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Introduction, parameters, and advantages of climate resilient cropping systems

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Background

- ❑ Climate change poses a significant threat to global agriculture, potentially reducing crop productivity.
- ❑ With an expected population of 9.8 billion by 2050, the demand for food will increase.
- ❑ Farmers face the dual challenge of meeting this demand while battling climate-related obstacles.
- ❑ Climate change can offset the benefits of genetically improved plants and advanced management practices.



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Historical Context

- ❑ Historical events, like the 2012 drought, showcase the economic impact of climate extremes on agriculture.
- ❑ Fluctuations in yields, largely due to climate variability, can lead to economic instability.
- ❑ Such instances underscore the need for adaptive agricultural strategies.



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Current Agricultural Challenges

- ❑ Modern agriculture grapples with declining soil fertility, reduced carbon sequestration, and diminished microbial activity.
- ❑ Predicted climate extremes like droughts, heavy rainfall, and increasing temperatures intensify these challenges.
- ❑ Additionally, there's a rising concern about increased occurrences of pests and pathogens.



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Introduction to Climate Resilient Agriculture

- ❑ Climate Resilient Agriculture (CRA) aims to sustainably use resources while ensuring consistent farm productivity.
- ❑ CRA emphasizes robustness, adaptability, and transformability in farming practices.
- ❑ The goal extends beyond just productivity to include ecosystem health and minimal environmental degradation.
- ❑ Three pillars: Robustness, Adaptability, Transformability.



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Climate Resilient Crops (CRCs)

- ☐ CRCs are specifically bred to withstand biotic and abiotic stresses like drought and floods.
- ☐ Examples include drought-resistant rice varieties in India that outperform traditional varieties under stress.
- ☐ Such crops offer a means for farmers to maintain yields and ensure stability in face of climate extremes.
- ☐ Examples: furrow irrigated raised bed, rainwater harvesting, micro irrigation.



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Water Management in CRCs

- ☐ One of the primary challenges CRCs address is efficient water management during droughts.
- ☐ Techniques like furrow irrigated raised beds, rainwater harvesting, and micro-irrigation help in optimal water utilization.
- ☐ Adjustments to fertilization and watering schedules also play a crucial role in combating drought conditions.
- ☐ Drought can cause up to a 20% yield loss in maize.
- ☐ Drought-resistant rice in India: 1t/ha higher yield than common varieties.



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CRCs in Different Crops

- ❑ Beyond rice, other staple crops like maize and wheat are also being developed with climate-resilient traits.
- ❑ Drought-tolerant maize varieties, for instance, can yield significantly higher even under stressed conditions.
- ❑ The cultivation of short-duration varieties in crops like peas and sorghum in flood-prone areas shows promising results.



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Tackling Soil and Pest Challenges

- ☐ CRCs are designed not just for weather extremities but also to combat soil salinity and pest invasions.
- ☐ These crops can improve soil health by enhancing its water retention capacity and reducing erosion.
- ☐ The development of pest-resistant varieties helps in reducing the dependency on chemical pesticides, promoting sustainable farming.
- ☐ Concerns about risk and profitability, reluctance to change traditional practices.



Economic Implications of CRCs

- ☐ Adopting CRCs can have significant economic advantages for farmers by ensuring stable yields.
- ☐ Less dependency on external inputs like pesticides and fertilizers can lead to cost savings.
- ☐ By mitigating the risks of crop failures due to climate events, farmers can foresee more consistent incomes.
- ☐ Genetic diversity in monoculture: Disease suppression and increased production stability.



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Benefits of CRCs

- ☐ CRCs are designed to consistently yield under challenging conditions.
- ☐ They play a pivotal role in improving soil water retention, enhancing soil quality, and mitigating erosion.
- ☐ Adopting CRCs can empower farmers to adapt their farm management, ensuring quality, stability, and profitability.
- ☐ Three principles: Minimal/no-till, permanent mulch cover, diversification of crop species.



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Challenges in Adoption

- ☐ Despite CRCs' benefits, their adoption, especially by small-scale farmers, may not be widespread.
- ☐ Farmers might be apprehensive due to perceived risks and profitability concerns.
- ☐ Transitioning to new agricultural methodologies requires both time and assurance of sustainability.



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Alternative Farming Systems

- ❑ Beyond traditional farming, alternative agricultural systems offer more climate-resilient options.
- ❑ These include practices like no-till, reduced tillage, and the use of cover crops.
- ❑ Research indicates that such systems can diminish environmental pollution and enhance soil and water quality.



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Importance of Biodiversity

- ☐ Diverse agricultural systems tend to be more resilient against changing environments.
- ☐ Biodiversity not only stabilizes yields but also helps in pest and disease resistance.
- ☐ A diverse farm ecosystem provides a buffer against climate shocks, ensuring food security.



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Conversion Agriculture

- ❑ FAO defines Conversion Agriculture as a practice focused on sustainability and productivity, built on three core principles.
- ❑ These principles include minimal soil disturbance, maintaining a ground mulch cover, and diversifying crop species.
- ❑ Compliance with these can lead to increased biodiversity, improved soil health, and higher yield stability.



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Conclusion & Future Outlook

- ❑ Climate change is irrefutably impacting agriculture, emphasizing the need for resilient practices.
- ❑ With tools like CRCs, alternative farming, and conversion agriculture, there's a roadmap towards sustainable farming.
- ❑ Embracing these methodologies is vital for future food security and sustainable agricultural development.



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CLIMATE CHANGE AND ITS GENERAL IMPACT ON AGRICULTURE

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Climate change and agriculture

- ☐ Agricultural production heavily relies on climate conditions, making it highly susceptible to the effects of climate change
- ☐ Research in this field primarily focuses on understanding the physical implications of climate change on crops and livestock and the associated economic consequences
- ☐ Agriculture, due to its scale and sensitivity to weather parameters, is considered **the most vulnerable sector in the face of climate change, resulting in substantial economic impacts**



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Climate change and agriculture

- ❑ Agriculture and climate change are interconnected in various ways, as climate change serves as a major cause of both biotic and abiotic stresses that negatively impact agricultural regions
- ❑ Climate change affects agricultural activities through alterations in:
 - annual rainfall patterns
 - average temperatures
 - occurrences of heatwaves
 - changes in weed and pest populations
 - modifications in microbial communities
 - fluctuations in atmospheric CO₂ levels
 - ozone depletion
 - changes in sea levels



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Climate change and agriculture

- ☐ **Extreme weather events** (droughts, floods) are expected to occur more frequently
 - Seasonal variations in weather events may pose risks to traditional crop production methods either due to water constraints or a surplus of water and erosion
- ☐ Soil stability will become crucial to storing water in the soil profile, resisting severe weather events, and minimizing soil losses
- ☐ Vulnerable regions such as tropical and subtropical areas and high mountain regions are expected to suffer the most from climate change
- ☐ The situation is generally more serious in less developed countries where agroecosystems are already fragile, investment in agriculture is limited, and climate change is predicted to have its most devastating effects



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Climate change and agriculture

