AgrEcoMed

FOSTERING AGROECOLOGICAL TRANSITION

“New AGRoecological approach for soil fertility and biodiversity restoration to improve ECOnomic and social resilience of MEDiterranean farming systems”

Deliverable 1.3
Database and reports

This project is part of the PRIMA Programme supported by the European Union, having received funding from it under grant agreement PRIMA21_00018

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

This project is part of the PRIMA Programme
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Acronym and abbreviations

VRT	Variable rate
RIA	Research and Innovation Action
CA	Conventional agriculture
AA	Agroecological approach
WP	Work package

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Executive summary

The AgrEcoMed project, supported by the European Union's Horizon 2020 research and innovation program PRIMA under Grant Agreement PRIMA21_00018, is a research initiative designed to address gaps in research for the implementation of a biodiversity-based strategy in primary cereal farming systems. The project adopts an agroecological approach tailored to Mediterranean environments, emphasizing the efficient use of natural resources, pollution reduction, and the promotion of a circular economy. The overarching goal is to achieve sustainable production of staple foods amid present and future climate changes. To attain this objective, the project employs innovative methods, including on-farm experimentations, focus groups, pilot actions, and demonstrative initiatives. A three-year open-field trial (2022-2024) is currently underway in real farms in the Mediterranean area (Italy and Morocco). This trial compares the conventional agriculture (CA) cropping system with an alternative approach based on agroecological principles (AA). The experimental fields feature various components, such as novel crop rotations, the cultivation of modern versus ancient wheat varieties, assessment of crop responses to both conventional and organic fertilizers, treatment of crops with biostimulants, evaluation of crop responses to uniform and variable rate fertilization, and the implementation of intercropping with cereals and legumes. This document, Deliverable 1.3, titled "Database and Reports," is a part of the AgrEcoMed project. It aims to provide pertinent information concerning the assessed strategies, agronomic responses of crops, and the inputs and outputs of the two cropping systems under scrutiny. The data will be available in the form of reports from the end of the first year of activity (18 months) until the completion of the project (36 months).

Keywords: PRIMA, AgrEcoMed, on-farm demonstration, agroecological transition, dissemination, conventional wheat, agroecological practices, sustainable agriculture, data, yield production, resource efficiency

1. Project basis

AgrEcoMed is a 36-month Research and Innovation Action (RIA) project under Grant Agreement No PRIMA21_00018 aiming to fill the research gaps for implementing a biodiversity-based strategy for primary crops as cereal farming systems through an Agroecological approach adapted to environments in Mediterranean countries, efficient use of natural resources, reduction of pollution, circular economy. The effective start of the project is 23/05/2022 and the project ends 36 months later, on 31/05/2025. The AgrEcoMed consortium consists of 8 partners from 4 countries (including two EU and non-EU countries). The project is coordinated by the University of Basilicata (UNIBAS, Italy). The list of Project Participants is included in the Grant Agreement, in the Consortium Agreement, and presented in Table 1. The project has an overall budget of 1,308,051.15 €. The budget detailed per beneficiary and the corresponding EU contribution of each beneficiary is detailed in Annex 2 to the Grant Agreement – Estimated budget of the action.

Table 1. Partners of the AgrEcoMed project and representatives.

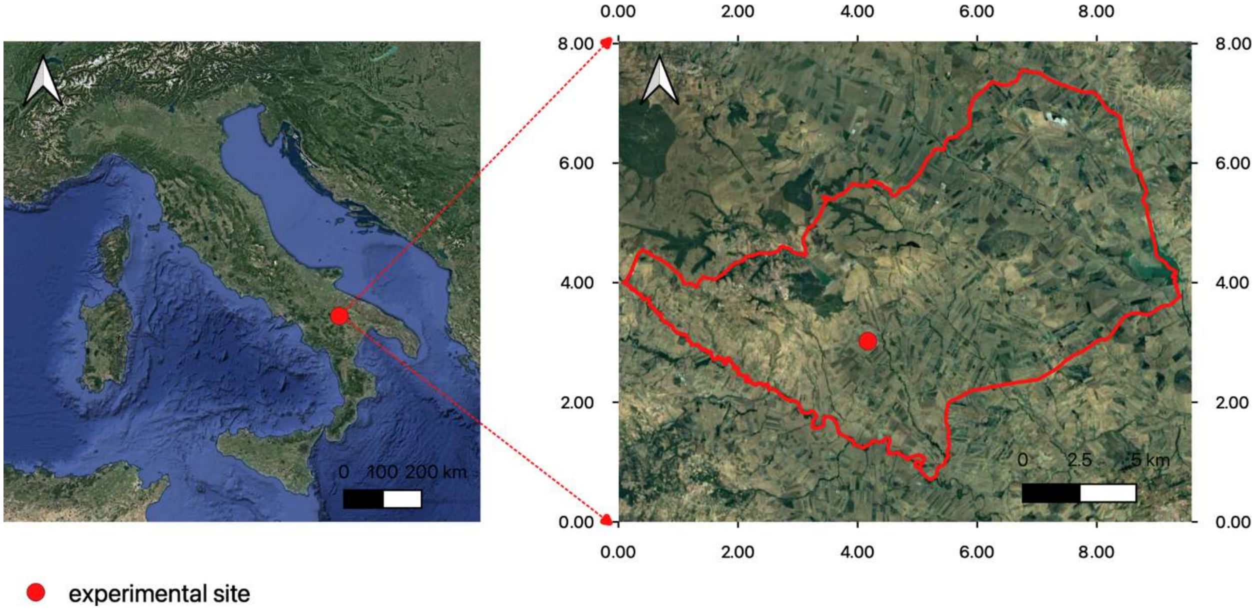
Participant No *	PI name	Organization	Short name	Country	Type of institution
P1	Michele Perniola	University of Basilicata	UNIBAS	Italy	Higher Education Institution
P2	Luigi Roselli	University of Bari	UniBa	Italy	Higher Education Institution
P3	Maria Assunta D'Oronzio	Council for Agricultural Research and Economics	CREA	Italy	Public Research organization
P4	Ines Yacoubi	Centre of Biotechnology of Sfax	CBS	Tunisia	Public organization
P5	Hanine Hafida	University Sultan Moulay Slimane Beni Mellal	USMS	Morocco	Higher Education Institution
P6	Said Ennahli	National School of Agriculture	ENAM	Morocco	Public Research Organisation
P7	Julio Berbel	Universidad de Córdoba	UCO	Spain	Higher Education Institution
P8	Neus Sanjuan Pellicer	Universitat Politècnica de València	UPV	Spain	Higher Education Institution

2. Demonstration fields

A 3-year field trial (2022-2023-2024) will be conducted in the real setting farm in the Mediterranean area, comparing the cropping system practiced (conventional agriculture CA) with an alternation one in which, in addition to the introduction of new alternative crops, the cultivation technique will be set based on agroecological principles, the agronomic correctness of the individual cultivation technique interventions (rotation, tillage, fertilization, defense, etc.) and the consistency that the specific methods of farm management demonstrate they possess concerning environmental, social, cultural, economic conditions, etc. of the cultivation site (AA). In the above-said farms, "conventional agriculture" (CA) will be compared with the proposed "agroecological approach (AA). On the same rotating plots cultivated in the farm, part of the surface will be used to test the management regime on an agroecological basis (AA). Specifically, wheat and legumes will follow the same rotation scheme already in place on the farm, but the newly established varieties grown on the farm will be compared with the alternative varieties. The rotation scheme will instead be expanded (to increase the degree of biodiversity) by introducing and allocating part of the area for the cultivation of a brassica crop and a medicinal plant. In this rotation, wheat maintains the role of the main crop (given its suitability to the cultivation area), the leguminous for the balance of nutrients in the soil, the grass for improving and refining crops against weeds, the brassica crop for the soil pathogens control and finally the medicinal crop for triggering green chemistry chains with the possibility of producing extracts also useful for the agricultural sector itself in a circular economy perspective. Following the rotation scheme, the 5 crops in the rotation will all be present in each of the three years of experimentation. To make the management of rotation more ecological, in compliance with the knowledge acquired in the agronomic research, the tillage plan in the AA rotation will provide for plowing at 30 cm on legumes and medicinal crops (to better contain both weeds and the pathogens on these two crops which are more sensitive) and the minimum tillage on wheat and brassicas (where the control of weeds and pathogens is easier). This is to contain the carbon footprint on the one hand due to fuel consumption and to take advantage of the positive effect of plowing on the control of pathogens, weeds, and the physical characteristics of the soil, also for successive crops in rotation. The plant nutrition will be ensured by calculating the plant needs according to the crop potential uptake, the spatial variability and availability of the soil, and crop status due to the climatic trend of the cultivation period. On this basis, the DSS for the fertilization plan will be customized and used for the variable rate distribution of fertilizers through the "precision farming" technique. In the calculation of nutrients, the contribution deriving from the burying of crop residues from previous years will be considered (and this will allow for reducing the fertilizer doses), and organ-mineral fertilizers from the composting of crop residues and urban waste will be used, with a view to of circular economy and low environmental impact. The crop residues will be managed both through the burying and possible shredding in the field, and, based on the physicochemical characteristics and the isoumic coefficient, to start the farm composting processes to obtain a more stable and more effective fertilizer-soil conditioner (ENAM). In particular, we will study the possibility of using medicinal crop residues to obtain macerates which are also useful for the control of some plant pathogens. The crop residues will also constitute the substrate for their enhancement through the bioconversion operated by the Diptera Hermetia Illucens (WP3, task2, UNIBAS). Also, plant health and performance will be assessed to evaluate the benefits of these treatments. An environmental analysis of the processes that allow the self-production of fertilizers and/or amendments for agricultural soil will be carried out, starting from the residues of crop cycles or other organic waste. These processes will be carried out on locally selected farms in participating countries. Weeds and pathogens control in the AA rotation will be carried out based on monitoring the damage threshold; commercially available low-impact bio-molecules will be used and will be compared to the traditional one.

