Transition
Innovative resilient farming systems in Mediterranean environments

Deliverable 3.3

Business model catalogue

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List of Abbreviations

Abbreviation	Definition
B	Business
C	Customer
CAPEX	Capital Expenditure
CCLS	Cooperative des Céréales et des Legumes Secs
COOPSSEL	Cooperative de Service Spéialisée en Élevage
FAO	Food and Agriculture Organisation
GHG	Greenhouse Gas
LER	Land Equivalent Ratio
MFVS	Mixed Fruit tree-Vegetable Systems
OPEX	Operational Expenditure
ROI	Return On Investment
WP	Work Package

1. INTRODUCTION

The growing interest in agroforestry and mixed farming systems must be supported with a clear and structured roadmap for their effective implementation, management, and sustainable scaling. Economic considerations are among the most important factors that will determine the ultimate value and feasibility of agroforestry farmers' adoption (Nair, 1993). According to a Food and Agriculture Organization of the United Nations (FAO) (2013) study, lack of knowledge, different labour requirements and less established markets lead to more uncertainties with agroforestry systems. In turn, this would limit the development of workable technical and business models.

According to a recent review on the socio-economic performance of agroecology by Mouratiadou et al. (2024), agroforestry, as a component of agroecology, exhibited positive outcomes in 53% of the socio-economic evaluations conducted. Specifically, they mentioned that agroforestry has an overall favourable potential for improving the socio-economic performance of farms. Despite these positive results, the authors also reported that such practices often require higher labour inputs and associated costs. Additionally, deeper work is being developed in other initiatives in the Mediterranean (Segre et al., 2019), projects at the European Union level (AF4EU) as well as in other latitudes (Applegate et al., 2022).

The Transition project wants to provide information regarding the Mediterranean region. This deliverable aims to present the compilation of six business models across the five different regions of study in the Mediterranean.

The current deliverable compiles various approaches to successful implementation and scaling. Four of them, are regarding different combinations of plants and trees, while two of them are focused on innovative systems that can be potentially integrated into the systems. Both groups, the selected systems, and the innovative crops, are derived from the work performed in the first Work Package (WP1) and their follow-up according to the WP2.

The business models detailed in this compilation emphasize the importance of defining clear value propositions, identifying key beneficiaries and partners, as well as designing effective implementation strategies. Each model highlights sustainable revenue generation methods and practical ways to disseminate knowledge and build capacity

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among farmers. Additionally, these models underscore the significance of establishing robust partnerships and collaborations, across the different regions and agricultural contexts.

By presenting different cases of study, this deliverable aims to offer a comprehensive overview of various strategies to foster agroforestry and mixed farming systems under different conditions of the Mediterranean basin. Furthermore, this compilation aims to inspire the adoption of these systems as a resilience strategy for climate change adaptation in the rural communities of the Mediterranean.

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2. METHODOLOGY

First, one or two agroforestry and mixed cropping systems of interest were selected in each participating region, based on the systems identified in WP1 and followed up in WP2. This selection was based on the relevance and implementation potential of each system in its specific regional context. Detailed information can be consulted in the deliverable D1.2 of the Transition project.

A canvas was chosen as a template to structure and organise the main ideas of each section of the business model (Figure 1). It was done following the business model concept proposed by Osterwalder and Pigneur (2004). This tool allowed the participating partners to list the key elements of the business model, ensuring a coherent and understandable presentation.

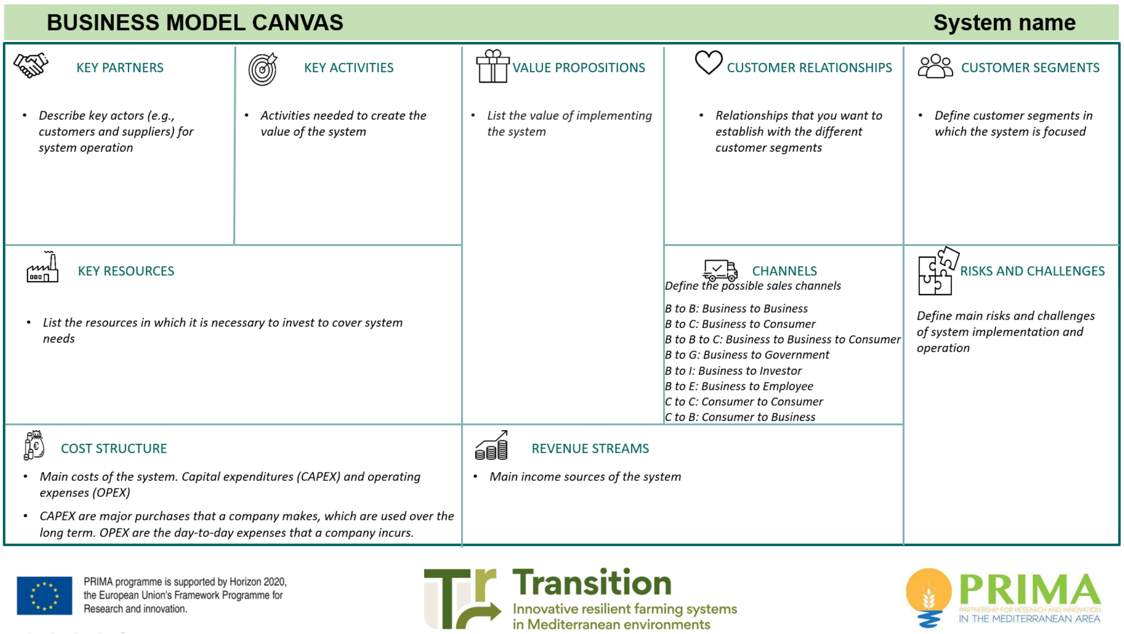

Figure 1. Selected business model Canvas.

Each participating partner filled in their initial canvas, detailing the specific aspects of their business model. This process was enriched by a series of feedback and revisions, which allowed the information gathered to be refined and validated to accurately reflect the particularities of each system.

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Once the Canvas was completed, each section was thoroughly detailed. As a summary, the business model canvas is included at the end of the full description. The objective was to provide a clear and comprehensive explanation to facilitate interpretation and understanding by external readers.

The description starts with a brief introduction, followed by the value proposition. Key aspects such as basic information for the system implementation (partners, activities, and resources) are then outlined. This is followed by customer-related information (relationships, segments, distribution channels), cost structure, and revenue streams. The cost structure of implementing an agroforestry system includes both capital expenditure (CAPEX) and operational expenditure (OPEX). Understanding these costs is crucial to ensure the viability and profitability of the system as farmers can optimise their operations and achieve sustainable agricultural practices. Revenues are related to the generated incomes from the sale of various products, but also by significant savings in the cost structure. Finally, the risks and changes observed in the region are also described.

Table 1 summarises the selected models for the schemes in each participating region, which are further described in the following section. This compilation provides a comprehensive and comparative overview of the strategies and approaches adopted, highlighting the specific opportunities and challenges of implementing agroforestry and mixed cropping systems in the Mediterranean context.

*Table 1. Summary of the selected system for the model business task. *Selected systems were based on the fields followed by the partners of the project. In this way, AFAF did not follow up any field site in the frame of the project but due to their experience working with Non-Timber Forest Products they provided valuable information regarding this system in France as an example that is compiled in the Anex.*

Country	**System type**	**Name**
Algeria	Innovative crop	Field pea (*Pisum sativum* L.)
Egypt	Agroforestry	*Jatropha curcas* trees and diverse vegetable crops
France	Mixed farming	Mixed fruit tree-vegetable system
France*	Agroforestry	Non-Timber Forest Products
Italy	Agroforestry	Olive trees and cereals (durum wheat, soft wheat, rye)
Spain	Agroforestry	Olive trees and winter cereal
Spain	Innovative crop	Kernza® (*Thinopyrum intermedium*)

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3. RESULTS. Business model compilation

3.1 Algeria. Innovative culture: field pea (*Pisum sativum* L.)

3.1.1 Market data

Conservation agriculture and sustainable farming are generally incompatible with the extensive monoculture and repeated wheat cropping that are prevalent in rainfed areas of the Mediterranean region. Including legumes in crop rotations would be particularly beneficial, as greater cultivation and use of these crops can contribute to climate change mitigation, reduce energy consumption, improve soil fertility, enhance the resilience of cropping systems, and boost both food and feed security, creating healthier food and living environments. However, legumes are scarcely cultivated in Europe and North Africa due to their significant profitability gap compared to wheat and other major cereals, which have benefited from far more crop improvement research and usually greater supporting measures than legumes.

Focusing on the legume targeted by the project, in 2022, Algeria had a total export quantity of peas (both dry and green) amounting to 24.4 tonnes, with a total export value of 43,865 EU (Food and Agriculture Organization of the United Nations, n.d.), which are relatively low figures compared to other regions. Regarding climatic conditions, coastal Algeria experiences moderate drought, characterized by substantial annual rainfall variability. A significant shift occurred in 1990, leading to a clear trend of declining rainfall. This trend is demonstrated by a reduction in the average annual rainfall from 731.25 mm (1968-1990) to 594.13 mm (1991-2022), representing a notable 19% decrease.

It is visible the interest of PRIMA programme to improve resilience in the Mediterranean region. Apart of Transition, CAMA project is also concerned about to improve resilience through producing new cultivars with higher grain yields for Algeria, Morocco, and Italy. For example, CAMA identified field peas (Pisum sativum) as a key focus of its breeding efforts. Further information can be consulted in **Annex I.**

3.1.2. Crop introduction

The dominant cropping systems in Algeria and more particularly in the semi-arid region of Sétif are systems based on monoculture (cereals-fallow). Cereal farming is conducted

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by adopting the conventional system (deep ploughing with a plough to Soc and/or disc), the use of chemical fertilizers, and postharvest, crop residues grazed by the herd.

In this context, we have introduced a fodder crop in this case the field pea as an alternative crop to fallow in a mixed farming system and as a cover crop in an agroforestry. The interest of field pea is due to several factors: (1) their wide adaptability to the soil, climate, and management conditions of the Mediterranean region, along with their relatively good drought tolerance (thanks to their winter-spring growth cycle and early maturity), (2) their familiarity to Mediterranean farmers, and (3) their flexibility and diversity in uses (for feed, food grain, fodder, or protein concentrates and isolates); (4) their competitive advantage over weeds compared to other grain legumes. The aim is to reduce the harmful effects of climate change as well as improve the quality of the soil and cereal yields at the same time provide feed for livestock.

Crop drivers

- Adaptation to climate: the Mediterranean environment, characterized by variable rainfall and mild winters, provides favourable conditions for the growth of field peas. These legumes have shown good adaptability to drought conditions typical of the region. Their winter-spring growth cycle and early maturity help them cope with water scarcity, a significant factor in coastal Algeria where rainfall has been declining since the 1990s.

- Soil fertility and nitrogen fixation: field peas are particularly valued for their role in improving soil fertility through nitrogen fixation. This characteristic makes them a key player in sustainable agriculture, especially in regions like Algeria where soil quality can be compromised by extensive monoculture practices and can be at risk of desertification.

- Economic and nutritional value: though less profitable than wheat and other cereals, field peas are a highly nutritious crop, rich in protein and essential minerals, making them a critical food source. Their ability to be used for both feed and food adds to their economic potential in diversified farming systems.

- Lower GHG emissions and/or lower energy consumption: field peas are a sustainable crop that contributes to lower GHG emissions compared to other legumes and cereals. This is due to their ability to fix nitrogen naturally, reducing the need for synthetic fertilizers, which are energy-intensive to produce and contribute to GHG emissions. Moreover, incorporating field peas into crop rotations improves soil health

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and reduces the carbon footprint of farming systems by enhancing the soil's capacity to store carbon, thus lowering overall emissions.

- Greater feed and food security: field peas are a versatile crop that supports both feed and food systems. Rich in protein and essential nutrients, they provide a reliable source of nutrition for human consumption, while also being an important ingredient in animal feed. This dual use helps improve food security by reducing dependence on other crops and contributing to more resilient agricultural systems. Additionally, their ability to thrive in diverse environmental conditions makes them a reliable food source in regions like the Mediterranean, where climate variability can affect other staple crops.

Crop barriers

- Profitability gap with major cereals: one of the major economic barriers to the cultivation of Pisum sativum is its profitability compared to dominant crops like wheat. Wheat and other cereals benefit from more research investment and governmental support, making them more profitable for farmers. This economic disadvantage discourages farmers from incorporating field peas into their crop rotations.

- Limitations in knowledge transfer: there are still many unresolved agronomic management issues, such as determining the optimal harvesting method, timing, and machinery settings. This lack of established best practices creates uncertainty, making it more challenging to adopt field pea successfully.

3.1.3. Business model description

The field pea (*Pisum sativum L.*), Sefrou variety was cultivated under the two systems at the level of the Sersour Salah pilot farm (Bir Haddada, Sétif).

The business model description aims to provide the benefits of introducing this crop into a monoculture system in a region exposed to drought (180 mm/year).

Value propositions

1. Adaptation to climate change
2. Fallow resorption
3. Diversifying crops on farms
4. Introduction of conservative techniques of soil and water (no-tillage and simplified tillage)

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5. Finding an integrated association between crops and livestock (grazing of stubbles)
6. Increase of farmers income
7. Contribution to rural development (avoiding rural exodus)

Growing field peas allows for the absorption of fallow periods as cover crops, thereby reducing soil erosion and enhancing soil fertility. This enables farmers to enhance their land, thereby strengthening their capacity to adapt to climate change, while also providing feed for their livestock or generating added value by selling it to breeders. It makes it possible to develop water in the soil, improving soil biology and fauna. It can also be cultivated in combination with other crops such as oats and barley (mixed crops). The adaptation to climate change will be by the adoption of the principles of conservation agriculture, the use of local resources resistant to climate change, and the introduction of the agroforestry system on the farm.

Key partners

1. Cereals and pulses cooperative (seeds and inputs supplier)
2. Private farmers
3. Public farms (pilot farms)
4. Intermediaries (trader)
5. Public administration (Department of Agriculture, Forest Conservation and Agriculture Chamber).

The seed can be obtained from different seed providers, such as the cooperative of cereal and pulses CCLS (*Cooperative des Céréales et des Legumes Secs*, by its original name in French) which is a governmental supplier of seeds and agricultural inputs. The stakeholders involved are the CCLS, private farmers, pilot farms, public administration, Department of Agriculture, Agriculture Chamber.

The role of these different stakeholders can be described as follows:

Farmers and livestock herders can cultivate this crop to improve their cereal yields and constitute forage stocks for their livestock. Public Administration and Agriculture Chamber play an essential role in financial and technical support for farmers in order to adopt this kind of crops and absorb the fallow.

For pilot farms, their role is focused on experimentation, extension and dissemination of innovative practices and crops with neighbouring farmers.

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Key activities

1. Cropping practices in drought conditions,
2. Contact with technicians/farm advisers, farmers and farms practising mixed farming systems
3. Identify and solve some technical obstacles

The cultivation of the fodder pea is similar to those of cereals except for the adjustment of the sowing machine and the higher nitrogen needs for cereals compared to legumes.

Research centres such as INRAA, are crucial to provide evidence-based data to farmers to identify and solve technical obstacles. On the one hand, the trials carried out in the field make it possible to evaluate the performance and growth parameters of the crop. They also make it possible to evaluate the different sowing, fertilization, weeding and harvesting strategies. On the other hand, the organization of field demonstration days allows farmers to improve their knowledge and skills in the management of cultivation and soil conservation and to ensure the profitability and sustainability of their farms. Effective collaboration between different agricultural stakeholders can lead to the development of new techniques to help adopt new systems (mixed farming and agroforestry) to mitigate the effects of climate change. The grouping of farmers into associations or cooperatives makes it possible to strengthen their power to influence administrative and political authorities in order to resolve and remove the obstacles that confront them.

Key resources

1. Crop technical itinerary and suitable livestock management practices document

The management of the field pea crop must follow a well-determined technical route. For that, a technical document (describing the whole process as choosing the sowing date, the type of fertilizer to use, the type of work of the soil to adopt (tillage or no tillage), the agricultural machines to be used) that farmers and technicians can consult would be necessary. In summary, resources to be considered are the type of weeding to drive as well as the harvest. For harvesting as fodder, the farmer must choose the optimum physiological stage for mowing (budding stage). For harvesting as a grain, the stadium before total maturity should be chosen by using the swather and the threshing swathes in order to reduce grain losses.

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Furthermore, specific machinery should be considered especially for harvesting as grain. In this case, a swather machine is needed to minimise the grain loss contrary, if a combined harvester is used.

Customer relationships

1. Short trade (direct selling from farmer to consumer)
2. Multi-clientele: a multitude of customers rather than single clientele

Since there is an outlet for the marketing of field pea grains, in this case, the CCLS or the livestock feed manufacturing units. The sale of fodder can also be done to landless breeders or breeders with reduced fodder areas. The adoption of this crop makes it possible to open other niches for livestock development since the market for livestock products is promising given that self-sufficiency in these products has not yet been achieved in addition to galloping population growth. The development of this crop will allow the entire agricultural and rural community to understand its economic, social, and ecological advantages.

Customer segments

1. Livestock farmers
2. cereals and pulses cooperative (CCLS)
3. Collectors and dairies (milk) (*Cooperative de Service Spéialisée en Élevage*, COOPSSEL, by its name in French)
4. Individual customers (cereal, legumes, milk, and dairy)

By identifying the clientele who will benefit from this crop, studying the needs of these different outlets such as farmers, breeders, cooperatives (CCLS, COOPSSEL, and others) as well as livestock feed units is essential. Creating a synergy between farmers and breeders makes it possible to strengthen the links between them, one provides the fodder and the other provides the animal manure. For cooperatives, they are a secure customer for receiving grain production. The same goes for livestock feed manufacturing units.

Channels

1. Local market or sale on-farm

The sale on the farm can be done for milk and dairy and other products (e.g., fruits, live animals, fruits and vegetables, olive oil) but for cereal and pulse, the sale should pass

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by cooperatives (because the government impose to farmers to deliver their production to cooperative). Which also delivers the products to the feed industry.

Cost structure

1. CAPEX – on-farm implementation (seeds, inputs, feeds, labour, common machinery costs)
2. OPEX – fixed costs (fuel, energy, paid labour common machinery rent for public cooperatives)

CAPEX includes land tenure, seeds and inputs purchase, machinery, and family labour. Seed and inputs purchase, storage, and handling are necessary to ensure the quality, and the better yield.

OPEX in the field pea crop is mainly associated with fuel energy and machinery rental (if required), and paid labour (seasonal or permanent labour). Fuel prices are fixed by the government, but other costs are variable.

The training programs for workers and farmers are supported by the government (PRCHAT: human capacity building and technical support program). Furthermore, private companies and the agriculture chamber provide training for farmers as workshops or field demo days.

These are the only costs, for taxes, farmers are exempt from taxes in Algeria.

Revenue streams

1. Sale of products and by-products (cereal, forage, legumes, straw, livestock, milk, and manure)

The revenue sources include grains delivered to CCLS, straw, and forage for livestock farmers. Additionally, the land harvested can be rented out to livestock farmers, particularly 'transhumants'. These crops can reduce input costs (such as fertiliser) by fixing atmospheric nitrogen, thereby improving soil fertility and water holding capacity, especially when practising no-tillage systems. Furthermore, cultivating these crops in an agroforestry system can enhance arboriculture yields. Overall, this integrated approach generates higher revenue compared to monoculture systems with fallow periods.

Risks and challenges

1. Climatic conditions (drought, cold and high temperature)
2. Cessation of government subsidies

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3. Fluctuation of inputs markets
4. Geopolitical issues

There are various advantages and opportunities gained from the development of fodder pea cultivation given the economic and ecological interests. However, it also faces some risks and challenges. Among these challenges, are recurrent and extreme droughts where the climate has advanced more than 100km to the north, recording extreme temperatures exceeding 45°C in summer and precipitation not exceeding 180 mm per year.

In addition to this, we are witnessing overlapping seasons with dry periods in winter and rainy periods at the end of spring and beginning of summer, this will affect plant physiology, which is pushing researchers and professionals to review the sowing dates in order to avoid harvest dates coinciding with rainy periods. The advance of the desert with the arrival of sand which invades all the coastal towns of the country, sounds the alarm to accelerate reforestation operations and the rehabilitation of the green dam project.

The other risk that can hinder the entire development process of these crops is the subsidies policy undertaken by the government (seed, energy, fuel, etc.) given that state revenues depend on oil resources, and each crisis on the world market will have repercussions on the economic and social policies of the country, particularly the subsidies it offers to agriculture.

In addition to this, the very slow bureaucratic apparatus and the archaic banking system also constitute major obstacles to the development of agroforestry and mixed farming.

Global and regional geopolitical issues are also major risk factors and challenges that any agricultural development process can face, particularly in Algeria amid the blockage caused by the COVID-19 health crisis, the Russian-Ukrainian conflict given that the two countries are suppliers of inputs and agricultural products, conflicts in sub-Saharan Africa and its consequences (migratory flow, epidemics, insecurity, etc.) and this applies to all Mediterranean countries.

Effective collaboration between all regional countries is necessary in order to face all the challenges and risks that threaten them. The exchange of experience and the sharing of knowledge in this area and to remove all obstacles to north-south cooperation.