- ☐ Predicted climate changes are also most likely to affect the **development and survival of pathogens**
- ☐ It is predicted that the climate or weather pattern change will increase the susceptibility of crops to various **pests, diseases, and weeds pressure**, which can decrease yield levels in general
- ☐ Moreover, pests and diseases are more prevalent in humid and warmer regions
 - During the climate change, precipitation patterns will change, with some areas becoming wetter but some leading agricultural regions becoming drier



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Climate change and agriculture

- ☐ With the rise of environmental legislation and increased public interest in protecting the environment, the significance of effective environmental management in agriculture is now widely acknowledged
- ☐ However, the increasing awareness of the environmental consequences associated with conventional farming systems has prompted a shift towards alternative approaches that explicitly address the externalities of farming
- ☐ Within the realm of sustainable and alternative practices, other approaches like **low-input, biodynamic, and regenerative systems** are gaining recognition



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Environmental Impact of Agriculture

- ☐ The interaction and reliance on the landscape are fundamental factors that must be taken into account when considering the potential for sustainable development, as our current landscape management practices are far from sustainable
- ☐ One of the most pressing issues we face today, and will continue to face in the coming decades, is **the problem of food production**
- ☐ As the global population continues to grow, the demands on our food supply will inevitably increase, leading to a rise in agricultural inputs
- ☐ However, this **increase in inputs in agriculture is likely to create even greater environmental challenges** from an agricultural standpoint than what we currently experience



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Expanding the agricultural area

☐ Soil degradation

- ☐ Soil is the basic unit of the ecological system and is largely a **non-renewable resource**
- ☐ Degradation of soil is a permanent and constant companion of agriculture and one of its most serious environmental problems
 - monocultures
 - mineral extraction
 - uncontrolled grazing
 - deforestation
 - inappropriate tillage
 - water erosion
 - incorrect application of agrochemicals
- ☐ One of the solutions to prevent soil degradation is the afforestation of arable land or the transition from arable land to meadows, however, in a state where the demand for meat is increasing



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Expanding the agricultural area

☐ Demand for meat products

☐ During the last 50 years, the global consumption of meat per person has doubled

☐ This problem will worsen over time as the population and incomes increase

☐ Meat, eggs, and dairy products will likely increase consumption, which will pressure the land to grow more corn, soybeans, and other crops needed to feed livestock



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Climate change adaptation in Crop production

- ☐ **Definition:** adaptation refers to actions that mitigate the negative impacts or enhance the positive effects of climate change
- ☐ The Intergovernmental **Panel on Climate Change (IPCC)** defines adaptation as adjustments made in natural or human systems in response to actual or anticipated climate-related stimuli or their effects aimed at minimizing harm or capitalizing on beneficial opportunities
- ☐ Climate adaptation can also be defined as any action that sufficiently improves **societal welfare** to offset losses related to climate change
 - However, the problem with broad definitions is that they lose their significance when it comes to assessing the impacts of greenhouse gas emissions



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Climate change adaptation in Crop production

❑ Even slight climate change poses significant challenges for agriculture

- Unlike other industries, which can often implement relatively quick solutions in response to climate change, agriculture operates differently
- It relies on natural processes that depend on specific proportions of nutrients, temperatures, precipitation, and other conditions

❑ Agriculture worldwide has been optimized based on local climate conditions through decades of experimentation

- If global warming continues at the current rate, adaptation will become **increasingly impossible** within a matter of decades

❑ Addressing the climate crisis in agriculture requires adaptation through the development of heat-resistant and **drought-resistant crops and cultivars**, as well as an urgent reduction of greenhouse gas emissions to minimize future climate-related damages



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Climate change adaptation in Crop production

1. Reduced tillage combined with crop residue retention can protect crops against severe climatic events, for example, by increasing water content in the soil

2. In addition, by improving the overall soil environment for root growth, such practices can support to fulfill of the yield potential of improved cultivars

3. Diversification of cropping systems helps to control soilborne diseases.

4. Reduced environmental impact through the precision in applying N and water in case of irrigation and reduced use of diesel fuel related to agrotechnological operations.

5. Support the soils less prone to becoming degraded even as climate change increases the need for more intensive cultivation in still productive regions.



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Conclusion

- ☐ The widespread interest lies in the **potential of adaptation** to reduce negative impacts or enhance the positive effects of climate change
- ☐ It is essential to quantify the risks associated with greenhouse gas emissions reduction to evaluate costs and benefits properly
- ☐ Additionally, there is a need to identify actions and investments that can improve prospects for food production and enhance food security



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Sustainable farming strategies and climate resilient cropping systems

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Introduction to Sustainable Agriculture in Europe

- ☐ Intensification of agricultural production in the EU has caused sustainability challenges.
- ☐ Overuse of fertilizers in the past still impacts today's environment.
- ☐ Addressing excessive nutrients is crucial for the common agricultural policy.
- ☐ Organic farming offers resistance to external economic shocks.



Organic Farming & Environmental Benefits

- ☐ Organic farming practices, like diverse sowing and conservation tillage, enhance fertilizer uptake by plants.
- ☐ These practices also reduce surface water runoff, retaining soil nutrients.
- ☐ Organic methods can make farming ventures resilient against economic shocks from fertilizer price changes



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Influence of Legislation on Sustainable Agriculture

- ☐ Regional and European legislation heavily influence sustainable agriculture strategies.
- ☐ Many of these legislations are binding directives shaping sustainable approaches.
- ☐ Knowledge of these regulations differentiates European sustainable farming from other regions.
- ☐ The climate changes predicted will affect pest dynamics and crop yield.
- ☐ The focus should be on adaptation for future food production.



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Climate Change Impacts on Food Production

- ☐ Climate change threatens food supply, socio-economic stability, and regional competitiveness.
- ☐ Changes might lead to more invasive pests, pathogens, and weeds.
- ☐ Extreme climate events like floods and droughts could alter global food systems.
- ☐ Modern agriculture is evolving towards diversification and organic practices.



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The Problem of Monocultures

- ☐ Monocultures dominate worldwide, leading to decreased crop diversity.
- ☐ Past catastrophes like the USA's corn blight epidemic and Irish potato famine highlight the risks.
- ☐ Reducing monocultures is crucial for ensuring global food security.
- ☐ Reduced diversity in cultivated plants threatens food production.



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Traditional Agriculture & Sustainability

- ☐ In developing countries, traditional agriculture still prevails, using time-tested methods.
- ☐ These methods enhance biodiversity and make agro-ecosystems resilient.
- ☐ Despite modernization, a move towards organic and diversified farming is on the rise.
- ☐ Traditional agriculture uses age-old techniques and emphasizes biodiversity.



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Biodiversity's Role in Agroecosystems

- ☐ Biodiversity is crucial for the functioning and resilience of agroecosystems.
- ☐ It provides essential ecosystem services beyond just food production.
- ☐ High biodiversity in agroecosystems ensures resistance to external changes.
- ☐ Maintaining biological integrity and diversity is crucial for sustainable agriculture.



Climate Change Challenges to Agriculture

- ☐ Agricultural intensification affects our atmosphere.
- ☐ Climate change affects both the atmosphere and global food security.
- ☐ Melting glaciers disrupt ocean patterns, potentially increasing atmospheric CO₂.
- ☐ Unfavorable climate changes can harm crop growth through droughts, diseases, and pests.



