Deliverable D3.1

Results from the case-studies of the cropping systems

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Executive summary

The MIDAS project promotes sustainable bioeconomy practices by growing industrial crops on marginal agricultural lands. The underutilized lands provide an opportunity for feedstock production with reduced risks of indirect land use change (iLUC) and minimal environmental impact.

Within the WP3, T3.2 focuses on the design and evaluation of farm-scale (demo fields) innovative intercropping systems (case studies), combining annual, perennial and forestry species, suitable for marginal lands. Each case study examines site-specific conditions, including soil characteristics, climate, and specific marginality factors based on location, as well as the selected crop types and agronomic techniques. The present deliverable shows the preliminary results collected in the first twogrowing seasons (2022-23 and 2023-24), providing an overview of crop performance, yield results, and adaptive strategies used to address challenges such as weed competition, water scarcity, and soil limitations.

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1. Introduction

The main objective of MIDAS is to develop low-iLUC risk industrial crops on marginal agricultural lands across Europe. Marginal land covers approximately 60 Mha in the EU and UK (Von Cossel et al., 2019) and represents a significant opportunity to produce raw materials, thereby supporting the development of a sustainable bioeconomy.

The Task 3.2 (*set up of local innovative cropping systems suited for marginal land*) is dedicated to the creation and evaluation of case studies (CS) at farm scale (field trials) on intercropping systems combining annual and perennial herbaceous crops (subtask 3.2.1, *Set up of local innovative cropping systems suited for marginal* land), or intercropping systems comparing annual herbaceous crops and short-rotation woody crops (agroforestry) (subtask 3.2.2, *Intercropping between short rotation forestry and annual crops*). Results will also contribute to comprehensive socio-economic, environmental, and biodiversity assessments, ultimately supporting the advancement of sustainable practices in the bio-based industry. Table 1 summarizes the list of established case-studies in the different Countries.

Table 1 Case studies implemented in the WP3 of the MIDAS project.

ID	Partner	Country	Marginality contraints	Perennial crops	Annual crops
1	UNIBO	Italy	Sand: >60%; Slope: 8-15%	Miscanthus	Crambe, hemp, safflower
2	UNICT	Italy	Slope: >15%; Precipitation/potential evapotranspiration <0.5	Cardoon	Safflower, hemp, castor
3	NVMT	Italy	Loam: >50%; pH: 8	Cardoon	Safflower, castor
4	CRES/AUA	Greece	Sand: >70%: Slope:>12%	Miscanthus, switchgrass, lavender, poplar	Castor, safflower, sorghum, crambe
5	UHOH	Germany	Shallow soil: < 35 cm; Stones: >15%; Clay: >40%	Miscanthus	Crambe, hemp, melilot
6	IFCV	Serbia	Excessive humidity; Salinity; High clay content	Miscanthus	Safflower, white mustard, crambe, sorghum
7	CIEMAT	Spain	Sand: >75%; Stones: >15%; Dryness	Elm, lavender	Crambe, safflower, melilot
8	ITAP	Spain	Sand: >70%; Dryness; Gypsiferous	Guayule	Safflower, Hemp
9	SOLTUB	Hungary	Slope: 5-10%; High sand content	Miscanthus, poplar	Carinata, sorghum, hemp
10	CZCHEMP	Czech Republic	Slope: 5-10%; High clay content: 15-20%;	Miscanthus	Sorghum,safflower,hemp
11	ECF	Poland	High sand content; Dryness	Poplar	Grass mixture (cocksfoot, meadow fescue, bromus)
12	GUATECS	France	Very high risk of asphyxia; Low structural stability; Poor biological activity	Guayule	Safflower, hemp
13	CREA	Italy	Dryness	Poplar	Crambe, safflower, sorghum

The CS are thought to mimic real farm conditions providing reliable outcomes to assess social, economic and environmental impacts. The present deliverable aims to provide a comprehensive framework of current status and results of two first years across Europe.

1.1 Sub-task 3.2.1 Intercropping between annual and perennial crops

1.1.1 Case study #1: UNIBO (University of Bologna)

The case study of UNIBO is located in Ozzano dell'Emilia (Bologna, Italy, Figure 1). The field has characterised by a sand content > 60% and an average slope of 12%. Three annual crops: crambe (*Crambe abyssinica* Hochst. ex R.E. Fr var. Galactica), industrial hemp (*Cannabis sativa* L. var. Futura 83), and safflower (*Carthamus tinctorius* L var. CW99OL) are intercropped with the perennial biomass crop miscanthus (*Miscanthus x giganteus*) under organic farming and without irrigation. Crops were established in large strips of about 1000 m².

Figure 1 View of UNIBO trial (Credits: ETA Florence)

The seedbed was prepared in autumn by plowing (0.35 m) and subsequent harrowing (0.2 m). An organicfertilizer (Guanito) was applied in pre-sowing at 500 kg ha-1. In both growing seasons, all the annual crops were sown with a mechanical seeder commonly adopted for cereals. The seed rate was 28 kg ha-1 for safflower, 45 kg ha-1 for hemp and 18 kg ha-1 for crambe. Miscanthus was planted using rhizomes at the density of 1.5 rhizomes m-2. Planting, sowing and harvest dates are reported in Table 2.

Table 2 – Planting, sowing and harvesting of annual crops and miscanthus.

Growing periods	Crop	Sowing date	Harvest date
2022-23	Safflower	06/02/2023	02/08/2023
	Crambe	09/03/2023	02/08/2023
	Hemp	23/03/2023	05/07/2023
	Miscanthus x giganteus	05/04/2023	
2023-24	Safflower	30/01/2024	30/7/2024
	Crambe	25/03/2024	02/7/2024
	Hemp	29/03/2024	07/08/2024
	Miscanthus x giganteus	02/04/2024	

The first growing season was characterized by unusual weather condition, with a dry winter/early spring followed by an intense rainfall event of about 300 mm in just 15 days (02-17 May). Despite the uneven rainfall distribution, a significant weeds pressure due to the organic farming system, seed yield was rather successfully: 2.0 and 1.7 Mg ha-1 for crambe and safflower, respectively. As for hemp, the above ground dry biomass was 15.2 Mg ha-1. Miscanthus has not been harvested yet as the establishment failed and was re-planted in early April 2024.

In the second growing season (23-2024), the annual crops were rotated: crambe followed hemp, hemp followed safflower, and safflower followed crambe. This season was even driest than in the previous year with only 280 mm of rainfall from late January to August. Among the oilseed crops, safflower suffered the greatest competition by weeds, that considerably contributed to seed yield reduction (30% lower than previous year). Crambe performed better than safflower, producing 1.9 Mg ha-1 of seeds, likely benefiting from the rotation with hemp (previous crop), that is broadly known for effectively contrasting weeds (Adesina et al., 2020). Hemp biomass was also higher in the second year (16.9 Mg (DM)/ha).

In summary, the two growing seasons presented very different weather conditions, with the first season characterized by a heavy rainfall event in May 2023, while the second growing season being significantly drier. Nevertheless, the annual crops, particularly crambe and hemp, showed promising yields in both years, while safflower was more damaged by weed competition, especially in the second season. The establishment of miscanthus failed in the first year and it has been replanted in April 2024.

1.1.2 Case study #2: UNICT (University of Catania)

The experimental site is located in Agira (Enna, Italy, Figure 2) and covers an area of 0.5 ha. The marginal conditions are given by soil slope greater than 15% and poor water availability, particularly in the spring-summer period. The crops used in the intercropping systems are, among the annuals, castor (*Ricinus communis* L. var. C1012), hemp (*Cannabis sativa* L. var. Tygre) and safflower, while the perennial is cardoon (*Cynara cardunculus* L. var. Trinaseed).

Figure 2 a) Drone photo of all the crops; b) focus of safflower strip.