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BUSINESS MODEL CANVAS — Innovative culture: Field pea

KEY PARTNERS

- Cereals and pulses cooperative (seeds and inputs supplier)
- Private farmers
- Public farms (pilot farms)
- intermediaries (trader)
- Public administration (Department of agriculture, Forest conservation and agriculture chamber)

KEY ACTIVITIES

- Cropping practices in drought conditions
- Contact with technicians/farm adviser, farmers, and farms practicing mixed farming systems
- Identify and solve some technical obstacles

KEY RESOURCES

- Crop technical itinerary and suitable livestock management practices document

VALUE PROPOSITIONS

- **Adaptation to climate change**
- **Fallow resorption**
- **Diversifying crops on farms**
- **Introduction of conservative techniques of soil and water (No tillage and simplified tillage)**
- **Finding integrated association between crops and livestock (grazing of stubbles)**
- **Increase of farmers income**
- **Contribution to rural development (avoiding rural exodus)**

CUSTOMER RELATIONSHIPS

- Short trade (direct sailing from farmer to consumer);
- multi-clientele; multitude of customers than single clientele

CHANNELS

- Local market or sale on-farm

CUSTOMER SEGMENTS

- Livestock farmers,
- cereals and pulses cooperative (CCLS)
- Collectors and dairies (milk) (COOPSSEL)
- Individual customers (cereal, legumes and milk and dairy)

RISKS AND CHALLENGES

- Climatic conditions (drought, cold and high temperature)
- cessation of government subsidies
- Fluctuation of inputs markets
- Geopolitical issues

COST STRUCTURE

- CAPEX – on-farm implementation (seeds, inputs, feeds, labour, common machinery costs)
- OPEX – fixed costs (fuel, energy, paid labour common machinery rent (only for public cooperatives))

REVENUE STREAMS

- Sale of products and by-products (cereal, forage, legumes, straw, livestock, milk and manure)

Figure 2. Business model canvas of field pea cultivated in the Sétif region, Algeria.

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3.2 Egypt. Agroforestry: Jatropha trees (*Jatropha curcas*) and diverse vegetable crops

3.2.1. Market data

Arid regions face many agricultural challenges, including scarce water resources, soil degradation, and extreme weather events, especially in the last decade. This necessitates a shift towards more resilient and sustainable management practices. Mixed and agroforestry systems, which integrate trees and crops under carbon farming practices, offer promising solutions. This increases the drought tolerance and resilience of the agricultural system, thereby mitigating climate change, a significant threat to arid regions. The combined benefits of the system and carbon farming practices represent a powerful approach to enhancing agricultural resilience and promoting long-term sustainability in arid environments.

Agroforestry systems in Egypt, specifically those involving *Jatropha curcas*, offer considerable benefits over traditional monoculture farming, particularly in sustainability, climate resilience, and productivity. Jatropha, a tree known for its drought tolerance, rapid growth, and ability to thrive in poor soils, is increasingly being used in Egypt due to its compatibility with wastewater irrigation. This unique model of using treated sewage water to cultivate Jatropha on marginal desert land not only helps rehabilitate degraded areas but also addresses environmental concerns by reusing water that would otherwise pose an environmental hazard. Furthermore, Jatropha holds potential for biodiesel production, adding economic value.

Egypt's agricultural sector faces significant challenges due to its limited arable land, with more than 90% of the country being desert. The total agricultural area is approximately 3.5 million hectares, representing only 3.5% of the country's total landmass. Water scarcity is a critical issue, as the Nile provides the majority of Egypt's water, with a limited amount of renewable surface and groundwater available. The Government of Egypt aims to expand the cultivated area to secure food for a growing population, but with limited water resources, this goal faces serious obstacles. By 2025, renewable water resources could drop to dangerously low levels, intensifying pressure on water supplies needed for agriculture, industry, and urban needs.

Vegetables are a critical component of Egypt's agricultural sector, as evidenced by the expansion of land dedicated to these crops, which grew from 636,169 hectares in 2019

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to 639,118 hectares in 2021. According to the Food and Agriculture Organization of the United Nations (FAO), vegetable production in Egypt reached 15.82 million metric tons in 2022. Additionally, government support, in collaboration with the US Agency for International Development (USAID), has empowered farmers to achieve increased production volumes. In 2022, the export value of vegetables, fresh, preserved and related by-products such as oil, waxes and juices, reached approximately 500 million EUR (Food and Agriculture Organization of the United Nations, n.d.). An example of a commercial agroforestry farm can be consulted in Annex II.

3.2.2. System introduction

Given the above-mentioned challenges and opportunities, Egypt is focusing on using forest plantations and agroforestry to address environmental concerns, such as desertification and wastewater reuse. Jatropha plantations, which are well-suited to Egypt's marginal lands and wastewater reuse projects, offer a promising solution. Approximately 67,200 hectares of desert land are available for forest plantations, with 36,960 hectares allocated to wastewater reuse projects across various governorates. In this regard, 4,620 hectares have already been cultivated with various crops, including Jatropha, supporting both environmental restoration and potential biofuel production (Abdel Wahaab, 2012). This integrated approach highlights the potential for agroforestry to contribute to Egypt's environmental sustainability and agricultural productivity while addressing its pressing water and land challenges. The implementation of an agroforestry system that integrates vegetable crops with *Jatropha curcas* cultivation can enhance soil quality and boost the productivity of the existing vegetable-growing hectares.

Additionally, Jatropha trees have the capacity to accumulate water in their roots, which helps maintain moisture levels in agricultural fields.

System drivers

- Soil improvement and desertification prevention: *Jatropha Curcas* enhances soil fertility by reducing erosion and increasing organic matter, making it ideal for degraded soils common in Egypt. Its drought resistance makes it suitable for arid regions, helping to restore degraded lands and prevent desert expansion.

- Water efficiency: Jatropha's ability to thrive in arid conditions is crucial in water-scarce Egypt. When combined with vegetable crops, Jatropha optimizes water use by providing shade and retaining soil moisture.

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• Biofuel production and income diversification: Jatropha produces seeds that can be used for biofuel, offering a renewable energy source and an additional income stream for farmers. Pairing Jatropha with vegetable crops allows farmers to generate income from both biofuel and vegetable sales, stabilizing and diversifying their earnings.

• Low input costs: Jatropha requires minimal inputs like fertilizers and pesticides, making it a low-cost crop

option, especially for farmers in rural or underdeveloped areas.

• Sustainable agriculture programs: agroforestry systems combining Jatropha and vegetable crops could benefit from international programs promoting sustainable agriculture and climate adaptation, such as the Egypt Vision 2030 encouraging sustainable development practices.

• Carbon sequestration: Jatropha trees capture carbon, contributing to Egypt's climate change mitigation efforts and helping meet carbon reduction targets.

System barriers

• Uncertain biofuel demand and limited market access: the biofuel market in Egypt is still underdeveloped, creating uncertainty about the demand for Jatropha-based products, which could deter investment. Farmers need reliable markets for selling vegetables, but poor infrastructure and limited market access in rural areas could reduce profitability.

• Lack of policy support and land ownership issues: current agricultural policies in Egypt may not fully support or incentivize agroforestry, especially biofuel crops like Jatropha, making it harder for farmers to access subsidies or programs. Fragmented or unclear land ownership could hinder long-term investment, especially for perennial crops like Jatropha, which require stable land tenure.

3.2.3. Business model description

Value propositions

1. Climate resilience strategies
   a) Water management by accurate requirements calculation and predictions for farms
   b) Optimized land use

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   c) Production stabilization
   d) Early warning system
2. Minimum mineral fertilizer usage combined with high economic productivity
3. Increasing the soil carbon content (Improving the carbon sequestration cycle)
4. Waste management that is easy and affordable to implement

Climate-smart agriculture solutions consist of water management by providing accurate water requirement calculations and predictions for farms. This enables efficient irrigation and reduces water waste. Additionally, these solutions help optimize land use practices, minimize unproductive areas, and maximize yield potential. Production stabilization offers strategies to mitigate climate risks and stabilize agricultural production, ensuring consistent harvests. Elevating the impact of the system value proposition, early warning systems alert farmers of weather events and potential disruptions, allowing them to take proactive measures.

Sustainable intensification: This proposition combines minimal mineral fertilizer usage with high economic productivity. By focusing on improved soil health and efficient nutrient delivery, we enable farmers to achieve high yields while minimizing environmental impact.

The mixed-farming system, implemented across 36 plots, has improved soil health. Soil organic carbon content increased significantly, ranging from 0.46% in the vegetative stage to 1.35% at harvest, representing a 4-fold increase compared to the initial level of 0.27%. A yield of 32 tons per acre was achieved in the first season under the experiment conditions; this is less than the yield achieved by the conventional practices, which could reach 40 tons but with different trade-offs, while the conventional practices use heavy mineral fertilizers and higher initial costs.

Simplified waste management: Offering affordable and easy-to-implement waste management solutions, helping farms reduce their environmental footprint and convert waste into valuable resources, and engaging the farms in the circular economy for a more sustainable and resilient system.

Key partners

1. Organic fertilizers suppliers (e.g., Tulipe)
2. Seeds provider (e.g., National Seed & Agriculture Services Co. BUTHOR)
3. Agriculture support services (e.g., SMART Lab. Co.)
4. Public administration:

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a) Faculty of Agriculture, Alexandria, and Matrouh University
b) Agriculture Research Center
c) Egyptian Authority for Development and Agricultural Expansion

Strategic key partnerships unlock resources, expertise, and ongoing support, maximizing success at every stage of crop production. Key partners such as Tulipe (Organic fertilizers suppliers), National Seed & Agriculture Services Co. BUTHOR (seeds provider), SMART Lab. Co. (Agriculture support services), and public administration, such as universities and official development authorities, are essential to the success of an innovative designed agriculture system, technology transferee, and policy management. Diverse partnership offers a comprehensive solution for sustainable farming. Each partner brings unique expertise in development, cultivation, processing, and marketability, ensuring a thriving system that delivers economic, environmental, and social benefits to the farming community.

Tulipe provided each component of the organic and inorganic fertilizers. Tulipe has long experience producing and marketing fertilizers in the region. BUTHOR provided the seeds and seedlings of the system's required crops. The long collaboration with the two partners ensured system stability and proposed management according to local market needs.

SMART Lab. Co. manufactured the required equipment to prepare the mixture of organic and inorganic fertilizers. The idea is to make the whole system available for local farmers on a small and large scale.

The support of public administration and governmental departments, such as universities and development authorities, in approving and monitoring agricultural practices, technology transfer in both directions, policy management, and promoting broader adoption of the system.

Key activities

1. Mixed-farming system design (trees – vegetables)
2. Soil/water management in mixed farming systems using carbon farming practices (e.g. efficient water management using our data support systems and monthly recommendations – cover cropping – the integration percentages between mineral and organic fertilizers for optimum production and economical ROI)
3. Field survey, lab tests, and land capability for the best-mixed system

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4. Technology transfer involving demonstrations, workshops, and extended services to help farmers adopt the new mixed farming, carbon farming practices, and water management techniques
5. Social awareness involving educational campaigns, Agri-fairs, and marketing initiatives to raise awareness about the benefits of the mixed farming system

Field assessment and design by conducting field surveys, lab tests, and land capability evaluation to design the optimal mixed-farming system integrating trees and vegetables. This includes determining the most suitable crop combinations and spatial arrangements.

Implementing sustainable practices involves implementing soil and water management strategies aligned with carbon farming principles. This consists of optimizing water usage through data-driven recommendations. Also, determine the ideal balance between mineral and organic fertilizers for maximizing production and economic ROI.

Knowledge dissemination fosters technology transfer through demonstrations, workshops, and extensive services. This empowers farmers to adopt carbon farming practices and efficient water management techniques.

Community outreach and awareness: developing social awareness campaigns through educational initiatives, participation in agri-fairs, and targeted marketing strategies aiming to highlight the benefits of mixed farming systems for increased sustainability and improved livelihoods.

Key resources

1. Agriculture system design according to the farmer/customer needs
2. Logistic and technological management plan of cultivation process and final production
3. Pilot farm for experiments and demonstration
4. Monitoring System Research & Development facilities

Influencing positive change in the bigger picture by identifying and securing the key resources—from the agriculture system design to the technology access ensures long-term success for the business and contributes to a thriving agricultural system. Understanding the long-term success of the business.

Focusing on mixed farming and agroforestry agricultural system design on the specific needs of farmers and customers promotes a more responsive and sustainable farming

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ecosystem. This ensures farmers have the tools and resources they need to thrive, such as detailed crop specifications tailored to their land's characteristics. These specifications can include considerations for tree and vegetable requirements, encompassing factors like sunlight, water needs, and potential pest vulnerabilities.

Additionally, incorporating a well-designed crop rotation plan helps maintain soil health and fertility in the long term. Finally, land preparation techniques are adjusted based on specific soil conditions and water availability, optimizing resource utilization and crop yields. By integrating these elements, the agricultural experience becomes more efficient and satisfying for farmers and customers, with farmers receiving the support they need and customers receiving the desired products cultivated sustainably.

Implementing a logistical and technological management plan for the cultivation process and final production is essential to optimizing resource use and enhancing the farm’s environmental economy. This plan includes the entire cultivation process, from planting to postharvest management, and integrates waste into the carbon farming cycle of the agricultural cycle system.

Providing Farmers and customers with access to the pilot farm is essential for further developing, planning, and continuously improving the knowledge transfer of the system. Also, continuing demonstrations with stakeholders foster interaction and better management.

Underline the crucial role of the farmers in the system's sustainability and resilience. By keeping them engaged, monitoring their production system, providing Research & Development support, making the system more powerful, and acknowledging their importance and responsibility in ensuring its success. This approach will help the system endure the management butterfly effect across the region.

Customer relationships

1. Long-term commercial relationships with small-scale crop farms and companies
2. Promotion of local agricultural market
3. Strategic governmental partners

The system's success largely depends on strong and strategic customer relationships and the effective promotion of the local agricultural market. Long-term strategic alliances provide the necessary stability and resources, while local market promotion ensures a

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loyal customer base and a more robust agricultural economy. Together, these elements create a favourable environment for innovation and sustainable growth in agriculture.

Building long-term commercial strategic alliances with key stakeholders such as food processors, distributors, and retailers ensures a consistent demand for more integrated system and resilient carbon farming systems. Farmers can secure contracts that provide predictable revenue streams by partnering with these entities, enabling better financial planning and investment in sustainable farming practices. These relationships also facilitate the development of value-added products.

Another strategic alliance is with universities, research institutions, and government organizations, especially those directly involved in planning and policy management. Through these alliances, farmers will gain access to new technologies and resources, enhancing the overall productivity and sustainability of the system.

Customer segments

1. Exporting agencies
2. Eco-friendly food stores
3. Agrifood trading companies (e.g., Mozare3 agency)
4. Individual customers
5. Resorts and restaurants

Defining customer segments within the Business Model is essential for building a targeted and effective strategy. By segmenting the customer base.

Export Agencies: This segment includes companies that facilitate the international trade of agricultural products fostering the ROI of the system. Offering a solution to streamline documentation, manage logistics, and ensure product quality compliance for canvas goods. Eco-Friendly food stores: This segment focuses on retailers who prioritize sustainability and ethical sourcing. They value a solution that highlights the eco-friendly aspects of canvas materials and their alignment with the store's brand identity. Mozare3 Agency for Agrifood Trading: This specific agency can be included as a unique customer segment with tailored needs. Understanding Mozare3's specific buying criteria and trading processes can help refine the value proposition for this segment. Individual Customers: This segment underlies the customers who are interested directly in carbon farming production and support environmental designs. Resorts and Restaurants: This segment includes tourist places across the region that are required to have eco-friendly products and promote carbon farming.

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Channels

1. Local B to C supply chain
2. B to B supply chain for resorts, restaurants, and exporting agencies

Local B to C Supply Chain: This channel focuses on reaching individual customers directly. It can involve online marketplaces, partnerships with local retailers, or even a branded physical store. In the case of our designed system, the fresh vegetables for direct sale or to be sent to the agro-processors can be offered directly to customers, as can fertilizer mixtures.

B to B Supply Chain for Resorts, Restaurants, and Exporting Agencies: This channel caters to businesses that purchase our final products (vegetables) in bulk. It might involve dedicated sales representatives, online ordering portals with bulk pricing options, and participation in industry trade shows.

Cost structure

1. OPEX:
   a) Soil preparation (tillage, manures purchase and application, etc.)
   b) Organic fertilizers mix preparation
   c) Seeds and plantation cost
   d) Official seasonal water requirement reports
   e) Irrigation pumping power (generators, diesel)
   f) Marketing
2. CAPEX:
   a) Farm rent and taxes
   b) Drip irrigation system components (pipes, filters, pumps, etc.)
   c) Organic fertilizers mix storage hub
   d) Fertiliser mixture machines

Implementing an agriculture system's cost structure includes CAPEX and OPEX. Understanding these costs is crucial to ensuring the system's viability and profitability. Farmers can optimize their operations and achieve sustainable agricultural practices by managing these costs effectively.

OPEX includes soil preparation (tillage, manures, etc.): This includes the ongoing costs associated with readying the soil for planting, such as tilling, applying organic amendments like manure, and any other necessary treatments. Organic fertilisers mix preparation: This covers the ongoing expenses for creating the organic fertilizer mix,

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including materials, labour, and any energy used for mixing. Seeds and plantation cost: This captures the variable cost of the seeds, and the labour involved in planting them. Official seasonal water requirement reports: This accounts for any fees associated with obtaining official reports on seasonal water requirements for your crops, climate change scenarios, and mitigation plans. Marketing: This encompasses all ongoing marketing and promotional activities to reach the customers.

CAPEX: The organic fertilizers mix storage hub represents the upfront cost of establishing a dedicated facility to store pre-mixed organic fertilizers. Fertilizer mixture machines: This covers the initial investment in equipment used to create an organic fertilizer mix.

Revenue streams

1. Product sales: vegetables (tomatoes and potatoes), Jatropha seeds, seed cake after oil extraction as forage), crop residuals for organic fertilizers preparations
2. Significant reduction in tomatoes and potatoes production cost with 29% per acre in the cost of production
3. Possible branding franchise in expanding stages

The revenue streams for the designed system are diverse and varied. Income can be generated from the sale of various products, while production costs are significantly reduced, with 29% per acre, and possible branding franchises are in expanding stages. By effectively leveraging these revenue streams, farmers can improve profitability and support sustainable agricultural practices and impacts.

Product sales: Revenue is generated through direct sales of the core product, from the end products of the agriculture system to the fertilizers sales.

Cost reduction efficiency: Reduced production costs by 29% per acre presents a solid opportunity to improve profit margins and offer competitive pricing strategies.

Scalable franchise model: The potential for a future branding franchise offers a lucrative revenue stream through expansion fees, royalties, or ongoing support services.

Risks and challenges

1. The velocity and quantity of the administrative procedures
2. Climatic changes (warmer climate, which exceeds 1.5 degrees in the study region the last 5 years affecting water management, soil degradation and pest control)
3. Social perception and acceptance of innovative culture

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4. Economical inflation

Mixed agroforestry systems can face challenges due to complex or time-consuming permitting processes, land-use regulations, and potential subsidies or incentives with lengthy application procedures.

Rising temperatures and extreme weather events can threaten farming systems. Increased heat may stress trees and vegetables, require adjustments to water management, and potentially accelerate soil degradation. Additionally, altered weather patterns may influence pest and disease pressures.

Communities that have successfully transitioned from traditional farming methods to our designed system stand as beacons of inspiration. By addressing concerns, providing educational resources, and showcasing these successful examples, we can foster a sense of optimism and promote wider acceptance and adoption.

Economic inflation can impact the establishment and maintenance of agricultural systems. Rising costs of materials, labour, and transportation can affect initial investment and ongoing operational expenses.

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BUSINESS MODEL CANVAS — Mixed farming system: Jatropha trees + vegetable crops

KEY PARTNERS
- Organic fertilizers suppliers (e.g., Tulipe)
- Seeds provider (e.g., National seed & agriculture services Co. BUTHOR)
- Agriculture support services (e.g., SMART Lab. Co.)
- Public administration: Faculty of Agriculture, Alexandria and Matrouh University, Agriculture Research Center, Egyptian Authority for Development and Agricultural Expansion)

KEY ACTIVITIES
- System design including previous research to ensure suitability
- Soil/water management using carbon farming practices
- Technology transfer involving demonstrations, workshops, and extended services
- Social awareness involving educational campaigns, agricultural fairs, and marketing initiatives

VALUE PROPOSITIONS
Climate resilience strategies:
- **Efficient water management**
- **Optimized land use**
- **Production stabilization**
- **Early warning system for weather events and potential disruptions**
- **Minimum mineral fertilizer usage combined with high economic productivity (focusing on improved soil health and efficient nutrient delivery)**
- **Increasing the soil carbon content (Improving the carbon sequestration cycle)**
- **Easy-to-implement waste management solutions**

CUSTOMER RELATIONSHIPS
- Long-term commercial relationships with small-scale crop farms and companies
- Promotion of local agricultural market
- Strategic governmental partners

CUSTOMER SEGMENTS
- Exporting agencies
- Eco-friendly food stores
- Agrifood trading companies (e.g., Mozare3 agency) Individual customers
- Resorts and restaurants

CHANNELS
- Local B to C supply chain
- B to B supply chain for resorts, restaurants, and exporting agencies

KEY RESOURCES
- Agriculture system design according to the farmer/customer needs
- Logistic and technological management plan of cultivation process and final production
- Pilot farm for experiments and demonstration
- Monitoring system Research&Development facilities

RISKS AND CHALLENGES
- The velocity and quantity of the administrative procedures
- Climatic changes (warmer climate, which exceeds 1.5 degrees in the study region the last 5 years effecting water management, soil degradation and pest control)
- Social perception and acceptance of innovative culture
- Economical inflation

COST STRUCTURE
- CAPEX - Farm rent and taxes, drip irrigation system components, facilities and machines for the (organic) fertilizers mixing and storage
- OPEX - Soil preparation operations, organic fertilizers preparation, seeds and plantation cost, official seasonal water requirement reports, irrigation pumping power, marketing

REVENUE STREAMS
- Product sales: Vegetables (tomatoes and potatoes), Jatropha seeds, seed cake after oil extraction as forage, crop residuals for organic fertilizers preparations
- Significant reduction in tomatoes and potatoes production cost with 29% per acre in the cost of production
- Possible branding franchise in expanding stages

Figure 3. Business model canvas of jatropha trees combined with vegetable crops, Egypt

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3.3 France. Mixed farming: Mixed Fruit tree-Vegetable Systems (MFVS)

3.3.1. Market data

Agriculture in France covers approximately 27 million hectares, representing 43% of the national territory. The main crops include cereals (34% of the area), permanent pastures (23%), and industrial crops (9%). In 2022, the agricultural land dedicated to fruits and vegetables was a significant component of production, with 530,000 hectares, placing France as the fourth largest European producer. The most important crops are apples (1.32 million tons), plums (189,000 tons), and tomatoes (643,000 tons).