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The Domino Effect of Climate Change on Agriculture

- ☐ Climate change affects more than just temperatures; it impacts entire ecosystems.
- ☐ Soil quality, water availability, and natural habitats are at risk, impacting the health of crops.
- ☐ As the foundation of the food chain, any shift in agriculture resonates through global food systems.



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The Socio-Economic Impacts of Climate Change

- ❑ Beyond direct crop impacts, climate change affects agricultural economics.
- ❑ Volatile weather can lead to unpredictable yields, affecting food prices and farmer incomes.
- ❑ Communities, especially in vulnerable regions, face risks of food scarcity and economic downturns.



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Embracing Technological Solutions for Resilience

- ☐ To combat these challenges, integrating technology into agriculture is vital.
- ☐ Innovations like precision agriculture, drought-resistant crops, and advanced irrigation can mitigate risks.
- ☐ Collaborative global research is needed to develop and share these solutions widely.



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Requirements for a Sustainable Agricultural Future

- ❑ Agroecology holds potential for ensuring food availability, accessibility, adequacy, and sustainability.
- ❑ The future agricultural system must prioritize diversity, productivity, and efficiency.
 - ❑ New technologies will be crucial in overcoming these challenges.
- ❑ Embracing environmentally friendly technologies is crucial, especially with diminishing arable land.



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Attributes of Sustainable Agriculture

- ☐ Sustainable farming prioritizes local crop varieties and avoids harmful agrochemicals.
- ☐ Efficient resource use, reduced emissions, and conservation of biodiversity are paramount.
- ☐ Embracing agroecological principles boosts nutrient cycling and biological control.
- ☐ Cultural identity and agricultural heritage play a role in fostering social cohesion.



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The Power of the Buyer in Promoting Sustainability

- ☐ Large buyers can drive change by requiring sustainable practices from suppliers.
- ☐ Uniform standards, potentially set by governments, can accelerate the shift to sustainable farming.
- ☐ Like organic farming, such standards unify efforts and elevate product quality.
- ☐ Educating the public can spur demand for sustainably produced items.



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Tillage systems under climate resilient cropping system and crop rotation, cover crops, and precrops effect

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Introduction

- ❑ Agriculture's vast footprint:
 - ❑ *38% of earth's surface.*
 - ❑ *Arable land: 12%, Grasslands: 26%.*
- ❑ Crop production surged from 1965-2005.
- ❑ Yield growth slowing, plateau anticipated.
 - ❑ *The agriculture industry occupies a significant portion of the planet, driving the need for sustainable practices.*



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Importance of Biodiversity

- ☐ Core of agriculture.
- ☐ Contains plants, animals, microorganisms.
- ☐ Provides genetic resources for breeding.
- ☐ Essential for ecological services.
- ☐ *Biodiversity fortifies ecological services, ensuring sustainability.*



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Reduced Tillage & Biodiversity

- ☐ Reduced tillage can maintain or improve biodiversity.
- ☐ It shapes the soil microbiome, affecting moisture retention and temperature.
- ☐ The changed microbiome can be antagonistic to pathogens.
 - ☐ *Strategic tillage can bolster beneficial microbiomes, enhancing soil health.*



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Plough Tillage & Environmental Implications

- ☐ Intensive tillage causes soil erosion, reducing agricultural productivity.
- ☐ Soil erosion leads to nutrient loss and water pollution with pesticides.
- ☐ Plowing disrupts soil structure and exposes it to wind and rainfall.
 - ☐ *Intensive tillage practices pose threats to soil health and sustainability.*



Benefits of Reduced Tillage

- ❑ Reduced tillage can enhance carbon sequestration, mitigating climate change.
- ❑ It results in increased organic matter and better soil properties.
- ❑ The improved soil can absorb and retain more water for crops.
- ❑ *Reduced tillage can counter environmental issues and promote soil health.*



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Impact on Soil Carbon

- ☐ Soil organic matter determines soil quality.
- ☐ Intensive land processing increases greenhouse gas emissions.
- ☐ Reduced tillage systems minimize carbon loss.
 - ☐ *Adopting gentle land management techniques can mitigate greenhouse gas emissions.*



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Global Warming & Tillage

- ☐ Increasing CO₂ in the atmosphere elevates concerns about global warming.
- ☐ Agricultural soils play a pivotal role in carbon sequestration.
- ☐ Suitable soil processing reduces greenhouse gas emissions.



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Crop Rotation and Its Importance

- ❑ Crop rotation disrupts disease cycles and improves soil health.
- ❑ The choice of crops depends on ecological, biotic, and economic factors.
- ❑ Crop rotation prevents monocultures and promotes resilient systems.
 - ❑ *Crop rotation's ecological and economic benefits ensure long-term agricultural viability.*



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Cover Crops in Resilient Systems

- ☐ Cover crops protect the soil from erosion and nutrient loss.
- ☐ They are beneficial in both temperate and tropical climates.
- ☐ Their integration provides various agroecosystem services.



Agroecosystem Services of Cover Crops

- ☐ Agricultural ecosystems provide and receive ecosystem services.
 - ☐ *Cover crops absorb nitrogen, reducing losses through leaching.*
- ☐ Cover crops ensure efficient nitrogen use, minimizing environmental impact.
- ☐ Intercropping efficiency is related to the root system's depth.



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Disease Control with Crop Rotation

- ☐ Different crops in sequence can break disease cycles.
 - ☐ *Crop rotation offers a natural, effective method for disease management.*
- ☐ Nematode control is particularly effective with crop rotation.
- ☐ Tillage practices can interact with crop rotation for disease management.



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Benefits of Cover Crops

- ☐ They take up nitrates from soil that might otherwise be leached.
- ☐ This process makes nitrogen available to following crops.
- ☐ Preemptive competition is observed in certain climates and conditions.
 - ☐ *Cover crops play a pivotal role in soil protection and enhancing its fertility.*



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Nitrogen Supply and Demand Asynchrony

- ☐ Cover crops accelerate organic nitrogen mineralization.
- ☐ This can sometimes cause a mismatch between nitrogen release and crop demand.
- ☐ Strategies over multiple years can help optimize nitrogen availability.



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The Way Forward

- ☐ Agriculture is the most significant land user, highlighting the need for sustainable practices.
- ☐ Practices like limited tillage and strategic crop rotation are essential.
- ☐ Adapting these techniques to specific agroecosystems is crucial.



Conclusion

- ❑ Addressing climate change and ensuring sustainable agriculture are pressing concerns.
- ❑ Practices promoting soil health and reduced environmental impacts are pivotal.
- ❑ A combined approach can lead to more sustainable and climate-resilient agriculture.



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MARGINAL CROPS CULTIVATION FOR FOOD PRODUCTION

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Impact of Climate Change on Central European Agriculture

- ❑ Central Europe is experiencing significant impacts from climate change. Rising temperatures, changes in precipitation patterns, and more frequent extreme weather events like droughts and floods are affecting agriculture.
- ❑ These changes influence crop yields, soil health, water availability, and pest and disease management, making the need for sustainable farming strategies crucial.



