).

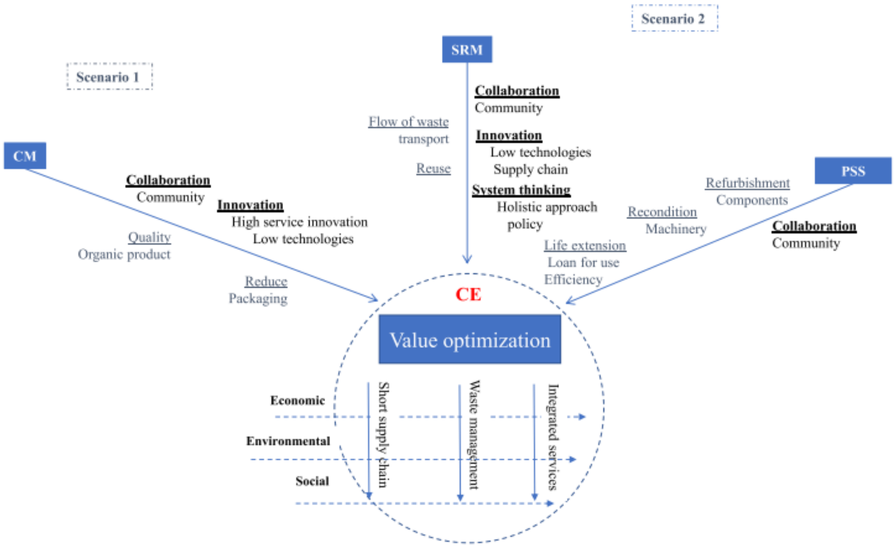

Figure 8. Value optimization conceptual model for Circular Agriculture (Poponi et al., 2023)**.**

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.

References

1. Lal, R. (2020). "Soil Science and the Carbon Civilization." Soil Science Society of America Journal.
2. Pretty, J. (2018). "Sustainable Agricultural Intensification." In Encyclopedia of Food Security and Sustainability.
3. Godfray, H.C.J., & Garnett, T. (2014). "Food security and sustainable intensification." Philosophical Transactions of the Royal Society B: Biological Sciences.
4. Lal, R. (2015). "Restoring soil quality to mitigate soil degradation." Sustainability.
5. Pretty, J., & Bharucha, Z. P. (2014). "Integrated pest management for sustainable intensification of agriculture in Asia and Africa." Insects.
6. Giller, K. E., et al. (2015). "Conservation agriculture and smallholder farming in Africa: The heretics' view." Field Crops Research.
7. Derpsch, R., et al. (2014). "The role of no-till agriculture in climate change mitigation." Carbon Management.
8. Hobbs, P. R., & Govaerts, B. (2010). "Sustainability of conservation agriculture in North America and Australia." Proceedings of the National Academy of Sciences.
9. Altieri, M. A., & Nicholls, C. I. (2017). "Agroecology and the design of climate change-resilient farming systems." Agronomy for Sustainable Development.
10. Akter, S., Ali, S., Fekete-Farkas, M., Fogarassy, C., & Lakner, Z. (2023). Why Organic Food? Factors Influence the Organic Food Purchase Intension in an Emerging Country

(Study from Northern Part of Bangladesh). *Resources*, *12*(1). https://doi.org/10.3390/resources12010005