Although monocultures and extensive agriculture dominate, mixed farming systems already exist in regions such as Sarthe and Maine-et-Loire. This land-use system, where multiple plant species are cultivated, presents both economic and environmental advantages. The diversification of vegetable and fruit crops generates more stable income, enhances resilience to market and climate fluctuations, and optimizes land use. Additionally, it promotes biodiversity, soil health, and more efficient water use, fostering a more sustainable and adaptable form of agriculture.

In France, the expansion of these systems is supported by research institutes AGROOF and INRAE, which are participating in different European initiatives and projects as Transition, MIXED or AGROMIX. All of them promote efficient and resilient development of mixed farming and agroforestry systems, promoting the development of polyculture systems in combination with livestock. Several French companies are expected to join these efforts in the future, given the growing interest at the European level. Further examples of companies in France are described in Annex III.

3.3.2. System introduction

Agricultural systems undergo a broad spectrum of undesired changes in their environments. Biodiversity-based agroecosystems are agricultural systems in which human control of nature is voluntarily reduced and the connection to the environment is high. When undergoing a given disturbance, this type of system behaves differently from conventional farming systems. Their high reliance on ecosystem functioning is an issue in the context of global change that strongly affects the dynamics of ecosystems but that is also a potential lever to overcome the effects of environmental variation.

In these circumstances, being resilient is a key property of agroecosystems that makes it possible to continuously change and adapt. Reliance on ecosystem services and more

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broadly on ecosystem functioning and diversification of farming systems are two types (non-exclusive) of strategies that are repeatedly put forward to increase the resilience of farms and to limit the negative impacts of agriculture on biodiversity and climate change.

In Europe, an emblematic ecosystem-based and diversified farming system is fruit and vegetable agroforestry in some of its diverse forms (forest garden, syntropic agriculture, permaculture). This wide variety of forms can be grouped under the term of mixed fruit tree-vegetable systems. An MFVS is a system where diversified fruit trees and diversified vegetables are intercropped. There is a growing interest in this type of system, and it is often perceived by farmers as being intrinsically resilient.

***System* drivers**

• Increased resilience: by diversifying crops, French farmers can reduce the risk associated with market fluctuations and adverse weather conditions.

• Research projects and funding: European initiatives, such as the MIXED project funded to promote mixed farming in European countries including France, act as key drivers for the adoption of these systems.

• Biodiversity: biodiversity in southern France has experienced a decline in recent decades due to pressure from human activities such as urbanization, intensive agriculture and climate change. In particular, the loss of biodiversity integrity is estimated at 70% for plants. Mixed farming promotes biodiversity, which contributes to greater ecological stability and improved soil health.

• Better use of resources: mixed farming allows for a more efficient use of water and other natural resources, which is essential in areas with water limitations. The Mediterranean climate of southeastern France is characterized by high annual sunshine (2,500 to 2,900 hours per year), high summer temperatures and rainfalls of 500 to 600 mm/year in the coastal plains, which makes it necessary to optimize water resources.

***System* barriers**

• Agricultural specialization and technological incompatibility: the French agricultural system has been highly specialized in monocultures and intensive agriculture, which limits crop diversification, mainly at the technological level. Current technology is designed for monocultures, and the implementation of new technologies to support diversification is not always immediate or feasible.

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• Lack of knowledge and training: farmers and advisors are more familiar with conventional agriculture, which hinders the adoption of mixed agriculture.

• Lack of technical-economic references to evaluate the benefits of these crops: there are currently few companies with this type of system, so there is no economic data to observe the profitability of the systems.

3.3.3. Business model description

The business model description aims to provide broader information on the relevant aspects of its implantation in the field.

Value propositions

1. Optimization of land use
2. Increase in LER (Land Equivalent Ratio)
3. Temporal complementarity of the productions (vegetable production when the young fruit trees don't produce)
4. Reduction of erosion and improvement of soil structure (enhanced soil fertility)
5. Improvement of landscape quality by the plantation of trees
6. Carbon sequestration (ecosystem services)
7. Biodiversity conservation (bird, insect, soil organism, mammal, etc.)

The MFVS offers a comprehensive range of value propositions that address both environmental and economic challenges. Optimisation of land use, increase in Land Equivalent Ratio (LER), temporal complementarity of the productions, erosion reduction, improvement of soil structure and landscape quality, carbon sequestration, and biodiversity conservation can ensure sustainable production. All the above-mentioned aspects will improve the farmers' resilience.

Using the space between the fruit trees for vegetable growing is a good manner to optimise and use the space compared to conventional orchards. Biological synergies, functional traits, and temporal complementarity of intercropped crops often increase LER (Paut et al., 2024). The presence of permanent deep-rooted trees contributes to the reduce erosion and improve soil structure. The presence of trees is often perceived as a key element in improving landscape quality and plays a major role in carbon sequestration. The diversity of habitats provided by the diversity of crops and trees is favourable to the conservation of biodiversity. Finally, trees being by nature carbon sinks, these systems are likely to bring a strong contribution to carbon sequestration.

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Key partners

1. Farmers
2. Agricultural suppliers (plants, green waste, machinery, tools)
3. Customers
4. Advice organizations
5. Public administration (chamber of agriculture, local authorities)
6. Research and innovation centres

Key partners provide essential resources, knowledge, and support throughout the lifecycle of the system. They are essential to the success of an innovative crop in the field. Each partner brings unique resources and expertise that contribute to the development, cultivation, processing, and marketability of the crop. Through collaborative efforts, these partners ensure that the innovative crop can thrive, and provide economic, environmental, and social benefits to the farming community.

Farmers are at the heart of the system. They are the ones who implement and pilot the system daily. They are in charge of the agronomic part but also of the administrative and economic management of the farm whose MFVS is part of.

Agricultural suppliers are key partners in providing the necessary inputs such as plants (if the farmer does not produce the plants by itself) green waste (for the ones who adopt no or low-tillage practices) machinery adapted to agroforestry systems and tools. There are dozens in France, and they highly depend on the crop at stake, the region, the type of practices, etc. Their role is to ensure that farmers have access to the products needed.

The customers are the ones who allow the products to be sold. They are essential as they give the aim of the farmers is to produce good quality food for humans.

Advice administration provides technical support and advice on the best practices to maintain soil health and productive crops. They can also be a support to deal with collective organization problems and to help the farmers in their administrative procedures.

The support of public administration and governmental departments in approving and monitoring agricultural practices ensures compliance with safety and environmental standards. Funding and incentives entities often provide financial support, grants, and incentives to encourage sustainable agricultural practices and innovation. Access to

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such resources can significantly reduce the financial burden on farmers and promote broader adoption of innovative crops.

Research and innovation centres can conduct studies that aim at giving credit to this innovative and little-known system. They contribute to a better understanding of soil health, pest management, and sustainable farming practices. These centres can also facilitate the knowledge transfer between researchers and farmers.

Key activities

1. Combined fruit and vegetable production
2. Eventually, other rewarding activities (teaching, hosting, poultry breading)
3. Contact with farm advisors
4. Training on fruit production
5. Strengthen the network with other practitioners and customers

Key activities for successful MFVS farming will collectively ensure that the crops can be grown efficiently, sustainably, and profitably, contributing to the advancement of sustainable agricultural practices and the development of resilient food systems. These include the combined production of fruits and vegetables, the integration of another rewarding activity, good contact with farm advisors, training in fruit production, and a strong network of other practitioners and customers.

The two central activities of an MFVS are the combined production of fruit and vegetables. Having another remunerative activity less dependent on climatic events can be a good strategy to ensure the resilience of the system by diversifying income sources. Engaging technicians and farm advisors is a good way to learn about the best practices and to access technical support to solve specific problems. Most of the time, farmers are better trained for market gardening than for tree cultivation. Investing time in training in arboriculture is a key element for success as trees are not self-producing crops, as is often perceived. Networking with other practitioners fosters a community of knowledge-sharing and collective problem-solving. By sharing experiences and engaging in collaborative projects, farmers and researchers can drive innovation and develop new techniques to improve the overall understanding and success of MFVS cultivation. Online communities such as the Landfiles, one initiated in the project, could be a good way to build such a network in this situation where farmers are scattered around the territory.

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Key resources

1. Land (with secured water access and fertile soil)
2. Ergonomic design of the parcel adapted to the farmer's specific needs or facilitates the adoption of a new parcel design
3. Crop management and good practices documents
4. Access to specific accessories to adapt agricultural machinery

Implementing and sustaining an innovative system like MFVS requires several key resources. These resources include land, an ergonomic design of the plot, documentation on crop management and best practices, and access to specific machinery. These resources ensure that the MFVS can be grown according to the farmers' objectives.

The land is a crucial resource for farmers. To implement agroforestry systems, it is often desirable to own the land to guarantee that the systems can be implemented on a multi-year basis. Farmers may therefore rely on public agencies (SAFER) or NGOs (e.g. Terre de Lien). The quality of the soil and effective water access is of paramount importance to ensure the productivity of the crop that most of the time in the Mediterranean needs to be watered.

The design of the system itself should not only be adapted to the pedoclimatic context but also to the farmer's objectives, needs, and capacities to preserve the farmer's working capacity and reduce the physical efforts made to produce the fruits and vegetables. This design should be done at the beginning considering that the trees cannot be easily moved.

A comprehensive document on crop management and good practices is important to allow farmers to find the information they require to solve the specific problems they may encounter. However, to date, such information is scattered around many different resources of heterogeneous quality and easily available. Such a document could include feedback on case studies that focus on soil preparation, planting, irrigation, pest control, and harvesting. Best practices for maintaining soil health, managing crop rotation, and optimizing yields, also should be considered. We recommend producing a well-documented guide based on farmers' experiences.

Specific machinery adapted to the presence of trees on the plot and to small-scale agriculture is a need that has often been expressed by farmers in order to improve the ergonomics of the working conditions.

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Customer relationships

1. Regular customers all year long
2. Intermittent customers to mobilize when there is an excess in production

For the farmers who expect their MFVS to be profitable, a strong and effective customer relationship is important. Two types of customers are the regular ones who guarantee to sell a certain amount of the production along the year, and some intermittent customers, who sell the products when there is a surplus of production or when there is a problem with the regular customers.

Customer segments

1. Individuals
2. Organic stores
3. AMAP
4. Restaurants
5. Collective point of sell

Identifying and understanding the specific customer segments that can benefit from MFVS is crucial for its adoption and market integration.

Short-line sales are often a good way to sell MFVS products, which are usually produced in a high diversity and a small quantity per product type. Direct sales to individuals, sales through the intermediary of an organic shop, community-supported agriculture (AMAP in French), restaurants and collective sales points can constitute these two types of customers.

Channels

1. Local supply B to C and B to B

Using diverse local supply channels can help farmers maximise the reach and impact of their activities. This approach ensures sustainable and profitable agricultural practices while releasing market potential.

In a B-to-B configuration, farmers can work with small-scale local food processors to incorporate their products into high-value-added products. Alternatively, the raw and value-added products can be supplied to local restaurants or speciality shops that prioritize farm-to-table and nutritious food options, helping to build trust and community ties.

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A B-to-C configuration requires time and a specific organisation. Products can be commercialised through farmers' markets and direct sales, offering Community Supported Agriculture subscriptions for regular deliveries of fresh produce, ensuring a steady income and customer loyalty. Developing an informative website and an online store for direct sales, using social media to reach a wider audience, and informing the customers about the offer of products are important aspects to make this commercialisation channel effective.

Cost structure

1. CAPEX – on-farm implementation and maintenance (land, machinery, buildings, fridge, transformation unit)
2. OPEX – diverse expenses (fuel, machinery rent, plants, electricity, organic fertilizers and treatment, small tools, commercialization packaging)

CAPEX can be divided into land, machinery, buildings, refrigeration, and transformation units. A good balance needs to be achieved between investing enough at the installation time to ensure the good functioning of the system and not investing too much in order to avoid over-indebtedness. The purchase of essential farm machinery can represent a significant up-front cost, depending on the level of mechanisation chosen. Regular maintenance, depreciation over time, and potential future replacement should be considered in the financial planning.

OPEX is related to the daily needs of the farmer to carry out its activity. Volatility can be observed in the price of these OPEX, so this possibility must be taken into consideration as much as possible in order to ensure the sustainability of the system.

These systems being very innovative and scarce, are still poorly recognized by public policies and would benefit from a better identification to be able to become the target of specific public incentives.

Revenue streams

1. Sale of products (fruits, vegetables, and eventually transformed products)
2. Savings in ordinary costs due to the optimization of land use (tillage, fertilizer, water)
3. Reduction of crop management costs thanks to the biological synergies
4. Other activities (laying hen farming, tourism, teaching)

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The revenue streams for farms that implement an MFVS can be varied. The sale of products is the main source of income for the MFVS. Additionally, significant savings can be made on ordinary costs such as tillage, fertilisers, and water. The reductions in crop management costs may contribute to the overall financial viability and sustainability of the system.

Savings in ordinary costs come from intercropping trees and market-gardening and crop management practices. The root depth of the trees may improve nutrient retention and increase soil organic matter, thus, the soil health. In consequence, it can be expected to reduce dependence on fertilisers over time. Conservation tillage practices also contribute to long-term soil health, reducing the need for future investment in soil restoration. The proximity between trees and vegetables may also reduce the need for watering. The water not used by the vegetable can be used by the trees.

Biological synergies between roots but also aerial interactions (e.g. volatile organic compounds, hosting beneficial insects) can contribute to improving yields and reducing pest infestation without using pesticides.

For the farmers with other activities, it can be an additional revenue stream that does not depend on the same parameters as the MFVS.

Risks and challenges

1. Complexity of management of highly diversified systems may lead to care more about vegetables than about fruit trees
2. Ensure a secured commercialization of the products
3. Administrative procedures
4. Climate change that can lead to water scarcity and pest invasion

Introducing an innovative system in the field as MFVS offers numerous opportunities, but also comes with significant risks and challenges. Effective management of these challenges can pave the way for successful integration and long-term sustainability of the innovative system in the agricultural landscape.

A balance must be found between the short-term and the long-term requirements of the different crops of the MFVS. One of the main challenges at the implementation time is that trees are not productive but need attention to grow properly, while market gardening is highly productive in the short term and can be very time-consuming. At this stage, the trees must not be forgotten.

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Maintaining secure and stable commercialization over the years can sometimes be a challenge as the market and the market prices can fluctuate, even in direct selling (as the COVID-19 crisis showed). Being flexible and reactive, by securing a diversity of commercial outlets, is a key element to facing this challenge.

Navigating the regulatory landscape of administrative procedures and bureaucracy to obtain the necessary approvals to plant and sell the products can be complex and time-consuming. It would help to ensure compliance with local and international standards for safety, environmental impact, and food quality to avoid legal issues, fines, or crop bans. Extensive documentation and regular reporting to the regulatory bodies can be costly, requiring dedicated resources and expertise.

A key challenge is to ensure that the system can grow in the specific climatic conditions of the region. This requires an understanding of the local climate, soil types, and potential environmental stressors such as drought, flooding, or pests. The species to be planted must then be selected according to these elements. In addition, given the unpredictability of climate change, special attention must be paid to identifying and mitigating potential crop issues. Extreme weather events and changing climate patterns can disrupt crop growth, making establishment and yield stability more difficult.

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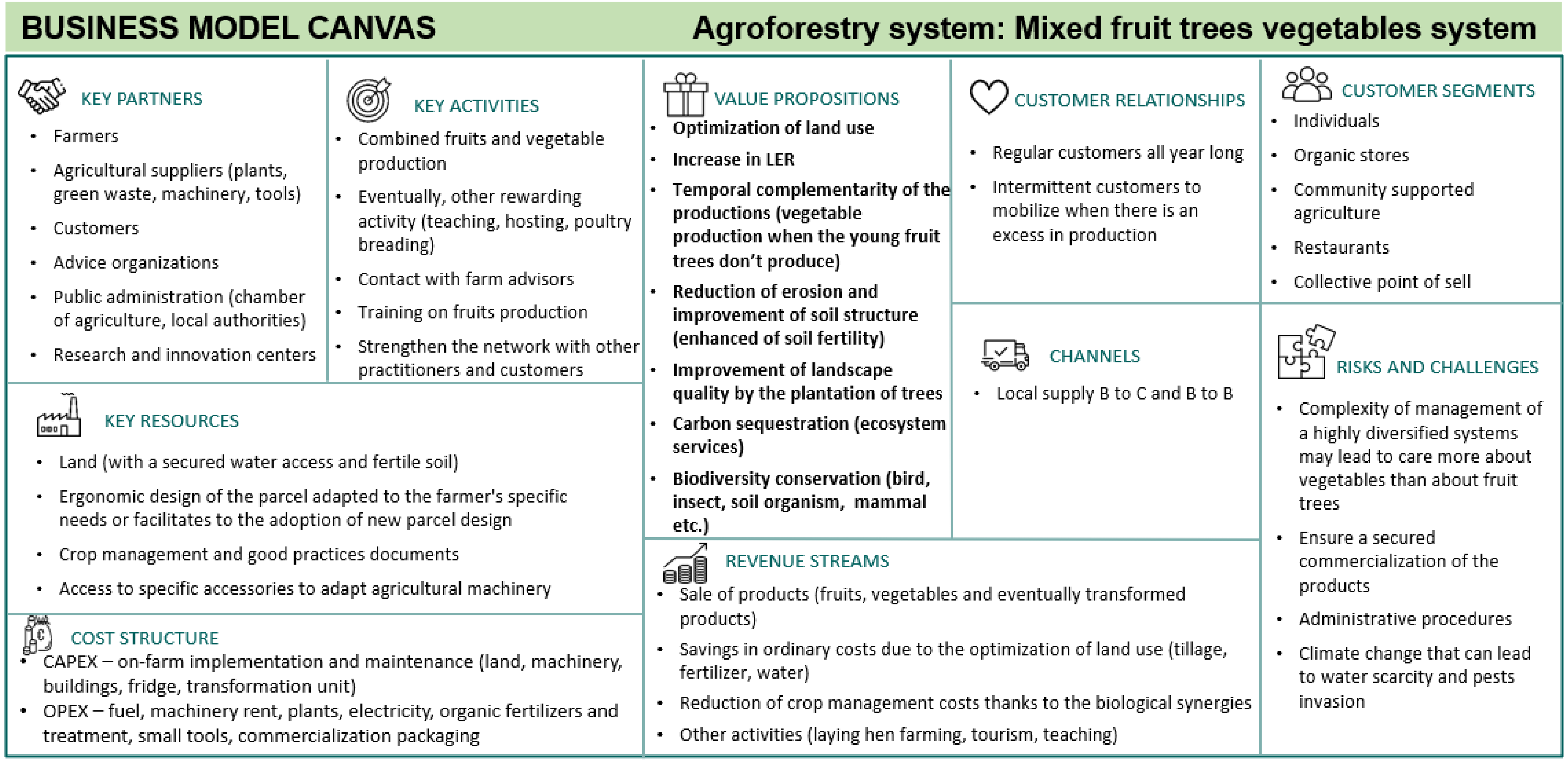

Figure 4. Business model canvas of mixed fruit trees vegetables system in France

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3.4 Italy. Agroforestry: Olive trees and cereals (durum wheat, soft wheat, rye)

3.4.1. Market data

Historically, agroforestry has played an important role in managing the landscape, integrating crops, livestock, and trees to produce food, feed, timber, and fibers while also providing key environmental benefits like preventing soil erosion and preserving biodiversity. The olive tree (*Olea europaea L.*) is one of Italy's most widely cultivated tree crops, covering around 1 million hectares as of 2023 (Chiappini et al., 2023). Formerly, some of these were part of agroforestry systems where they were intercropped with grains, legumes, forages, and even vines. These mixed systems were not only used for fruit production but also for animal grazing, weed control, and natural fertilization. However, the area of olive agroforestry systems has declined over the past century due to the rise of more specialized, high-density orchards aimed at increasing productivity.

From 1960 to 2010, Italy's Environmental Sensitive Areas Index (ESAI) rose by 1.5%, signalling increased vulnerability to land degradation, particularly in Sicily. In recent years, the practice of green mulching in olive orchards has been increasingly recommended and adopted as a strategy to combat soil erosion and degradation while enhancing biodiversity. However, surprisingly little attention has been given to the use of economically viable crops for this purpose, possibly due to cultural attitudes toward intercropping. Implementing systems that combine olive trees and cereals, such as durum wheat, soft wheat, and rye, could potentially increase the financial benefits of the fields. In addition, olive trees in Italy are protected due to their landscape value, making their removal largely illegal, and the low profitability of olive farming poses a risk of large-scale land abandonment. Transitioning these orchards into more productive and economically sustainable agroforestry systems could help preserve both the orchards and the scenic olive landscapes, which are key to supporting tourism.