Seedbed preparation was carried out in October 2023 through plowing (0.3 m depth) followed by harrowing and sowing (mechanical seeder Terradonis). Regarding fertilization, two mineral fertiliz- ers (superphosphate and ammonium sulphate) were applied at rates of 80 and 30 kg ha-1, respec- tively. The seed rate was 15 kg ha-1 for safflower, 40 kg ha-1 for hemp, 18 kg ha-1 for castor and 6.75 kg ha-1 for cardoon. All the sowing dates are reported in Table 3; only safflower was harvested.

Table 3 Sowing and harvest date for annual and perennial crops.

Growing periods	Crop	Sowing date	Harvest date
2023-24	Safflower	30/11/2023	24/7/2024
	Castor	15/04/2024	Not applicable
	Hemp	15/04/2024	Not applicable
	Cardoon	28/11/2023	Not applicable

Only the number of plants and number of flower heads per m^2 of cardoon were determined. Be- cause of the severe drought the early growth of castor and hemp failed. Cardoon benefited from the late rainfall in August and it will be harvested shortly after the winter season. In the next growing season, the annual crops will be rotated. The next sowing for safflower has been planned to occur in November 2024. Overall, the autumn crops seem the most feasible for this specific site as they can benefit from the autumn-winter rainfall. Considering this aspect, the project consortium agreedto substitute Castor with Crambe for the next season. Regarding hemp, the idea is to sow it earlier than last year to anticipate the cycle.

1.1.3 Case study #3: NVMT (Novamont)

In Fiumicino (Rome, Italy), two Case Studies in experimental sites with similar soil characteristics (high loam content >50% and pH 8.0 that make this site marginal) have been established to conduct two trials in the growing season 2023/24. In an area of 16 hectares (Figure 3) an intercropping trial of safflower and cardoon was implemented. The same trial has been used by CREA for harvesting tests (Task 3.5 - *Innovative harvesting solutions on selected non-edible crops*). In another 1-ha field, a trial was conducted using pelargonic acid as a pre-harvest desiccant on castor bean. In this trial, castor bean (var. C1016) was not intercropped due to the delay in the delivery of safflower and cardoon seeds.

Figure 3 Location of intercropping trial (Fiumicino, Rome).

The cardoon had already been established five years before the trial. The seedbed preparation for annual crop sowing was carried out in late October 2023, starting with plowing to a depth of 0.3 m,followed by harrowing before sowing. The safflower crop was sown with mechanical seeder and thecastor bean with a pneumatic seed drill. The seed rate was 24 kg ha^{-1} for safflower, 8 plants m^{-2} forcardoon and 8 plants m^{-2} for castor. All the sowing and harvest date are reported in the subsequentTable 4.

Table 4 Sowing and harvesting of Safflower, Cardoon and Castor.

Growing periods	Crop	Sowing date	Harvest date
2023-24	Safflower	30/10/2023	06/08/2024
	Cardoon	5 years plantation	06/08/2024
	Castor	06/06/2024	Not applicable

The growing season was characterized by unusual weather condition, with a dry winter followed by increased rainfall in the early spring. The total rainfall from sowing to harvesting was 369 mm, with periods of higher precipitation in February and March 2024 (168 mm). Despite these weather conditions and marginality constrain, the intercropping trial showed a good establishment of cardoon and safflower but there was significant growth competition between the crops. The harvest was performed on 6 august 2024, using a New Holland L524 combine harvester equipped with cereal header. Both cardoon and safflower were harvested on the same day without separating the seedsof the two crops. Total seed yield of the intercropping system was 2.8 Mg ha^{-1}. Prior to harvesting, three 1 m² samples were randomly harvested for quantitative and qualitative determinations (still pending). As for the castor bean trial, the delay in seeding, the absence of rainfall from July 2024, and high temperatures caused the death of the plants after germination, making mechanical harvesting impossible. However, this trial was used in connection with Task 2.2.3 "*Circular use of MIDASproducts on marginal land*" and Task 4.1.7 “*Bio-based phytosanitary products*” by testing pelargonicacid in pre-harvest.

Overall, the intercropping system (cardoon and safflower) showed a good adaptability to marginal conditions under a low input agronomic management. A more adequate ratio between the two crops should be likely identified to reduce competition between them.

1.1.4 Case study #4: CRES/AUA (Centre for Renewable Energy / Agricultural University of Athens

Two case studies have been established in Greece: the first one (site 1) is located in Lexaina (Ilia) covering an area of 0.3 ha. This experimental site is characterized by a high sand content (>68%), a basic pH of 8.1, and low organic matter content that make it a marginal land. In this site, an inter-cropping trial with three annual crops (sorghum, safflower and castor) and the perennial crop mis-canthus has been organized (Fig. 4).

Figure 4 View of Lexaina trial (from left to right: miscanthus, sorghum, safflower, castor been, miscanthus).

Seed yields of safflower were 1.2 and 1.5 Mg ha-1 in 2023 and 2024, respectively. Similarly, castor bean yielded 1.7 Mg ha-1 (2023) and 1.9 Mg ha-1 (2024). For sorghum, the dry matter yield in 2023 reached 22.0 Mg ha-1, while in 2024 it has been planned to harvest in early November. Miscanthus was not harvested in the establishment year; the first harvest has been planned by the end of 2024.

The second experimental site (site 2) is situated in Vonitsa (Aitoakarnania, Greece, Figure 5) also covering 0.3 ha. The experimental field is characterized by a slope greater than 12% and poor drainage during winterand summer. In this second site, the annual crops remain the same as in the first site, while the perennial crop is switchgrass (*Panicum virgatum* L.).

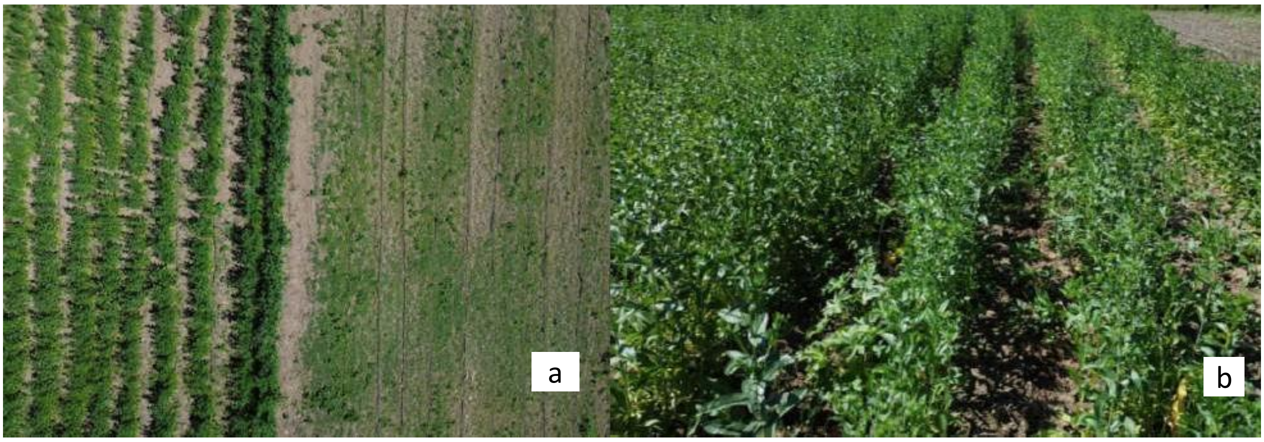

Figure 5 View of Vonitsa trial a) sorghum, switchgrass, b) safflower.

During the first growing season, the establishment of switchgrass faced challenges, resulting in poor growth. To address this, the crop was re-established in 2024. As for castor bean, seed yield increased from 1.6 Mg ha^{-1} in 2023 to 1.8 Mg ha^{-1} in 2024.

Similarly, safflower yields improved from 1.4 Mg ha^{-1} in 2023 to 1.7 Mg ha^{-1} in 2024. Sorghum was notably productive in 2023 reaching 23.1 Mg ha^{-1} of dry biomass.

In February 2024, a new crop trial was initiated in Nea Gonia, northern Greece, focusing on one perennial crop, lavender, and two annual crops, safflower and crambe (Figure 6). The establishment of lavender took place at the end of February, followed shortly by the sowing of safflower and crambe. However, due to the drought conditions during spring, crambe encountered significant challenges in establishing successfully.