11. Annarelli, A., Battistella, C., & Nonino, F. (2016). Product service system: A conceptual framework from a systematic review. *Journal of Cleaner Production*, *139*, 1011–1032. https://doi.org/10.1016/j.jclepro.2016.08.061
12. Burgess, R. A., Hamilton, D. E., & Beruvides, M. G. (2018). *Process Biomimicry: Understanding When to Imitate Nature*.
13. Dicks, H. (2016). The Philosophy of Biomimicry. *Philosophy & Technology*, *29*(3), 223–243. https://doi.org/10.1007/s13347-015-0210-2
14. Eid, M. A. H., & Al-Abdallah, G. (2024). Sustainable development through biomimicry: Enhancing circular economy practices for environmental sustainability. *Sustainable Development*. https://doi.org/10.1002/sd.3010
15. Gejdoš, M., Tončíková, Z., Němec, M., Chovan, M., & Gergeľ, T. (2018). Balcony cultivator: New biomimicry design approach in the sustainable device. *Futures*, *98*, 32–40. https://doi.org/10.1016/j.futures.2017.12.008
16. Kolling, C., De Medeiros, J. F., Duarte Ribeiro, J. L., & Morea, D. (2022). A conceptual model to support sustainable Product-Service System implementation in the Brazilian agricultural machinery industry. *Journal of Cleaner Production*, *355*, 131733. https://doi.org/10.1016/j.jclepro.2022.131733
17. Li, S., Chan, C. Y., Sharbatmaleki, M., Trejo, H., & Delagah, S. (2020). Engineered biochar production and its potential benefits in a closed-loop water-reuse agriculture system. *Water (Switzerland)*, *12*(10). https://doi.org/10.3390/w12102847
18. Nasiri, M., Rantala, T., Saunila, M., Ukko, J., & Rantanen, H. (2018). Transition towards Sustainable Solutions: Product, Service, Technology, and Business Model. *Sustainability*, *10*(2), Article 2. https://doi.org/10.3390/su10020358
19. OECD. (2023). *Policies for the Future of Farming and Food in the European Union*. Organisation for Economic Co-operation and Development. https://www.oecd-ilibrary.org/agriculture-and-food/policies-for-the-future-of-farming-and-food-in-the-european-union_32810cf6-en
20. Othmani, N. I., Mohamed, S. A., Abdul Hamid, N. H., Ramlee, N., Yeo, L. B., & Mohd Yunos, M. Y. (2022). Reviewing biomimicry design case studies as a solution to sustainable design. *Environmental Science and Pollution Research*, *29*(46), 69327–69340. https://doi.org/10.1007/s11356-022-22342-z
21. Othmani, N. I., Sahak, N. M., & Yunos, M. Y. M. (2021). Biomimicry in agrotechnology: Future solution of water problem for the agriculture industry? *IOP Conference Series: Earth and Environmental Science*, *756*(1), 012051. https://doi.org/10.1088/1755-1315/756/1/012051
22. Poponi, S., Arcese, G., Ruggieri, A., & Pacchera, F. (2023). Value optimisation for the agri-food sector: A circular economy approach. *Business Strategy and the Environment*, *32*(6), 2850–2867. https://doi.org/10.1002/bse.3274
23. Ragany, M., Haggag, M., El-Dakhakhni, W., & Zhao, B. (2023). Closed-loop agriculture systems meta-research using text mining. *Frontiers in Sustainable Food Systems*, *7*, 1074419. https://doi.org/10.3389/fsufs.2023.1074419
24. Sreekumar, N. M., Sudheep, N. M., & Radhakrishnan, E. K. (2024). Framework for implementing circular economy in agriculture. In *The Potential of Microbes for a Circular Economy* (pp. 25–52). https://doi.org/10.1016/B978-0-443-15924-4.00009-6
25. Tagarakis, A. C., Dordas, C., Lampridi, M., Kateris, D., & Bochtis, D. (2021). A Smart Farming System for Circular Agriculture. *Engineering Proceedings*, *9*(1), Article 1. https://doi.org/10.3390/engproc2021009010

26. Yang, G., Li, J., Liu, Z., Zhang, Y., Xu, X., Zhang, H., & Xu, Y. (2022). Research Trends in Crop–Livestock Systems: A Bibliometric Review. *International Journal of Environmental Research and Public Health*, *19*(14). https://doi.org/10.3390/ijerph19148563
27. Bastos, T., Teixeira, L. C., Matias, J. C. O., & Nunes, L. J. R. (2023). Agroforestry Biomass Recovery Supply Chain Management: A More Efficient Information Flow Model Based on a Web Platform. *Logistics*, *7*(3), 56-. https://doi.org/10.3390/logistics7030056
28. Braškių auginimas skirtingais būdais: sužinokite ir pasirinkite. https://geltonaskarutis.lt/braskiu-auginimas-skirtingais-budais-suzinokite-ir-pasirinkite/;
29. FB „Ateities lysvės“: https://www.facebook.com/profile.php?id=100063625985909
30. Goddek, S. (2019). *Aquaponics food production systems : combined aquaculture and hydroponic production technologies for the future* (1st edition 2019.; Simon. Goddek, Alyssa. Joyce, Benz. Kotzen, & G. Burnell, Eds.). Cham: Springer Nature. https://doi.org/10.1007/978-3-030-15943-6
31. Kakamoukas, G., Sarigiannidis, P., Maropoulos, A., Lagkas, T., Zaralis, K., & Karaiskou, C. (2021). Towards Climate Smart Farming—A Reference Architecture for Integrated Farming Systems. *Telecom (Basel)*, *2*(1), 52–74. https://doi.org/10.3390/telecom2010005
32. Martin, G., Moraine, M., Ryschawy, J., Magne, M.-A., Asai, M., Sarthou, J.-P., … Therond, O. (2016). Crop–livestock integration beyond the farm level: a review. *Agronomy for Sustainable Development*, *36*(3), 1–21. https://doi.org/10.1007/s13593-016-0390-x
33. Mugwanya, M., Kimera, F., Madkour, K., Dawood, M. A. O., & Sewilam, H. (2023). Influence of salinity on the biometric traits of striped catfish (Pangasianodon hypophthalmus) and barley (Hordeum vulgare) cultivated under an integrated aquaculture-agriculture system. *BMC Plant Biology*, *23*(1), 1–417. https://doi.org/10.1186/s12870-023-04422-5