Cereals, which occupy approximately 3,105,043 hectares (as of 2018; IndexMundi, n.d.), hold great potential for agroforestry integration. In 2022, the export value of olives, olive oil, and related by- products reached approximately 1.9 billion EUR, while cereals and their by-products generated around 192 million EUR in exports (Food and Agriculture Organization of the United Nations, n.d.). Combining olive cultivation with cereals would create a sustainable and beneficial system for both soil health and crop quality, as well as for farmers' economy. Additionally, Sicily has witnessed a significant growth in organic

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farming, now covering 40,338 hectares of olive groves out of 126,906 hectares, an increase of more than 5,300 hectares since 2022, which make it a potential region for the implementation of these systems.

3.4.2. System introduction

Due to adverse climate conditions like drought, farming is becoming more challenging. Agroforestry systems like intercropping could be a solution since they allow the cultivation of different species (trees and herbaceous crops) on the same land. After decades of monocropping and extensive land use, the soil for cultivation has become poor with a very low biodiversity and lacking organic matter. The adoption of different species could help to overcome these problems by offering some interesting ecosystem services. Sicily has always been suited to olive trees and winter cereals cultivation, and the intercropping between them is promising. Among the various cereals, an ancient variety of durum wheat (Timilia), a variety of Rye (Irmano), and an evolutive mix of soft wheat varieties (MixWheat) were chosen.

System drivers

- Soil health and climate resilience: agroforestry improves soil fertility, reduces erosion, and enhances water retention, which is crucial for desertification-prone regions like southern Italy. It contributes to carbon sequestration, combats climate change, and provides shelter for crops against heat stress and extreme weather.

- Biodiversity preservation: integrating trees into farms fosters biodiversity, supports wildlife habitats, and benefits pollinators and beneficial insects, vital for sustainable agriculture.

- Income diversification and market access: agroforestry allows farmers to diversify income by producing both timber and non-timber products (e.g., olives, flour, semolina). It opens opportunities in premium markets for organic and sustainably sourced products, like olives and products derived from the processing of cereals.

- EU support: the EU's Common Agricultural Policy (CAP) promotes agroforestry through subsidies and

incentives, supporting biodiversity and climate resilience.

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• Historical roots and sustainability awareness: Italy's long tradition of integrating trees with crops (e.g., olive orchards, vineyards), known as Coltura promiscua, supports the resurgence of agroforestry. Growing consumer demand for sustainable, environmentally friendly products aligns with agroforestry principles.

• Research, innovation, and climate mitigation: research institutions, like the Research Institute on Terrestrial Ecosystems, focus on agroforestry's long-term benefits, supported by advancements in precision agriculture. Agroforestry plays a role in Italy's climate action strategies, helping reduce greenhouse gas emissions.

System barriers

• Complex regulations and land tenure issues: bureaucratic challenges and unclear agricultural policies make agroforestry harder to implement. Fragmented land ownership complicates the long-term management needed for agroforestry systems.

• High initial costs, delayed returns, and limited funding: significant upfront investment is needed for planting trees and machinery. Long maturation periods for trees delay financial returns, which discourages adoption. In addition, farmers may struggle to access EU subsidies due to a lack of awareness or complex application processes.

• Lack of awareness and technical expertise: many farmers are unfamiliar with agroforestry and its benefits. Agroforestry requires different skills than conventional farming, with a need for training in tree-crop management and biodiversity. Additionally, there is a lack of awareness amongst policy makers and stakeholders in the value chain regarding agroforestry systems which hinders the adoption of these systems.

3.4.3. Business model description

The business model description tries to summarize all the relevant aspects related to the agroforestry system olive-cereal studied in Sicily.

Value propositions

1. Maintenance of plants and soil biodiversity could lead to a lower incidence of weeds and pests by reducing the use of chemical inputs
2. Production diversification
3. Yield stability and LER increase
4. Reduction of soil degradation and erosion

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5. Improvement of soil quality (e.g., organic matter, water holding capacity)

The agroforestry system brings economic and environmental benefits. As mentioned before, the system, compared to a monocropping system, increases plants and soil biodiversity resulting in a lower incidence of weeds and pests allowing to reduce the use of chemicals. The olive-cereal system allows product diversification and the possibility of selling the products in different markets.

Another important aspect to consider is that the selling price of winter cereals is sometimes too low and dependent on the international markets, while the olive oil price is steadily increasing. This situation makes the system balanced and less risky. Furthermore, the system's higher stability is due to the shifted ripening season of the olives (autumn) compared to the winter cereals (summer). This has a double advantage in terms of water competition. It is low because the trees' peak water requirement occurs in the summer when the cereal cycle is concluding, while cereal's peak water occurs at the end of the winter. Furthermore, from a management point of view, the system is functional since the olive harvest happens when the rows between the trees are empty and the cereal sowing occurs after the olive harvesting.

In the last decades, in Sicily, farmers tend to keep the inter-rows without any cover, with the soil exposed to erosion, and with higher inputs required for mechanical and chemical weed control. The cover of the soil with herbaceous crops improves the quality of the soil due to the increase of organic matter and enhances the water-holding capacity and nutrient retention.

Because of lower light availability for the cereal strips close to the tree, the grain production is lower compared to the monocropping, also considering the olive production the whole system production is higher. This is the so-called "Land Equivalent Ratio" which is the ratio between the yield per unit of area obtainable from the agroforestry system and the yield per unit of area obtainable from the monoculture system.

Furthermore, the soft wheat mix has the advantage of having higher genetic variability that can allow the crop to adapt to different pedo-climatic conditions with a selection imposed by the site.

Key partners

1. Seed provider
2. Farmer networks

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3. Agronomic consultants
4. Agricultural suppliers
5. Flour and oil producers
6. Seed-sharing association for the preservation of genetic variability
7. Research and innovation centres

Key partners are important because they provide important sources for the entire process. In this system, there are different seed providers, the soft wheat mix is provided by "SOLIBAM TENERO LI ROSI", while the provider of the specific used variety "Irmano" of rye is the owner of the farm where UNICT is running the trial. The variety is not registered yet so, currently, the farmer is the only keeper of the variety. Timilia (durum wheat) is commercially available.

Key partners are also the postharvest processors who transform the seeds into flour and the olive in oil. In the case of this specific case study, the farmer can transform the products directly in the farm but in other cases, external transformers are needed.

Being some of the varieties used are not yet registered it is crucial the link between farmers, seed providers, and research and innovation centres that can evaluate production and quality stability year by year.

Key activities

1. Olive trees management and use of varieties that historically adapt well to the condition of the area of cultivation
2. Cereal crop cultivation, choosing local and ancient varieties can bring a higher yield stability of the crop
3. Cereal seed production by selected farms
4. System design: The system should be designed with an extensive tree spacing (9*9m or greater) in order to allow machinery operations

The key activities for the introduction of resilient olive-cereal intercropping consist of the identification of management practices and varieties that are suitable for the agroforestry system and for constraining local climatic conditions.

Local cereal varieties and evolutionary populations obtained by participatory plant breeding programs are often less productive than commercial varieties under optimal growing conditions but offer greater yield stability under constraining climatic and soil

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conditions, while offering the possibility to further adapt to the particular conditions of the agroforestry system (Bocci et al., 2020).

These varieties and populations can be reproduced and further bred by selected local farms, thus reducing farmers' dependence on seed producers and breeders.

The agronomic practices for olive production in agroforestry systems are designed not to hinder the agronomic practices for cereal production, therefore the olive grove should be designed with an extensive tree spacing (e.g., 9m x 9m or greater) and the olive tree varieties should be selected to reach the ripening stage before the optimal period for the sowing of the cereal crop.

Key resources

1. Farms suitable for olive and/or cereal intercropping
2. Experienced farmers or farmers who are willing to learn new practices related to agroforestry
3. Access to training programs
4. Specific machinery for trees and crop management and cereal harvesting

The adoption of the described agroforestry system needs different key resources.

First, there is a need to find lands suitable to this system. In the Sicilian scenario, sometimes, the spacing between tree rows is too narrow to allow cereal management (from sowing to harvest). In a long-term vision, there is the possibility to implant a new olive grove with the required distance for the agroforestry system.

Farmers are historically used to monocropping systems and now have to adapt to these new systems and acquire more knowledge about them. Therefore, training programs for farmers and technicians could give essential information and transfer new skills.

Given a scalable production, the use of diversified and specific machinery is fundamental to allow the execution of all agronomic practices.

Customer relationships

1. Long-term commercial relationship
2. Promotion of high-added value agricultural market
3. Quality linked to the area of origin

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The long-term commercial relationship is important, especially for olive oil. This relationship can be promoted thanks to the productivity process that can make the product different from the conventional product in the market building customer loyalty.

The quality, particularly one of the soft wheat mix, is strictly linked to the growth environment and this can change the quality of the flour depending on the area of cultivation and the climatic conditions of the season.

It would be very interesting to analyse the quality characteristics of the products to compare them with the products produced in monocropping.

Customer segments

1. Local food services
2. Flour and olive oil producers who are sensitive to sustainability

Having products with some peculiar characteristics that change from location to location and from year to year it can be sometimes seen as a problem because the quality differs but, at the same time, some customers appreciate this diversity as they see a better connection and identification with the territory. It is important to promote the diversity as a quality treat of the products.

Channels

1. Local supply B to C and B to B
2. Direct link between farmers and local food services

The local supply for the system considered can be done directly from the business (farm) to the individual customer (B to C) and from business to business (B to B) meaning that different companies can integrate their products and services. The current situation is dominated by the B to B supply chain, having many intermediate players between the farmers and the final customer. However, the olive-cereal agroforestry business model could promote the creation of a direct link between farmers and local food services (B to C) to allow better selling conditions.

Cost structure

1. CAPEX – on-farm implementation (common machinery acquisition, seeds)
2. OPEX – fixed costs (fuel, common machinery rent, HR)

CAPEX can be divided into seed purchase, machinery, technology implementation, and infrastructure investment. Agroforestry can be performed by olive farmers or cereal

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farmers who are willing to introduce an additional crop to their farm. In this case, the additional equipment required for the production of the new crop (machinery for sowing and harvesting of cereal or olives) can be acquired as capital expenditure or through additional operational costs such as renting, leasing or external services.

Higher cost is expected for the management of the agroforestry system (OPEX) in comparison with monocropping. The higher cost is balanced by higher revenue due to the increased production and the higher system efficiency in terms of land use, resource (water, fertilizer) use and reduction of soil degradation.

Revenue streams

1. Sale of products (cereal, flour, and olive oil)
2. Saving in water input due to the land use intensification
3. Saving in treatment costs like weed control

The revenue streams for the olive – cereals system regard the sale of the products and the reduction of crop management costs. The cultivation of cereals, or other herbaceous corps, in the strips between the rows of trees reduces the emergence of weeds resulting in saving costs for the treatments.

Another revenue stream that is not considered generally is selling by-products like the wood produced after the pruning of the tree and the cereal straw obtained after the harvest and used as animal feeding.

Risk and challenges

1. The higher complexity of the agroforestry system could require an adaptation of agronomic management
2. Promotion of farmers' associations or interactions to reduce the production costs of machinery due to the increased diversification of machinery
3. Optimise the system to minimise the loss of absolute yield compared to conventional systems
4. Need for specific policies for intercropping and agroforestry systems

The introduction of an agroforestry system in a pre-existing olive grove can be challenging and risky at the same time. The management of the system is more complex, and it requires more effort and machinery for the different crops and, therefore, higher costs. To overcome these challenges there is a need for sensibilization of farmers to create associations and cooperate to reduce the production costs.

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There is a need for knowledge to make the system work well and optimize the system to minimize the loss of absolute yield.

Another challenge is to disseminate these “new” practices to raise society's awareness.

What is still missing is a group of tailored policies for intercropping and agroforestry systems that can support the farmers and encourage them to change their way of doing agriculture.

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BUSINESS MODEL CANVAS — Agroforestry system: Olive trees – cereals

KEY PARTNERS
- Seed provider
- Farmer networks
- Agronomic consultants
- Agricultural suppliers
- Flour and oil producers
- Seed-sharing association for the preservation of genetic variability
- Research and innovation centers

KEY ACTIVITIES
- Olive tree management and use of varieties that historically adapt well to the condition of the area of cultivation
- Cereal crops cultivation, choosing local and ancient varieties that can bring to a higher yield stability of the crop
- Cereal seed reproduction by selected farms
- System design: The system should be designed with an extensive tree spacing (9x9) in order to allow machinery operations

KEY RESOURCES
- Farms suitable for olive and/or cereal intercropping
- Experienced farmers or farmers who are willing to learn new practices related to agroforestry
- Access to training programs
- Specific machinery for trees and crop management and cereal harvesting

VALUE PROPOSITIONS
- **Maintenance of plants and soil biodiversity could lead to a lower incidence of weeds and pests reducing the use of chemical inputs**
- **Production diversification**
- **Yield stability and Land Equivalent Ratio increase**
- **Reduction of soil degradation and erosion**
- **Improvement of soil quality (e.g., organic matter, water holding capacity)**

CUSTOMER RELATIONSHIPS
- Long-term commercial relationship
- Promotion of high-added value agricultural market
- Quality linked to the area of origin

CHANNELS
- Local supply B to C and B to B
- Direct link between farmers and local food services

CUSTOMER SEGMENTS
- Local food services
- Flour and olive oil producers who are sensitive to sustainability

RISKS AND CHALLENGES
- The higher complexity of the agroforestry system could require an adaptation of agronomic management
- Promotion of farmers associations or interaction to reduce the production costs of machinery due to the increased diversification of machinery
- Optimisation of the system to minimise the loss of absolute yield (despite higher LER) compared to conventional systems
- Need of specific policies for intercropping and agroforestry systems

COST STRUCTURE
- CAPEX – on-farm implementation (common machinery acquisition, seeds)
- OPEX – fixed costs (fuel, common machinery rent, HR)

REVENUE STREAMS
- Sale of products (cereal, flour and olive oil)
- Savings in water input due to the land use intensification
- Saving in treatment costs like weed control

Figure 5. Business model canvas of mixed fruit trees vegetables system in Italy

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3.5 Spain. Agroforestry: Olive trees and winter cereal

3.5.1. Market data

Agroforestry systems in Spain offer significant advantages over monocultures, particularly in terms of sustainability, climate resilience, and productivity. While monocultures tend to deplete soil resources and are more vulnerable to the effects of climate change, agroforestry systems combine tree cultivation, such as olives, with cereals or other crops. This approach optimizes the use of available resources and enhances biodiversity. This method aligns with the adaptation strategies to climate change promoted by the new Common Agricultural Policy (PAC) 2023-2027 in Spain, which recognizes these systems as a key tool for a more sustainable and profitable agricultural future (Bertomeu et al., 2024).

Particularly, it is estimated that more than two-thirds of Spanish territory is at risk of desertification, with a very high risk in 11% of the land (Instituto Geográfico Nacional, n.d). According to the National Action Program against Desertification by the Ministry of the Environment, the areas at the highest risk include much of the mediterranean coast, including Catalonia. Therefore, agroforestry systems are crucial for soil protection and water conservation in these regions.

Various agroforestry systems could be implemented in Spain for this purpose. However, amongst the most predominant crops olives, covering around 2.8 million hectares (69% of these dedicated to rainfed farming, Ministerio de Agricultura, Pesca y Alimentación, 2019), and winter cereals, covering approximately 5.35 million hectares (data from 2023, (Red ARAX, 2023) are particularly interesting for this purpose. The combination of both would be a sustainable and beneficial system for the soil and crop quality and the farmers. In fact, olives, olive oil, and other subproducts of olive had in 2022 a total export value of approximately 5.0 billion EUR (Food and Agriculture Organization of the United Nations, n.d.) whilst winter cereals and their subproducts had an export value of approximately 6.4 billion EUR (Food and Agriculture Organization of the United Nations, n.d.), so these are profitable and demandable export products.

In Catalonia, although the development of agroforestry systems is still incipient, with only 5.5% of the Spanish area dedicated to silvoarable systems, most crops remain monocultures, with around 300.000 hectares of cereals and around 100,000 hectares of olives (2022 data; Instituto de Estadística de Cataluña, n.d.). In fact, the production of olives and olive oil in Catalonia in the year 2022 generated 20.36 million EUR and 79.91 million EUR respectively. This concentration in monocultures increases susceptibility to climatic, economic, and pest-related issues. Integrating both crops into an agroforestry system could mitigate these risks, improve long-term profitability, and provide greater economic stability for farmers. Annex V provides an example of commercial agroforestry farm.

3.5.2. System introduction

Agroforestry systems in the Mediterranean region, which integrate olive trees with cereal production, represent a harmonious blend of traditional agricultural practices and ecological sustainability. This methodology involves the strategic interplanting of olive trees with winter cereals such as wheat or barley, thereby optimizing land and resource utilization. The interrelationship between olive trees and cereals not only enhances overall farm productivity but also increases biodiversity and resilience against climate change. The combination of these crops ensures diverse revenue streams for farmers, thereby improving economic stability while preserving the ecological integrity and health of the Mediterranean landscapes.

Olive trees are iconic to the Mediterranean landscape, symbolizing both cultural heritage and economic vitality. Native to this region, olive trees thrive in the Mediterranean's hot, dry summers and mild, wet winters, making them exceptionally well-suited to the climate. These resilient trees are renowned for their exceptional drought tolerance and capacity to grow in poor, rocky soils, which makes them a sustainable option for marginal lands. Olive cultivation is integral to the region's agriculture, producing olives for both direct consumption and oil extraction, a staple in Mediterranean diets and a valuable export commodity. Beyond their economic significance, olive trees also contribute to environmental sustainability by preventing soil erosion and enhancing biodiversity.

The ancient practice of olive farming, combined with modern agricultural advancements, continues to support livelihoods and maintain the cultural landscapes of the Mediterranean area.

Winter cereal production in the Mediterranean region is a cornerstone of agricultural practices, leveraging the region's climate to cultivate crops such as wheat, barley, and oats. These cereals are sown in the autumn, allowing them to germinate and establish root systems before the onset of colder months. As temperatures rise, these cereals subsequently exhibit robust growth. This seasonal cycle capitalizes on natural rainfall, reducing the need for irrigation and making cereal farming more sustainable and cost-effective. The Mediterranean's diverse microclimates and soil types support a variety of cereal strains, contributing significantly to local food security and economies. The adoption of advanced farming techniques and the utilization of improved seed varieties continue to enhance crop yields and resilience against pests and climate variability. The studied rainfed system is configured by fields of conventional-managed winter cereal crop production (wheat) surrounded by a line of old olive trees (> 50 years old). The tree line is present in three of the four margins of the crop field, and they are no-till managed.

System drivers

- Ecological resilience and biodiversity: Catalonia faces significant environmental challenges, including soil degradation and loss of biodiversity. The region's vulnerability to desertification, particularly in areas like Tarragona and Lleida, highlights the need for sustainable practices that can restore soil health and biodiversity. Agroforestry systems promote greater biodiversity by increasing the variety of plant species and creating ecotones, which enhance ecological resilience and restore nutrient cycles in the soil.

- Productive and economic resilience: diversification in agroforestry systems, considering the land equivalent ratio in monoculture systems, allows for more efficient use of light, water, and nutrients, resulting in more stable overall productivity and reduced vulnerability to market fluctuations. Additionally, these systems offer opportunities to generate high-value products, such as carbon credits, improving the profitability of farms.

- Climate change adaptation: these systems reduce the impact of drought and other extreme weather events by creating more favourable microclimates for cereal and olive crops. This is crucial in a changing climate where droughts and adverse weather phenomena are increasingly common. In particular, a system combining olive and cereal cultivation can better retain soil moisture compared to an olive monoculture due to reduced evaporation, improved soil structure, and more efficient use of water resources.

- Mitigation of nitrate pollution: nearly half of the municipalities in Catalonia are classified as vulnerable to nitrate pollution, a problem that has worsened over time. Agroforestry systems can help mitigate this issue by improving soil management and reducing nutrient leaching.

- Agronomic innovations: the adoption in Spain of new cereal varieties, as well as the recovery of traditional varieties, better adapted to water stress, along with increased use of certified seeds (around 40% of the seeds used currently), has enhanced crop resilience, supporting the transition to more diversified and sustainable systems with cereal crops.

System barriers

- Economic viability of olive groves: the profitability of olive groves is limited and highly dependent on fluctuations in olive oil prices. This causes many plantations to be at risk of semi-abandonment during periods of low prices, making it difficult to invest in agroforestry systems.

- Resistance to change: farmers accustomed to monoculture systems may be reluctant to adopt agroforestry systems due to a lack of knowledge, training, or simply the perceived risk of replacing traditional methods with new approaches.

- Initial investment: transitioning to agroforestry systems requires a significant initial investment in terms of time and financial resources, which can be a major barrier for farmers.