Figure 6 View of Nea Gonia trial.

1.1.5 Case study #5: UHOH (University of Hohenheim)

The experimental site is located in Hohenheim (Germany, Figure 7) and covers an area of 0.5 ha. The site is characterized by shallow soil (0.35 m), high stone content (>15%), and high clay content (>40%). The crop used in the intercropping system are, among the annuals, crambe, hemp and melilot (*Melilotus officinalis* (L.) Lam.), while the perennial is miscanthus.

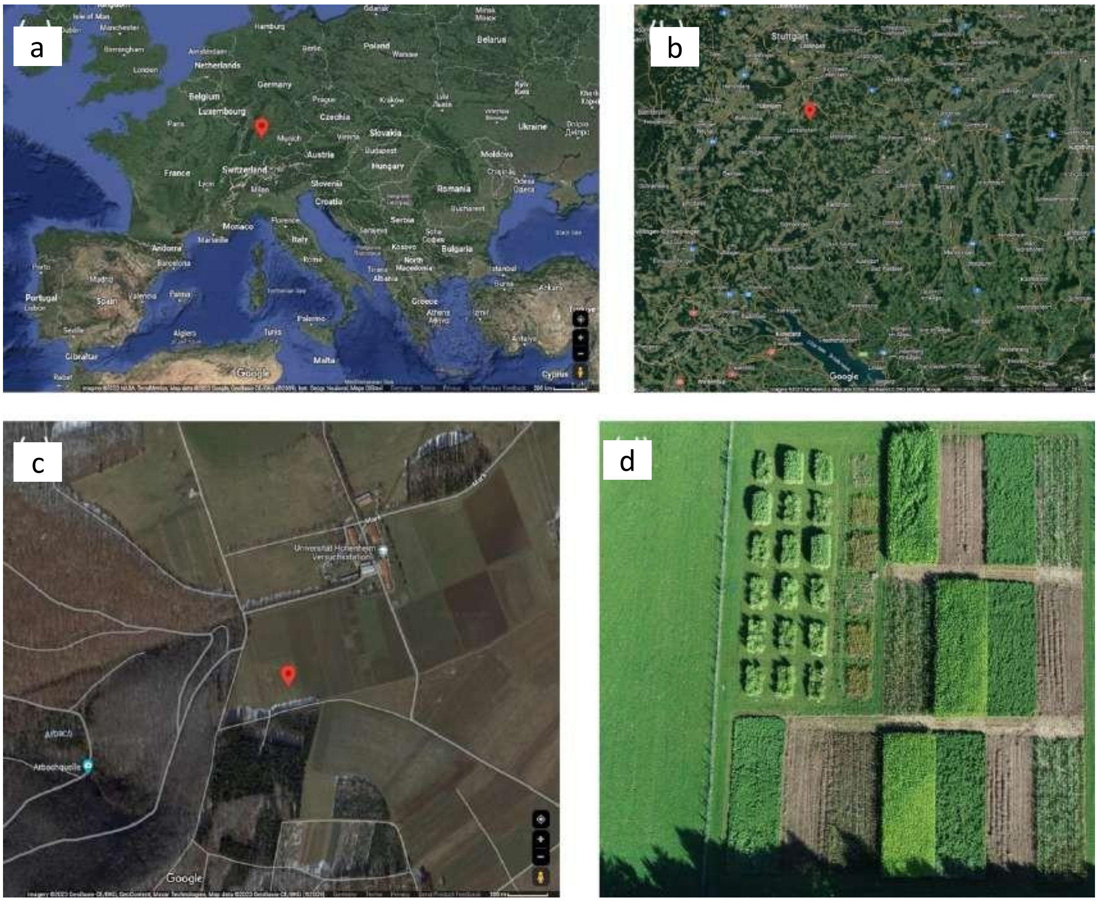

Figure 7 Location of the field trial of UHOH (adapted from Loew et al., 2024, https://doi.org/10.1016/j.jcle- pro.2024.142376).

Seedbed preparation was carried out with rotary harrow to a depth of 0.1 m, followed by additional harrowing before sowing. Regarding fertilization, no fertilizer was applied, because soil samples (carried out on a regular, annual basis) revealed that there is no need for application of any of the main nutrients (N, P, K, Mg) nor for liming.

In both growing seasons all the annual crops were sown as planned. The seed rate was 13 kg ha-1 for crambe, 40 kg ha-1 for hemp, and 10 kg ha-1 for melilot.

For miscanthus rhizomes has been used for the establishment at the density of 1.7 plants m^{-2}.
All the planting, sowing and harvest dates are reported in Table 5.

Table 5 Planting, sowing and harvest date for annual and perennial crops.

Growing periods	Crop	Sowing date	Harvest date
2022-23	Crambe	26/05/2023	05/09/2023
	Melilot 1st year	26/05/2023	29/09/2023
	Melilot 2nd year	Not applicable	Not applicable
	Hemp	26/05/2023	29/09/2023
	Miscanthus	04/05/2023[a]	-[c]
2023-24	Crambe	17/05/2024	12/08/2024
	Melilot 1st year	17/05/2024	30/10/2024[d]
	Melilot 2nd year	26/05/2024	01/08/2024
	Hemp	17/05/2024	07/09/2024
	Miscanthus	14/05/2024[b]	18/03/2025[d]

[a] Miscanthus was planted via rhizomes (not sown). First re-planting carried out on 13/07/2023.

[b] Second re-planting (because some plants were killed over winter).

[c] After first growing season, miscanthus is usually not harvested, because there is not enough bio-mass yet.

[d] Expected date.

The first growing season was characterized by an average annual temperature of 9.4°C and a precipitation sum of 1020 mm. During May and June 2023, low precipitation was observed at the site which is why manual irrigation was needed for Miscanthus in early summer of 2023. The second growing season was characterized by an estimated average annual temperature of 9.5°C and an estimated precipitation sum of 1200 mm. Despite these conditions, the harvest of the annual crop showed promising results: Crambe produced Mg ha-1 of seed, Melilot (1st year) produced about 4 Mg (DM) ha-1 of biomass (in first year of this biennial crop, that is an acceptable biomass yield level), and hemp produced on average 9.9 Mg (DM) ha-1 of stem biomass.

Miscanthus was not harvesting after the establishment year, because it usually does not grow enough biomass in first year during the establishment phase. In the second growing season, the annual crops were rotated as planned (Crambe-Melilot-Hemp-Crambe-Melilot ...). However, it was necessary to adapt the cultivation du-ration of melilot, because the sowing in autumn was not successful. Therefore, melilot cultivation was changed from winter-annual (sowing in autumn, harvest in summer of the following year) to fully biennial (sowing in May, harvest in summer of the following year). This required the inclusion of a fourth link to the annual crop rotation chain of the large-scale field trial, by dividing four plots (representing four replicates of one link of the crop rotation chain) in half (from 12 m to 6 m width). This means that each crop (hemp, crambe and fully developed two years old melilot) can be har- vested each year. In 2025, crambe produced 0.9 Mg ha-1 of seed, melilot produced 10.1 Mg ha-1 of seed, and hemp produced 8.9 Mg (DM) ha-1 of stem biomass. The miscanthus plant stands have developed well so far, as evidenced by the almost 100 per cent coverage of the area despite the site conditions (shallow clay soil with a high stone content) and the partly heavy weed pressure (grass and herb species). Therefore, it can be assumed that miscanthus could eventually reach full yield potential after the third growing season (at harvest in March 2026). This is quite fast given the fact that the establishment of an adjacent miscanthus field trials needed four years to reach full yield potential. The estimated biomass dry matter yield for harvest in March 2025 is 14.0±2.0 Mg ha-1. For March 2026, we estimate an average biomass dry matter yield of >20 Mg ha-1.

1.1.6 Case study #6: IFCV (Institut Za Ratarstvo I Povrtarstvo Institut od Nacionalnog Znacaja za Republiku Srbiju)

The experimental site is located in Žabalj (Serbia, Figure 8) and covers an area of 0,65 ha. The soil is characterized by a high clay content, excessive humidity, and salinity.