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Changes in Climate Variables

- ☐ **Mean Annual Temperature:** Increased by 1.5-2.0°C (IPCC, 2014). Warmer temperatures affect plant growth and development.
- ☐ **Winter Temperature:** Increased by 2.0-3.0°C (Beniston et al., 1997). Alters the timing of growth stages.
- ☐ **Summer Temperature:** Increased by 1.5-2.0°C (IPCC, 2014). Impacts heat stress on crops.
- ☐ **Precipitation:** Increased in winter, decreased in summer (IPCC, 2014). Alters water availability.
- ☐ **Extreme Precipitation Events:** Increased in frequency and intensity (IPCC, 2014). Increases the risk of floods and soil erosion.
- ☐ **Vegetation Period:** Extended by 10-30 days (Menzel et al., 2006). Changes in growing seasons affect crop planning.



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Challenges of Climate Change

- ☐ **Heat Stress:** High temperatures reduce photosynthesis, inhibit growth, and increase vulnerability to pests and diseases.
- ☐ **Drought Stress:** Altered rainfall patterns lead to water scarcity, reducing yields and grain quality.
- ☐ **Extreme Weather Events:** Frequent floods, storms, and hail damage crops, leading to yield losses.
- ☐ **Changes in Pests and Diseases:** Altered climate conditions affect the distribution and behavior of pests and diseases.
- ☐ **Soil Degradation:** Changing weather patterns cause soil erosion, nutrient depletion, and reduced fertility.
- ☐ **Reduced Water Availability:** Changing weather reduces water availability, causing water stress in cereal crops.



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Strategies in Crop Production

- ☐ **Diversification of Crops and Use of Drought-Tolerant Crops:** Planting a variety of crops that can thrive in different climate conditions.
- ☐ **Crop Mixtures and Intercropping:** Growing two or more crops together in the same field.
- ☐ **Conservation Agriculture:** Practices like reduced tillage, cover cropping, and intercropping to improve soil health.
- ☐ **Efficient Irrigation:** Use of systems like drip and sprinkler irrigation to conserve water.
- ☐ **Soil Management:** Techniques like soil testing, fertilization, and organic matter to enhance soil quality.
- ☐ **Crop Rotation:** Rotating crops to manage pests, diseases, and improve soil health.
- ☐ **Agroforestry:** Integrating trees into farming systems for shade, soil protection, and fertility.
- ☐ **Use of Weather Information:** Employing weather data for informed decision-making.
- ☐ **Use of Improved Seed Varieties:** Selecting seeds resistant to pests, diseases, and adapted to local climate.



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Diversification of Crops

- ☐ Cereals are crucial in agriculture, and they face climate challenges.
- ☐ Diversifying crops and cultivating drought-tolerant varieties is essential for resilience.



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Einkorn Wheat (*Triticum monococcum* L.)

- ☐ Einkorn's deep root system accesses water from lower soil layers.
- ☐ A thick wax layer reduces water loss through transpiration.
- ☐ Einkorn wheat shows higher yields under drought conditions.





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Emmer Wheat (*Triticum diccocus* (Schränk.) Schuebl.)

- ☐ Deep roots allow access to deep soil moisture, reducing reliance on rainfall.
- ☐ Thick wax layer prevents water loss and protects against high temperatures.
- ☐ Osmotic adjustment and stomatal regulation enhance drought tolerance.





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Spelt Wheat (*Triticum spelta* L.)

- ☐ An extensive root system accesses deep soil moisture.
- ☐ High wax content minimizes water loss through transpiration.
- ☐ Good baking quality and processability make it valuable.





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Millet (*Panicum milliaceum* L.)

- ☐ Thrives in hot and dry conditions, requiring significantly less water.
- ☐ Fibrous roots access moisture from various soil layers.
- ☐ Leaf rolling mechanism maintains water status during drought.





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Sorghum (*Sorghum bicolor* L.)

- ☐ Extensive root system accesses moisture from deep soil layers.
- ☐ Leaf rolling reduces water loss through transpiration.
- ☐ Osmotic adjustment and stomatal regulation maintain photosynthesis under drought.





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Buckwheat (*Fagopyrum exculentum* Moench.)

- ☐ Tolerant to cooler temperatures, potentially drought-resistant.
- ☐ Fibrous roots access moisture from various soil layers.
- ☐ High water-use efficiency leads to more biomass with less water.





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Barley (*Hordeum vulgare* L.)

- ☐ Well-suited to cooler temperatures and diverse soils.
- ☐ Drought-tolerant traits, including deep roots and water use efficiency.
- ☐ Adaptable to various climate conditions.





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Quinoa (*Chenopodium quinoa* Willd.)

- ☐ Tolerant to extreme temperatures, from freezing to high heat.
- ☐ Survives with minimal water, efficiently using soil moisture.
- ☐ Efficient water use due to small leaf area and deep roots.



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Conclusion: Benefits of Climate-Resilient Crops

- ☐ Adaptation to Changing Climate
- ☐ Improved Food Security
- ☐ Potential for Organic Farming
- ☐ Nutritional Advantages and Gluten-Free Options
- ☐ Enhanced Biodiversity
- ☐ Reduced Environmental Impact
- ☐ Soil Health Improvement



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University of South Bohemia
in České Budějovice



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ALTERNATIVE CROPS GROWING FOR BIOMASS PRODUCTION

PR-2-6

Climate Resilient Cropping Systems Learning Module

University of South Bohemia - Czech Republic



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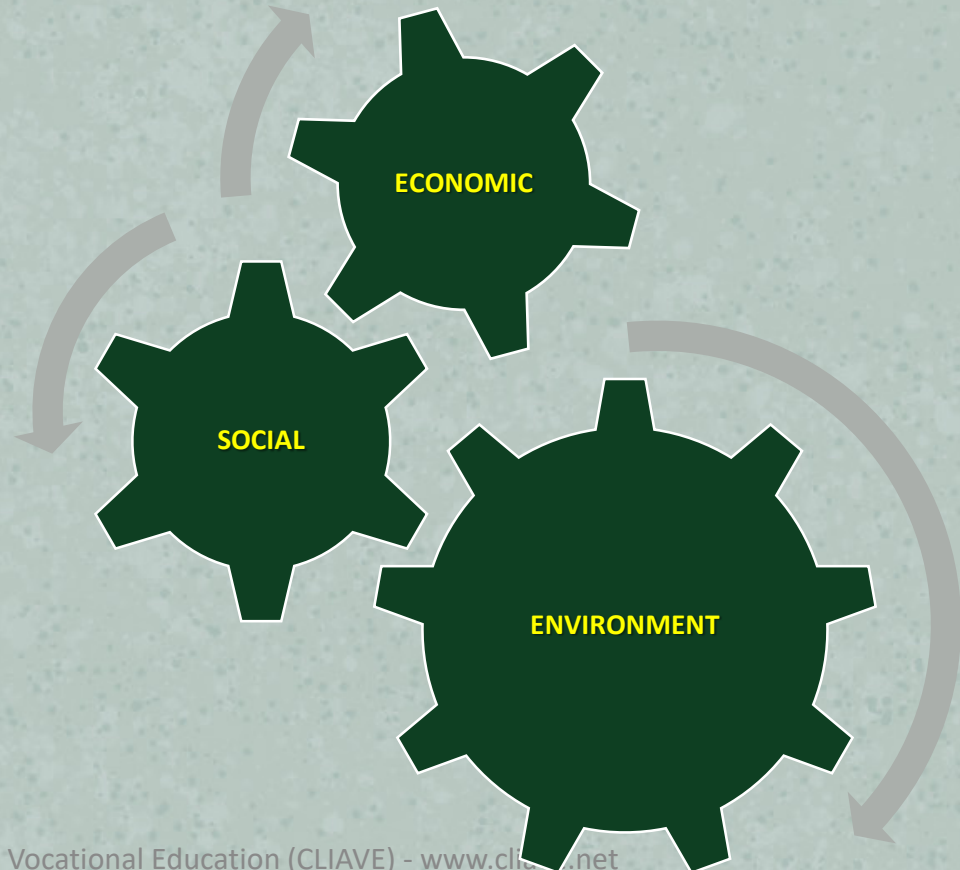
Multifunctionality of Biomass