2.1 Experimental site description – Italian site

The site is within L'azienda Soc. Coop. Agricola La Generale [latitude: 40.82460° N, longitude: 6.09348° N.] located in C.da Pezzalonga c.p.24, 85013 Genzano di Lucania, Potenza, the Basilicata region of southern Italy. The territory of the municipality of Genzano di Lucania has an area of 208.92 km^2 and a population density of 27.23 inhabitants/km^2.



Source (Denora et al., 2022)

Figure 1. Location of AgrEcoMed demonstration fields, Italian site.

The experimental site is characterized by hot summers followed by cold winters and with rainfall concentrated in the autumn-winter seasons. The mean annual precipitation is nearly 610 mm (Table 2). The average annual temperature is 19.2 °C. The maximum average of the hottest month (July) reaches 28.1 °C, and that of the coldest month (January) is 3.3 °C.

Table 2. Climatic parameters for Genzano di Lucania, Basilicata region, Southern Italy.

Month	Precipitation (mm/month)	Wet days	Tmp. min. (°C)	Tmp. max. (°C)	Tmp. mean. (°C)	Rel. Hum. (%)	Sunshine (%)	Wind (2m) (m/s)
Jan	59	11.5	3.3	9.7	6.5	76.3	42.1	3.1
Feb	55	11.1	3.5	10.4	6.9	73.8	42.8	3.2
Mar	52	11.2	4.8	12.6	8.7	71.2	44.8	3.2
Apr	49	10.3	7.4	16.2	11.8	69	49.4	3.1
May	40	7.8	11.4	21	16.2	68.1	56.1	2.6
Jun	35	6.7	15	25.1	20	65.1	61.4	2.5
Jul	23	4	17.5	28.1	22.8	61.7	69.9	2.5
Aug	33	5.6	17.8	28	22.9	63.6	69.9	2.4
Sep	51	7.1	15.1	24.5	19.8	66.1	63.5	2.2
Oct	67	9.7	11.3	19.4	15.3	71.2	55.5	2.4
Nov	72	11	7.4	14.8	11.1	75.7	47.1	2.8
Dec	71	12.1	4.5	10.9	7.7	77.3	40.8	3.1

The average relative content of particles of various sizes in the soil is 39.3% for clay, 25.9% for silt, and 34.9% for sand. Therefore, the soil of Genzano di L. is classified as clay loam and is moderately calcareous with a moderate alkaline pH being more than 8.2 (Figure 2). The textural class of top and subsoil using the triangular diagram is shown in Figure 3. The average soil Electrical conductivity (EC) 1:2.5 is 0.26 mS/cm. The average available water content is 100 mm. The average field capacity of the soil is 35% while the wilting point is 22%. The average humidity is 30%. Elevations range from 347 to 365 meters above sea level (Figure 4). The average nitrogen content is 1.2 g/kg while organic carbon is 1.2%.

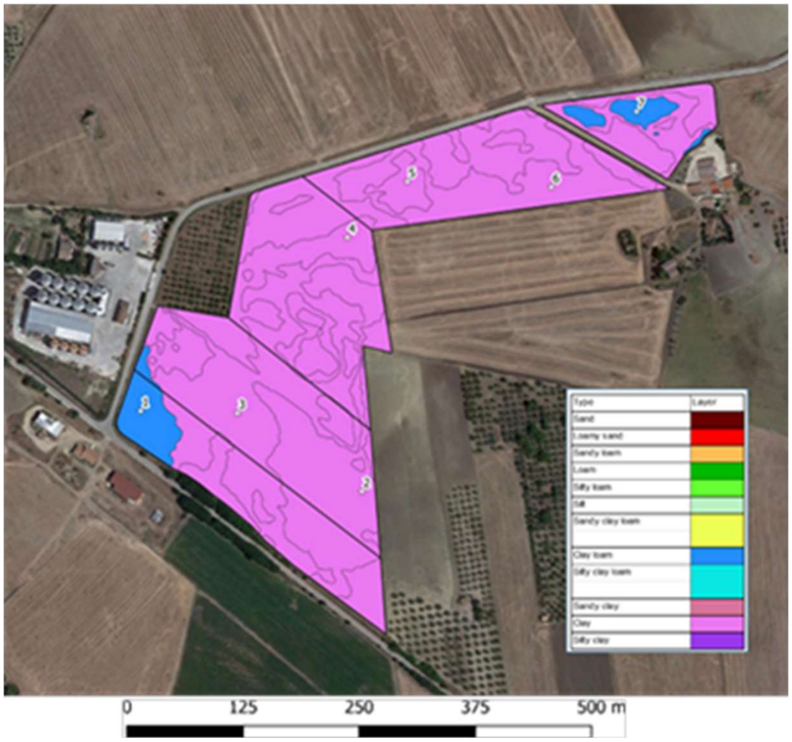


Figure 2. Soil texture of demonstration fields, Italian site.

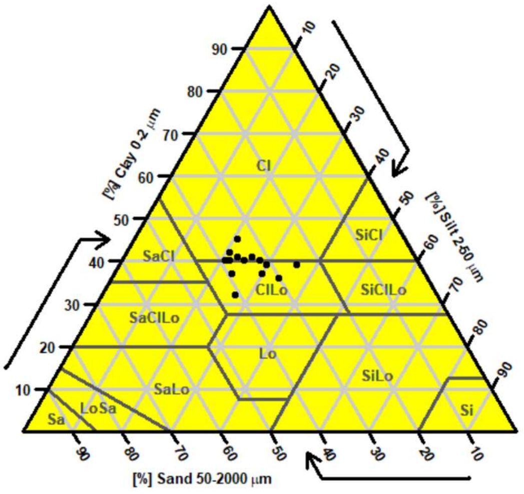


Figure 3. The triangular diagram of the basic soil textural classes of topsoil (yellow/left) and subsoil (blue/right).

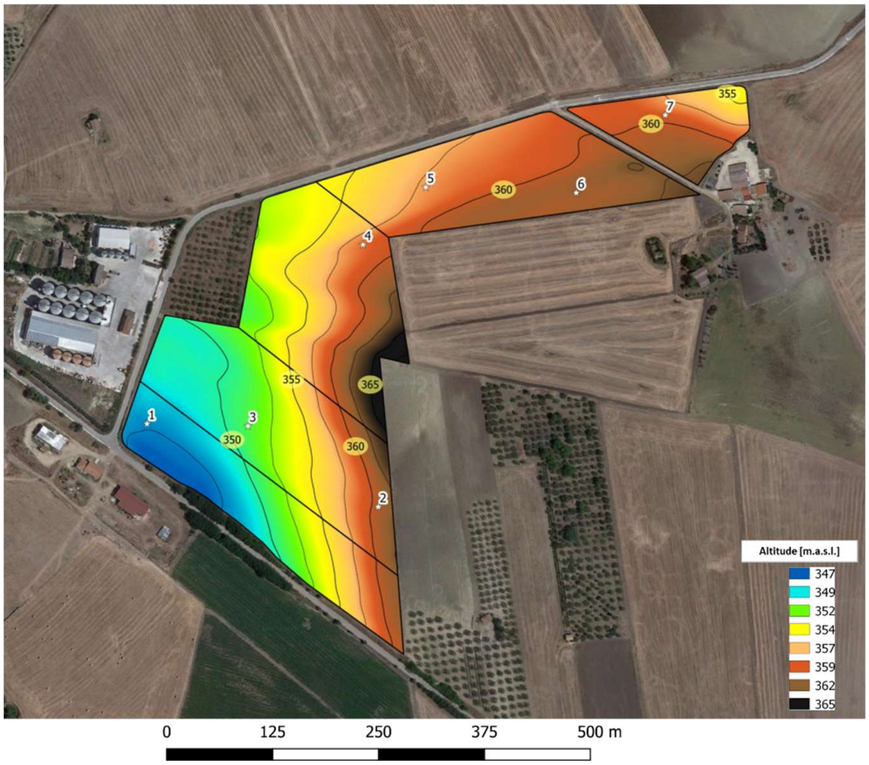


Figure 4. The altitude map of demonstration fields, Italian site.

2.2 Experimental design and management

The demonstration fields consist of various demonstration plots (refer to Figure 5), categorized as mono-cropping, legumes, intercropping, cereals, and medicinal crops. The experiment will be carried out in rain-fed conditions, employing a randomized block design. Field operations encompass primary and secondary tillage, fertilizer application, planting, harvesting, and post-harvest straw management for all designated plots.