The crops used in the intercropping system include the annuals crambe, white mustard (*Brassica alba* (L.) Rabenh. var. NS Bela) in the first year, sorghum (*Sorghum bicolor* L. Moench var. NS GOLD), safflower (*Carthamus tinctorius* L. var. Lana), and the perennial crop, miscanthus.

Figure 8 a, b. View of IFCV trial.

Seedbed preparation was carried out, with plowing, followed by harrowing before sowing. Regarding fertilization, experimental trials were not fertilized. In both growing seasons all the annual cropswere sown with a mechanical seeder adopted for cereals. The seed rate was 5 kg ha^{-1} for white mustard, 5 kg ha^{-1} for crambe, 10 kg ha^{-1} for sorghum, and 20 kg ha^{-1} for safflower. Miscanthus was planted manually using rhizomes at the density of 4 rhizomes m^{-2}. All the planting, sowing and harvest date are reported in Table 6.

Table 6 Planting, sowing and harvest date for annual and perennial crops.

Growing periods	Crop	Sowing date	Harvest date
2022-23	White mustard	26/05/2023	01/08/2023
	Safflower	26/05/2023	22/08/2023
	Sorghum	26/05/2023	14/09/2023
2023-24	Crambe	22/04/2024	16/07/2024
	Safflower	22/04/2024	15/08/2024
	Sorghum	22/04/2024	12/09/2024
	Miscanthus	22/04/2024	To be done

In April 2023, there was snow cover ranging from 0.5 to 0.18 m. April rains provided moisture in the soil. Cold weather persisted through May, delaying the growth and emergence of summer crops. Conditions improved in the latter half of May, but frequent rainfall, hail, and strong winds caused localized flooding. Frequent rains also encouraged weed growth. In June, variable agrometeorological conditions were observed, with 24 days of rain and totals between 50 and 300 mm. The cooler weather and limited sunshine hindered the development of most crops. However, soil moisture reserves increased, supporting vegetative growth and setting favorable conditions for upcoming crop development. Extremely high summer temperatures caused heat stress, disrupting physiological processes in crops. Rain was accompanied by disasters in the form of stormy winds and hail, which caused significant damage to crops and agricultural facilities. Harvest of the annual crops showed following results: White mustard produced 0.05 Mg ha^{-1} of seeds, safflower produced 0.3 Mg ha^{-1} of seed, and sorghum produced 1.3 Mg ha^{-1} of seed and 14.00 Mg (DM) ha^{-1} of straw. Mis- canthus was not successfully established in the first year.

In the second growing season, the annual crops were rotated: sorghum was followed by crambe and safflower, safflower by crambe and sorghum, and white mustard by sorghum and safflower. Inthis season, temperatures in May were generally favorable for the initial stages of the developmentof summer crops. Season was characterized with temperatures above multiyear average, especially during second decade of July and August, when temperatures were 8°C and 7°C higher than multi-year average. There was extensive drought from second decade of July until September. Crambe produced 0.86 Mg ha^{-1} of seed, Safflower produced 0.41 Mg ha^{-1} of seed, and sorghum produced 0.98 Mg (DM) ha^{-1} of above ground biomass.

In the first season, the experimental field needed to be replaced because of heavy flooding, and the sowing time was very late (May 26th.). Due to the very low germination rate, re-sowing was re-peated on June 14th. Sowing was very challenging and demanding: bad weather conditions pre-vented optimal soil preparation, the field was heterogeneous, a significant percentage of the filed was flooded, or it was over compacted by the machinery, so the seeds were left on the surface.

With regard to miscanthus, in first year main reason for failure in establishing plants was prolonged wetness of soil in spring and autumn. Limited soil drainage and underground water sources represented a particular problem during wet springs, when we witnessed flooding and excess moisture in the soil.

In second year, after re-planting miscanthus in second decade of April, rhizomes dried off due to high temperatures. Challenges emerged with weed pressure, particularly from chamomile, which is typical in saline soils, as well as damage from birds and wild animals, such as rabbits and roe deer, which affected the crops, especially sorghum.

In summary, the two growing seasons presented different weather conditions especially in the first months after crop establishment. Strong wind and flooding occurred in May during first season, and high temperatures in second season. Safflower had similar yields in both years. Sorghum had prom sing results in first season. However, in second season sorghum plants suffered from drought and high temperatures during most critical phases, flowering and seed formation.

1.1.7 Case study #7: CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas)

The experimental site is located in Cubo de la Solan (Castile and León, Spain, Figure 9) and covers an area of 0.5 hectares. The soil is characterized by a high sand content and significant stoniness (>15%), conditions that enhance drainage but may require measures to improve water retention and fertility. Climate conditions were Continental Mediterranean with cold winters, warm summers and low rainfall level. The crops used in the intercropping system are, among the annuals, crambe, melilotus, safflower, while the perennial is lavender (*Lavandula angustifolia* Mill.).

Figure 9 a) Location of experimental fields of the CEDER- CIEMAT and planting design; b) general view of the trial in June; c) harvesting of lavender.

During the first growing season seed bed preparation was done by applying primary tillage with molboard plow in December 2022 and then two cultivator passes in February 2023 and April 2023. Crambe, melilot and safflower were established in April using a seed drill while lavander was established with a semiautomatic planter in May 2023. No fertilization was applied. The seed rates were 20 kg/ha for crambe, 21 kg/ha for melilot and 23 kg/ha for safflower. Lavander was established at the density of 9375 plants/ha.

In the second year, soil preparation was carried out by using a moldboard plow at a depth of 0.3 m. Regarding fertilization, a mineral fertilizer (NPK 22-8-10) was applied at a dose of 260 kg/ha in May 2024, followed by two cultivator passes performed the same month. Sowing rate was the same as the previous year. All the planting, sowing and harvest date are reported Table 7.

Table 7 Planting, sowing and harvest date for annual and perennial crops.

Growing periods	Crop	Sowing date	Harvest date
2022-23	Safflower	04/2023	09/2023
	Crambe	04/2023	08/2023
	Melilotus	04/2023	
	Lavender	05/2023	
2023-24	Safflower	05/2024	09/2024
	Crambe	05/2024	Non applicable
	Melilotus	05/2024	07/2024
	Lavender	-	06/2024

The first growing season was marked by exceptionally high precipitation in June, exceeding 120 mm, contrasted with very low precipitation in July and August (30 mm and 0 mm, respectively) and consistently high temperatures throughout June, July, and August, with monthly average temperaturesexceeding 30°C. Nonetheless, among the annual crops, safflower performer better than crambe, yielding 1.28 Mg ha^{-1} and 0.43 Mg ha^{-1} of seeds, respectively. As the perennial crop was in its establishment phase, no harvesting was performed.

The second growing season was characterized by extreme drought and high temperatures similar to the previous season. These conditions made planting particularly challenging, causing low germination rates and, consequently, reduced crop productivity. Safflower produced 0.36 Mg ha^{-1} of seeds this second season, while crambe was not harvested at all. In contrast, melilotus and lavender produced 5.24 and 1.12 Mg (DM) ha^{-1} of biomass, respectively, which were considered satisfactory yields. Given the minimal rainfall during the summer months in Soria, adjustments to the sowing date for crambe are being considered, moving it to September in the third season to assess whether autumn rains and moderate temperatures can lead to better crop performance.

1.1.8 Case study #8: ITAP (instituto tecnico agronomico provincial sa)

This trial features a plantation of the industrial crop guayule intercropped with the annual crops; safflower and hemp, as proposed in the project. Intercropping trials offer numerous benefits, such as soil improvement, increased biodiversity, enhanced resource use efficiency, and greater productivity. By growing multiple species together, the total yield per unit area can increase compared to monocultural crops. Additional advantages include reduced erosion due to the diverse root structures, which help improve soil structure, among other benefits.