- ☐ Food production, energy and feed sources, biodiversity conservation, and social services in society
- ☐ As a RES (Renewable source of energy)
 - Huge potential for mitigating the effects of global warming
- ☐ Potential to positively contribute to the climate resilient cropping systems

The importance of alternative crops for biomass production

□ can be summarized in accordance with three main pillars

- **Social**
- **Environmental**
- **Economic**





Social benefits

of alternative crops for biomass production

- ☐ Energy crops could benefit the production of indigenous renewable energy, which in turn increases energy security and improves trade balances
 - This will lead to the creation of alternative sources of employment in rural areas
- ☐ Production of energy crops could lead to the creation of farmers' associations/cooperatives
- ☐ Energy crops growing could improve the education, training, and assistance services provided by farmers



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Economical benefits of alternative crops for biomass production

- ☐ The production of energy crops can lead to the development of new and profitable markets (biofuels, chemicals, materials, foods, feeds, etc.) that could provide farmers with new sources of income and employment
- ☐ Incorporation of energy crops into the cropping systems can promote the development of regional economic structures and can create higher-value coproducts



Environmental benefits of alternative crops for biomass production

□ From the perspective of **climate resilient cropping systems**, the environmental benefits are crucial because the production of dedicated lignocellulosic biomass crops (energy crops in this case) has the potential to provide a range of benefits for:

- water quality improvements
- Phytoremediation
- treatment of wastewater and sludges
- carbon emission reductions (GHG)
- carbon sequestration
- support biodiversity



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Environmental benefits of alternative crops for biomass production

- ☐ The soil degradation problems could also be reduced when perennial crops are grown on arable land
- ☐ Thanks to the implementation of energy crops into the growing system, the pressure on finite natural resources can be reduced
- ☐ Energy crops can significantly promote the use of marginal lands and can support wildlife, natural habitats, and overall agrobiodiversity



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Threat of drought

- ☐ The frequency and extent of the regional dry season are constantly increasing
- ☐ Recently predicted scenarios of more frequent dry spells and heat waves for Europe and the Mediterranean region have come true, and so have most climate change scenarios that predicted increasingly extreme precipitation fluctuations, i.e., longer dry spells alternating with extreme sum of precipitation



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Alternative crops potential in relation to the threat of drought

- ☐ Drought can significantly affect the composition and functioning of all cropping systems and needs to be responded to appropriately
- ☐ Alternative energy or forage crops can bring certain solutions
- ☐ Water stress limits biomass yields more than all other biotic and abiotic factors combined
- ☐ A number of alternative energy crops are included in cropping systems precisely because of **drought resistance** or the low water requirement



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Drought resistance

- ☐ Drought resistance is a property that allows plants to endure a period of drought (water deficit in the soil) or a period of high temperatures and associated air dryness without significant deterioration of development and reduction of production
- ☐ Species that are inherently drought-resistant or generally have low water availability requirements can also be selected for plant production systems
 - This refers to the selection of alternative energy crops suitable for energy or forage purposes
- ☐ Drought resistance and high temperature resistance and their combinations are advantageous for arid regions, but they do not have such applications in regions with highly variable weather, only as part of broad adaptability



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Drought resistance

- ☐ Drought resistance is a complex property and depends on a number of circumstances and factors:
 - the amount and strength of the root system
 - the ratio of above-ground and underground mass
 - the morphological and anatomical peculiarities of stems and leaves that can affect the water management of crops
 - the regenerative capacity and speed of development, etc
- ☐ The genetics of drought resistance are very complex due to the many factors that condition or influence it
- ☐ Drought resistance is a complex trait, and it is, therefore, difficult to test it, unlike a number of other traits, only in field conditions, where a number of different stressors act and the reproducibility of results in individual years is difficult
- ☐ Testing drought resistance is methodically quite difficult
- ☐ Laboratory methods are chosen by comparing the formation of mass (dry matter) in drought conditions and in irrigation conditions, in climate chambers, or indirect methods are also used
- ☐ In field conditions, the production achieved by new breeding or with varieties in dry areas and in areas with a normal course of the year is compared



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Alternative energy crops

- ☐ There are already selected potential crops for bioenergy production in European environmental areas
- ☐ The potential crops for bioenergy production within different European environmental zones belong:
 - Maize, Mustard seed, Hemp, Linseed, Castor bean, Clover or alfalfa, Sugarbeet, Oil seed rape, Sunflower, Potato, Wheat, Other cereals, Sorghum, Cardoon, Giant reed, Reed canary grass, Miscanthus, Switchgrass, Eucalyptus and Poplar and willow. These crops vary in terms of yield, agri-environmental ranking, and geographical suitability



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Alternative crops growing for energy and forage in relation to climate change mitigation

- ☐ Agricultural activity contributes significantly to environmental damage
 - Because of land use, fertilizer use, and other agrochemicals or energy consumption
- ☐ In general, there are main criteria for rating the sustainability of energy:
 - Use/change the land/landscape, the water footprint of energy crops, the impact of energy crops on biodiversity, climatic change adaptation, C sequestration, mitigation of GHG, and maintenance of soil fertility



Alternative crops growing for energy and forage in relation to climate change mitigation

- ❑ To apply the principles of sustainability, it is necessary to identify cost-effective ways to avoid, at least in part, GHG in the agricultural sector as well
- ❑ If we are to think about mitigating GHG production within the selected cultivation processes, it is necessary to focus primarily on their strongest sources
 - These are the production and use of nitrogenous fertilizers and field emissions related to their production and application
 - The amount of GHG from agriculture is also affected by the management system. Conventional agricultural systems are based on higher inputs of fertilizers, which are key factors for the mitigation of N_2O and NO emissions from soil



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Alternative crops growing for energy and forage in relation to climate change mitigation

- ❑ Another way to reduce GHG is to replace traditional crops with another crop that is also suitable for the chosen purpose, i.e., forage or energy purposes
 - Respectively, the possibilities of GHG mitigation can be achieved through the cultivation of less intensive perennial crops
- ❑ These can be, for example, perennial grasses, which are also suitable due to their properties, highly productive species of annual and perennial crops, or their mixtures that have already been selected and particularly implemented