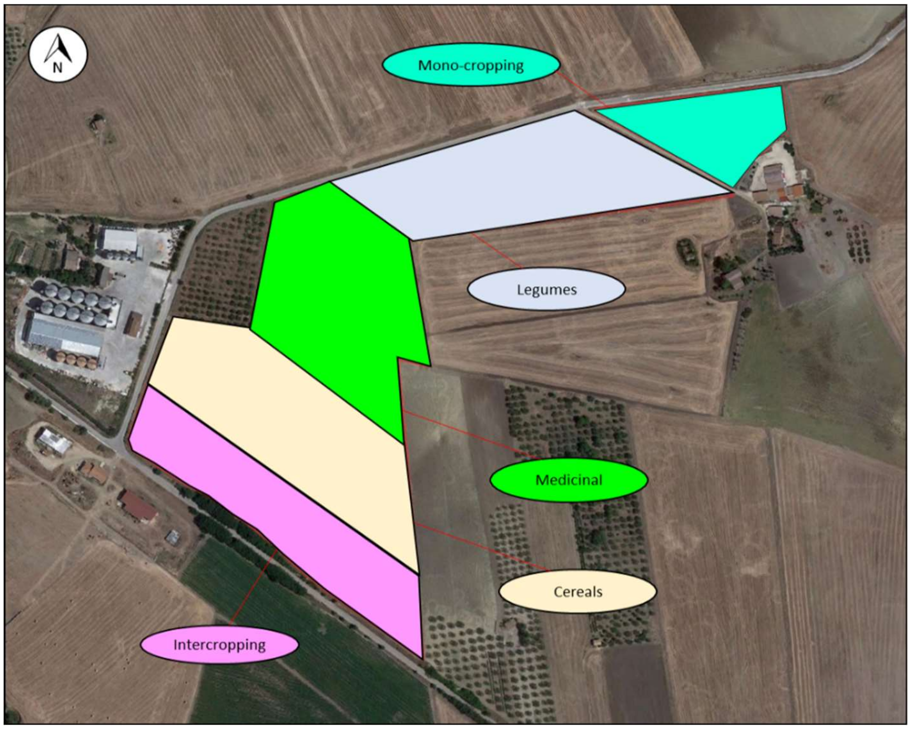


Figure 5. The layout of AgrEcoMed demonstration fields at the Italian site in Genzano di Lucania, Basilicata region, Southern Italy.

Table 3. Demonstration plots, their size, and crops selected.

Plot names	Area [ha]	Crops
Mono-cropping	1.04	Wheat (cv. Tirex)
Legumes	2.73	Protein pea (cv. Aviron), Chickpea (cv. Pascià), Chickpea (cv. Sultano), Lentil (cv. Eston), Lentil (cv. Laird)
Intercropping	2.1	Wheat (cv. Tirex), Vetch (cv. Ereica), Trifolium incarnatum (cv. Kardinal)
Cereals	3.04	Wheat (cv. Tirex), Wheat (cv. Svevo), Wheat (cv. Marco Aurelio); Wheat (cv. Senatore Capelli)
Medicinal	2.91	Rapeseed (cv. SY Harnas), Coriander (Coriandrum sativum), Mugworts (Artemisia)

Table 4. Cropping strategies of AgrEcoMed project in at the Italian site in Genzano di Lucania, Basilicata region, Southern Italy.

No	Cropping strategy	Plot location
1	Wheat mono-cropping (cv. Tirex) - seeding rate at 230 kg/ha	Mono-cropping
2	High input wheat mono-cropping (cv. Tirex) - seeding rate at 230 kg/ha	Cereals
3	Wheat (cv. Tirex) - seeding rate at 230 kg/ha	Cereals
4	Wheat with Trichoderma technology/strains - seeding rate at 230 kg/ha	Cereals
5	Wheat (cv. Tirex) - seeding rate at 230 kg/ha - with compost	Cereals
6	Wheat (cv. Svevo) - seeding rate at 230 kg/ha - with compost	Cereals
7	Wheat (cv. Tirex, M. Aurelio, Svevo, and Cappelli) - seeding rate at 230 kg/ha - with inorganic soil conditioner (Bioreactive)	Cereals
8	Wheat (cv. Tirex, M. Aurelio, Svevo, and Cappelli) - seeding rate at 230 kg/ha - without inorganic soil conditioner (Bioreactive)	Cereals
9	Wheat (cv. Tirex) - seeding rate at 230 kg/ha - with only biostimulants (BlueN)	Cereals
10	Wheat (cv. Tirex) - seeding rate at 230 kg/ha - with only fertilization	Cereals
11	Wheat (cv. Tirex) - seeding rate at 230 kg/ha - with fertilization and biostimulants (BlueN)	Cereals
12	Wheat (cv. Tirex) - seeding rate at 230 kg/ha	Intercropping
13	Wheat (cv. Tirex) - seeding rate at 150 kg/ha	Intercropping
14	Wheat (cv. Tirex) - seeding rate at 150 kg/ha (cv. Tirex) with Vetch (*Vicia sativa* L.) seeding rate at 80 kg/ha	Intercropping
15	Wheat (cv Tirex) seeding rate at 150 kg/ha with Clover (trefoil) seeding rate at 35 kg/ha	Intercropping
16	Protein pea (cv. Aviron) - seeding rate at 180 kg/ha	Legumes
17	Chickpea (cv. Pascià) - seeding rate at 230 kg/ha	Legumes
18	Chickpea (cv. Sultano) - seeding rate at 200 kg/ha	Legumes
19	Lentil (cv. Eston) - seeding rate at 100 kg/ha	Legumes
20	Lentil (cv. Laird) - seeding rate at 120 kg/ha	Legumes
21	Rapeseed (cv. SY Harnas) - seeding rate at 3.5 kg/ha	Medicinal
22	Coriander (Coriandrum sativum) - seeding rate at 20 kg/ha	Medicinal
23	Mugworts (Artemisia) - seedling rate at 22.7 and 44.45 seedling/ha	Medicinal

During the field traits, all the data for monitoring cropping system behavior (crop growth analysis, yield quantitative and qualitative response, soil organic matter and nutrient balance, etc.) and the input of cultivation (seeds, fertilizers, energy for machinery, etc.) was collected for the computation of energy balance and efficiency, economic profitability and environmental sustainability. Some of the core data collected included:

i. Soil map and soil analysis and statistics;
ii. Electric resistivity of soil;
iii. Spatial analysis of soil physical-chemical characteristics;
iv. Climate indexes (Average annual precipitation, Number of wet days per year, Mean elevation);
v. Crop chlorophyll content and leaf area index (LAI);

vi. Timing of soil cultivation, sowing, and harvesting;
vii. The seed rate and number of seedlings used for cultivation;
viii. Type and quantity of N-P-K fertilizers and agro-chemicals for plant protection;
ix. Fertilization maps;
x. Soil amendment quantities;
xi. Fuel and machinery expenditures for farming activities;
xii. Human labor working hours;
xiii. Type and quantity of soil conditioners and compost;
xiv. The yield of main products and yield by-products;

2.2.1 Mono-cropping and high input demonstration fields

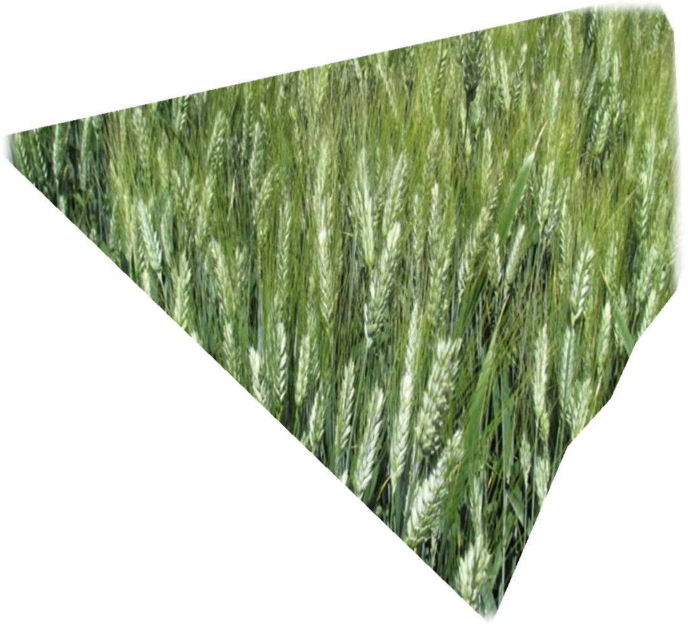


Figure 6. The layout of mono-cropping demostration fields.

Mono-cropping or continuous monoculture is the agricultural practice of growing a single crop year after year on the same land. Wheat, corn, and soybeans are three common crops often grown using mono-cropping techniques. By growing just one crop species in a field at a time, monocultures enable farmers to use machinery, increasing the efficiency of activities like planting and harvesting. Moreover, it saves time and reduces the demand for manual labor, is easier to manage, and enables high production efficiency, resulting in high yields. Winter wheat monoculture is recommended due to its economic impact (Bouatrous et al., 2022). Wheat-based monoculture is common in the Mediterranean region. It is applied commonly in several parts of Mediterranean countries such as Morocco, Syria, and Turkey. Crops produced on monoculture plantations are often subsidized by the government. Despite the economic and yield advantages, cultivating cereals in monoculture systems impoverishes both organic matter and microbiological life in the soil (Woźniak, 2020), increases the risk of disease and pest outbreaks, increased weed infestation contributing to the decrease in grain yield and quality and soil fertility (Bouatrous et al., 2022). Monoculture cereal systems could reduce productivity in dry areas (Gandía et al., 2021). The effects of mono-cropping can be extremely detrimental to the environment as it is associated with the intensive use of agricultural inputs.