A guayule plantation has been established in Fuentidueña de Tajo (Madrid) to provide practical examples of innovative non-food crop systems that showcase sustainable agriculture best practices on marginal lands. Guayule, a natural rubber-producing plant of the tribe Heliantheae in the family Asteraceae, is noteworthy because it is the only species among 16 in its family that produces high-molecular-weight rubber of commercial interest. Each guayule plant contains an average of 10% rubber, with approximately two-thirds found in the stems and branches and the remainder in the roots (George et al., 2005).

The taxonomic classification of guayule, according to the International Code of Botanical Nomenclature (Abdel-Haleem et al., 2018), is as follows:

- **Kingdom:** Plantae
- **Division:** Magnoliophyta
- **Class:** Magnoliopsida
- **Subclass:** Asteridae
- **Order:** Asterales
- **Family:** Asteraceae
- **Genus:** Parthenium
- **Species:** *Parthenium argentatum*

The experimental site (Figure 10) located in Fuentidueña de Tajo (Madrid, Spain), covers an area of 0.5 hectares. Alterations in weather patterns, such as more frequent or intense droughts and temperature fluctuations, directly impact agricultural production, affecting both crops and water re- source availability. To assess soil characteristics, a soil test was conducted to a depth of 2 meters. The soil is characterized by a high sand content (>70%), along with gypseous conditions and dryness(300-400 mm of rainfall per year). The crops used in the intercropping system are, among the annuals safflower and hemp (*Cannabis sativa* L. var. FIBROR 79) while the perennial is Guayule (*Parthenium argentatum* accession AZ-5).

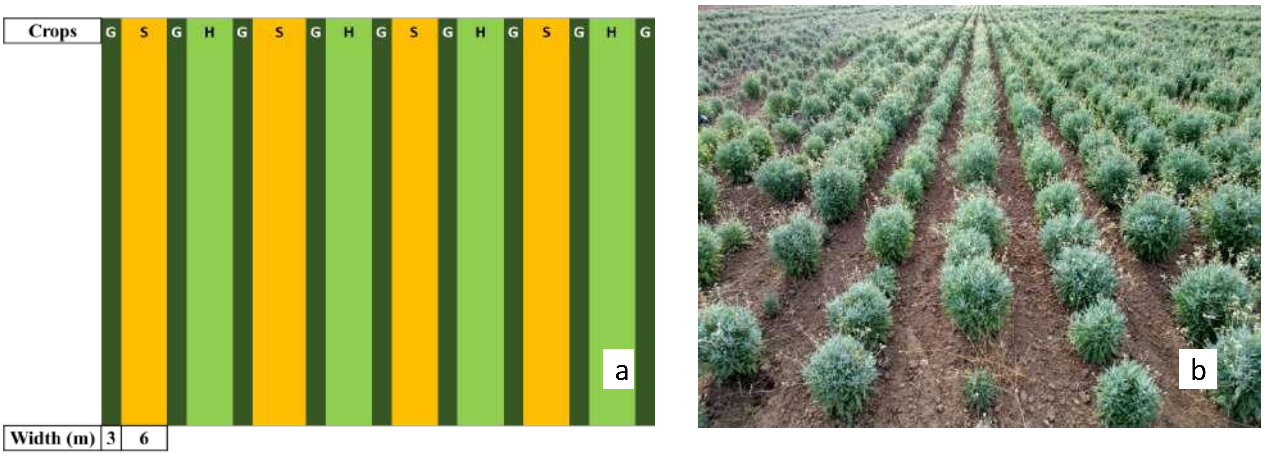

Figure 10 a) intercropping design, d) guayule plantation of ITAP trial.

The seedbed was prepared by plowing to a depth of 0.2 m. Fertilization was applied at a rate of 150kg ha^{-1} of the compound fertilizer with 15% N, 15% P and 15% K, followed by cultivator passes in the total area of the trial. In both growing seasons all annual crops were sown with a pneumatic seed drill. The machinery used for sowing is shown in the following in Figure 11.

Figure 11. Seed drill for annual crops in the intercropping trial.

The sowing rate for the annual safflower crop was between 30-33 kg ha^{-1}, with a sowing depth of approximately 0.02 m. This crop was not treated with herbicides or fungicides. At harvest time, the plant indicated maturity by drying its leaves and taking on a dry, yellow appearance.

For the annual hemp crop, the sowing rate was between 40-43 kg ha^{-1}, with a similar sowing depth of about 0.02-0.04 m. Like the safflower, the hemp crop was grown without the use of herbicides or fungicides. The harvest timing depends on the intended use; in this case, the crop was grown for fiber. The estimated harvest date is around 20 days after the female plants begin flowering, but before seed development, as the quality of the fiber decreases once seeds begin to form.

As for guayule, the sowing rate was set at a density of 26,000 plants per hectare. The guayule plants were initially sown in a greenhouse before being transplanted into the field Figure 12.

Figure 12 Image taken from the intercropping trial.

As can be seen in the figure above, an irrigation system has been installed in the trial plot.
All the sowing dates and harvest dates are reported on Table 8.

Table 8 Planting, sowing and harvest date for annual and perennial crops.

Growing periods	Crop	Sowing date	Harvest date
2023-24	Safflower	24/04/2024	22/10/2024
	Hemp	24/04/2024	-
	Guayule	14/11/2024	-

The first growing season was marked by an exceptionally unusual climate in the marginal area of Fuentidueña de Tajo (Madrid) and in Spain as a whole.

The Spanish State Meteorological Agency (AEMET), part of the Ministry for Ecological Transition and

the Demographic Challenge, published its climate summary for April 2023. It was recorded as the warmest April since the beginning of the series in 1961, surpassing the previous record set in April 2011 by 0.1°C. Additionally, April was extremely dry in terms of precipitation, with an average precipitation across mainland Spain of 14.2 mm, representing only 22% of the normal value for the month (reference period: 1991-2020). This made it the driest April since the series began in 1961.
The attached graph (Figure 13) shows the temperatures and precipitation levels recorded and accumulated over the year 2023.

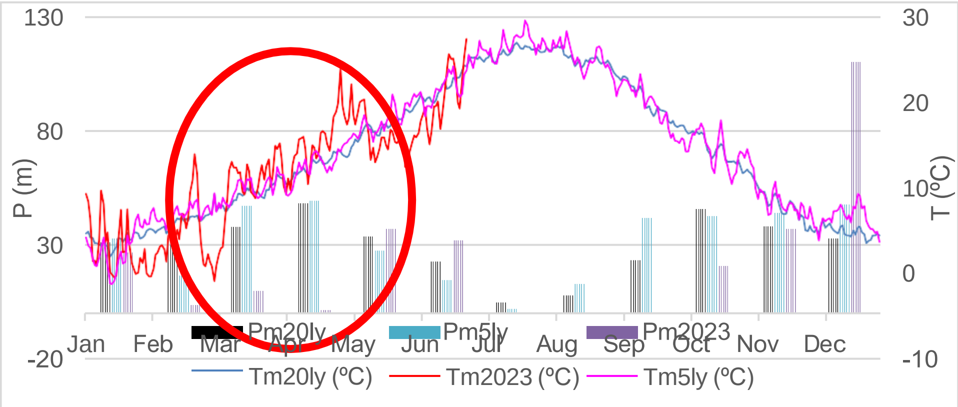

Figure 13. Average temperatures and precipitation in 2023 and in comparison, with the other years. Graphicinformation on the decision not to have growing season 2022/2023.

Summary of the acronyms in the graph:

- **Pm20ly:** Accumulated monthly mean precipitation over the last 20 years.
- **Pm5ly:** Accumulated monthly mean precipitation over the last 5 years.
- **Pm2023:** Accumulated monthly mean precipitation for 2023.
- **Tm20ly:** Average temperature over the last 20 years.
- **Tm5ly:** Average temperature over the last 5 years.
- **Tm2023:** Average temperature for 2023.