3.5.3. Business model description

Value propositions

1. Resilience to climate change environmental challenges (production stability)
2. LER until 1,2 (more production per area than the monoculture)
3. Improved use of soil resources (i.e., efficiency in water management)
4. Water conservation (increase up to 80% of soil water content)
5. Mitigation of elevated air & crop temperatures (mean of -2ºC)
6. Potential increase of carbon sequestration of ~200-300 kgC/ha/yr depending on several factors (ecosystem services & carbon credits)
7. Generation of lignified pruning remains (obtention of resources to improve the soil fertility)
8. Multi-benefit production (long-term stability of economic incomes)
9. Contribution to rural development (i.e., agritourism)

Agroforestry systems are inherently more resilient to climate change and environmental challenges than monoculture systems. The integration of olive trees and cereal crops creates a diverse ecosystem, which enhances resilience against extreme weather events, pests, and diseases. This diversity reduces the risk of complete crop failure, as different species may respond differently to the same stressors. For example, during a severe drought that significantly affects cereal crops, olive trees, known for their drought tolerance, may continue to thrive, thereby ensuring some level of production stability. This resilience is particularly important in the face of increasing climate variability and extreme weather events. Additionally, selecting drought-resistant or climate-adaptive crop varieties can further enhance the system's resilience as well as adopting adaptive management practices (flexible decision-making that can be adjusted in the face of uncertainties).

A higher LER could be achieved in these systems compared to monoculture systems, meaning more production per unit area. The complementary interactions between olive trees and cereal crops can lead to more efficient use of sunlight, water, and soil nutrients, resulting in higher overall productivity. For example, the deep root systems of olive trees can access water and nutrients that are out of reach for cereal crops, while the cereal crops can utilize surface water and nutrients, creating a synergistic effect. A LER of up to 1.2 indicates that the combined productivity of the intercropped species is 20% higher than if they were grown separately. To maximize the benefits of a higher LER, farmers should carefully plan the spatial arrangement and species selection in their agroforestry systems. Proper spacing between olive trees and cereal rows can optimize light penetration and reduce competition for resources.

The efficiency of soil resources use could be enhanced through the complementary interactions between different plant species. Olive trees and cereal crops, by accessing different soil layers, improve overall resource use efficiency. These results in improved soil structure, reduced erosion, and enhanced soil fertility over time. Tree roots play a crucial role in soil binding, preventing erosion, and improving water infiltration. Furthermore, organic matter from leaf litter and pruning remains contributes to soil organic carbon, thereby promoting soil health and fertility.

The combination of trees and crops significantly improves water conservation by increasing soil water content and reducing water loss through evaporation. The shade provided by olive trees reduces soil temperature and evaporation rates, while their deep root systems help in accessing and utilizing subsoil water. As a result, both olive trees and cereal crops benefit from more efficient water use and improved drought resilience. Research indicates that agroforestry systems can increase soil water content by up to 80%, offering a critical buffer against dry spells and droughts. To maximize water conservation, farmers could implement mulching around the base of trees to preserve soil moisture levels.

The tree’s presence can mitigate elevated air and crop temperatures by providing shade and reducing the heat island effect, leading to cooler microclimates within the farm. This temperature reduction, typically around 2°C, can significantly improve crop health and productivity, especially during hot summer months. The shade provided by trees also reduces the risk of heat stress and sunburn on crops, enhancing their quality and yield. Farmers should strategically plant olive trees to maximize shading benefits for cereal crops, considering factors such as tree height, canopy density, and row orientation. Implementing tree and crop distribution that optimizes airflow and reduces heat buildup can further enhance temperature mitigation.

This system presents substantial potential for carbon sequestration, capturing and storing carbon dioxide in both tree biomass and soil. Integrating olive trees into cereal cropping systems allows farmers to sequester an additional 200-300 kg of carbon per hectare per year. This not only contributes to mitigating climate change but also offers farmers an opportunity to earn carbon credits.

In addition, trees generate lignified pruning remains, which can be utilized to improve soil fertility and organic matter content. Pruning olive trees regularly produces substantial biomass that can be composted or directly applied to the soil as mulch. This organic matter enriches the soil, enhancing its structure, water-holding capacity, and nutrient availability. The addition of lignified material helps in building long-term soil health, benefiting both olive trees and cereal crops. Farmers could implement systematic pruning practices to manage tree growth and maximize the production of lignified remains.

The multi-benefit production is one of the key points of agroforestry systems, ensuring the long-term stability of economic incomes. The integration of olive trees and cereal crops diversifies income sources, reducing the risk associated with market fluctuations and crop failures. This diversified production system offers a consistent revenue stream throughout the year, enhancing the farm's financial resilience. Moreover, the combination of tree and crop products can cater to diverse market segments, expanding the farm's customer base. Farmers should consider exploring value-added processing and marketing strategies to optimize the economic advantages of their multi-benefit production system.

Furthermore, it is possible to contribute to rural development by providing agritourism opportunities. Agritourism involves inviting visitors to experience farm life, participate in activities such as olive picking and cereal harvesting, and learn about sustainable farming practices. This not only generates additional revenue but also creates a platform for educating the public about the benefits of agroforestry, as mentioned above. By diversifying into agritourism, farmers can contribute to the economic vitality of rural communities.

Key partners

1. Seed providers
2. Agricultural suppliers
3. Postharvest processors (both for olives and for cereal)
4. Farmers' cooperative
5. Public administration and departments related to agriculture and tourism

Seed providers are key partners in supplying high-quality, region-specific seeds essential for both olive trees and cereal production. It is crucial to prioritize the selection of seeds from varieties adapted to local climatic conditions and find a balance between productive and rustic traits. Potential collaborators could include local seed banks or commercial seed companies.

Agricultural suppliers provide necessary inputs such as farming equipment, fertilizers, and pesticides if necessary. Potential partners could be private companies or farmers' associations to share farming machinery.

Postharvest processors handle the processing, packaging, and distribution of harvested olives and cereals, as much as the farmer could not manage by himself. A key point is to select postharvest processors with adapted distribution networks for effective market penetration and differentiation of these agroforestry products. Potential partners could be local or regional cooperatives, grain processing companies for the cereal or olive oil mills for the olives.

As previously mentioned, farmers' cooperatives play an important role in various facets of olives and cereals production within agroforestry systems. Empowering, shared resources, and support for marketing and distribution are some examples of the advantages of working with farmers' cooperatives. In addition, they could provide agricultural advisory and technical assistance. Regional agricultural cooperatives and alliances of small-scale farmers represent potential partners in this context. Government bodies provide regulatory oversight, financial incentives, technical support, and tourism promotion. They are key to promoting this type of systems in the mentioned aspects since an olive tree combined with a cereal production system could be affected by both agricultural and forestry regulations and incentives, in addition to tourism as a complementary part of the business. In this aspect is highly recommended to be involved in some collaborative strategy between farmers and public administration, such as specific programs or projects about agroforestry systems with a regional approach, or to participate in the regional government participatory platforms.

Key activities

1. Formation of olive trees and water management
2. Perform a marketing plan
3. Contact with technicians/farm advisors/other farmers working on agroforestry systems
4. Network with other practitioners
5. Identify and solve possible administrative barriers

Formation of olive trees and water management is crucial to ensure efficient cultivation, tree maintenance, optimisation, and increase water use efficiency. Training for farm workers and managers on best practices for olive tree cultivation, including planting, pruning, and harvesting techniques but also specialized courses on water conservation techniques, and soil moisture management. Some agricultural schools organize this type of training. Another example could be local agricultural services or universities that deliver hands-on training sessions. In some cases, it is possible to find specific training or exchange knowledge sessions on different types of agroforestry systems.

Performing a marketing plan could be useful to develop strategies for effectively marketing olive and cereal products to identify target markets and create promotional campaigns. Market research to identify target demographics, market trends, and potential competitors is needed in this activity. The use of online tools and surveys to gather data on consumer preferences and market demands could help in this point. The creation of a brand identity that reflects the sustainable and eco-friendly nature of agroforestry products, and the designing of a logo, packaging, and promotional materials that emphasise product benefits are also included in this activity. Additionally, there is a necessity to develop and execute advertising campaigns across various platforms including social media, print media, and local events. Contact with technicians, farm advisors, and other farmers working on similar systems could be crucial to gain insights and advice from experts and to share knowledge and experiences with other practitioners. This activity could include engaging with experts from local agricultural services or research institutions in specific interactive platforms such as thematic social networks and visiting other farms practising agroforestry to learn from their experiences and innovations. Networking with other practitioners is essential to build a community of practice around this type of system.

Identifying and addressing potential administrative barriers is crucial since administrative procedures often pose significant obstacles to the implementation of a system involving trees and crops. Ensuring compliance with local regulations and obtaining necessary permits is essential for the successful implementation and functioning of the system, particularly considering potential overlaps between agricultural and forestry regulations.

Key resources

1. Crop management and good practices document
2. Access to specific-sized machinery
3. Access to technological centres working on agroforestry systems
4. Logistic & technological management plan of cultivation and production

A crop management and good practices document is considered necessary for an accurate management of the agroecosystem. This document aims to establish guidelines and protocols for optimal crop management, ensuring high yields and sustainable practices, as well as for tree management. Some items to be included should be detailed information on planting, watering, pruning, and harvesting techniques, strategies for pest control that minimize environmental impact, guidelines on maintaining and improving soil fertility, and practices that promote ecological balance and biodiversity. An example of this document is the “Agroforestry Handbook” in the United Kingdom but is essential the use a regionally adapted document due to the huge heterogeneity of the Mediterranean region. An excellent alternative is the materials provided by projects focused on agroforestry systems, which usually publish factsheets containing detailed and specific examples of these systems.

Access to specific-sized machinery may be necessary in certain systems, depending on the distance between olive tree lines. In cases where the distance between the tree lines is less than the usual width of the machinery used for the cereal crops, specialized machinery will be essential for the efficient cultivation, maintenance, and harvesting of olives.

Access to technological centres specializing in agroforestry systems could significantly benefit farmers by providing essential research, innovation, and technical support essential to advance agricultural practices. Potential partners include agricultural research institutes, universities, or innovation hubs. Collaborating with these entities could grant access to the latest research findings and innovations, expertise, and guidance on implementing advanced techniques, and opportunities to participate in research projects and trials. The logistical and technological management plan for cultivation and production is due to the inherent complexity of the system. This plan should include strategies for transportation, storage, and distribution of inputs and outputs, as well as the utilization of digital tools and platforms for monitoring and managing farm operations. It should also include strategies for the optimal use of water, soil, and other resources, along with timelines for planting, maintenance, harvesting and postharvest activities. All the activities must be coordinated effectively for both components of the system, olive trees and cereals, to avoid overlap and promote efficiency.

Customer relationships

1. Get closer to consumers (products & agritourism customers)
2. Long-term commercial relationship (strategic alliances)
3. Promotion of local agricultural market

Establishing a closer relationship with consumers can significantly enhance the value of the products and agritourism services. Direct engagement allows farmers to build trust and loyalty, making consumers more likely to support their business consistently. By providing a transparent view of the farming practices and the benefits of agroforestry, farmers can educate consumers about the environmental and health benefits of their products. Farmers could use various communication channels to connect with consumers, such as social media, farm newsletters, and on-farm events. Sharing stories about the farm, the people behind it, and the sustainable practices used can create a compelling narrative that resonates with consumers. Additionally, building a direct sales platform, whether through a farm shop, farmers' market, or an online store, can further facilitate strong, lasting customer relationships.

Establishing long-term commercial relationships and strategic alliances can foster stability and growth opportunities for the businesses. Such partnerships may involve collaborating with local restaurants, grocery stores, and speciality food shops that prioritize high-quality, sustainably produced goods. By establishing reliable supply agreements, farmers can secure a steady market for their products, thereby mitigating the uncertainties associated with fluctuating market prices and demand. Strategic alliances also offer opportunities for co-marketing and joint promotions, increasing visibility and reach.

Promoting the local agricultural market is essential for fostering a supportive community and enhancing the sustainability of the businesses. By prioritizing local sales, farmers can reduce transportation costs and carbon footprints. Engaging with the local market also supports the regional economy, creating a positive feedback loop that benefits both producers and consumers. Farmers could participate in local farmers' markets and local food cooperatives to increase their visibility and accessibility within the community. Collaborating with local schools, community centres, and non-profits for educational programs can further promote the benefits of local agriculture. Highlighting the freshness, quality, and sustainability of locally produced goods in marketing materials can attract health-conscious and environmentally aware consumers.

Customer segments

1. Livestock farmers
2. Postharvest processors
3. Associations (e.g., farmers cooperatives)
4. Companies linked to agrifood activities with high-added value
5. Individual customers interested in local and high-added value commerce & agritourism

Livestock farmers represent a crucial customer segment for agroforestry systems that integrate olive trees and cereal production. These farmers can benefit mainly from the straw from cereal crops as feed. Additionally, the mixed-use landscape provides shaded grazing areas that can enhance animal welfare and potentially improve livestock productivity. In this way, agroforestry farmers can create symbiotic relationships with livestock farmers. For instance, scheduling the availability of feed by-products to coincide with livestock feeding cycles can increase the appeal of agroforestry products.

Postharvest processors, such as mills, granaries, and packaging companies, play a crucial role in converting raw agricultural products into market-ready goods. Establishing strategic partnerships with these entities can result in premium products that command higher prices. Farmers should consider identifying and collaborating with local processors experienced in handling both olives and cereals.

Farmers cooperatives and associations play a pivotal role in supporting and advocating for the interests of agricultural producers. By joining these organizations, farmers can access a wealth of resources, including shared knowledge, collective bargaining power, and marketing support. These associations often facilitate networking opportunities, provide training, and help farmers stay updated with industry trends and best practices.

Companies involved in high-value agrifood activities, such as gourmet food producers, health food manufacturers, and speciality retailers, represent lucrative customer segments. These companies often seek premium, sustainably produced ingredients that align with their brand values. The varied outputs from an agroforestry system, including high-quality olive oil and cereals, are well-suited to meet the demands of these discerning buyers and command premium prices. To capitalize on this market, farmers should prioritize producing high-quality, distinct products that align with the specific requirements of high-value agrifood companies.

Individual consumers who prioritize local, high-quality, and sustainable products are an important customer segment. These customers often value the environmental benefits and superior quality of the products, making them willing to pay a premium. Additionally, agritourism activities can attract this segment, providing additional revenue streams and enhancing customer loyalty.

Channels

1. Local supply B to C and B to B
2. Online and offline marketing and promotion strategies

Utilizing local supply channels for both business-to-consumer (B to C) and business-to-business (B to B) interactions can significantly enhance the distribution efficiency and community engagement of the farm. For B to C, direct sales at farmers' markets, farm stands, and local food festivals allow farmers to connect personally with consumers, fostering trust and loyalty. For B to B, local supply channels such as partnerships with local grocery stores, restaurants, and speciality food shops ensure a stable market for products. These relationships can be mutually beneficial. For instance, local businesses can market their use of sustainable, locally sourced ingredients, which can attract eco-conscious customers.

A robust combination of online and offline marketing strategies is crucial for maximizing the reach and visibility of products and services. Online marketing can include social media campaigns, email newsletters, and e-commerce platforms that allow farmers to reach a broader audience. High-quality content such as blog posts, videos, and customer testimonials can educate and engage potential customers about the unique benefits of agroforestry products, driving online sales and brand loyalty. Offline marketing strategies, such as attending local fairs, participating in community events, and hosting on-farm events like open days or workshops, provide opportunities for face-to-face engagement. Traditional advertising methods, such as flyers, local newspaper ads, and radio spots, could be considered to reach different segments of the community. Creating a brand is vital for distinguishing the unique benefits and quality of products derived from this sustainable agricultural practice. A robust brand effectively communicates the ecological and health benefits of this integrated system, highlighting advantages such as enhanced biodiversity, soil conservation, and reduced chemical inputs, appealing to environmentally conscious consumers.

Cost structure

1. CAPEX – on-farm implementation (common machinery acquisition)
2. OPEX – fixed costs (fuel, common machinery rent, HR, seeds)

CAPEX represents the upfront investments required to establish the olive tree-cereals system. One of the significant costs under CAPEX is the acquisition of common machinery essential for both olive and cereal production. This includes tractors, olive harvesters, and combine harvesters. These pieces of equipment are crucial for efficient farm operations, enabling tasks such as planting, pruning, harvesting, and irrigation to be performed effectively. Farmers should explore financing options or grants available for sustainable agriculture projects to alleviate the initial financial burden. Moreover, implementing the system may require modifications to existing infrastructure or the installation of new systems tailored to the requirements of both olive trees and cereal crops. This could include for example constructing storage facilities for both types of produce if the farm was not adapted to this. Collaborating with other local farmers to share machinery costs and resources can also be a strategic way to reduce individual financial burdens.

OPEX encompass the ongoing costs associated with running the production system. Key fixed costs include fuel, machinery rent, human resources, and seeds. Fuel costs are a significant part of OPEX, as machinery such as tractors and harvesters require a steady supply of diesel or gasoline. To manage these expenses, farmers can adopt fuel-efficient practices, such as regular maintenance of machinery and optimizing field operations to minimize fuel consumption. Additionally, exploring alternative energy sources, like biofuels or electric machinery, could provide long-term savings and reduce environmental impact. Another option is to adopt a holistic approach to farm management based on reduced tillage to soil regeneration. Renting common machinery can be considered as part of OPEX, particularly for specialized equipment that is used infrequently. Renting enables farmers to access advanced technology without the hefty initial investment, offering a cost-effective solution to manage peak season demands.

Human resources represent another substantial fixed cost, covering salaries for permanent staff and seasonal workers. Investing in training programs to enhance workers' skills can improve efficiency and productivity, ultimately reducing operational costs. Lastly, the cost of seeds for both olive saplings and cereal crops is a recurring

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expense. Farmers should prioritize selecting high-quality, disease-resistant seeds locally adapted to ensure healthy crop growth and maximize yields. Engaging in bulk purchasing and forming cooperatives to procure seeds at reduced rates can also effectively manage these costs.

Revenue streams

1. Sale of multiple products (olive oil, olives, cereal, forage)
2. Possible carbon credits
3. Other activities (i.e., agritourism)

One of the primary revenue streams of this system includes the sale of multiple products such as olive oil, olives, cereal grains, and forage. Diversifying products ensures multiple income sources, thereby enhancing the farm's revenue stability throughout the year. For example, olives and olive oil can be harvested and sold during one season, while cereals can be harvested during another, providing a continuous flow of income. Additionally, forage produced from the same land can be sold or used to support livestock, further enhancing the farm's productivity and profitability.

Another significant revenue stream is the potential sale of carbon credits. Agroforestry systems are recognized for their capacity to sequester carbon. By adopting practices that capture and store carbon dioxide, farmers can generate carbon credits. These credits can be sold to companies and organizations seeking to offset their carbon emissions, thereby offering an additional source of income. This not only contributes to the farm's revenue but also promotes environmental sustainability. To benefit from carbon credits, farmers need to measure and verify the amount of carbon sequestered on their land, typically requiring certification from recognized carbon credit organizations. Farmers interested in carbon credits should first understand the certification process and criteria for earning these credits. Engaging with experts or organizations that specialize in carbon trading, such as “carbon credit project developers” can provide valuable guidance.

Diversifying revenue through agritourism offers another lucrative opportunity. Agritourism involves inviting visitors to experience the farm, which can include activities like farm tours, olive picking, cereal harvesting, workshops on sustainable farming practices, and even farm stays. This initiative not only generates additional income but also serves as a platform for educating the public about the benefits of agroforestry and sustainable agriculture. Agritourism can attract a diverse range of visitors, including local school groups and families to tourists seeking unique rural experiences. Developing facilities such as visitor centres, accommodation, and recreational areas can enhance the visitor experience and boost income. Farmers should consider the potential of their location and existing infrastructure to develop agritourism activities. Additionally, farmers can offer seasonal events, such as harvest festivals or olive oil tasting sessions, to draw in visitors during peak farming seasons. By diversifying into agritourism, farmers can create a steady, year-round revenue stream that complements their traditional agricultural activities.

Risks and challenges

1. High annual variability in olive production in some varieties as a climatic consequence
2. Possible requirement of specific-sized machinery
3. Differentiation in the market
4. Administrative procedures
5. Promotion of incentives for environmentally friendly agricultural practices

One of the notable risks in this olive trees-cereal system is the considerable annual variability in olive production, especially in certain varieties that are sensitive to climatic conditions. Factors such as temperature fluctuations, droughts, and unexpected frosts can significantly impact yield. This variability can lead to inconsistent production levels, which complicates planning and can affect the financial stability of the farm. To mitigate this risk, farmers should consider including those varieties that are more resilient to climatic variations. Additionally, maintaining a buffer stock from good years can help manage shortfalls during low-yield years.

Agroforestry systems frequently require specific-sized machinery to navigate the mixed landscape of trees and crops effectively. This requirement poses challenges, as specialized equipment can be expensive and may not always be readily accessible. Moreover, the necessity for particular machinery can also increase operational complexity and maintenance expenses. Farmers should conduct thorough research to understand the machinery requirements specific to their setup and consider options such as leasing equipment or forming cooperatives with other farmers to share the cost and use of specialized machinery.

In a competitive market, differentiating products can be challenging, particularly when consumer awareness of the benefits of such systems is limited. Establishing a unique selling proposition and effectively communicating the environmental and health advantages of agroforestry products are essential for market differentiation. Farmers should prioritize building a robust brand that emphasizes the sustainability and high quality of their offerings. Participating in certification programs, such as organic or fair-trade labels, can enhance credibility and attract conscious consumers.

The amount and velocity of administrative procedures could be limited in these types of systems. These procedures often involve obtaining permits, complying with agricultural regulations, and applying for subsidies or grants. The complexity and variability of these requirements can pose a significant challenge, particularly for small-scale farmers. Joining farmers' associations or cooperatives can offer support and share insights from other farmers who have successfully navigated similar administrative procedures. Keeping detailed records and staying organized can streamline the process of complying with administrative requirements and applying for financial incentives.