The AgrEcoMed project will investigate the effects of continuous wheat mono-cropping on the yield, yield components, and grain quality of durum wheat. In the experimental fields, a wheat mono-cropping system (see Figure 6) was specifically devised. On December 22, 2022, durum wheat (cv. Tirex) was planted using a conventional seeder, with a seeding rate set at 230 kg/ha. Tirex is an early variety of Italian origin, recognized for its high yield and resilience to cold and diseases. Simultaneously, harrowing with a vibrocultor was performed along with sowing. Basic fertilization occurred on the same day, employing simple superphosphate fertilizer (CaO-SO3) 19 (4-21). Earlier in the agricultural cycle, on October 5, 2022, plowing was executed, followed by harrowing with a rotary harrow on October 31, 2022. The first nitrogen fertilization using Rhizovit 26% N (26-0-0) was implemented on February 20, 2023. Weed control and fungicide application occurred on April 13, 2023, along with the second nitrogen fertilization using ammonium nitrate (26-0-0). The cultivation process involved the application of 120 kg N/ha of nitrogen fertilizer, 70 kg P_2O_5/ha of phosphorus fertilizer, the use of plant protection products at a rate of 3.00 kg/ha, utilization of diesel machinery at 54 l/ha, and engagement of human labor input at 169 h/ha. The agricultural cycle concluded with the combine harvest on July 13, 2023. The recorded yield for was 4.12 t/ha with a corresponding protein content of 15%.

Table 5. Yield and resource inputs for monocultured durum wheat in Genzano di Lucania, Basilicata Region, Southern Italy.

Data	Monocropping
Parcel	Monocropping
System	Conventional
Crop name	Durum Wheat
Variety	cv. Tirex
Area (ha)	1
Date of sowing crop (dd.mm.yyyy)	22/12/2022
Date of harvest crop (dd.mm.yyyy)	13/07/2023
Crop biomass (t/ha)	-
Crop yield (t/ha)	4.12
Protein content (%)	15%
Seeds rate (kg/ha)	230
Nitrogen fertilizer (kg N/ha)	120
P_2O_5 fertilizer (kg P_2O_5/ha)	70
Plant protection products (kg/ha)	3.00
Active ingredient (kg A.S/ha)	0.43
Diesel machinery (l/ha)	54
Tractor hours (hour/ha)	6.1
Human labor (h/ha)	169

We gathered data specific to the region to depict a common wheat production system, marked by its significant reliance on resources and inputs, detailed in Table 6. This portrayal reflects the conventional, typical approach to wheat farming in the area. Our research will employ this information as a foundation for conducting comparative analyses. Cultivation on a 0.7-hectare area initiated with the sowing of the crop on December 22, 2022, employing a seed rate of 230 kg/ha. Simultaneously, harrowing with a vibrocultor was conducted along with sowing, and basic fertilization took place on the same day, utilizing simple superphosphate fertilizer (CaO-SO3) 19 (4-21). Earlier in the agricultural cycle, plowing occurred on October 5, 2022, followed by harrowing with a rotary harrow on October 31, 2022. The first nitrogen fertilization, using Rhizovit 26% N (26-0-0), was implemented on February 20, 2023. Weed control and fungicide application took place on April 13, 2023, coinciding with the second nitrogen fertilization using ammonium nitrate (26-0-0). The cultivation process included nitrogen fertilizer application at 120 kg N/ha, phosphorus fertilizer at 70 kg P_2O_5/ha, the use of plant protection products at a rate of 3.00 kg/ha, utilization of diesel machinery at 54 l/ha, and human labor input at 139 h/ha. The agricultural cycle concluded with the combine harvest on July 13, 2023. In this high-input scenario, the recorded yield for Durum Wheat was 3.371 tons per hectare, accompanied by a protein content of 14.9%.

Table 6. Crop yield and resource inputs for durum wheat cultivation in high input mode at Genzano di Lucania, Basilicata region, Southern Italy.

Data	High input
Parcel	Cereals
System	Durum Wheat
Crop name	Conventional
Variety	cv. Tirex
Area (ha)	0.7
Date of sowing crop (dd.mm.yyyy)	22/12/2022
Date of harvest crop (dd.mm.yyyy)	13/07/2023
Crop biomass (t/ha)	-
Crop yield (t/ha)	3.371
Protein content (%)	14.9%
Seeds rate (kg/ha)	230
Nitrogen fertilizer (kg N/ha)	120
P_2O_5 fertilizer (kg P_2O_5/ha)	70
Plant protection products (kg/ha)	3.00
Active ingredient (kg A.S/ha)	0.43
Diesel machinery (l/ha)	44.16
Tractor hours (hour/ha)	4.95
Human labor (h/ha)	139

2.2.2 Cereals demonstration fields

Wheat represents a target crop for Mediterranean agriculture. Wheat provides 20 % of calories to the world population, highlighting the relevance of this crop for current and future strategic cultivation. In this context, we have to intensify efforts toward crop improvement and yield stability under conditions of sustainable agricultural production (Royo et al., 2017). To achieve this goal it is crucial to use crop varieties that are either best adapted to the specific environments or have the potential and flexibility of becoming adapted to a more dynamic environment. This requires the growth of plants that show greater resistance to abiotic and biotic stresses and can maintain yields under adverse or low-input conditions. The use of improved cultivars and the adoption of appropriate crop management practices have significantly increased yields. It is known that a well-planned crop rotation (with the adoption of legume and/or cruciferous crops within the cereal rotation scheme) can increase the sustainability of the system in dry regions of the Mediterranean basin (Ryan et al., 2008).

Within the AgrEcoMed project, wheat and legumes will adhere to the existing rotation scheme practiced on the farm. However, the growth dynamics and productivity of modern wheat varieties (such as cv. Marco Aurelio, Tirex, Svevo) cultivated on the farm will be compared with the modern and ancient varieties of durum wheat (e.g., cv. Senatore Capelli). The project will specifically assess the impact of repurposed by-products and waste, utilized as compost, on soil fertility, crop protection, and weed control. To optimize fertilization, a customized plan will be implemented, incorporating variable rate distribution of fertilizers through the "precision farming" technique.

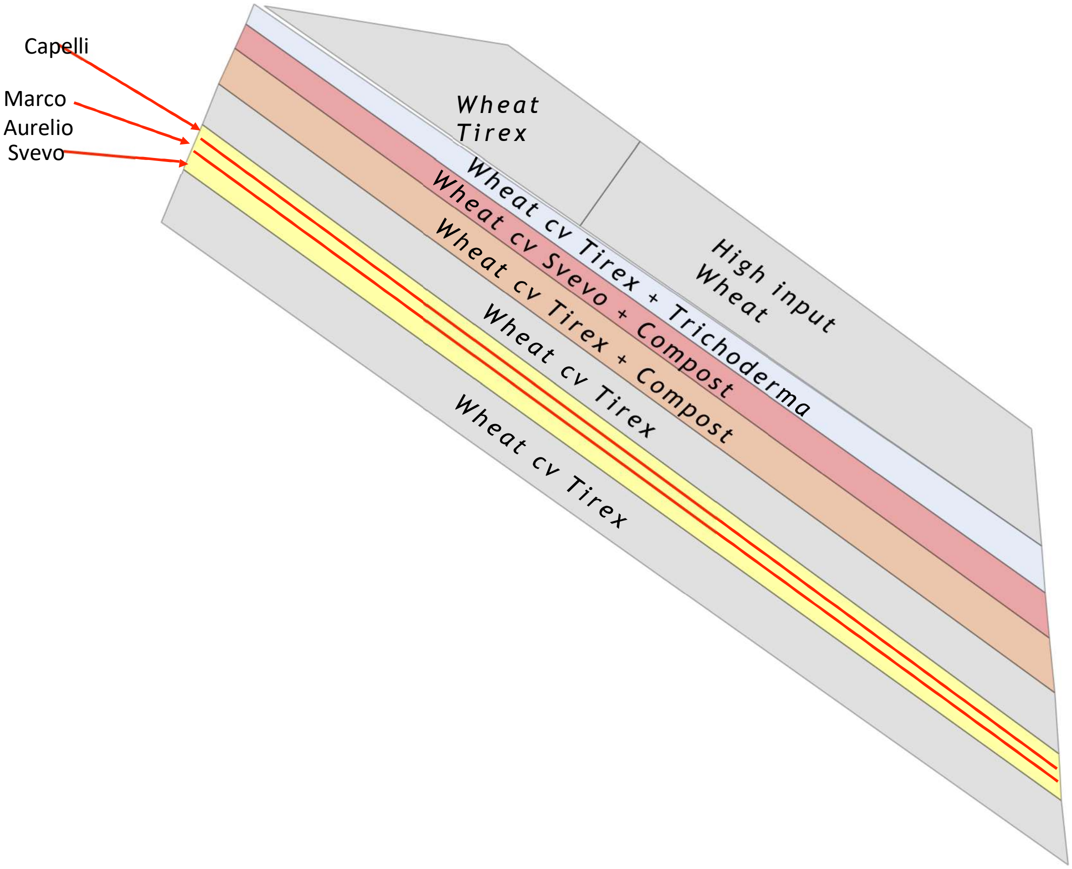


Figure 7. The layout of cereal demonstration fields and associated strategies.

2.2.2.1 Cereal cultivation using compost

Manipulation of crop fertilization is a promising agronomic practice in reducing weed interference in crops. Many weeds are high N consumers, thus limiting N for crop growth. Research has shown that crop–weed competitive interactions can be altered by N dose, source, application timing, and application method. At present, composts are mostly used within agriculture as a source of organic matter. Soil organic matter concentrations are declining in intensive arable rotations and the loss of organic matter from the soil is associated with increased soil erosion, particularly from fields of winter-sown cereals. Compost is the product of artificially controlled bio-oxidation and humification of a mix of organic materials such as solid organic waste from green and woody biodegradable plant residues such as pruning waste, manure, and sewage waste. When compost is added to soil, it has multiple positive effects on its physical, chemical, and biological properties, which result in improvements in the productivity and quality of crops (Ho et al., 2022). Using agricultural by-products, predominantly manure, as compost may also be an effective way to sequester carbon. A trial ran for 19 years (Tautges et al., 2019) showed that the use of compost and cover crops boosted soil carbon content by 12.6%. The use of bio-waste compost on land can have beneficial effects on the plant-soil system. Nine environmental benefits were identified in an extensive literature review: nutrient supply, carbon sequestration, weed pest, and disease suppression, increase in crop yield, decreased soil erosion, retention of soil moisture (blue water is saved), increased soil workability, enhanced soil biological properties and biodiversity, and gain in crop nutritional quality (Martínez-Blanco et al., 2013).