Yield improvement potential

- ☐ The possibility of improving the yield potential is in the **selection of appropriate crop species and genotypes for the given locations to suit the specific soil types and climate**
- ☐ If alternative energy or forage crops are to be produced sustainably, cultivation practices for energy crops should be optimized rather than maximized, as generally low-input systems requiring reduced inputs of nutrients and agrochemicals are needed
- ☐ Major advances in bioenergy crop yields, for example, through genetically and non-genetically modified crops, can be expected in the next few decades
 - Both quantity (the amount of biomass yield) and quality (for example, plant structure or the chemical nature of the input raw material) are identified as the goals of future breeding
 - The main task will be to support the resistance of plants to climate fluctuations, **the support of a climate resilient cropping system**, respectively



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Perspective

- ❑ In general, agronomic research, development, and management of alternative energy crops lag far behind established annual food crops
 - The reason is mainly that in the past, the role of agriculture in energy production was not considered a strategic issue
- ❑ The production of energy crops is expected to benefit the development of new markets, support regional economic structures, provide alternative sources of employment in rural areas, promote the use of marginal lands, bring a reduction of CO₂ levels, and reduce dependence on centralized resources
- ❑ Therefore, in the long term, successful implementation of energy crop systems should strive to ensure income generation, environmental sustainability, energy security, flexibility, and replicability



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INTERCROPPING AND AGROFORESTRY

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Introduction

- ❑ **Intercropping and Agroforestry** are sustainable practices vital for climate-resilient agriculture.
- ❑ Harness diversity and complementarity to mitigate climate change's impact on farming.
- ❑ These practices are environmentally friendly and support the United Nations' Sustainable Development Goals.



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Intercropping

- ❑ **Intercropping** is the simultaneous cultivation of multiple crop species.
- ❑ Maximizes land use efficiency and minimizes vulnerability to erratic weather patterns.
- ❑ Commonly used in regions with unpredictable climate patterns such as Europe.



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Intercropping Benefits

- ☐ **Diverse crop mix for climate resilience:** Mix drought-resistant and wet-tolerant crops.
- ☐ **Improved resource efficiency:** Utilize water, nutrients, and sunlight more effectively.
- ☐ **Reduced pest and disease management:** Natural defense against changing pest patterns.
- ☐ **Enhanced soil health and carbon sequestration:** Mitigating climate change.
- ☐ **Crop stability for long-term food security:** Mitigating extreme weather fluctuations.
- ☐ **Economic benefits:** Diversify income sources for farmers, reducing financial risks.



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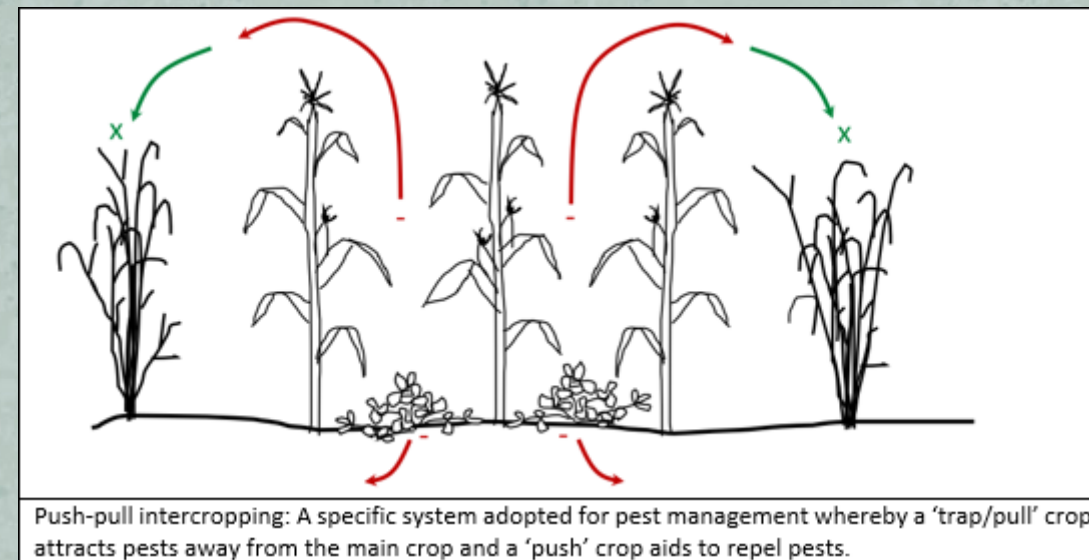


Intercropping Methods

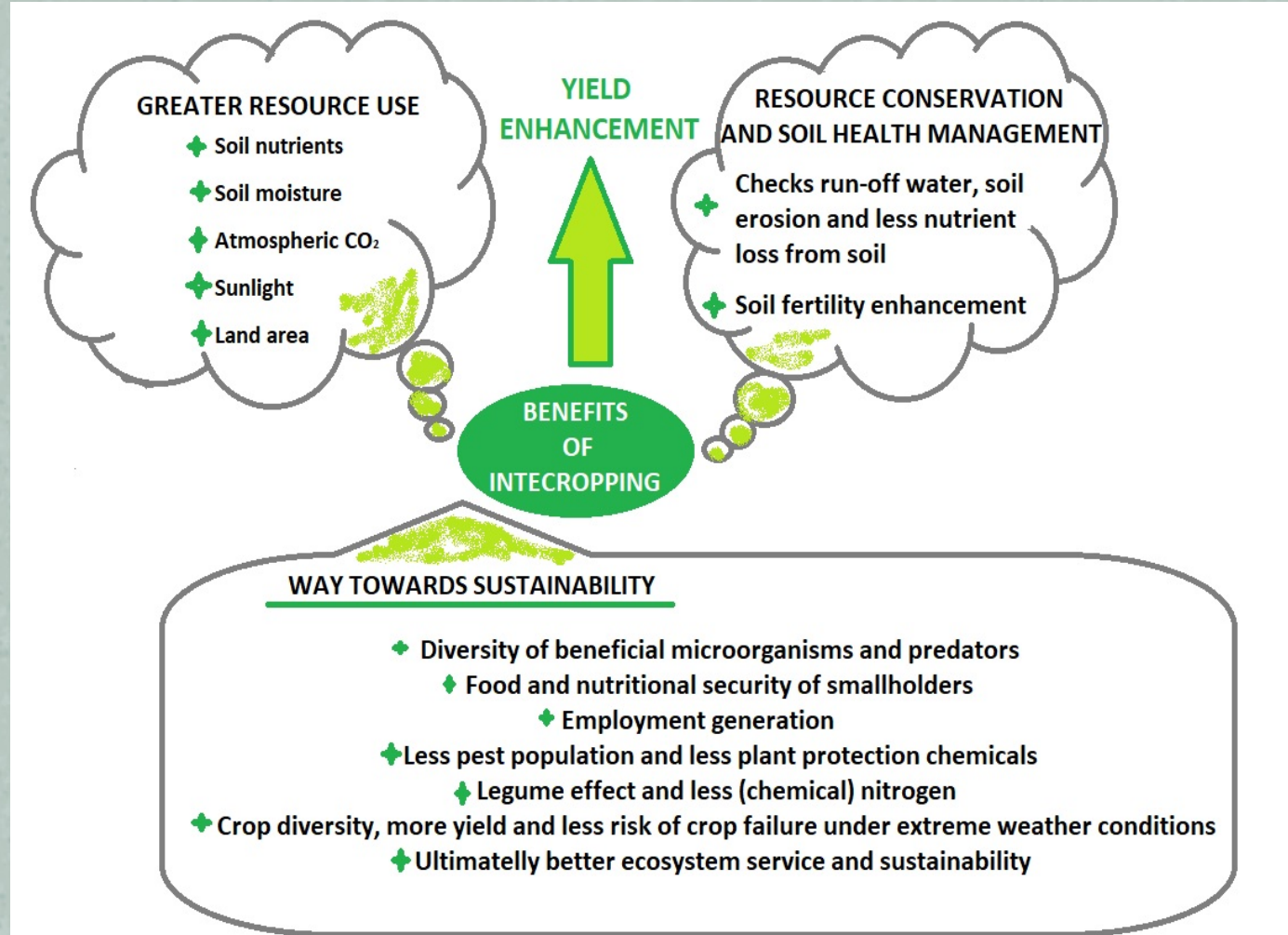
- ☐ Row intercropping: Crops planted in rows for resource sharing.
- ☐ Strip intercropping: Alternating strips of different crops.
- ☐ Mixed intercropping: Mixing crops across the field.
- ☐ Relay intercropping: Planting the second crop before the first is harvested.
- ☐ Push-pull intercropping: Using repellent plants to protect the main crop.