Due to the unusual weather conditions, the guayule crop could not be planted in the spring of 2023 and was rescheduled for November of the same year. Guayule is particularly sensitive during its initial months of establishment; therefore, to preserve the integrity of the intercropping trial, the trial was postponed to the 2023/2024 season. During this season, planting of the intercropping trial was successfully conducted under more typical local climate conditions, allowing both the annual crops and the perennial guayule crop to be planted together. The guayule crop requires one year after planting to enter production; thus, it was not ready for harvest. The safflower crop, however, was harvested on October 22, yielding a production of 0.68 Mg ha^{-1}. As for the hemp crop, issues with germination were encountered, necessitating three separate sowings. An evaluation of the germination rate revealed that the seed quality was poor, with a germination rate of less than 5%, meaning the crop has yet to be harvested. For the 2024/2025 season, the first guayule harvest is planned as part of the MIDAS project, along with the rotation of the annual safflower and hemp crops.

1.1.9 Case study #9: SOLTUB (Trade and Service Providing Limited Liability)

The experimental site for the MIDAS project is located in Gödöllő (Hungary, Figure 14) where SOLTUB Ltd. conducted case study activities and covers an area of 0.5 hectares. SOLTUB Ltd subcontracted this land from MATE Tangazdaság Nonprofit Kft., situated in Gödöllő, approximately 35 kmfrom Budapest. The subcontracted partner manages a fenced area of 35 hectares of arable land, where various agri-food companies conduct crop cultivation experiments and grow cash crops. Theprimary marginality factor of the soil in this area is its heterogeneity, which includes spots of stonesand varies from sandy to brown clay soils, with a slope of 5-10% and potential erosion issues. The intercropping system includes several crops. In 2023, the annual crops utilized are sorghum, carinata (*Brassica carinata* A. Braun), and hemp. In 2024, the annual crops have changed to include sorghum, safflower and hemp. The perennial crops include miscanthus (*Miscanthus × giganteus* Greef & Deuter) and poplar (*Populus* spp.). It is important to emphasize that the activities carried out also apply to subtask 3.2.2.

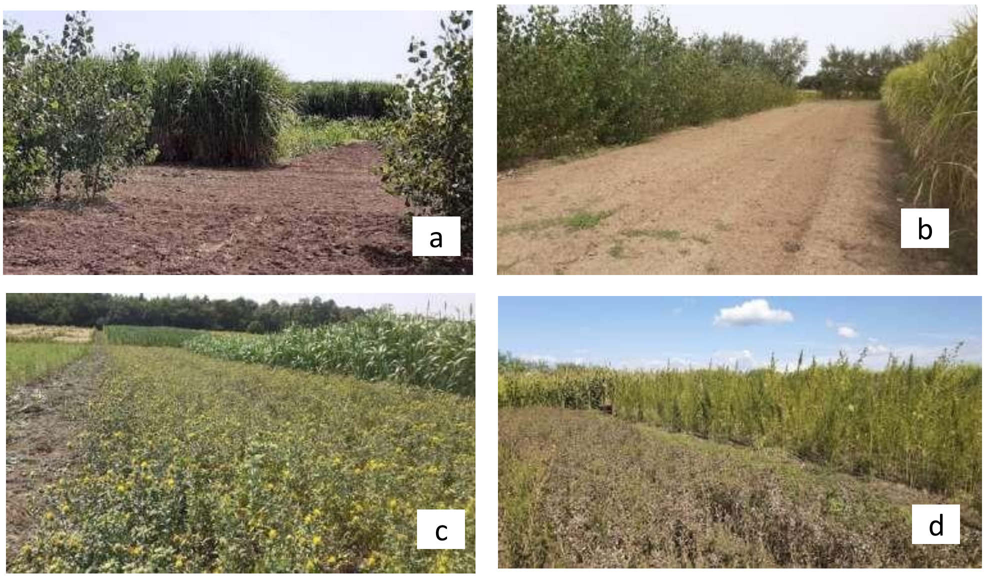

Figure 14 a, b, c, d View of SOLTUB trial.

During the growing season, the planned observations were conducted, which included the following parameters: planting, sowing and harvest date reported in Table 9, emergence dates and percentages, occurrences of diseases and insect damage maturity dates, growth intensity measured at two-week intervals, maximum height, daily average temperature, and monthly precipitation.

No fertilization or irrigation was performed before or during the growing season. One treatment of pesticide was applied to carinata to combat the cabbage stem flea beetle. However, since carinata did not produce seeds in 2023 (due to a lack of flowering), it was not possible to evaluate seed production. Consequently, it was replaced in 2024 with safflower.

Sampling and harvesting of the annual crops were conducted on October 10, 2023, for laboratory analysis, which included determining the dry matter content of both vegetative parts and seeds. The perennial crops were not harvested or sampled. In 2024, in addition to the first year miscanthus and poplar species, the sowing of annual crops hemp, safflower, and sorghum was carried out on

May 15, 2024. The plots maintained the same sizes and repetitions as in 2023 and were arranged randomly. Required observations during the growing season will continue until harvest. Sampling and laboratory analyses will be conducted for all five crops (two perennial and three annual).

Table 9 Planting, sowing and harvest date for annual and perennial crops.

Growing periods	Crop	Sowing date	Harvest date
2022-23	Hemp	05/05/2023	10/10/2023
	Carinata	05/05/2023	10/10/2023
	Sorghum	05/05/2023	10/10/2023
	Poplar	14/04/2023	Not applicable
	Miscanthus	14/04/2023	Not applicable
2023-24	Hemp	15/05/2024	15/10/2024
	Carinata	15/05/2024	15/10/2024
	Sorghum	15/05/2024	15/10/2024
	Poplar	Not applicable	Not applicable
	Miscanthus	Regrowth	To be done

Based on the results from 2023, it can be concluded that four out of the five crops two annuals (hemp and sorghum) and two perennials (miscanthus and poplar) can be successfully grown under the marginal conditions of the area. The harvest results for the annual crops, excluding carinata, indicate that sorghum performed the best, yielding 20-25 Mg (DM) ha^{-1}, while hemp produced 2.5-3.5 Mg (DM) ha^{-1}. The miscanthus and poplar crops are scheduled to be harvested in the autumn of 2024.

1.1.10 Case study #10: CZECHEMP (Cesky Konopny Klastr ZS)

The experimental site is located in Chomutov (Czech Republic, Figure 15) covering an area of 0.5 hectares. The soil is characterized by high clay content (15-20%) and compaction, which, along with marginality factors such as water and wind erosion, slope (5-10%), and low fertility (less than 1% organic matter), presents challenges for crop cultivation. The hydropedological characteristics of the soil include high infiltration and permeability rates of 0.20 mm min^{-1}, low water retention capacity of up to 100 l m^{-2}, and low usable water capacity of up to 79 l m^{-2}. Geographically, the site issituated in a flat foothill area within a rain shadow climate zone, at an altitude of 363 meters above sea level.

Figure 15 Localization of CZHEMP trial.

The average annual temperature ranges from 8 to 9°C, with a cumulative temperature above 10°C, and average annual rainfall between 500 and 600 mm. There is a 20-30% probability of experiencing dry growing seasons.

The field trials include three annual crops: hemp, safflower (*Carthamus tinctorius* L var. Ara), and sorghum (*Sorghum bicolor* L. Moench, variety Ruzrok), alongside one perennial crop, miscanthus. The experimental design includes six repetitions for each annual crop and four repetitions for miscanthus, with each plot measuring 180 m² in size.

Seedbed preparation is carried out in, with plowing, followed by harrowing before sowing. Regarding fertilization, only autumn spreading of digestate in the dose of 40 Mg ha^{-1} on the whole trial plot was used every year started in 2022.

In both growing season all the annual crops were sown with the seeder "Farmet falcon 6" pulled by a "Fend 500 vario" wheeled tractor. The seed rate was uniformly 30 kg ha^{-1} for all annual crops. For miscanthus rhizomes has been used for the establishment at the density of 4 plants per square meter. All the planting, sowing and harvest date are reported Table 10.

Table 10 Planting, sowing and harvest date for annual and perennial crops.