The AgrEcoMed project will specifically evaluate the impact of repurposed by-products and waste as compost on soil fertility, crop protection, and weed control. The Tirex-Compost and Svevo-Compost field experiments will analyze winter wheat growth dynamics with different synthetic fertilizer levels, nitrogen management approaches, and fertilization methods, including a novel concept using organic micro granular fertilizers with biostimulant properties (Table 7).

Table 7. Crop yield and resource inputs for cereal cultivation using compost at Genzano di Lucania, Basilicata region, Southern Italy.

Data	Low input Wheat (cv. Svevo) with compost	Low-input Wheat (cv. Tirex) with compost
Parcel	Cereals	Cereals
Crop name	Durum Wheat	Durum Wheat
Variety	cv. Svevo	cv. Tirex
Area (ha)	0.33	0.46
Date of sowing crop (dd.mm.yyyy)	22/12/2022	22/12/2022
Date of harvest crop (dd.mm.yyyy)	13/07/2023	13/07/2023
Crop biomass (t/ha)	-	9.03
Crop yield (t/ha)	3.818	4.20
Protein content (%)	15.2%	15.30%
Specific weight	76.10	69.70
Seeds rate (kg/ha)	230	230
Compost (kg/ha)	200	200
Compost name	Cifo Top N	Cifo Top N
Nitrogen fertilizer (kg N/ha)	111	111
P_2O_5 fertilizer (kg P_2O_5/ha)	58	58
Pesticide rate (kg/ha)	3	3
Active ingredient (kg A.S/ha)	0.43	0.43
Diesel machinery (l/ha)	50	55
Tractor hours (hour/ha)	5.61	6.20
Human labor (h/ha)	156.5	172.2

The cultivation of Wheat (cv. Svevo) on a 0.33-hectare area commenced with the sowing of the crop on December 22, 2022, utilizing a seed rate of 230 kg/ha. Simultaneously, harrowing with a vibrocultor was conducted along with sowing. On the same day, compost distribution (Cifo Top N) and basic fertilization occurred, employing simple superphosphate fertilizer (CaO-SO3) 19 (4-21). In the earlier stages of the cycle, on October 20, 2022, soil leveling took place through harrowing with a tiller. The first nitrogen fertilization, utilizing Rhizovit 26% N (26-0-0), was implemented on February 20, 2023. Weed control and fungicide application occurred on April 13, 2023, coinciding with the second nitrogen fertilization using ammonium nitrate (26-0-0). The recorded yield for this cultivation was 3.818 tons per hectare, accompanied by a protein content of 15.2%. The consumption of diesel machinery was at 50 l/ha, with human labor input recorded at 156.5 h/ha. Similarly, the cultivation of Wheat (cv. Tirex), covering an area of 0.46 hectares, followed the same practices. It commenced with the sowing of the crop on December 22, 2022, and concluded with the harvest on July 13, 2023. The recorded yield was 4.2 tons per hectare, accompanied by a protein content of 15.3%. The cultivation process involved a seed rate of 230 kg per hectare, nitrogen fertilizer application at 111 kg N/ha, phosphorus fertilizer at 58 kg P_2O_5/ha, utilization of plant protection products at a rate of 3.00 kg/ha, using diesel machinery at 55 liters per hectare, and employing human labor input at 172.2 h/ha.

The compost used was Cifo Top N a new concept organic microgranular fertilizer, particularly rich in controlled release organic nitrogen which ensures a balanced and modulated nutrition in line with the needs of the crop. TOP N application in early stages improves the vegetative and productive development and increases the potential production. Due to presence of APR®, TOP N has a biostimulant action on root, soil, nutrient absorption and increases plant tolerance to environmental stresses

2.2.2.2 Cereal cultivation using bioformulation Trichoderma harzianum (Th3)

Fusarium head blight (FHB) is the principal disease affecting wheat worldwide, decreasing grain quality, and production. This disease is mainly caused by members of the *Fusarium graminearum* species complex (FGSC), which can produce mycotoxins in the contaminated grains. The pathogen overwinters on crop residues (wheat straw). Trichoderma spp. is the most popular research tool as a microbial inoculant which has been largely used against several plant pathogenic fungi causing soil-borne, airborne, and post-harvest diseases of the plant through their high antagonistic and mycoparasitic potential.

Another objective of the agrEcoMed project is to evaluate the growth-promoting ability of wheat crops treated with bioformulation Trichoderma harzianum (Th3), as outlined in Table 8. Trichoderma spp. is the most popular research tool as a microbial inoculant which has been largely used against several plant pathogenic fungi causing soil-borne, airborne, and post-harvest diseases of the plant through their high antagonistic and mycoparasitic potential.

The cultivation of cv. Tirex, covering an area of 0.46 hectares, commenced with the sowing of the crop on December 22, 2022, followed by rolling and background fertilization on the same date. The cultivation process involved a seed rate of 230 kg per hectare, nitrogen fertilizer application at 85 kg N/ha, phosphorus fertilizer at 58 kg P_2O_5/ha, utilizing plant protection products at a rate of 3 kg/ha, using diesel machinery at 43.8 l/ha, and using human labor input at 136 h/ha. Nitrogen fertilization takes place twice, on February 20, 2023 (I nitrogen fertilization), and on April 13, 2023 (II nitrogen fertilization). Tricoboost, derived from Trichoderma harzianum IAB/01, was administered as a biostimulant at a dosage of 0.5 kg/ha. Tricoboost stimulates plant development, increases soil fertility and competes for space and nutrients by avoiding the development of harmful organisms (especially fungi). Compost distribution and weed control with fungicide occured, along with biostimulant application, all on December 22, 2022. The crop cycle concluded with the harvest on July 13, 2023. The recorded yield was 3.318 tons per hectare, accompanied by a protein content of 14.9%.

Table 8. Crop yield and resource inputs for cereal cultivation using trichorderma strain at Genzano di Lucania, Basilicata region, Southern Italy.

Data	Wheat (cv. Tirex) with Trichoderma
Parcel	Cereals
Crop name	Durum Wheat
Variety	cv. Tirex
Area (ha)	0.46
Date of sowing crop (dd.mm.yyyy)	22/12/2022
Date of harvest crop (dd.mm.yyyy)	13/07/2023
Crop biomass (t/ha)	10.77
Crop yield (t/ha)	3.318
Protein content (%)	14.9%
Gluten content (%)	14.6%
Specific weight	76.10
Seeds rate (kg/ha)	230
Biostimulant (kg/ha)	0.5
Biostimulant name	Tricoboost (Trichoderma spp IAB/01)
Nitrogen fertilizer (kg N/ha)	85
P_2O_5 fertilizer (kg P_2O_5/ha)	58
Pesticide rate (kg/ha)	3
Active ingredient (kg A.S/ha)	0.43
Diesel machinery (l/ha)	43.8
Tractor hours (hour/ha)	4.9
Human labor (h/ha)	136

2.2.2.3 Cereal cultivation using different wheat varieties

Another key goal within the AgrEcoMed project is to conduct a comparative analysis (Table 9) of wheat growth patterns and productivity of modern wheat varieties (cv. Marco Aurelio, Tirex, and Svevo) with ancient varieties exemplified by cv. Senatore Capelli. By examining these various wheat strains, we aim to better understand the factors contributing to their respective growth dynamics and productivity, which can be valuable information for future agricultural practices and crop selection. The crop cycle began with plowing, followed by harrowing using a rotary harrow and tiller on October 20, 2022. The seeding rate for all varieties was set at 230 kg/ha occurred December 22, 2022. Nitrogen fertilizer was applied at a rate of 85 kg N/ha, phosphorus fertilizer at 58 kg P_2O_5/ha, and plant protection products were used at a rate of 3 kg/ha. The most notable difference is observed in the crop yield, where Tirex Wheat stands out with the highest yield at 4.18 tons per hectare. Cappelli Wheat, on the other hand, has the lowest recorded yield among the mentioned varieties at 1.78 t/ha. Marco Aurelio and Svevo Wheat fall in between, with Marco Aurelio having a yield of 4.10 t/ha and Svevo at 3.92 t/ha. These differences in crop yield highlight the varying performance and productivity of these agroecological wheat varieties under similar agroecological conditions.

Table 9. Crop yield and resource inputs for cereal cultivation using different Wheat varieties at Genzano di Lucania, Basilicata region, Southern Italy.