Promoting incentives for environmentally friendly agricultural practices is essential for the long-term viability of agroforestry systems. However, the availability and accessibility of such incentives can vary widely, and the application process can be complex. Ensuring that these incentives are effectively promoted and utilized by farmers is a critical challenge, which could be addressed by fostering informative channels between farmers and administrative bodies. This could include the use of specific platforms or conferences to facilitate communication and dissemination of information.

BUSINESS MODEL CANVAS — Agroforestry system: Olive trees + cereal crop

KEY PARTNERS

- Seeds providers
- Agricultural suppliers
- Postharvest processors (both for olives and for cereal)
- Farmers cooperative
- Public administration and departments related to agriculture and tourism

KEY ACTIVITIES

- Formation on olive trees and water management
- Perform a marketing plan
- Contact with technicians/farm advisors/other farmers working on agroforestry systems
- Network with other practitioners
- Identify and solve possible administrative barriers

KEY RESOURCES

- Crop management and good practices document
- Access to specific-sized machinery
- Access to technological centers working on agroforestry systems
- Logistic & technological management plan of cultivation and production

COST STRUCTURE

- CAPEX – on-farm implementation (common machinery acquisition)
- OPEX – fixed costs (fuel, common machinery rent, HR, seeds)

VALUE PROPOSITIONS

- **Resilience to climate change environmental challenges (production stability)**
- **LER until 1,2 (more production per area than the monoculture)**
- **Improved use of soil resources (i.e., efficiency in water management)**
- **Water conservation (increase up to 80% of soil water content)**
- **Mitigation of elevated air & crop temperatures (mean of -2ºC)**
- **Potential increase of carbon sequestration of ~200-300 kgC/ha/yr depending on several factors (ecosystem services & carbon credits)**
- **Generation of lignified pruning remains (obtention of resources to improve the soil fertility)**
- **Multi-benefit production (long term stability of economic incomes)**
- **Contribution to rural development (i.e., agritourism)**

CUSTOMER RELATIONSHIPS

- Get closer to consumers (products & agritourism customers)
- Long-term commercial relationship (strategic alliances)
- Promotion of local agricultural market

CHANNELS

- Local supply B to C and B to B
- Online and offline marketing and promotion strategies

REVENUE STREAMS

- Sale of multiple products (olive oil, olives, cereal, forage)
- Possible carbon credits
- Other activities (i.e., agritourism)

CUSTOMER SEGMENTS

- Livestock farmers
- Post harvest processors
- Associations (e.g., farmers cooperatives)
- Companies linked to agrifood activities with high-added value
- Individual customers interested in local and high-added value commerce & agritourism

RISKS AND CHALLENGES

- High annual variability in olive production in some varieties as a climatic consequence
- Possible requirement of specific-sized machinery
- Differentiation in the market
- Administrative procedures
- Promotion of incentives for environmentally friendly agricultural practices

Figure 6. Business model canvas of olive trees with cereal crop in Catalonia Region, Spain

3.6. Spain. Innovative crop: Kernza® (*Thinopyrum intermedium*)

3.6.1. Market data

Most of the agricultural systems in the Mediterranean operate under dryland conditions. In the case of winter cereals, they are usually sown in autumn and harvested at the end of the spring season. This practice combined with an increase in extreme events such as heavy precipitations or drought, would promote soil degradation (e.g., wind and water erosion) and loss of fertility (e.g., organic matter) during the period without cover crops.

Agriculture in Spain faces challenges such as soil degradation, water scarcity, and the need to reduce greenhouse gas emissions. To address these issues, it is essential to explore innovative crops that promote sustainability, resource efficiency, and food security. Innovative crops such as perennial cereals are a suitable option for adapting to climate change in Mediterranean environments with special attention to be considered in the agroforestry and mixed farming systems. These are plants that live and remain productive for two or more years. Their implementation in the field would reduce the impact of extreme climatic events while increasing soil carbon storage through the addition of continuous plant debris and deep root systems.

Kernza (*Thinopyrum intermedium*), a deep-rooted perennial grain, is a promising option: it improves soil health, reduces erosion, and sequesters carbon, making it a viable alternative for more resilient and sustainable farming.

3.6.2. Crop introduction

Kernza is a versatile and sustainable crop with multiple uses. Its grain is used to produce flour for products such as bread, cookies, and beer, offering a slightly sweet taste and higher fiber content compared to wheat. It also produces significant biomass, making it an excellent forage crop for livestock. Furthermore, its deep root system makes it ideal for soil conservation and regeneration projects, enhancing soil structure and water retention, which are key benefits for regenerative agriculture.

Although still a novel crop in Spain, Kernza has been extensively studied in countries like the United States. For example, Patagonia Provisions has produced “Long Root Ale,” a beer brewed with 15% Kernza grain. General Mills recently announced plans to incorporate Kernza into some of its products under the organic Cascade Farms brand (Gelski, 2022). Additionally, many restaurants and bakeries are incorporating Kernza into their menus and baked goods.

Research-wise, there have been many initiatives in the United States that promote these types of crops. For example, The Foundation for Food & Agriculture Research (FFAR) awarded a 992,419 USD grant to the University of Minnesota to accelerate the development of Kernza (The Land Institute, 2020). Not only monocultures have been studied, but also Kernza perennial wheat with intercropping grain legumes to increase its profitability (Law & Ryan, 2019).

Kernza yields have been increasing rapidly. Grain yields range from 400 to 900 pounds per acre in the first year (Kenyon & Vincent, 2017). However, its productivity is measured not only in grain yield, but also in forage yield, as it can produce up to 5 tons per acre of forage, which can be grazed or harvested for hay (Kenyon & Vincent, 2017). Moreover, inputs such as fertilizers, pesticides, and machinery are minimal, making Kernza a low-cost alternative to annual crops.

In Spain, Kernza is currently in an experimental phase, with pilot projects in not that many regions. It has been tested in semi-arid areas and in regions focused on soil quality improvement, such as Catalonia, to evaluate its potential for agroforestry systems and grain production (RuralCat, 2022).

Crop drivers

- Soil quality improvement: Kernza's deep roots improve soil structure, reduce compaction, and increase organic matter, which are key benefits for agricultural soils in Catalonia, especially in areas where soil quality is an issue.
- Erosion reduction: as a perennial crop, Kernza maintains soil cover year-round, reducing water and wind erosion. In regions like Catalonia, where erosion and desertification can be problematic, this is a crucial aspect. Also, the lack of annual tilling prevents soil degradation and carbon release into the atmosphere, thus protecting local ecosystems. On the other hand, Kernza can remain productive for 10 to 20 years, reducing the need for annual replanting and thereby lowering establishment costs and soil impact.
- Carbon sequestration: Kernza roots sequester carbon more efficiently than traditional annual crops, contributing to climate change mitigation, a priority in Catalonia’s agricultural and environmental policies.

• Reduction in water usage: Kernza's deep roots access water from the subsoil, reducing the need for irrigation. This is especially relevant in Catalonia, where water scarcity and efficiency are critical challenges.

• Adaptability to existing agricultural practices: Kernza can be planted using standard forage crop machinery and harvested with a small grain combine. This facilitates its integration into current agricultural practices, reducing the need for additional investments.

• Reduction in agricultural inputs: as a perennial crop, Kernza requires fewer fertilizers and pesticides compared to annual crops, lowering production costs and environmental impact, aligning with the shift towards more sustainable agriculture in Catalonia.

• Opportunities for innovation and added value: Catalonia, with its dynamic agri-food sector, can leverage Kernza cultivation to develop innovative products (bread, beer, etc.) that add value and diversify the agricultural offer.

Crop barriers

• High production costs: Kernza is significantly more expensive than wheat, costing 10 to 20 times more due to its current lower yields, which are less than half of a typical wheat crop. This makes it less economically attractive for farmers and buyers in Catalonia.

• Limited adoption and initiatives in Spain: the cultivation of Kernza is not widespread in Spain, and there are few initiatives promoting its use. This lack of widespread adoption limits knowledge transfer and reduces the support network available for farmers considering this crop in Catalonia.

• Agronomic Management Challenges: as a new crop, there are still many unresolved agronomic management issues, such as determining the optimal harvesting method, timing, and machinery settings. This lack of established best practices creates uncertainty for farmers in Catalonia, making it more challenging to adopt Kernza successfully.

3.6.3. Business model description

Kernza® (*Thinopyrum intermedium*), a perennial cereal, was sown during the winter of 2020 on a commercial farm in northeastern Spain. The crop was managed according to the assessment of the Land Institute (United States of America).

The business model description aims to provide broader information on the relevant aspects of its implantation in the field.

Value propositions

1. Resilience to climate change environmental challenges (production stability)
2. Reduction of the soil tillage (less fuel consumption)
3. Reduction of erosion and improvement of soil structure (enhanced soil fertility)
4. Improvement of nutrient retention (lower use of fertilizers)
5. Carbon sequestration (ecosystem services and carbon credits)
6. Multi-benefit production (long-term stability of economic incomes)

The Kernza® installed in the field offers a comprehensive range of value propositions that address both environmental and economic challenges. Soil tillage and erosion reduction, nutrient retention improvement, carbon sequestration capability, and multi-benefit production ensure a sustainable and profitable future for modern agriculture. All the above-mentioned aspects will improve the farmers' resilience to climate change through adaptability to extreme weather conditions and ensure production stability. Adopting such crops is a forward-thinking approach that benefits farmers, the environment, and the global community.

Recent studies with Kernza® under dryland Mediterranean conditions have shown that the cereal can withstand extreme weather conditions, such as drought. This resilience ensures continued production even in the face of climate variability, helping safeguard farmers' livelihoods and contribute to long-term food security.

Kernza® requires significantly less tillage than traditional annual crops. As a result, farmers can reduce their fuel consumption and lower their overall production costs. This saves money and reduces greenhouse gas emissions associated with fuel use. Less tillage also decreases de use of farm equipment, extending its life and reducing maintenance costs.

The cover crop along the year prevents surface erosion caused by wind and water but also increases soil organic matter through the continuous addition of plant debris. For example, soil organic matter increased by 21-24% when the results of the third year of Kernza® were compared with the initial soil levels. Increased soil organic matter is reflected in improved soil nutrient retention, fertility, and health, and supports the growth of other crops in combination with Kernza®.

Kernza®'s deep root system helps to anchor the soil, reducing soil erosion and improving soil structure. It improves its porosity and water available to plants can be stored for longer periods. Deep roots access nutrients beyond the reach of shallow-rooted crops, reducing nutrient leaching and improving the efficiency of fertiliser use. As a result, farmers can use less fertiliser, saving money and reducing the environmental impact of agricultural runoff.

One of the most significant environmental benefits of Kernza® is its ability to sequester carbon. Recent results from Kernza® trial sites have shown an average increase in the total carbon of 3-11% when comparing the third-year results with the initial soil levels. The perennial nature of Kernza® allows it to store carbon in its extensive root system and surrounding soil. In addition, farmers can potentially earn carbon credits for the carbon sequestered by their Kernza® crops, providing an extra source of income while contributing to climate change mitigation. These carbon credits can be traded in carbon markets, promoting environmentally friendly agricultural practices.

Kernza® offers multiple benefits that help increase the economic resilience of farming communities by diversifying income sources and reducing dependence on external inputs. In addition to the direct grain sails, Kernza® can be used for forage, providing an additional product for livestock farmers. The improved soil health and reduced input costs associated with Kernza® cultivation lead to more sustainable and profitable farming operations.

Key partners

1. Land Institute (seeds provider)
2. Livestock and crop farmers
3. Agricultural suppliers
4. Postharvest processors
5. Public administration and departments related to agriculture and the environment
6. Research and innovation centers

Key partners provide essential resources, knowledge, and support throughout the lifecycle of the crop. Key partners such as the Land Institute, livestock and crop farmers, agricultural suppliers, postharvest processors, public administration, and research and innovation centres are essential to the success of an innovative crop in the field. Each partner brings unique resources and expertise that contribute to the development, cultivation, processing, and marketability of the crop. Through collaborative efforts, these partners ensure that the innovative crop can thrive, and provide economic, environmental, and social benefits to the farming community.

Seeds were provided by the Land Institute, which has expertise in breeding resilient and productive Kernza® crop varieties. Close collaboration with the Land Institute allows the initial crop establishment.

Livestock and crop farmers are at the forefront of implementing and growing Kernza®. Their practical experience and local knowledge are invaluable in optimising farming practices, refining cultivation techniques and improving future crop cycles. Livestock farmers can provide manure from nearby farms to fertilise the Kernza®.

Agricultural suppliers are key partners in providing the necessary inputs such as fertiliser, pesticides, and farm equipment. Their role is to ensure that farmers have access to the products needed, as well as technical support and advice on the best practices to maintain soil health and productive crops.

Postharvest processors can change depending on the final use of the crop. On the one hand, if it is harvested for forage, it is necessary to have contact with farmers to purchase the product. On the other hand, if it is used for seed, post-harvest processors transform the raw crop into marketable products such as packaged food, animal feed, or bio-products. This added value and quality assurance are critical for expanding market opportunities and increasing profitability.

The support of public administration and governmental departments in approving and monitoring agricultural practices ensures compliance with safety and environmental standards. Funding and incentives entities often provide financial support, grants, and incentives to encourage sustainable agricultural practices and innovation. Access to such resources can significantly reduce the financial burden on farmers and promote broader adoption of innovative crops.

Research and innovation centres are needed to conduct advanced studies on crop genetics, soil health, pest management, and sustainable farming practices. Their findings will help to optimise the cultivation techniques and enhance the resilience of the innovative crop. These centres can also facilitate knowledge transfer to ensure that the latest innovations can be effectively implemented. This partnership fosters a culture of continuous improvement and adaptation with the results obtained.

Key activities

1. Field test and continuous improvement

2. Contact with technicians/farm advisors in Kernza® culture
3. Formation of Kernza® production
4. Network with other practitioners
5. Identify and solve possible administrative barriers

Key activities for successful Kernza® cultivation will collectively ensure that the crop can be grown efficiently, sustainably, and profitably, contributing to the advancement of sustainable agricultural practices and the development of resilient food systems. These include field testing and continuous improvement, working with technicians and farm advisors, training on Kernza® production, networking with other practitioners, and overcoming administrative barriers.

Management practices for Kernza® are similar to those for the cereals. Field testing and continuous improvement involve conducting rigorous trials to assess the Kernza® performance under various environmental conditions, monitoring growth patterns, and analysing data to make evidence-based decisions. This process includes iterative improvements based on lessons learned from field trials, ensuring that cultivation techniques, fertilisation strategies, and pest management strategies are continually optimised.

Engaging with technicians and farm advisors is necessary to obtain expert guidance on best practices, access technical support and help implement advanced farming technologies and troubleshoot Kernza® cultivation issues.

Training on Kernza® production through workshops, and demonstration days will provide farmers with the necessary knowledge and skills. Educational materials such as manuals, videos, and online resources will support ongoing learning and serve as reference guides to ensure farmers are well-prepared to manage the crop effectively.

Networking with other practitioners fosters a community of knowledge-sharing and collective problem-solving. By sharing experiences and engaging in collaborative projects, farmers and researchers can drive innovation and develop new techniques to improve the overall understanding and success of Kernza® cultivation.

Farmers are encouraged to participate in farmer groups and discussions to share their experiences in the field, and to identify and find solutions to possible administrative barriers. Identifying and resolving administrative barriers involves navigating regulatory requirements, advocating for favourable policies, and ensuring compliance with agricultural regulations. Meticulous documentation and reporting to regulatory bodies will help policymakers promote policies that benefit Kernza® and other perennial cereals.

Key resources

1. Crop management and good practices document
2. Access to technological centres working on Kernza® culture
3. Logistic and technological management plan of cultivation process and final production
4. Access to specific accessories to adapt agricultural machinery

Implementing and sustaining an innovative crop like Kernza® requires several key resources. These resources include documentation on crop management and good practice, access to technology centres specialising in Kernza® cultivation, a logistical and technological management plan for the cultivation process and final production, and access to specific accessories to adapt agricultural machinery. These resources ensure that Kernza® can be grown efficiently, sustainably, and profitably. In consequence, farmers can contribute to the implementation of sustainable agricultural practices.

A comprehensive crop management and good practices document is essential to guide farmers through each stage of Kernza® cultivation. This document should include detailed instructions on soil preparation, planting, irrigation, pest control, and harvesting. Best practices for maintaining soil health, managing crop rotation, and optimizing yields, also should be considered. A well-documented guide ensures that farmers can implement standardised and effective practices, resulting in consistent and high-quality production.

Access to technology centres working on Kernza® will provide farmers with the latest scientific knowledge and technological innovations. Collaborating with these institutions will allow farmers to stay updated on new developments in sustainable farming techniques.

A logistical and technological management plan for the cultivation process and final production is essential to optimise the use of resource use, reduce waste, organise, and streamline operations. In other words, to improve the overall efficiency of the growing process. This plan outlines the steps required from planting to harvesting and postharvest processing. It includes the coordination of logistics, such as transport and storage, and the integration of technological solutions (e.g., precision agriculture tools).

Crop management practices of Kernza® as those common to the cereals. As a result, standard farm machinery can be used without any adaptation when Kernza® is harvested for forage. Harvesting for grain can also be done with normal machinery by controlling the plant moisture. It is recommended to make some proof before harvest to ensure that the machinery and equipment are adjusted to reduce the risk of crop damage, improve operational efficiency, and support large-scale production.

Customer relationships

1. Long-term commercial relationship (strategic alliances)
2. Promotion of local agricultural market

The success of the innovative Kernza® crop largely depends on strong and strategic customer relationships and the effective promotion of the local agricultural market. Long-term strategic alliances provide the necessary stability and resources, while local market promotion ensures a loyal customer base and a stronger agricultural economy. Together, these elements create a favourable environment for innovation and sustainable growth in agriculture.

Building long-term commercial strategic alliances with key stakeholders such as food processors, distributors, and retailers ensures a consistent demand for Kernza® products. By partnering with these entities, farmers can secure contracts that provide predictable revenue streams, enabling better financial planning and investment in sustainable farming practices. These relationships also facilitate the development of value-added products, such as Kernza®-based foods, which can be marketed to health-conscious consumers and speciality markets.

Another strategic alliance is with research institutions and agricultural organisations. Through these alliances, farmers will gain access to new technologies and resources, enhancing the overall productivity and sustainability of the Kernza® crop.

Promoting the local agricultural market is crucial for the widespread adoption and acceptance of Kernza®. Local marketing efforts include participating in farmers' markets, collaborating with local food cooperatives, and participating in community-supported agriculture programmes. These initiatives will increase the visibility of Kernza® and educate consumers about its environmental, and health benefits and build a loyal customer base that values sustainability and supports local agriculture.

Customer segments

1. Livestock and crop farmers

2. Associations (e.g., farmers cooperatives)
3. Companies linked to agrifood activities with high-added value

Identifying and understanding the specific customer segments that can benefit from Kernza® is crucial for its adoption and market integration. By addressing the specific needs and opportunities of livestock and crop farmers, associations such as farmers' cooperatives, and companies linked to high-value-added agri-food activities, the innovative crop can bring significant economic and environmental benefits, fostering a more resilient and sustainable agricultural sector.

As crop farmers are directly involved in Kernza® cultivation, they can establish interactions with livestock farmers, especially if Kernza® is suitable as a high-quality animal feed. Furthermore, by integrating crop and livestock production, farmers can create more sustainable and efficient systems, using manure for crop fertilisation.

Farmers cooperatives and agricultural associations can collectively invest in innovative crops, share resources, access larger markets, and negotiate better prices. Cooperatives can facilitate training programs to educate members on best practices for growing innovative crops, ensuring optimal performance and knowledge. In terms of policy, associations can advocate for policies that support the adoption of perennial cereals, securing funding and resources for farmers.

Companies linked to agri-food activities can benefit from Kernza® by having access to high-quality raw materials. This can inspire new product lines.

Channels

1. Local supply B to C and B to B
2. Online and offline marketing and promotion strategies

By utilising diverse local supply channels and implementing comprehensive online and offline marketing strategies, farmers can maximise the reach and impact of the innovative crop. This approach ensures sustainable and profitable agricultural practices while releasing market potential.

Local supply can be addressed in several ways. In the case of Kernza® as forage, sales can be made directly to other livestock farmers, to a processing industry or used for self-consumption. In the case of Kernza® as a grain option for human consumption, farmers can collaborate with local food processors to integrate the crop into high-value-added products. These products can be commercialised through farmers' markets and direct sales, offering Community Supported Agriculture subscriptions for regular deliveries of fresh produce, ensuring a steady income and customer loyalty. Alternatively, the value-added products can be supplied to local restaurants, cafes, schools, hospitals, and corporate cafeterias that prioritise on farm-to-table and nutritious food options, helping to build trust and community ties.

Online and offline marketing and promotional strategies can be especially useful when introducing the crop to a new area, regardless of its end use (forage or grain). Develop an informative website and an online store for direct sales and customer education. Use social media campaigns and influencer partnerships to reach a wider audience. Publish blogs, articles, newsletters, and videos to drive traffic and educate customers about the crop.

Offline strategies can include using local print media for advertising Kernza® derived products. Hosting workshops, demonstrations, and sponsoring local events to educate and connect with the community will also enhance the commercial channels.