Intercropping Methods (source Burgess et al., 2022)

Row intercropping: The cultivation of two or more crops at the same time with at least one crop planted in rows.	Strip intercropping: The cultivation of two or more crops together, wide enough such that they permit access to separate machinery but close enough for the crops to interact.
Mixed intercropping: The cultivation of two or more crops together in no distinct row arrangement.	Relay intercropping: Planting a second crop into a standing crop part way through its development but prior to harvesting.



Benefits of intercropping (Maitra et al., 2021)





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Intercropping's Role in European Agriculture

- ☐ Significance in enhancing biodiversity: Supports a variety of pollinators and wildlife.
- ☐ Soil health improvement: Enhanced organic matter content and nutrient cycling.
- ☐ Pest management: Natural predators thrive in diverse crop environments.
- ☐ Alignment with EU sustainability goals: Supports environmentally friendly agriculture.



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European Policy Support

- ☐ Promotion of intercropping through research funding and agri-environmental schemes.
- ☐ Future policy developments for wider adoption and sustainability: Potential for increased incentives and subsidies.
- ☐ Knowledge-sharing programs to encourage widespread adoption.



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Agroforestry

- ☐ **Agroforestry** combines agriculture and forestry for diversified land-use systems.
- ☐ Potential for carbon sequestration and climate resilience.
- ☐ Suited for regions experiencing extreme weather patterns, making it essential in Europe.



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Agroforestry: Diversifying Crops and Income

- ☐ Agroforestry's dynamic blend of tree and crop species.
- ☐ Distributing risks and adapting to changing climate conditions.
- ☐ Diverse income sources: Fruits, nuts, timber, and crop yields.



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Agroforestry: Environmental Benefits

- ☐ Trees enhance water retention and prevent soil erosion.
- ☐ Carbon sequestration and reduced greenhouse gas emissions.
- ☐ Biodiversity and pest control: Birds and beneficial insects thrive.
- ☐ Improved air and water quality in surrounding areas.



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Agroforestry and Climate Adaptation

- ☐ Shade and shelter for crops and livestock: Essential in regions with extreme weather.
- ☐ Soil fertility enhancement and nutrient balance.
- ☐ Microclimate control for changing weather conditions: Vital for European agriculture.

Agroforestry Methods (source Burgess et al., 2022)

Silvopastoral: Combining forestry and grazing of domesticated animals on pastures, rangelands or onfarm.	Agrosilvopastoral: Combining trees crops and animals in the same area.
Agrisilvicultural: Combining crops and trees in the same area: this can come under different spatial arrangements detailed below.	Random planting: Trees are randomly distributed throughout the field.

Boundary planting: Trees are planted around the edge of the field to form a boundary.	Riparian buffer: Linear bands of permanent vegetation, such as trees, shrubs etc, are grown adjacent to an aquatic ecosystem to maintain or improve water quality



Ecosystem Services from Agroforestry: Three ecosystem services from agroforestry systems, adapted from Palacios and Bokelmann (2017)





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Promising Agroforestry Systems in Europe and support

- ☐ Silvoarable and silvopastoral systems.
- ☐ Alignment with EU goals for biodiversity, climate change adaptation, and improved agricultural resilience.
- ☐ Suited for European agricultural landscapes and diversified land use.
- ☐ Land tenure issues and limited awareness: Policy adjustments needed.
- ☐ EU's Common Agricultural Policy (CAP) post-2020: Increasing support for agroforestry practices.
- ☐ Addressing barriers to unlock agroforestry's full potential in Europe.



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Conclusion

- ☐ **Intercropping and Agroforestry** are essential for climate-resilient European agriculture.
- ☐ Policy support, technical assistance, and adaptation are key to maximizing their benefits.
- ☐ These sustainable practices can serve as a cornerstone for future agriculture in Europe and worldwide.



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ECOSYSTEM SERVICES WITHIN CLIMATE RESILIENT CROPPING SYSTEM

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Ecosystem services and climate resilient cropping systems are closely connected

- ❑ Ecosystem services play a crucial role in ensuring the resilience of crop systems to climate change
- ❑ **Ecosystem services are benefits that humans derive from ecosystems**
- ❑ Climate resilient cropping systems are those designed to be more resilient to the impacts of climate change, such as drought, floods, and extreme weather events
 - These systems include practices that, among other benefits, increase soil health, reduce soil erosion, save water, and improve nutrient cycles in general
- ❑ Ecosystem services provide the basis for climate resilient cropping systems by providing the necessary resources and functions to support overall crop production
 - For example, healthy soil provides the basis for crop growth, and clean water is essential for irrigation. Biodiversity also plays a key role in pollination and pest control, among others
- ❑ The promotion and maintenance of ecosystem services are essential for the development of climate resilient cropping system
 - This can be achieved through practices such as conservation agriculture, agroforestry, or integrated pest management, which are designed to improve ecosystem services while increasing crop productivity and reducing agriculture's environmental impacts



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Categories of Ecosystem Services

- ☐ Ecosystems around the world provide key services that essentially enable human society to function
- ☐ Ecosystem services can be divided into several categories:
 - ☐ (1) Provisioning services
 - ☐ (2) Regulating services
 - ☐ (3) Cultural and social services
 - ☐ (4) Supporting services



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Provisioning (production) services

□ Provisioning (production) services cover all the goods and services produced by ecosystems that can be used for the material consumption of a global society

□ These include:

- the production of plants that provide **food, fiber, fuel**, and other goods
- the production of **drinking water**
- abiotic natural resources
- etc



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Regulating services

- ☐ **Regulating services** regulate key natural processes, such as the **water cycle**, or provide for the **regulation of greenhouse gases** and related climate change
- ☐ Regulating services thus largely creates a framework of environmental conditions in which our society operates, the importance of which is usually only realized when there is a deviation in their smooth functioning
- ☐ Such a deviation (nonlinear change in ecosystem) can be a **flood, drought, dust storm, or climate change**
- ☐ It also follows that these services are not usually subject to the market but become subject to regulations arising from laws and other regulations