Data	Agroecological Wheat - Tirex	Agroecological Wheat - Cappelli	Agroecological Wheat – Marco Aurelio	Agroecological Wheat - Svevo
Parcel	Cerals	Cerals	Cereals	Cereals
Crop name	Durum Wheat	Durum Wheat	Durum Wheat	Durum Wheat
Variety	cv. Tirex	cv. Senatore Cappelli	cv. Marco Aurelio	cv. Svevo
Area (ha)	0.34	0.18	0.18	0.18
Date of sowing crop (dd.mm.yyyy)	22/12/2022	22/12/2022	22/12/2022	22/12/2022
Date of harvest crop (dd.mm.yyyy)	13/07/2023	13/07/2023	13/07/2023	13/07/2023
Crop biomass (t/ha)	10.65	12.18	10.88	8.31
Crop yield (t/ha)	4.18	1.78	4.10	3.92
Protein content (%)	14.3	16.1	14.3	14.4
Gluten content (%)	11.80	-	11.63	11.87
Colour	14.61	-	13.94	14.00
Specific weight	71.9	68.60	76.10	76.10
Seeds rate (kg/ha)	230	230	230	230
Nitrogen fertilizer (kg N/ha)	85	85	85	85
P_2O_5 fertilizer (kg P_2O_5/ha)	58	58	58	58
Pesticide rate (kg/ha)	3	3	3	3
Active ingredient (kg A.S/ha)	0.4	0.4	0.4	0.4
Diesel machinery (l/ha)	54.70	46.00	54.00	51.50
Tractor hours (hour/ha)	6.15	5.20	6.05	5.77
Human labor (h/ha)	171.5	148.0	168.0	161.0

2.2.2.4 Cereal cultivation using biofertilizers

The experimental stage of our research involved growing cereal crops in two distinct conditions: one with the application of biostimulants for nutrient efficiency and the other without. Among these biostimulants, a noteworthy addition was a product containing Methylobacterium symbioticum SB23, an exclusive and patented endophytic bacterium. This unique bacterium has the remarkable ability to inhabit and proliferate within plant tissues, simultaneously metabolizing atmospheric nitrogen and converting it into a more readily absorbable form for crops. Biofertilizer Blue N, a 100% biological and sustainable solution, utilizes this bacterium to improve atmospheric nitrogen use by 60%, promoting environmental preservation. Approved for organic farming and special environmental protection areas, Blue N offers benefits like atmospheric nitrogen fixation at the leaf level, reduced soil mineral fertilization, decreased reliance on soil characteristics, and enhanced photosynthetic activity through its bio-stimulant action.

Our main goal in using this biostimulant was to assess its impact on improving the nutrient efficiency of cereal cultivation (see Table 10).

Table 10. Crop yield and resource inputs for cereal cultivation using nutrient efficiency biostimulants at Genzano di Lucania, Basilicata region, Southern Italy.

Data	Wheat Tirex with no N input	Wheat with only N chemical fertilizer	Wheat with only Methylobacterium symbionticum (Blue N)	Wheat with N chemical fertilizer and Methylobacterium symbionticum (Blue N)
Parcel	Cereals	Cereals	Cereals	Cereals
Crop name	Durum Wheat	Durum Wheat	Durum Wheat	Durum Wheat
Variety	cv. Tirex	cv. Tirex	cv. Tirex	cv. Tirex
Area (ha)	0.15	0.15	0.15	0.15
Date of sowing crop (dd.mm.yyyy)	22/12/2022	22/12/2022	22/12/2022	22/12/2022
Date of harvest crop (dd.mm.yyyy)	13/07/2023	13/07/2023	13/07/2023	13/07/2023
Crop biomass (t/ha)	10.84	10.81	10.27	11.12
Crop yield (t/ha)	3.43	3.90	4.007	3.55
Protein content (%)	12.30	13.50	12.80	13.17
Gluten content (%)	10.07	11.00	10.40	10.90
Colour	14.20	14.23	14.40	14.23
Specific weight	77.80	77.20	77.20	77.90
Seeds rate (kg/ha)	230	230	230	230
Biostimulant (kg/ha)	-	-	0.5	0.5
Biostimulant name	-	-	BlueN	BlueN
Nitrogen fertilizer (kg N/ha)	-	120	-	120
P_2O_5 fertilizer (kg P_2O_5/ha)	58	58	58	58
Pesticide rate (kg/ha)	2.0	2.0	2.0	2.0
Active ingredient (kg A.S/ha)	0.4	0.4	0.4	0.4
Diesel machinery (l/ha)	44.93	51.05	52.49	46.51
Tractor hours (hour/ha)	5.04	5.72	5.88	5.21
Human labor (h/ha)	140.6	159.8	164.3	145.6

Different wheat cultivation methods were compared including Wheat Tirex with no nitrogen input, wheat with only N chemical fertilizer, wheat with only Methylobacterium symbionticum (Blue N), and wheat with both N chemical fertilizer and Methylobacterium symbionticum (Blue N). The use of both the tiller and vibrocultor occurred on 20/10/2022, with the latter exclusively applied on 22/12/2022—an arrangement replicated across all nitrogen application methods. The sowing stage, with a seed rate of 230 kg/ha, was consistently carried out on 22/12/2022 across all strategies. The background fertilization process, involving the use of superphosphate fertilizer (CaO-SO3) 19 (4-21), was uniformly implemented on the same date. Weed control and fungicide application occurred on 13 April 2023. The crop cycle concluded with the harvest on July 13, 2023.

Preliminary observations from the AgrEcoMed cereals field suggest that introducing BlueN to wheat fields is associated with favorable impacts on wheat growth, leading to a notable 15.5% increase in crop yield compared to fields without nitrogen fertilizer application. Blue N also demonstrates a slight advantage over wheat with only nitrogen chemical fertilizer, resulting in comparable yields (4.007 tons/ha versus 3.9 tons/ha) while saving 120 kg of nitrogen per hectare. This outcome demonstrates that Blue N contributes to cost reduction by lowering fertilizer usage, thereby decreasing input expenses for farmers. This economic advantage has the potential to improve the overall profitability of farming operations. Moreover, the reduction in fertilizer application aligns with sustainable and environmentally friendly farming practices.

2.2.2.5 Cereal cultivation using precision farming

Precision agriculture (PA) is widely acknowledged as a contributor to farming efficiency and environmentally friendly farming practices, and it is essential to long-term intensification (Lindblom et al. 2017). It assists farmers in making precise and optimized use of crop-specific inputs, resulting in lower production costs and environmental impact (Bacenetti et al. 2020; Canaj et al. 2021). Variable-rate technology (VRT) is a pivotal technology PA, aiming to perform site-specific chemicals, lime, gypsum, irrigation water, and other farm inputs input management across a field (Vatsanidou et al. 2020). Variable-rate fertilization is a tool for more effective site-specific management because it addresses in-field variation in soil N availability and crop response (Stamatiadis et al. 2018). AgrEcoMed will evaluate the effectiveness of precision agriculture (PF) techniques to optimize and make more efficient the use of production factors. More specifically, will investigate the application of PF in optimizing the input of fertilizers, starting from quantifying and classifying soil spatial variability, using the response of the soil to electromagnetic radiation to determine the original causes of the variability. After delineating homogeneous areas (Figure 8), fertilizer input and subsequent dosages were computed, taking into account crop status determined by vegetational indexes measured via remote sensing. Analyses was conducted to assess the impact of this technique on nutrient utilization efficiency. The calculation of fertilizer quantities to be applied (Table 11) was based on the estimated nutrient uptake by the crop and the soil characteristics of each previously identified homogeneous area as determined from the resistivity maps.

Figure 8. Prescription maps for nitrogen fertilization in AgrEcoMed fields.

Commencing sowing on 22/12/2022 and culminating the harvest on 13/07/2023, both systems maintained a consistent seeding rate of 230 kg/ha. Notably, Wheat UA utilized 120 kg N/ha, whereas Wheat VRT employed a more efficient approach with 85 kg N/ha. The nitrogen application rates varied across zones (Figure 8), with 68 kg N/ha for zone 1, approximately 85 kg N/ha for zone 2, and 94 kg N/ha for zone 3. These results suggest that the implementation of VRT led to a reduction of at least 20% in nitrogen fertilizer usage while preserving an equivalent yield compared to Uniform Application UA. Regarding crop yield (t/ha), Wheat UA achieved 4.2 t/ha, while Wheat VRT attained a marginally lower yield of 4.18 t/ha. Both systems applied 58 kg P_2O_5/ha, and they shared identical pesticide application rates of 3 kg/ha, utilizing the same active ingredient (0.43 kg A.S/ha). There is a slight difference in human labor, with Wheat UA requiring 173 h/ha and Wheat VRT using 171.5 h/ha.

Table 11. Crop yield and resource inputs for cereal cultivation using uniform (UA) and variable rate fertilization (VRT) at Genzano di Lucania, Basilicata region, Southern Italy.

Data	Wheat UA	Wheat VRT
Parcel	Cereals	Cereals
Crop name	Durum Wheat	Durum Wheat
Variety	cv. Tirex	cv. Tirex
Area (ha)	0.34	0.34
Date of sowing crop (dd.mm.yyyy)	22/12/2022	22/12/2022
Date of harvest crop (dd.mm.yyyy)	13/07/2023	13/07/2023
Crop biomass (t/ha)	-	10.65
Crop yield (t/ha)	4.2	4.18
Protein content (%)	-	14.3
Gluten content (%)	-	11.8
Colour	-	14.61
Seeds rate (kg/ha)	230	230
Nitrogen fertilizer (kg N/ha)	120	85
P_2O_5 fertilizer (kg P_2O_5/ha)	58	58
Pesticide rate (kg/ha)	3	3
Active ingredient (kg A.S/ha)	0.43	0.43
Diesel machinery (l/ha)	54.70	54.70
Tractor hours (hour/ha)	6.15	6.15
Human labor (h/ha)	173	171.5

2.2.3 Intercropping demonstration fields

Nitrogen management adapted to crop and field conditions ensures higher yield and protein content However, several abiotic and biotic factors (e.g. water deficit and weed competition, respectively) may limit the profitability of spring nitrogen fertilization, and the high cost of off-farm organic fertilizers may be prohibitive (Vrignon-Brenas et al., 2016). If forage legumes are associated with wheat, simultaneously or successively, they can help to reduce the impact of limiting factors through the ecological services they provide. Intercropping is defined as the agronomic practice of growing two or more crops on the same field at the same time. The major benefits of intercropping are (1) increasing the rate of crop production, with the advantage of simultaneously decreasing the risk of total crop reduction, and (2) controlling weeds. Intercropping is considered by its advocates to be a sustainable, environmentally sound, and economically advantageous cropping system (Khanal et al., 2021).