Cost structure

1. CAPEX – on-farm implementation (common machinery acquisition, seeds)
2. OPEX – fixed costs (fuel, common machinery rent, HR)

CAPEX can be divided into seed purchase, machinery, technology implementation, and infrastructure investment. Seed purchase, treatment, storage, and handling are necessary to ensure the quality, germination rates and viability. Although it would be considered an operational expenditure, the perennial treat of the crop reduces the investment and sets it as a CAPEX cost.

The purchase of essential farm machinery (e.g., tractors, ploughs, seeders, and irrigation systems) represents a significant up-front cost. Machinery is necessary to prepare the land, plant, maintain, and harvest the Kernza® crop. However, regular maintenance, depreciation over time, and potential future replacement should be considered in the financial planning. The introduction of modern technologies (e.g., precision agriculture tools, GPS-guided equipment, automated systems) can improve efficiency but also increase initial capital requirements.

OPEX in the Kernza® crop is mainly associated with the ongoing fuel cost, the machinery rental (if required), and the human resources. Fuel prices can be volatile, affecting overall operating costs. Thus, investing in energy-efficient machinery or alternative energy sources, such as biofuels or solar-powered equipment, can help manage and potentially reduce fuel costs in the long term. If purchasing machinery is not feasible, renting it is an alternative. This includes the costs associated with leasing agreements, which may offer flexibility but can add up over time. Additionally, the availability of rental equipment during peak seasons can be a challenge as prices may increase during these periods.

Human resources include both permanent staff and seasonal labour. Wages for farm workers involved in planting, maintaining, and harvesting Kernza are the major fixed costs. Training programmes for workers to effectively handle innovative farming techniques and machinery should be considered as an investment to increase productivity.

Revenue streams

1. Sale of products (forage, cereal, others)
2. Savings in ordinary costs (tillage, fertilizer, forage, etc.)
3. Reduction of crop management and application costs
4. Possible carbon credits

The revenue streams for Kernza® crop in the field are diverse and varied. Income can be generated from the sale of various products, while significant savings can be made on ordinary costs such as tillage and fertilizers. Additionally, reductions in crop management and application costs, combined with the potential to earn carbon credits, contribute to the overall financial viability and sustainability of the innovative crop. By effectively leveraging these revenue streams, farmers can improve profitability and support sustainable agricultural practices.

Currently, Kernza® has two main outputs. On the one hand, it can be used as a forage, with high nutritional value for local livestock farmers, making it a preferred choice and potentially allowing for premium pricing. On the other hand, selling the Kernza® grain to grain markets or food processors can generate significant income (e.g., sales to mills, bakeries, and other food manufacturers). Processing the seed into value-added products offers additional income opportunities. Furthermore, branding the grain as an organic, innovative and/or sustainable product can further enhance its market appeal.

Savings in ordinary costs come from plant characteristics and crop management practices. Root depth improves the nutrient retention and increases the soil organic matter from the first cropping season. It improves the soil health and reduces dependence on chemical fertilisers over time. Moreover, the perennial nature of the crop reduces the need for tillage, resulting in significant savings in fuel, labour, and machinery wear. Conservation tillage practices also contribute to long-term soil health, reducing the need for future investment in soil restoration. Farmers who grow Kernza® for forage reduce the need to purchase external feed for their livestock, thereby saving costs. This self-sufficiency enhances overall farm profitability and stability.

The use of precision agriculture techniques can optimise input use, ensuring that fertiliser, pesticides, and water are applied more efficiently and reducing labour costs. Automated irrigation, fertiliser, and monitoring systems can further reduce waste, lowers, and labour expenses. Beyond the monetary costs, efficient machinery and reduced tillage practices increase the cost savings and reduce the farm's carbon footprint.

Kernza®'s ability to enhance soil carbon sequestration can qualify the farm for carbon credits. These credits can be sold on carbon markets, providing an additional source of income. Kernza also could be considered as a way of gaining access to agri-environmental grants for adopting environmentally friendly agricultural practices for implementing and maintaining this type of cropping system.

Risks and challenges

1. Culture implementation in specific climatic conditions
2. Social perception and acceptance of innovative culture
3. Administrative procedures
4. Elaboration and promotion of derivate products (e.g., bread)
5. Promotion of incentives for environmentally friendly agricultural practices

Introducing an innovative crop in the field as Kernza® offers numerous opportunities, but also comes with significant risks and challenges. Effectively addressing these challenges can pave the way for successful integration and long-term sustainability of innovative crops in the agricultural landscape.

A key challenge is to ensure that the innovative crop can grow in the specific climatic conditions of the region. This requires an understanding of the local climate, soil types, and potential environmental stressors such as drought, flooding, or pests. In addition to extensive research, it is necessary to invest in field trials and continuous monitoring to identify and mitigate potential crop issues given the unpredictability of climate change. Extreme weather events and changing climate patterns can disrupt crop growth, making establishment and yield stability more difficult.

Social perception and acceptance of Kernza® is also related to the consumer confidence, which may be sceptical of newly introduced crops. Cultural barriers, misinformation and resistance to change can hinder market acceptance of the crop. These can be addressed by building a positive social perception, which involves transparent communication and tangible benefits demonstration. It underlines the importance of engaging with the local community, including farmers, consumers, and stakeholders, to educate them about the benefits of the innovative crop.

Navigating the regulatory landscape of administrative procedures and bureaucracy to obtain the necessary approvals to plant and sell the Kernza® can be complex and time-consuming. It would help to ensure compliance with local and international standards for safety, environmental impact, and food quality to avoid legal issues, fines, or bans on the crop. Extensive documentation and regular reporting to the regulatory bodies can be costly, requiring dedicated resources and expertise.

Developing high-value-added derivative products from Kernza®, such as bread, requires investment in research and development to ensure that these products meet consumer expectations for taste, quality, and nutritional value. Once the product is developed, bringing new products to market requires a significant marketing effort and overcoming consumer resistance to change. Effective branding and promotion strategies are essential to gain market acceptance. Finally, the establishment of a reliable supply chain for the processing and distribution of derivative products is necessary to complement the whole process.

Advocating for policies that promote incentives for environmentally friendly practices requires effective lobbying and collaboration with government agencies and non-governmental organisations. This collaboration would increase financial incentives, such as grants, subsidies, or tax breaks for farmers who adopt sustainable practices requires, by demonstrating the long-term benefits and cost-effectiveness of these practices. They should be accompanied by providing farmers with the necessary education and training to implement environmentally friendly practices.

BUSINESS MODEL CANVAS — Innovative culture: Kernza®

KEY PARTNERS

- Land Institute (seeds provider)
- Livestock and crop farmers
- Agricultural suppliers
- Post harvest processors
- Public administration and departments related to agriculture and the environment
- Research and innovation centres

KEY ACTIVITIES

- Field test and continuous improvement
- Contact with technicians/farm advisors in Kernza® culture
- Formation on Kernza® production
- Network with other practitioners
- Identify and solve possible administrative barriers

KEY RESOURCES

- Crop management and good practices document
- Access to technological centers working on Kernza® culture
- Logistic and technological management plan of cultivation process and final production
- Access to specific accessories to adapt agricultural machinery

VALUE PROPOSITIONS

- **Resilience to climate change environmental challenges (production stability)**
- **Reduction of the soil tillage (less fuel consumption)**
- **Reduction of erosion and improvement of soil structure (enhanced soil fertility)**
- **Improvement of nutrient retention (lower use of fertilizers)**
- **Carbon sequestration (ecosystem services and carbon credits)**
- **Multi-benefit production (long term stability of economic incomes)**

CUSTOMER RELATIONSHIPS

- Long-term commercial relationship (strategic alliances)
- Promotion of local agricultural market

CHANNELS

- Local supply B to C and B to B
- Online and offline marketing and promotion strategies

CUSTOMER SEGMENTS

- Livestock and crop farmers
- Associations (e.g., farmers cooperatives)
- Companies linked to agrifood activities with high-added value

RISKS AND CHALLENGES

- Culture implementation in specific climatic conditions
- Social perception and acceptance of innovative culture
- Administrative procedures
- Elaboration and promotion of derivate products (e.g., bread)
- Promotion of incentives for environmentally friendly agricultural practices

COST STRUCTURE

- CAPEX – on-farm implementation (common machinery acquisition, seeds)
- OPEX – fixed costs (fuel, common machinery rent, HR)

REVENUE STREAMS

- Sale of products (forage, cereal, others)
- Savings in ordinary costs (tillage, fertilizer, forage, etc.)
- Reduction of crop management and application costs
- Possible carbon credits

Figure 7. Business model canvas of olive trees with cereal crop in Catalonia Region, Spain

4. CONCLUSIONS

- Agroforestry systems in Spain, which integrate crops such as olive trees and cereals, represent a key solution to improving sustainability, climate resilience, and agricultural productivity, especially in regions with a high risk of desertification, affecting more than two-thirds of the territory. These systems are essential for soil and water conservation and allow for more efficient use of available resources. Predominant crops like olive trees, which cover 2.8 million hectares, and winter cereals, which span 5.35 million hectares, hold significant value both in the local and international markets, with exports reaching €5.0 billion and €6.4 billion, respectively, in 2022. The implementation of agroforestry systems that combine these crops could enhance economic stability for farmers by reducing their vulnerability to climatic, economic, and pest-related factors.

- In France, mixed farming systems offer significant economic and environmental advantages by allowing, amongst other benefits, crop diversification. This strategy optimizes the use of natural resources, such as water, and increases resilience against market fluctuations and adverse weather conditions. Additionally, mixed farming can help reverse the significant loss of biodiversity in the southern part of the country due to agricultural intensification and urbanization. European projects, such as MIXED and AGROMIX, are actively promoting the adoption of these systems, providing funding and research that fosters their development.

- In Algeria, peas (*Pisum sativum*) stand out as a promising crop in innovative agricultural systems due to their ability to adapt to Mediterranean drought conditions and improve soil fertility through nitrogen fixation. While less profitable than cereals like wheat, peas offer high nutritional value and can be used for both human and animal consumption, making them a valuable option for food security. Projects like CAMA are researching new pea varieties that offer higher yields and can be integrated into intercropping systems with barley, improving the overall profitability of the system.

- In Italy, agroforestry systems that combine olive trees and cereals not only improve soil health and water retention but also offer a sustainable solution to combat desertification in regions like the south of the country. Despite the growing trend toward high-density monocultures, a return to diversified agroforestry systems could increase the profitability of farms through the production of organic and sustainable products such as olive oil and flour. Additionally, the European Union's Common Agricultural Policy (CAP) actively supports these practices with subsidies, encouraging their adoption.

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Through research and innovation, agroforestry systems in Italy are also aligned with efforts to mitigate climate change by capturing carbon and enhancing biodiversity.

- Agroforestry systems in Egypt, focused on the cultivation of *Jatropha curcas* in combination with vegetables, provide an innovative strategy to maximize the use of limited resources such as water while improving agricultural productivity in marginal and desertified lands. Jatropha, with its ability to thrive in poor soils and be irrigated with treated wastewater, not only contributes to the rehabilitation of degraded areas but also offers significant economic potential through biofuel production. This approach allows farmers to diversify their incomes by generating products for both the food market and renewable energy, while the optimization of water use and soil improvement are key in a country where over 90% of the territory is desert and water scarcity is a critical challenge.

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5. REFERENCES

1. Abdel Wahaab, R. (2012). Wastewater Reuse in Egypt: Opportunities and Challenges. Holding Company for Water and Wastewater. Retrieved from https://kh.aquaenergyexpo.com/wp-content/uploads/2023/01/Wastewater-Reuse-in-Egypt-Opportunities-and-Challenges.pdf

2. AGROOF SCOP & INRAE. (n.d.). MIXED: Multi-actor and transdisciplinary development of efficient and resilient mixed farming and agroforestry systems in France. Retrieved from https://projects.au.dk/fileadmin/projects/mixed/PAs/New_PAs/MIXED_PAs_France_EN_2.pdf

3. Alhaithloul, H. A. S. (2021). Cultivation of the Multipurpose Tree, Jatropha curcas Using Recycled Water in Saudi Arabia: A forward-looking Study. Egypt. Acad. J. Biolog. Sci. (H. Botany), 12(2), 179–189. https://doi.org/10.21608/EAJBSH.2021.246506

4. Alherbawi, M., McKay, G., Mackey, H., Al-Ansari, T. (2021). Jatropha curcas for jet biofuel production: Current status and future prospects. Renewable and Sustainable Energy Reviews: 135, 110396. https://doi.org/10.1016/j.rser.2020.110396.

5. Araguás, N. (2017, January 31). Kernza, el alimento del futuro que puede salvar el planeta del cambio climático. S Moda, El País. Retrieved from https://elpais.com/smoda/placeres/kernza-el-supergrano-que-puede-salvar-el-planeta-del-cambio-climatico.html

6. Bernigaud, N., Bondeau, A., Guiot, J., Bertoncello, F., Ouriachi, M.-J., Bouby, L., Leveau, P., Bernard, L., & Isoardi, D. (2024). The impact of climate change on the agriculture and the economy of Southern Gaul: New perspectives of agent-based modelling. PLOS ONE, 19(3), e0298895. https://doi.org/10.1371/journal.pone.0298895

7. Bertomeu, M., Coello, J., Lawson, G., Armengot, L., Baiges, T., Borràs, G., Casadesús, A., Pascual, D., Pauné, F., Rull, J., Sánchez, L., & de Torre Barrio, B. (2024). Los sistemas agroforestales en el Plan Estratégico de la PAC Español: análisis y reflexiones. European Agroforestry Federation (EURAF). https://doi.org/10.5281/zenodo.11071948

8. CAMA Project. (n.d.). Nuevas selecciones de guisante para la costa de Argelia. Retrieved from http://www.camamed.eu/es/pdfs/Fact_Sheets/WP4-New_field_pea_selection_for_coastal_Algeria.pdf

9. Chiappini, S., Balestra, M., Galli, A., & Malinverni, E. S. (2023). Time series analysis of olive orchard coverage in the rural landscape: a case study of the Cartoceto Municipality. In 2023 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor). https://doi.org/10.1109/MetroAgriFor58484.2023.10424269

10. Eurostat. (2012, November). Agricultural census in France. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Agricultural_census_in_France&oldid=170352

11. Food and Agriculture Organization of the United Nations. (n.d.). FAOSTAT. Retrieved from https://www.fao.org/faostat/en/#home

PRIMA programme is supported by Horizon 2020, the European Union's Framework Programme for Research and innovation.

12. Gelski, J. (2022, April 11). Kernza, a grain used by General Mills, increases in acreage. Food Business News. Retrieved from https://www.foodbusinessnews.net/articles/21098-kernza-a-grain-used-by-general-mills-increases-in-acreage

13. Generalitat de Catalunya, Departament d'Agricultura, Ramaderia, Pesca i Alimentació. (2019). Dossier Tècnic nº 99: Los sistemas agroforestales. Retrieved from https://ruralcat.gencat.cat/documents/20181/7548318/Dossier%2BTecnic%2B99_ES_WEB.pdf

14. GEXSI. (2008). Global Market Study on Jatropha. Retrieved from http://www.ascension-publishing.com/BIZ/jatropha.pdf

15. Iglesias-García, R., Prats, E., Flores, F., Amri, M., Mikic, A., & Rubiales, D. (2017). Assessment of field pea (Pisum sativum L.) grain yield, aerial biomass and flowering date stability in Mediterranean environments. Crop and Pasture Science, 68(11), 915-923. https://doi.org/10.1071/CP16423

16. IndexMundi. (n.d.). Italia - Tierra utilizada para la producción de cereales. Retrieved from https://www.indexmundi.com/es/datos/italia/tierra-utilizada-para-la-producci%C3%B3n-de-cereales

17. Instituto de Estadística de Cataluña. (n.d.). Superficie agrícola. Principales productos. Provincias. Retrieved from https://www.idescat.cat/indicadors/?id=aec&n=15423&tema=agrar&lang=es

18. Instituto Geográfico Nacional. (s.f.). España en mapas. Una síntesis geográfica. Retrieved from https://educativo.ign.es/atlas-didactico/

19. Kamali, B., Rahemi Karizaki, A., Biabani, A., & Mollashahi, M. (2021). Analysis of the limiting factors of pea (Pisum sativum L.) yield in the Mediterranean conditions, case study: Gonbad Kavus. Retrieved from https://agris.fao.org/search/en/records/647480b379cbb2c2c1b8fbe8

20. Kenyon , S., & Vincent, B. (2017, October 16). Kernza: Perennial Crop with Perks. GROW Magazine. Retrieved from https://grow.cals.wisc.edu/departments/living-science/kernza-perennial-crop-with-perks

21. Kenyon, S., & Vincent, B. (2017, October 16). Kernza: Perennial Crop with Perks. GROW magazine University of Wiscounsin Madison. Retrieved from https://grow.cals.wisc.edu/departments/living-science/kernza-perennial-crop-with-perks

22. Khan, M. A. H., Mia, M. A. B., Quddus, M. A., Sarker, K. K., Rahman, M., Skalicky, M., Brestic, M., Gaber, A., Alsuhaibani, A. M., & Hossain, A. (2022). Salinity-Induced Physiological Changes in Pea (Pisum sativum L.): Germination Rate, Biomass Accumulation, Relative Water Content, Seedling Vigor and Salt Tolerance Index. Plants, 11(24), 3493. https://doi.org/10.3390/plants11243493

23. Law, E., & Ryan, M. (2019). Increasing the profitability of Kernza perennial wheat with intercropped grain legumes. Sustainable Agriculture Research and Education (SARE). Retrieved from https://projects.sare.org/project-reports/gne17-156/

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24. Meynard, J.-M., Charlier, A., Charrier, F., Fares, M., Le Bail, M., Magrini, M.-B., & Messéan, A. (2015). La diversification des cultures : comment la promouvoir ?. Ministère de l'Agriculture, de la Souveraineté alimentaire et de la Forêt. Retrieved from https://agriculture.gouv.fr/la-diversification-des-cultures-comment-la-promouvoir

25. Meynard, J.-M., Messéan, A., Charlier, A., Charrier, F., Fares, M., Le Bail, M., Magrini, M.-B., & Savini, I. (2013). Freins et leviers à la diversification des cultures : Étude au niveau des exploitations agricoles et des filières. INRAE. OCL, 20(4), D403. https://doi.org/10.1051/ocl/2013007

26. Ministère de la Transition Écologique et de la Cohésion des Territoires. (2023). Biodiversity loss. In France and the nine planetary boundaries. Retrieved from https://www.statistiques.developpement-durable.gouv.fr/edition-numerique/la-france-face-aux-neuf-limites-planetaires/en/5-biodiversity-loss

27. Ministère de l'Agriculture, de la Souveraineté alimentaire et de la Forêt. (2023, March 17). Infographie - Les fruits et légumes: une production arboricole, fruitière et maraîchère très diversifiée. Retrieved from https://agriculture.gouv.fr/infographie-les-fruits-et-legumes-une-production-arboricole-fruitiere-et-maraichere-tres

28. Ministerio de Agricultura, Pesca y Alimentación. (2019). Análisis de las Plantaciones de Olivar en España. https://www.mapa.gob.es/es/estadistica/temas/estadisticas-agrarias/olivar2019_tcm30-122331.pdf

29. Ministry of Agriculture and Rural Development. (2020). Algeria Agricultural Production: Vegetable: Dry Vegetables: Dry Peas. Retrieved from https://www.ceicdata.com/en/algeria/agricultural-production/agricultural-production-vegetable-dry-vegetables-dry-peas

30. Nwokolo, C. P. (2022). Evaluating the dynamics of consumer preference, perception, attitude and behaviour towards meat consumption in Awka, Anambra State. Food & Agribusiness Management, 3(1), 20–24. Retrieved from https://fabm.org.my/archive/1fabm2022/1fabm2022-20-24.pdf

31. Paris, P., Camilli, F., Rosati, A., Mantino, A., Mezzalira, G., Dalla Valle, C., Franca, A., Seddaiu, G., Pisanelli, A., Lauteri, M., Brunori, A., Re, G. A., Sanna, F., Ragaglini, G., Mele, M., Ferrario, V., & Burgess, P. J. (2019). What is the future for agroforestry in Italy? Agroforestry Systems, 93(6), 2243–2256. https://doi.org/10.1007/s10457-019-00346-y

32. Powers, S. E., & Thavarajah, D. (2019). Checking Agriculture's Pulse: Field Pea (Pisum sativum L.), Sustainability, and Phosphorus Use Efficiency. Frontiers in Plant Science, 10, 1489. https://doi.org/10.3389/fpls.2019.01489

33. Red ARAX. (2023). Dossier Cereal Invierno Red ARAX 2022-2023. Retrieved from https://www.redarax.com/wp-content/uploads/2023/10/DOSSIER-CEREAL-INVIERNO-RED-ARAX-2022-2023.pdf

34. Région Pays de la Loire. (n.d.). Les productions agricoles. Retrieved from https://www.paysdelaloire-eco.fr/ressources-analyses/agriculture/productions-agricoles/#poly

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PARTNERSHIP FOR RESEARCH AND INNOVATION
IN THE MEDITERRANEAN AREA

35. Roca i Farré, J. M. (2021, March 12). El cultivo del olivo en secano: nuevas técnicas y antecedentes. Agromillora. Retrieved from https://www.agromillora.com/olint/cultivo-del-olivo-en-secano/

36. RuralCat: Panificadora Alimentaria. (2022, September). Implantación, estudio y valorización de un nuevo cereal eco-sostenible. Retrieved from https://ruralcat.gencat.cat/documents/20181/117530/CAST%2BINICIAL%2Bpilot%2B2019_034_panificadora%2Balimentaria_21_09.pdf/48138634-a2a6-428e-98c8-2e8c06ceda02

37. Salvati, L., & Carlucci, M. (2021). Desertification risk fuels spatial polarization in affected and surrounding areas. Scientific Reports, 11, 24632. https://doi.org/10.1038/s41598-021-04638-1

38. Soliman, W. M., & He, X. (2015). The Potentials of Jatropha Plantations in Egypt: A Review. Modern Economy, 6(2), 190–200. https://doi.org/10.4236/me.2015.62016

39. The Land Institute. (2020, December 3). FFAR Funds the Future of Sustainable Perennial Crops. Retrieved from https://landinstitute.org/ffar-funds-the-future-of-sustainable-perennial-crops/

40. Trading Economics. (2024). France - Agricultural Land (% of Land Area). Retrieved from https://tradingeconomics.com/france/agricultural-land-percent-of-land-area-wb-data.html

6. ANNEX

Some examples searched additional to the study sites were described for each country

6.1. ALGERIA

6.1.1. Case study: CAMA project

Business model

In this case, the business model proposed is not based on a company but on a research project, CAMA, part of the TRANSITION project which looks for innovative resilient farming systems in Mediterranean environments. Within the framework of this project, 10 varieties of Pisum sativum, previously studied and selected by INRA, were analyzed in Algeria, under pure stand and mixed stand with barley during 2021 and 2022. The study showed that, on average, the mixtures had a slightly higher total grain yield than

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the barley pure stand. Additionally, it is noteworthy that the evaluated population was the highest-yielding pea material in the mixed stand, reaching a proportion of nearly 30% in the mixture, which allowed for a balance between the crops and produced almost three times more peas than the top-yielding pea line in the pure stand. An example of a business model for an agri-food system as described in the study, could be the following: The target customers could include farmers and agricultural cooperatives looking to improve yields through intercropping, and food industries that process peas for plant-based products. Barley could be sold locally or to food processing companies, while peas could be marketed for human consumption or animal feed. Distribution channels could involve direct sales to local markets and exports to countries with high demand for barley and peas. Revenue streams could come from harvest sales and key resources might include suitable farmland, technology, and expertise in intercropping. The cost structure could involve production costs, training investments, and logistics.