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Cultural and social services

- ☐ **Cultural and social services** are the sum of what nature means for our psyche, culture, artistic and spiritual inspiration, etc.
- ☐ Although these services **make a large contribution to the economy** of many sectors of human activity, such as the tourism and entertainment industries, literature, and the arts, **they are not generally subject to the market**
- ☐ However, for example, attractive tourist places, or places with generally rich biodiversity, can be subject to the market and generate profits



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Supporting services

- ☐ **Supporting services**, such as **primary production**, **pollination**, **nutrient cycling**, etc., are, with the exception of some services, not directly subject to the market
- ☐ This makes their evaluation very difficult
- ☐ The use of nature and natural resources often leads to a reduction in the capacity of ecosystems to provide ecosystem services
- ☐ As human populations grow and opportunities increase, so does the production volume or frequency of transport
- ☐ In general, human influence on the functioning of ecosystems and geochemical processes is increasing
- ☐ Mediterranean and temperate biomes are most affected, i.e., in areas that were the cradle of advanced civilizations



Agriculture and basic ecosystem services

- ☐ Most of the landscape has been altered by agricultural activity, and most natural ecosystems lie in the matrix of agricultural soils
- ☐ **The conversion of natural ecosystems into agricultural systems, i.e., agroecosystems, can have a strong impact on the system's ability to provide important ecosystem services**
- ☐ Agroecosystems also provide supporting services such as:
 - pollination
 - pest control
 - support for genetic diversity for future agricultural use
 - retention of water in the landscape
 - protection against soil erosion
 - support nutrient cycles



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Agriculture and basic ecosystem services

- ❑ Quality of services depends on the management
- ❑ Agroecosystems can provide various regulating and cultural services to humans, too
 - Regulating services from agriculture can include:
 - flood threat control
 - water quality control
 - carbon sequestration, and climate control through mitigation of GHG
 - disease control
 - provision of decomposition processes
- ❑ Cultural services related to agroecosystems can include landscape appearance, education and research, recreation, tourism, or religious aspects
- ❑ On the other hand, biodiversity can contribute a range of supporting services to agroecosystems and surrounding ecosystems



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Agriculture and basic ecosystem services

☐ Biological pest control

- one of the essential benefits of ecosystems for agriculture
- Natural ecosystems often support it

☐ Unmanaged habitats provide spaces and diverse food resources for natural enemies of agricultural pests (so-called **antagonists**), which in turn provide biological regulating services in agroecosystems

☐ Such biological controls can reduce the pressure on populations of harmful insects, ultimately **reducing the need for pesticides and their production and distribution**

- For example, ecosystem services provided by pest antagonists can directly replace insecticides. The value of such an ecosystem service can thus be quantified and expressed economically



Agriculture and basic ecosystem services

- ❑ One of the most important ecosystem services for agriculture is **pollination**
 - This ecosystem service is initiated by natural habitats in agricultural landscapes, i.e., places where pollinators can reside
 - It is estimated that **around 65% of the world's plant species require pollination by fauna (mainly insects), and about 75% of all cultivated crop species of global importance for food production depend on pollination**
- ❑ Pollination services are **quantifiable** and thus can also be expressed economically, which is not the case for most other ecosystem services
- ❑ Agriculture is highly vulnerable to the potential loss or degradation of the ecosystem service of pollination
 - One factor that may amplify this loss or degradation is climate change and its consequences



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Agriculture and basic ecosystem services

- ☐ Agriculture is the largest global water consumer (about 70%)
- ☐ Providing sufficient amounts of clean water is a basic ecosystem service provided to agroecosystems
- ☐ The value of ecosystem services associated with the availability and quality of water for agriculture is only partially reflected in most estimates
- ☐ The vegetation of natural ecosystems, such as forests, can significantly influence the accumulation, infiltration, and retention of water in the landscape



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Agriculture and basic ecosystem services

- ❑ However, about 80% of water consumption in agriculture comes from rainfall, which is stored in soil moisture and vegetation
 - Such water is referred to as green water
- ❑ In addition to vegetation cover, organic matter (its quantity and quality) and soil biotic communities (edaphon) significantly influence the quantity and quality of water in the soil and thus provide other basic ecosystem services to agriculture
- ❑ In this relation, predictions of water availability for agriculture are based mainly on assumptions of **blue water availability** (i.e., surface and groundwater) but often neglect the contribution of **green water** (i.e., rainwater in soil and vegetation)



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Agriculture and basic ecosystem services

- ❑ The basic ecosystem services that are also available to agroecosystems are the structure of the soil and its fertility
- ❑ Agricultural practices that degrade soil structure and soil microbial communities include traditional ploughing, frequent harrow by disc, or harvesting processes (= strong soil compaction; **pedocompaction**)
 - Farming practices can also be applied to protect the soil and reduce the risk of erosion and water run-off
- ❑ Reduced soil processing/cultivation (e.g., no-till technologies) and other soil protection measures such as the implementation of green manure or intercropping (as cover crops), the application of composts, and appropriate crop rotation under the cropping process can preserve soil fertility by contributing to good soil structure, minimizing nutrient losses and keeping them available for crops
 - cover crops
 - crop rotation
 - landscape and its structure
 - incorporation of post-harvest residues



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Agriculture and Negative Impacts on Ecosystem Services

- ☐ The value of ecosystem services linked to agriculture is enormous and often underestimated
- ☐ Agriculture can provide so-called negative services
 - habitat loss
 - nutrient leaching associated with erosion
 - greenhouse gas emissions
 - pesticide pollutant loads, etc
- ☐ Agriculture itself represents a significant pressure on ecosystem services
 - a large amount of nutrients are supplied each year by humans
 - this can lead, for example, to **eutrophication or ecotoxicity**



Agriculture and Negative Impacts on Ecosystem Services

- ❑ For example, from a global perspective, the application of mineral fertilizers has doubled the nitrogen input from the atmosphere into ecosystems
 - Thus, increasing production (i.e., intensification of agriculture) due to nutrient inputs can lead, for example, to a reduction in ecosystem services such as the provision of drinking water
 - The intensification of agriculture increases the total consumption of agrochemicals
- ❑ In many regions of the world, the intensification of agriculture has led to a simplification of the landscape structure through the expansion of farmland, increasing the size of fields, reducing vegetation at the edges of fields, and eliminating the natural environment
 - The simplification of the landscape structure contributes to increasing pest pressure through the possibilities offered by monocultures and their area



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Support for Farm Ecosystem Services and Appropriate Management

- ☐ Management on farms can significantly improve the overall volume and quality of ecosystem services provided by agriculture
- ☐ Proper management can also improve ecosystem services such as pollination, biological pest control, soil fertility and structure, water regulation, biodiversity promotion, etc.
- ☐ Tools (examples)
 - management of marginal habitats
 - perennial plants in cropping practices to promote biodiversity
 - support for crop diversity through polycultures, cover crops, or agroforestry
 - reduce the need for ploughing
 - Soil carbon sequestration
 - Effective manure management
 - Replacing synthetic nitrogen fertilizers with legumes



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