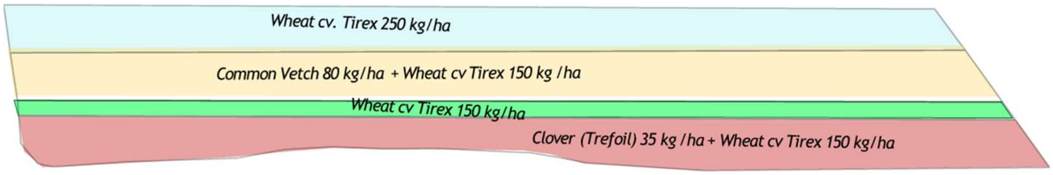


Figure 9. The layout of intercropping demonstration fields.

Intercropping legumes with cereals for forage production is a sustainable technique showing several environmental benefits (Lithourgidis et al., 2007). Intercropping has shown significant potential to increase resource efficiency and resilience against biotic and abiotic stresses, thereby allowing to deliver yield gains without increased inputs or stabilizing yields with decreased inputs[1]. Most research findings showed that the yield of intercropping is often higher than sole cropping (Bitew et al., 2021). Intercropping also enhances the competitive ability of crops for nutrients and water related to monoculture systems. It provides year-round ground cover, or at least for a longer period than monocultures, to protect the soil from desiccation and erosion. It improves soil health and delivers multiple ecosystem services. by increased yield, better soil quality, and soil C sequestration (Cong et al., 2015) through decreasing tillage frequency and soil disturbance, and increasing soil organic matter and carbon storage. Economic analyses (Arsyad et al., 2020; Huang et al., 2015) of the different intercropping systems have indicated that farm incomes were increased from intercropping as it is leading to on-farm cost savings and reduced reliance on external inputs.

In Mediterranean region, common vetch, an annual legume with high protein levels and climbing growth, is widely used in intercropping with cereals. It serves as an alternative grain legume to fava beans, peas, lupins, and soybeans due to its elevated grain protein content. Common vetch thrives in marginal cropping zones, displaying resilience to drought and varying annual weather patterns (Nguyen et al., 2020). Clover is a forage legume cultivated in the temperate world, noted for its high-protein feed. Intercropping white clover with cereals is advocated for low-input farming, offering sustainability benefits such as atmospheric nitrogen fixation, soil conservation, structural soil improvements, and various agroecosystem services like enhanced soil microbial activity and phytoremediation (Thorsted et al., 2006; McKenna et al., 2018).

Another goal within the AgrEcoMed project is to assess the impacts, including yields, quality, and growth rates, of concurrent intercropping strategies (see Figure 9). These strategies involve clover (Trifolium repens L. cv. Kardinal) combined with durum wheat (Trefoil 35 kg/ha + Wheat cv Tirex 150 kg/ha) and common vetch (Vicia sativa L. cv. Ereica) paired with durum wheat (Vetch 80 kg/ha + Wheat cv Tirex 150 kg/ha). To establish a baseline for comparison, two independent wheat cropping strategies with seed rates of 150 kg/ha and 230 kg/ha are also employed within the study. The crop yield and resource inputs of these strategies for the first cropping season are presented in Table 12.

Different seed rates were applied based on the cropping strategy, with specific rates for wheat and accompanying crops (Vetch/Trefoil). Nitrogen fertilizer was not applied in any of the scenarios, and P_2O_5 fertilizer was consistently applied at 70 kg/ha. All scenarios used a pesticide rate of 2.0 kg/ha with an active ingredient of 0.4 kg A.S/ha.

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[1] https://cordis.europa.eu/programme/id/HORIZON_HORIZON-CL6-2022-BIODIV-01-05

Table 12. Crop yield and resource inputs for cereal cultivation intercopped with legumes at Genzano di Lucania, Basilicata region, Southern Italy.

Data	Wheat with seed rate at 230 kg/ha	Wheat with seed rate at 150 kg/ha	Wheat intercropped with common vetch	Wheat intercropped with Trefoil
Parcel	Intercropping	Intercropping	Intercropping	Intercropping
Crop name	Durum Wheat	Durum Wheat	Durum Wheat	Durum Wheat
Variety	cv. Tirex	cv. Tirex	cv. Tirex	cv. Tirex
Area (ha)	0.28	0.28	0.62	0.55
Date of sowing crop (dd.mm.yyyy)	22/12/2022	22/12/2022	22/12/2022	22/12/2022
Date of harvest crop (dd.mm.yyyy)	13/07/2023	13/07/2023	13/07/2023	13/07/2023
Crop yield, wheat (t/ha)	1.72	1.53	1.39	3.455
Crop yield, other crop (t/ha)	-	-	1.07	3.455
Protein content (%)	11.80%	11.80%	-	12.60%
Gluten content (%)	10.07	11.00	10.40	10.90
Colour	14.20	14.23	14.40	14.23
Protein content (%)	-	-	-	-
Specific weight	76.60	76.60	-	75.00
Seeds rate, Wheat (kg/ha)	230	150	150	150
Seeds rate, Vetch/Trefoil (kg/ha)	-	-	80	35
Nitrogen fertilizer (kg N/ha)	0	0	0	0
P_2O_5 fertilizer (kg P_2O_5/ha)	70	70	70	70
Pesticide rate (kg/ha)	2.0	2.0	2.0	2.0
Active ingredient (kg A.S/ha)	0.4	0.4	0.4	0.4
Diesel machinery (l/ha)	44.93	41.92	34.06	45.26
Tractor hours (hour/ha)	5.04	4.70	3.82	5.07
Human labor (h/ha)	140.6	131.2	164.3	141.7

The preliminary results indicate that common vetch intercropped with wheat shows a higher yield compared to standalone wheat with a seed rate of 230 kg/ha. The preliminary results indicate that common vetch intercropped with wheat shows a 6.4% higher fresh biomass, 37.1% higher LAI, and 9.2% higher chlorophyll content compared to standalone wheat with a seed rate of 230 kg/ha.

2.2.4 Legumes demonstration fields

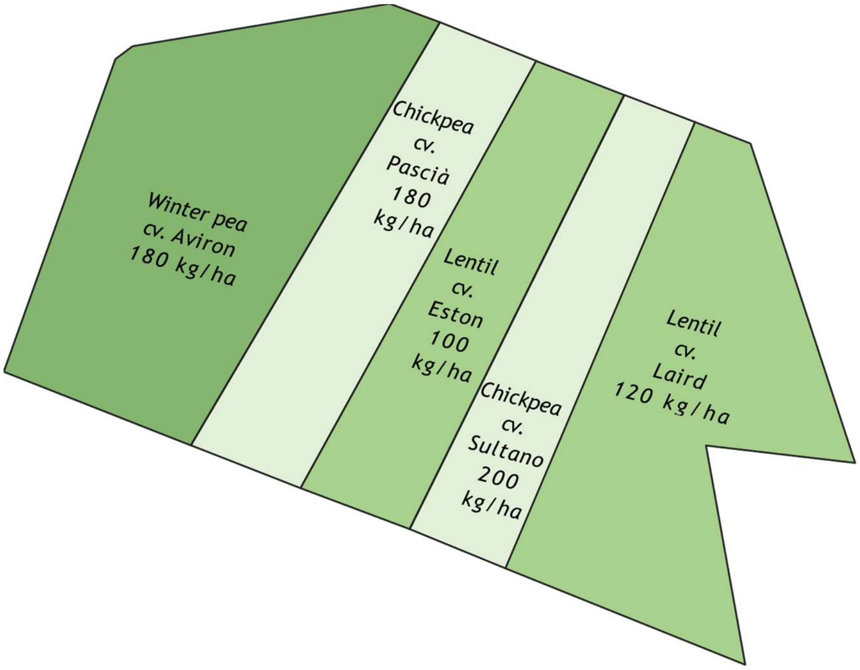

Figure 10. The layout of legume demostration fields.

Loss of biodiversity in the Mediterranean Region is one of the main reasons for the negative effect on the environment and crop yields, soil degradation, and water over-exploitation, particularly in the rain-fed cropping systems of Mediterranean areas. The rotation of crops is one of the most important agronomic practices that may have a significant effect on crop quality and quantity. Crop rotation has been suggested as a general strategy to sustain yields and reduce the risk of yield losses (Marini et al., 2020). It is used to overcome soil sickness, improvement of soil physical structure and aggregation, the increasing diversity of soil microbiota and associated beneficial microbes, and control soil-borne, as well as airborne, pathogens by breaking their natural life cycle (Woo et al., 2022). It could also mitigate the effects of climate change and market variability (Selim, 2019).