Growing periods	Crop	Sowing date	Harvest date
2022-23	Hemp	28/04/2023	26/09/2023
	Safflower	28/04/2023	26/09/2023
	Sorghum	28/04/2023	26/09/2023
	Miscanthus	18/05/2023	24/10/2023
2023-24	Hemp	10/06/2024	10/10/2024
	Safflower	10/06/2024	10/10/2024
	Sorghum	10/06/2024	10/10/2024
	Miscanthus	03/05/2023	Not applicable

The 2023 growing season was marked by varying success among the tested crops, with total above-ground biomass yields as follows: sorghum produced 7.43 Mg (DM) ha^{-1}, safflower yielded 3.07 Mg (DM) ha^{-1}, hemp generated 9.89 Mg (DM) ha^{-1}, and miscanthus achieved 4.18 Mg (DM) ha^{-1}. Among the crops, miscanthus proved to be the most problematic for cultivation under the prevailing soil-climatic conditions. Newly established stands in 2023 did not take root, and a repeated attempt to establish this crop in 2024 met with the same fate. Consequently, only one strip (comprising four plots) of miscanthus was used for yield determination, which consisted of a stand established earlier (2020/2021). Unfortunately, even this stand did not achieve the condition observed in those on regular agricultural soils within the same region. Furthermore, mechanization of miscanthus planting faced challenges due to the poor physical quality of the tested soils, adversely affected by miningactivities, as well as unfavorable physical parameters of the planting material, which included irregular and twisted forms of cuttings with lateral shoots.

The second problematic crop was safflower, which had the lowest yields among the tested crops. In 2024, the safflower stand did not take root at all due to the extremely early onset of high temperatures.

1.1.11 Case study #12: GUATECS

The experimental site is located near Montpellier (France, Figure 16) and consists of clay soil with a pH of 8.5 and a soil organic matter (SOM) content of 1.6%. The soil is also characterized by very low phosphorus availability, poor biological activity, low structural stability, and a very high risk of asphyxia. The field trials include two annual crops: hemp, safflower and one perennial guayule.

Figure 16 View of GUATECS trial.

Guayule was planted in the spring of 2023 (15000 plants ha^{-1}) and no problem has occurred until now. The full evaluation will be at the end of summer 2025.

Intercropping (hemp and safflower) will be tested in spring 2025, once the guayule matures.

1.2 Sub-task 3.2.2 *Intercropping between short rotation forestry and annual crops*

1.2.1 Case study #4: CRES/AUA (Centre for Renewable Energy/Geoponiko Panepisstimion Athinon)

Within sub-task 3.2.2, there are two experimental sites in Greece. The first experimental site (Site 1) is located in Stylida (Fthiotida, Greece) and covers an area of 0.30 hectares. This site is characterized by high sand content (>50%) and elevated salinity. Unfortunately, the site was abandoned dueto repeated destruction of the annual crops by local pig activity during the growing period. This sitewas originally designed for an intercropping trial with annual crops such as sorghum, safflower, andcastor, alongside the perennial crop, poplar.

The second experimental site (site 2) is situated in Krini (Thessaloniki, Greece, Figure 17) also covering 0.35 hectares. The soil in this site is characterized by a poor texture and low organic matter. In this second site, the annual crops remain the same as in the first site, while the perennial crop are poplar and Paulonia (*Paulownia tomentosa* (Thunb.) Steud).

Figure 17 View of Krini trial.

The perennial crop trials, including poplar and Paulownia at site 2, began with the poplar setup at the end of February 2024. However, due to dry conditions and high temperatures from early March,the establishment of the annual crops, crambe and safflower, was unsuccessful.

1.2.2 Case study #13: CREA (Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria)

CREA agroforestry field has an extension of 0.54 ha and is located near Monterotondo (Rome, Italy, Figure 18), in an area with strong marginality constraints given by water logging in the autumn-winter monthly. The agroforestry field was obtained through the conversion of 12-year-old poplar plantation (clone AF-8) for biomass production at the second harvest cycle. The layout before the conversion in agroforestry field was 3 meters between the trees line and 1 meter among the plants, but by removing alternatively one of the rows now there are eight tree lines with inter-row of 6 meters for a total of 5400 m². The last utilization was carried out in 2022. To understand the effect of this cropping system, the tests were implemented in comparison with a field next to the agroforestry stand, in which there are the same soil characteristics and managed with the same agricultural operations but without trees.

Figure 18 Agroforestry field in different views: satellite; drone; photo.

The test for the first year was focused on the comparison from mechanical, agricultural, and productive aspects of the two selected crops (i.e. safflower and crambe). The two herbaceous crops were cultivated in seven rows, four for safflower and three for crambe. Furthermore, was also made a growing evaluation on the Poplar plantation to verify whether the presence of herbaceous crops in the inter-row could change the normal development. Soil preparation was carried out in the second week of February 2023, with deep tillage using a ripper and superficial chisel tillage before seeding. A fertilization was performed before sowing using Diammonium Phosphate (18% N, 46% P_2O_5) and Urea fertilizers (46% N). The sowing was performed during the last week of March 2023. The seeding rate was 25-30 kg ha^{-1} with a final layout of 0.03 m of distance between the seedlings and 0.14 m between the rows.

In the first year, the study focused on the biomass production of two herbaceous species and the seed yield and losses of safflower. Both in the agroforestry and control fields, safflower produced more biomass yield than crambe. Specifically, safflower yielded 6.7 Mg (DM) ha^{-1} in the intercropping system and 7.0 Mg (DM) ha^{-1} in monoculture, while crambe produced 0.7 Mg (DM) ha^{-1} in intercropping and 0.7 Mg (DM) ha^{-1} in monoculture. Regarding seed yield, safflower produced 1.0 Mg ha^{-1} in the intercropping system compared to 1.1 Mg ha^{-1} in monoculture. Seed loss was also recorded at an average of 6% in the intercropping system, whereas the monoculture system experienced a 7% seed loss for safflower. Furthermore, the growth rate of poplar in the agroforestry plantation showed no significant difference compared to the dedicated plantation, with a total biomass recorded at 4721 FM (Fresh Mass) kg.

During the second year, the same parameters were studied for safflower and poplar. Respect to the first year the differences were in the sowing period, carried out on 22 November 2023 and in the cultivation of safflower only, given the lower results of the crambe. In the agroforestry field there wasn't safflower emergence probably for the effect of poplar on shadow and water logging. For this reason, another sowing was carried out in April 2024. Compared to the first year, yield and biomass production increased in both systems (intercropping and monoculture), and the poplar plantation aligned with the growth rate of the dedicated plantation. The productivity of safflower in the intercropping system was 1.14 Mg ha^{-1}, while in monoculture it was 1.20 Mg ha^{-1}. For poplar, the recorded productivity in the entire plantation was 17478 kg FM. Productivity in the agroforestry systemwas similar across all investigated factors compared to the traditional agricultural system during thestudy period. However, the harvesting process proved complicated due to the presence of poplar branches. Throughout the experiment, the effective distance between tree rows was monitored, revealing that the poplar branches reduced the original 6-meter distance during the vegetative period. Consequently, the combine harvester (Figure 19) used was equipped with a 4-meter cereal header, which is more challenging to source, as modern machinery typically utilizes headers of at least 5.5 meters. Despite this harvesting issue, the agroforestry system provides greater overall yield(including both intercropping species and tree plantations) and enhances ecosystem services. Additionally, if the layout is designed with appropriate spacing, it does not hinder mechanical operations. In conclusion, while there are challenges to be addressed in the harvesting process, the agro- forestry system demonstrates its potential for increased productivity and environmental benefits.

Figure 19 The combine harvester.

1.2.3 Case study #7: CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas)

On page 25, the experimental site in Cubo de la Solan (Castile and León, Spain, Figure 20) was described, covering an area of 0.5 hectares with soil characterized by high sand content and significant stoniness (>15%). In relation to subtask 3.2.2, the partner is also conducting work in this area and has established an agroforestry trial. This experimental site is similar to the one mentioned previously. However, in this specific case, the perennial crop is elm (*Ulmus pumila* L.). The annual crops remain the same and include safflower, crambe, and melilotus.