Value proposition

The potential value proposition for a business that involves the described business model could be the following. The business model could offer a mixed-cropping solution that optimizes total yields (pea + barley) compared to pure stands, improving profitability and sustainability for farmers. By combining pea and barley production, this model maximizes land use and reduces the need for synthetic fertilizers, thanks to the pea's nitrogen-fixing abilities that also benefit barley growth. Additionally, peas provide a source of plant-based protein, which is increasingly in demand by the food industry, contributing to the growing trend of plant-based products.

6.1.2. Case study: Ferme Pilote Laghmara Rabah

Business model

The Ferme Pilote Laghmara Rabah operates as a specialized agricultural entity under a public sector framework, with a capital of approximately 2.4 million Algerian dinars (16.560 EUR). The farm is involved in a variety of agricultural activities, including the cultivation of crops, soil preparation, fertilization, and pest control services, using both conventional and aerial methods. It also engages in the raising of domestic animals such as cattle and sheep.

The farm is part of the larger Algerian initiative to develop agriculture through pilot farms designed to serve as models for modern agricultural practices. The goal is to improve productivity and reduce reliance on imports, especially in vital sectors like vegetable oils.

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One of the key crops studied at this farm is rapeseed, with research showing promising yields under semi-arid conditions.

Although no public information has been found regarding pea cultivation in these farms, key stakeholders in Argelia have shared that this is a crop that is being investigated to improve productivity, promote market diversification and endorse biodiversity.

Value proposition

It is a pilot farm designed to enhance Algeria's agricultural sector by introducing innovative practices and increasing productivity. These farms are intended to be models of modern agricultural techniques, aiming to strengthen food security and improve the overall agricultural framework in the country. By focusing on nontraditional crops and sustainable practices, it’s positioned to demonstrate the viability of alternative agricultural models that can be replicated across the region.

Moreover, these pilot farms aim to foster partnerships with both national and international stakeholders, which can lead to fresh investments, research advancements, and efficient production methods. This collaborative approach is crucial in revitalizing the sector, especially considering the current challenges faced by existing farms, such as financial mismanagement and inefficient supply chains.

6.2. EGYPT

6.2.1. Case study: SEKEM Group

Business model

SEKEM's business model is built around sustainable development that integrates economic, ecological, and social value creation. By applying agroforestry systems and cultivating various vegetables in the same field, SEKEM has transformed desert land into productive agricultural fields, producing organic foods, textiles, and phytopharmaceuticals.

SEKEM generates revenue primarily from the sale of organic products both locally and internationally while maintaining key partnerships with financial institutions like Triodos Bank and Oikocredit to support long-term projects.

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By incorporating the cultivation of *Jatropha curcas*, the farms participating in this project could enhance the productivity of their fields. Jatropha is a tree known for its drought resistance, fast growth, and ability to prosper in poor soil conditions. Treated wastewater can be used to cultivate Jatropha on marginal desert land, which not only aids in the rehabilitation of degraded areas but also addresses environmental concerns through water reuse. Additionally, Jatropha offers promising prospects for biodiesel production, creating further economic opportunities for the farmers.

Value proposition

Its value proposition extends beyond products to environmental and social impact. SEKEM's holistic approach has contributed to significant environmental improvements, job creation, and increased community well- being over the past 40 years.

The company ensures long-term contracts and fair-trade practices with local farmers, providing stability and fair pricing. In addition to agriculture and manufacturing, SEKEM invests heavily in social initiatives, such as running schools, vocational training centers, and healthcare clinics for its employees and surrounding communities. Through these efforts, SEKEM promotes ecological restoration, community development, and fair economic participation.

6.2.2. Case study: Governmental Jatropha farm

Business model

In 2018, the governor of the New Valley (Egypt) allocated approximately 840 hectares for the cultivation of non-traditional species through agroforestry systems. Among the selected crops are *Jatropha curcas* and jojoba, both of which possess significant economic value due to their industrial applications. The jojoba plant is well-known for its contributions to the cosmetic industry. The oil extracted from its seeds is in demand in beauty products for skin and hair care, due to its exceptional moisturizing and protective properties. On the other hand, the jatropha tree provides oil which demonstrates promising potential for biodiesel production.

This business model could aim to develop products for both the beauty sector and the energy industry. The crops will be sold to companies that manufacture beauty products or produce fuels, such as jet oils. Additionally, the by-products, including seed husks from jojoba and wood from jatropha trees, can be commercialized for producing organic fertilizers or repurposed as biomass for energy generation. This project represents a

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unique opportunity to diversify agriculture in the Egyptian desert, targeting key industrial markets and creating revenue streams from multiple sectors.

Value proposition

In addition to enhancing the economic benefits of cultivation in the New Valley, these farms aim to establish a more sustainable agricultural system by utilizing groundwater and wastewater for irrigation. This approach reflects a more efficient use of water resources in the arid New Valley region.

Furthermore, the biodiesel produced from the jatropha tree serves as a vital renewable fuel source, playing a key role in facilitating the transition to cleaner energy practices.

6.3. FRANCE

6.3.1. Case study: Non-Timber Forest Products

Due to their experience working with Non-Timber Forest Products AFAF provided valuable information regarding this system in France as an example, as they did not follow up any field site in the frame of the project.

Business model

Non-Timber Forest Products (NTFPs) encompass a diverse array of natural resources harvested from forests, excluding timber or wood-based products. In the Mediterranean region of France, these products hold significant ecological, economic, and cultural value, with forests offering edible plants, medicinal herbs, aromatic species, mushrooms, resins, and fibers. Traditionally harvested by local communities, NTFPs have played a crucial role in rural livelihoods for centuries.

In southern France, the collection of NTFPs is deeply rooted in traditional knowledge and practices. Cork oak forests provide high-quality cork, while aromatic plants such as thyme, rosemary, and lavender are essential to local markets and the global perfume industry. Additionally, prized wild mushrooms like truffles and chanterelles contribute to the region’s renowned gastronomy.

Beyond their commercial significance, NTFPs promote sustainable forest management by providing an alternative to timber extraction while helping to preserve biodiversity and

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ecological balance. However, increasing demand and climate change pressures make sustainable management essential to prevent overexploitation.

When combined with forest grazing, the collection of NTFPs can further enhance ecological, economic, and social benefits. This integrated approach supports biodiversity, strengthens rural economies, and encourages sustainable land use practices. The business model description will explore the advantages of combining both practices to maximize their potential benefits.

Value propositions

1. Optimization of land use and increase in Light-enhance respiration (LER)
2. Complementarity of the productions
3. Diversifies economic opportunities
4. Reduction of forest fire
5. Introduction of conservative techniques of soil and water (no-tillage and simplified tillage)
6. Reduction of erosion and improvement of soil structure

Integrating forest grazing with the collection of Non-Timber Forest Products (NTFPs) offers a unique, sustainable, and mutually beneficial approach to land management. This combined strategy enhances biodiversity, provides economic opportunities, supports cultural heritage, and helps ensure long-term ecological health. By blending livestock grazing with the sustainable harvest of wild plants, mushrooms, fruits, and resins, this model creates a holistic framework for forest and land stewardship that benefits local communities, economies, and the environment.

Key partners

1. Farmers
2. Foresters
3. Agricultural and forestry suppliers Customers
4. Advice and support organizations
5. Research and innovation center

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Combining forest grazing with the collection of NTFPs is a collaborative effort that requires the engagement of diverse stakeholders. Effective partnerships between local communities, government agencies, environmental organizations, businesses, and research institutions are essential for promoting sustainable land use, enhancing biodiversity, and ensuring that these models can scale and thrive in the long term. Each partner brings unique resources, knowledge, and expertise that contributes to the overall success of this integrated approach to forest and land management.

Key activities

1. Wood, meat and non-timber forest production
2. Formation on wood production and forest grazing
3. Contact with technicians/farm and forest advisor
4. Complementary activity

The key issue is the connection between the forestry and agricultural sectors. By developing such models, we're also supporting interaction between two complementary sectors. The result will be mutual benefits for both sectors.

What's more, these complementary activities provide a diversity of income streams for the various economic players. These new economic activities are also adapted to climate change adaptation for farmers and foresters.

Key resources

1. Land (with a good soil management -> careful about overgrazing)
2. Appropriate and ergonomic design of the parcel
3. Forest and pasture management

When combined, forest and pasture management ensure that grazing activities do not harm the forest ecosystem and that forest resources are harvested sustainably. It helps in creating a balanced environment where both livestock and forest products can thrive, benefiting local communities economically and maintaining ecological health.

Customer relationships

1. Regular customers during the four seasons

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2. Intermittent customers to mobilize when there is an excess in production

Since there is an outlet for the marketing of field pea grains, in this case, the CCLS or the livestock feed manufacturing units. The sale of fodder can also be done to landless breeders or breeders with reduced fodder areas. The adoption of this crop makes it possible to open other niches for livestock development since the market for livestock products is promising given that self-sufficiency in these products has not yet been achieved in addition to galloping population growth. The development of this crop will allow the entire agricultural and rural community to understand its economic, social, and ecological advantages.

Customer segments

1. Individual
2. Organic stores
3. Sawmills
4. Restaurants

The clientele for products stemming from forest grazing and NTFP collection spans a broad range of sectors; local consumers, organic stores, sawmills and restaurants. The key is to understand the specific product being offered (whether it's food, health products, or cosmetics) and target the market that values sustainability, ethical sourcing, and high-quality, natural products. With the growing demand for sustainable and locally sourced goods, there is significant potential for these products to reach diverse and profitable markets.

Channels

1. Local supply B to C and B to B

Cost structure

1. CAPEX – on-farm/forest implementation (seeds, inputs, feeds, labour, common machinery costs)
2. OPEX – diverse expenses (mushrooms material, fuel, machinery rent, electricity, fences, small tools, commercialization packaging)

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These are the only costs, for taxes, farmers are exempt from taxes in France. The training programs for workers and farmers are supported by the government, agricultural chambers and training schools and companies.

Revenue streams

1. Sale of products (wood, meat, fruits, mushrooms, syrups, resins, nuts, spices and eventually transformed products)
2. Savings in ordinary costs (no tillage, no hay supply, less irrigation)
3. Other activity (eco-tourism)

Combining forest grazing with the collection of Non-Timber Forest Products (NTFPs) offers multiple benefits, both economic and environmental. The sale of products such as wood, meat, fruits, mushrooms, syrups, resins, nuts, spices, and even transformed products like essential oils or gourmet food items provides a diverse and profitable income stream. Additionally, this integrated approach leads to savings in ordinary farming costs, such as eliminating the need for tillage, reducing hay supply, and requiring less irrigation, which ultimately lowers operational expenses. Furthermore, this model can support additional revenue through eco-tourism activities, offering experiences like foraging tours or nature-based visits, further diversifying income opportunities for local communities.

Risks and challenges

1. Ensure a secured commercialization of the products
2. Transportation facilities can be a challenge for the systems implemented in mountain areas
3. Regulation and administrative complexity – need to have a strong understanding about what is possible

Implementing a new business model is always fraught with risks and opportunities. These risks can be seen as disincentives to launching a diversified business on the part of industry players. Regulation and administrative complexity can pose challenges for implementing sustainable forest grazing and NTFP collection, requiring a deep understanding of legal frameworks to navigate what is permissible. Additionally, ensuring secure and reliable commercialization of the products is essential to maintain a stable market presence. In mountain areas, transportation facilities can also be a significant

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hurdle, making it difficult to move products efficiently and cost-effectively, which may impact the overall viability of the system.

As a conclusion, combining forest grazing with the collection of Non-Timber Forest Products (NTFPs) presents significant economic opportunities by diversifying income streams and promoting sustainable land use. This integrated approach allows communities to generate revenue from a wide range of products, including wood, livestock, fruits, mushrooms, herbs, resins, and even transformed goods like essential oils or gourmet food items. In addition to direct sales, the model reduces operational costs, such as the need for tillage, hay supply, and irrigation, leading to savings that enhance profitability. Furthermore, this system supports eco-tourism ventures, creating additional revenue through nature-based experiences. While challenges like regulatory complexities, secure commercialization, and transportation logistics exist, the overall economic potential is substantial, offering a sustainable pathway for rural development and long-term forest management.

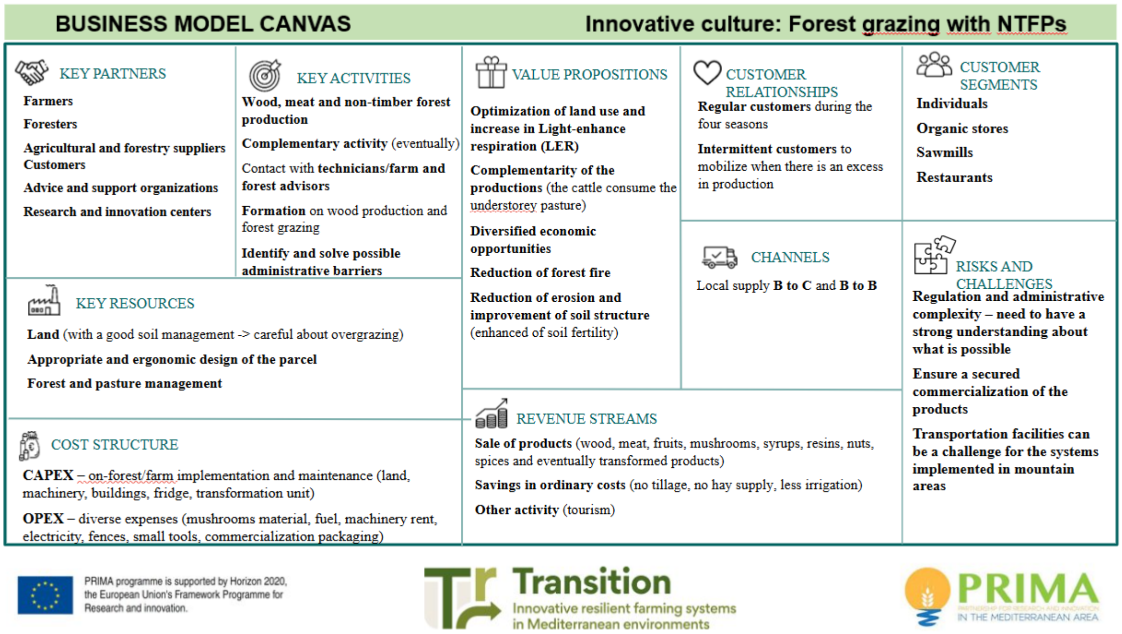

Figure Annex -1. Business model of combining forest grazing with the collection of Non-Timber Forest Products (NTFPs) in PACA and Occitanie regions, Francee.

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6.3.2. Case study: Domaine de Mirabeau

Business model

The business model of this company is based on the concept of “farm to table”, they grow their own products and sell them directly to consumers. The company is based in Fabrègues, Montpellier, France, having 15-50 employees. This sale takes place both on the farm itself and at a flea market in the centre of Montpellier. The main offer includes a catalogue of baskets of locally grown fruits and vegetables, with prices ranging from 6 to 40 EUR. In addition, the farm offers annual memberships, providing regular access to its products. To expand its offerings, the farm partners with other local small farmers, organizing flea markets where products such as honey, cheeses and other artisanal foods are marketed. These events help create a sense of community and support other producers in the region.

In terms of communication, the main channel is their website, although they also have a presence on Facebook and collaborate with various institutional partners to give visibility to their initiative.

A distinctive aspect of this farm is its focus on agroecology and agroforestry, practices that have been recognized by CEN (Conservatoire des Espaces Naturels). The farm manages a 4-hectare plot with mixed farming systems on the Domaine de Mirabeau, where they are implementing projects to enhance biodiversity.

Value proposition

The company is dedicated to the production of organic fruits and vegetables, with a focus on social integration of people in precarious situations, helping them to access employment through agricultural work. Its model promotes biodiversity through mixed, resilient and environmentally friendly agriculture, contributing to the regeneration of local ecosystems. Another point of value is its direct sales in short circuits, which allows quick and efficient access to fresh, quality food. In addition, the company operates under the principles of the circular economy, making the most of natural resources. For example, it uses manure to improve crops and relies on bees for pollination, which strengthens its self-sufficiency and sustainability.

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6.4. ITALY

In the case of Italy it was not possible to find case studies external of the Transition project experimental plots

6.5. SPAIN

6.5.1. Case study: Oli Les Cabanes

Business model

The business model of Oli Les Cabanes is based on the production and sale of extra virgin olive oil, from Arbequina olives, with D.O.P. Les Garrigues certification of origin. The company is located in Lleida, Catalunya, Spain, with an annual turnover of 3.325.149€ and less than 15 employees. Key activities include the production, direct sale, and distribution of oil. Their key resources include farmland and the infrastructure for oil production. As communication channels, they use their website and social media (Facebook, Instagram, Twitter and, YouTube). Their clients include individuals, as they have an online store, and professionals, as they have distribution channels to retailers. Although their main source of income is the sale of oil, they also carry out guided tours of the cooperative and oil tastings as a strategy for customer outreach and transparency.

They have the certification of integral production, which promotes the basis of an agroforestry system: the use of biodiversity, flora and, fauna in the environment or the minimization of water consumption, among others. The company's olive trees are located in an agroforestry system, together with pine trees, bushes, aromatic plants and cereal crops. It has not been identified whether they profit from these other crops, however, they emphasize as a value proposition that this diverse ecosystem gives olive oil unique characteristics.

Value proposition

The value proposition of Oli Les Cabanes is based on the production of 100% natural extra virgin olive oil, free from additives or preservatives, made from Arbequina olives. The cultivation takes place in Les Garrigues, a diverse agricultural environment that includes pines, cereals, and aromatic plants. This ecosystem imparts specific and unique characteristics to the oil, distinguishing it from oils produced in other regions. The

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company emphasizes the natural environment as a key factor in the oil’s quality and aromatic profile.

6.5.2. Case study: Panificadora Alimentaria

Business model

In 2020, the BETA technology center, in collaboration with Panificadora Alimentaria and Murucuc, initiated a project in Catalonia to evaluate the cultivation of Kernza. Panificadora Alimentaria is dedicated to the production of flours, milling products, pastas, and other derivatives, while Murucuc specializes in pig farming and also cultivates cereals to feed its animals.

The project aimed to analyse the productive potential of Kernza under the climatic conditions of Catalonia, as well as the quality of its grain for the production of flours intended for human consumption. It also sought to study its environmental impact by evaluating the root system's capacity to sequester carbon and reduce nitrate leaching into groundwater. Additionally, the project investigated technologies for processing Kernza flour and its incorporation into various agri-food products.

The results showed a significant increase in forage biomass production in the second year, although grain production was low due to the lack of suitable machinery. The crop's root system demonstrated a high potential for water and nutrient absorption in areas inaccessible to other crops, making it promising for use in soils with limitations.

Value proposition

On one hand, Panificadora Alimentaria aims to diversify its crops by exploring alternatives to wheat and barley, experimenting with new cereals that offer a unique identity, and promoting product innovation. On the other hand, Murucuc seeks to use Kernza as a supplementary feed for their livestock, improve the soil health of their cereal fields, and reduce long-term land management costs.

Following the project, it was concluded that Kernza is a viable option as a forage crop in Catalonia, especially due to its perennial ability to regrow each year and its potential for carbon sequestration and nitrate leaching reduction. However, the small grain size and the presence of a hull make flour production challenging. Therefore, it is recommended to blend Kernza flour with other flours to maximize its nutritional and organoleptic

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benefits. Further research is suggested to improve agricultural management and explore commercial applications of this crop.

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