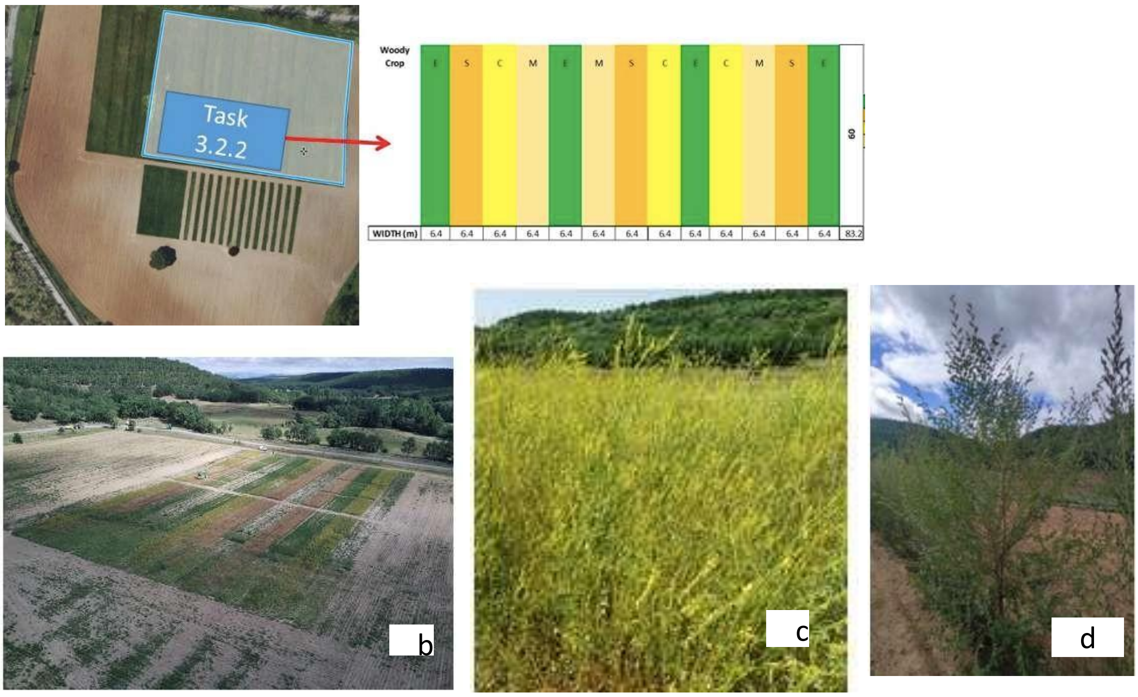

Figure 20 a) Location of experimental fields of the CEDER- CIEMAT and planting design; b) generalview of the trial; c) melilotus; d) Elm.

The agronomic strategy for the annual crops shared by the two tasks was the same, as previously reported. Elm was established at the density of 4688 plants ha^{-1}. All the planting, sowing dates and harvest date are reported in Table 11.

Table 11 Planting, sowing and harvest date for annual and perennial crops.

Growing periods	Crop	Sowing date	Harvest date
2022-23	Safflower	04/2023	09/2023
	Crambe	04/2023	08/2023
	Melilotus	04/2023	Non applicable
	Siberian Elm	05/2023	Non applicable
2023-24	Safflower	05/2024	09/2024
	Crambe	05/2024	Non applicable
	Melilotus	05/2024	07/2024
	Siberian Elm	-	Non applicable

The meteorological data for the two growing seasons have already been previously described.

In this specific case, in the first year of trial among the annual crops, safflower was more productive than crambe, yielding 1.2 Mg ha^{-1} compared to crambe 0.4 Mg ha^{-1} of seeds. As melilot and lavender are managed as biennial and perennial plants, they were not harvested in this growing season. In the second growing season, the annual crops were rotated. In the second growing season as well, crambe was not harvested due to the extremely dry weather conditions, while safflower produced 0.5 Mg ha^{-1} of seeds and melilot yielded 3.2 Mg ha^{-1} of biomass. Since elm is a perennial plant, it is common not to harvest it during the establishment phase.

In general, between annual crops safflower appear to have greater drought resilience than crambe, which did not achieve sufficient productivity for harvest under arid conditions. Melilot, while requiring more time to establish, showed good biomass productivity.

1.2.4 Case study #11: ECF (European Carbon Farmers)

The case study is located in the Żuławy Wiślane Region, Vistula Delta (northern Poland). While the Region itself is one of the most fertile regions in Poland, the alluvial nature of Region's soils makes soil conditions very varied, including marginal lands. On such field, characterized by high sand content and dryness, the demo field is located (Figure 21).

As presented above, the demo site of 0.55 ha has been designed consisting of three rows of perennial grasses mixture of cocksfoot (Dactylis glomerata L.), meadow fescue (Festuca Pratensis (Huds.) Darbysh.), timothy (Phleu pratense L.) and bromus (Bromus L.) with three rows of energy poplar trees. The grass has been established at seeding rate of 10 kg ha-1 in April 2023 and re-seeded at the same seeding rate in October 2023. 600 energy poplar trees have been established at the demo field in April 2023 and 50 energy poplar trees have been re-planted in April 2024. In Figure 22 is possible to see the view of the plantation from 19 October 2024. In the first harvest year the first cut of hay was not harvested as it was very small and was conducted to manage weeds pressure on newly established perennial grass bed. The second grass cutting was conducted on 20th August 2023 with bailing of hay conducted three days later, on 23rd August 2023, with the yield of approximately 1.5 Mg ha-1 at 13% moisture.

Figure 21 View of ECF trial.

Figure 22 View of the ECF plantation.

In the second harvest year 2024 the first cut of hay was visibly greater than the previous year's harvest and yielded approximately 2,5 Mg ha^{-1} at 13,5% moisture. The cutting was conducted on 18 June 2024 and bailing on 27 June 2024. The second cutting was conducted on the 19 of August and given its very small quantity due to the low rainfall since the first cut was not harvested. In years 2023 and 2024 harvesting of energy poplar trees was not conducted, as there were still in the initial stages of growth.

In general, given the marginality criteria and challenging weather conditions, the demo site is doing very well with significant productivity gains recorded in the perennial grasses production. Production of biomass at the demo field is still expected to be challenging; however, the development of the demo field is anticipated to make a successful contribution to the growth of bioeconomy valuechains in Poland and the broader MIDAS Project.

Outlook

Overall, the case studies show promising results and potential of intercropping systems, though in most cases significant challenges and obstacles still have to be overcome mainly due to marginal conditions. Although still at an intermediate stage, these results provide an interesting picture of the adaptability of the tested crops, especially in contexts with limited water availability and low- fertility soils, advancing the path toward a more sustainable bioeconomy. So far, intercropping systems have shown potential for optimizing resource use in marginal lands, although crop performance has varied significantly from place to place. In some cases, trends have emerged; for example, castor, safflower, sorghum, melilot, and hemp have proven to be resilient crops under environ-mental stress. Safflower, sorghum and hemp, in particular, have shown the highest adaptability andyield potential among annual crops. Hay (grass mixture) and melilot also showed good adaptabilityand biomass potential. Crambe showed moderate potential, suffering from extreme drought and poor soil fertility that caused low yields (< 1 Mg ha^{-1} of seed). Carinata showed also difficulties due mainly to pest problems, particularly cabbage beetle, and white mustard faced challenges due to marginal soil conditions and environmental stress, resulting in generally lower productivity.

Since these are the first two years of the project and perennial crops require at least two years to establish, comprehensive case study data is not yet available. However, it is notable that in some case studies, establishing miscanthus and switchgrass has presented significant challenges, mainly due to marginal soil conditions and weed competition. Poplar and guayule showed a better adapt-ability to marginal conditions, while lavender demonstrated satisfactory biomass production, although its establishment required careful management in drier locations. Such preliminary results will help to further improve the proposed intercropping systems during the second half of the project.

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