Grain legumes grown in rotation with annual cereal crops contribute to the total pool of nitrogen in the soil and improve the yields of cereals (Danga et al., 2009). However, the anticipated N benefits of the legume may be positive or negative depending on the legume species and its interaction with the environment. Dry peas, lentils, and chickpeas are the most common pulses produced in the world and are typically grown in rotation (i.e., alternating years) with cereal grains. Consumer demand for pulses has increased due to the demand for plant-based protein (Thavarajah et al., 2022). The Chickpea (Cicer arietinum L.) is the third most important grain legume in the world, after the bean and the pea. It is an important cool-season food legume crop that is mainly cultivated as a rain-fed crop.

The cultivated area in the world is about 11 million hectares. India is the largest chickpea producer in the world producing more than 60 % of the world's chickpeas[2]. Chickpea is native to the Mediterranean region and the Middle East. The seeds are high in fiber and protein and are a good source of iron, phosphorus, and folic acid (Sellami et al., 2021). Lentil (Lens culinaris Medikus) is a protein-rich cool-season food legume with an excellent source of protein, prebiotic carbohydrates, minerals, and vitamins (Choukri et al., 2020). Lentils contain a high level of protein (20-30%) and have been reported as tolerant to high

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[2] https://www.atlasbig.com/en-us/countries-chickpea-production

temperatures and drought. Worldwide more than 6.3 million tons of lentils are produced per year with Canada, India, and Turkey as the biggest world producers[3]. Dry pea or field pea (Pisum sativum L.) is one of the most important and highly productive cool season pulse crops grown worldwide. Yellow peas and green peas are the two most commonly available varieties of dry peas. Nutritionally, dry pea (*Pisum sativum* L.) is a rich source of low-digestible carbohydrates, protein, and micronutrients (Thavarajah et al., 2022). The top producer of green peas – by far – is China, followed by India, USA, France, and Egypt.

A goal of the AgrEcoMed initiative is to explore broader crop rotations (refer to Figure 10) that incorporate legumes, forage crops, and alternative crops, including medicinal species. This approach aims to enhance land management practices within the production system and contribute to the sustainability of the agroecosystem. The three-year rotation plan within the AgrEcoMed project integrates grain legumes, such as chickpeas, lentils, and peas, in fields with wheat and medicinal plants. Notably, the legume plots outlined in Table 13 feature Sicilian organic chickpeas (cv. Pascià) with a seeding rate of 230 kg/ha, chickpeas (cv. Sultano) at 200 kg/ha, Canadian lentil cultivars “Eston” and “Laird” with seeding rates of 100 kg/ha and 120 kg/ha, respectively, and winter peas (cv. Aviron) at 180 kg/ha. The nitrogen fertilizer rate applied was 9 kg N/ha, while the phosphorus fertilizer rate was set at 28 kg P_2O_5/ha.

Table 13. Crop yield and resource inputs for legume crop cultivation at Genzano di Lucania, Basilicata region, Southern Italy.

Data	Chickpea Pascia	Chickpea Sultano	Lentil-Laird	Lentil-Eston	Protein Pea
Parcel	Legumes	Legumes	Legumes	Legumes	Legumes
Crop name	Chickpea	Chickpea	Lentil	Lentil	Protein pea
Variety	cv. Pascia	cv. Sultano	cv. Laird	cv. Eston	cv. Aviron
Area (ha)	0.42	0.42	0.42	0.6	0.84
Date of sowing crop (dd.mm.yyyy)	7/1/2023	7/1/2023	7/1/2023	7/1/2023	5/11/2022
Date of harvest crop (dd.mm.yyyy)	23/07/2023	23/07/2023	23/07/2023	23/07/2023	8/7/2023
Crop yield (t/ha)	0.762	0.905	0.333	1.3	1.92
Seeds rate (kg/ha)	230	200	120	100	180
Nitrogen fertilizer (kg N/ha)	9	9	9	9	0
P_2O_5 fertilizer (kg P_2O_5/ha)	28	28	28	28	27
Pesticide rate (kg/ha)	2.75	2.75	2.75	2.75	2.75
Active ingredient (kg A.S/ha)	1.18	1.18	1.18	1.18	1.18
Diesel machinery (l/ha)	32.00	38.01	9.43	17.03	53.38
Tractor hours (hour/ha)	3.59	4.26	1.06	1.91	5.98
Human labor (h/ha)	122.7	145.7	165.0	286.0	125.0

Chickpea Pascia is cultivated on a 0.42-hectare parcel as part of the Legumes system. Sown on 7/1/2023 and harvested on 23/07/2023, the crop achieved a yield of 0.762 t/ha. The seeding rate was set at 230 kg/ha, accompanied by a nitrogen fertilizer application of 9 kg N/ha and P_2O_5 fertilizer at 28 kg P_2O_5/ha.

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[3] https://www.atlasbig.com/en-ca/countries-by-lentil-production

The crop management strategy included a pesticide rate of 2.75 kg/ha with an active ingredient of 1.18 kg A.S/ha. Diesel machinery consumption was recorded at 32.00 l/ha, requiring 3.59 tractor hours/ha and 122.7 hours/ha of human labor.

Chickpea Sultano, also part of the Legumes system, was cultivated on a 0.42-hectare parcel. The crop, sown and harvested on 7/1/2023 and 23/07/2023, respectively, yielded 0.905 t/ha. The seeding rate for Chickpea Sultano was 200 kg/ha, accompanied by nitrogen and P_2O_5 fertilizers applied at 9 kg N/ha and 28 kg P_2O_5/ha, respectively. The crop received a pesticide application of 2.75 kg/ha with an active ingredient of 1.18 kg A.S/ha. Diesel machinery usage was 38.01 l/ha, requiring 4.26 tractor hours/ha and 145.7 hours/ha of human labor.

Lentil-Laird, part of the Legumes system, was cultivated on a 0.42-hectare parcel with a sowing date of 7/1/2023 and a harvest date of 23/07/2023. The crop achieved a yield of 0.333 t/ha with a seeding rate of 120 kg/ha. Nitrogen and P2O5 fertilizers were applied at 9 kg N/ha and 28 kg P2O5/ha, respectively. A pesticide rate of 2.75 kg/ha, including an active ingredient of 1.18 kg A.S/ha, was employed. Diesel machinery usage was 9.43 l/ha, requiring 1.06 tractor hours/ha and 165.0 hours/ha of human labor.

Lentil-Eston, part of the Legumes system, was cultivated on a 0.6-hectare parcel. Sown and harvested on 7/1/2023 and 23/07/2023, respectively, the crop achieved a yield of 1.3 t/ha with a seeding rate of 100 kg/ha. Nitrogen and P_2O_5 fertilizers were applied at 9 kg N/ha and 28 kg P_2O_5/ha, respectively. Similar to other legumes, a pesticide rate of 2.75 kg/ha with an active ingredient of 1.18 kg A.S/ha was used. Diesel machinery usage was 17.03 l/ha, requiring 1.91 tractor hours/ha and 286.0 hours/ha of human labor.

Protein Pea, cultivated on a 0.84-hectare parcel as part of the Legumes system, was sown on 5/11/2022 and harvested on 8/7/2023. The crop exhibited a yield of 1.92 t/ha with a seeding rate of 180 kg/ha. Unlike other legumes, no nitrogen fertilizer was applied. The P fertilizer was used at a rate of 27 kg P_2O_5/ha. The pesticide rate was 2.75 kg/ha, including an active ingredient of 1.18 kg A.S/ha. Diesel machinery usage was 53.38 l/ha, requiring 5.98 tractor hours/ha and 125.0 hours/ha of human labor.

2.2.5 Medicinal plants demonstration fields

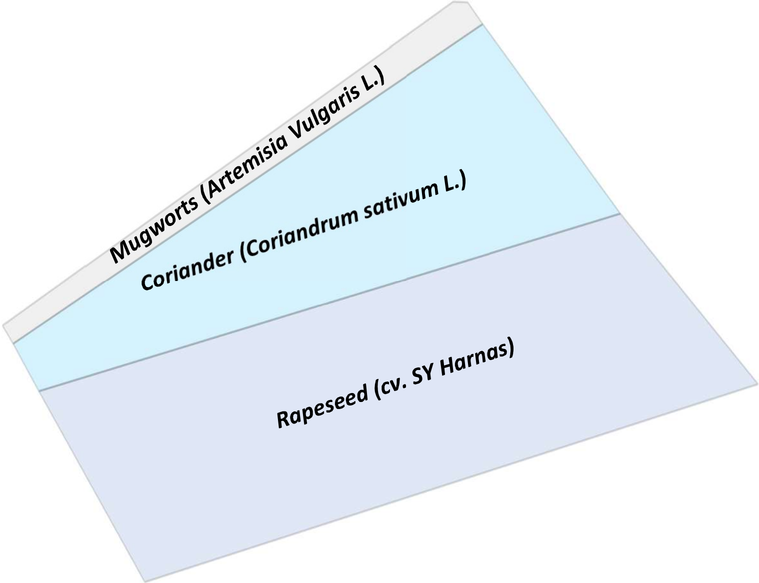

Figure 11. The layout of medicinal demonstration fields.

In agriculture farming systems, the valorization of biodiversity is strictly related to the planning of wide and rational crop rotations also with alternative species as medicinal plants, and to the valorization of local genotypes and restoration of Mediterranean biodiversity. Brassica napus L. (B. napus L) commonly known as rapeseed (or canola), is one of the cultivated medicinal food plants in Middle Asia, North Africa, and West Europe (Soodabeh Saeidnia, 2012).

Rapeseed oil is used for industrial and culinary purposes. Rapeseed is reported to have three to four times higher proteins than rice and wheat (Raboanatahiry et al., 2021). Rapeseed crop in rotation with wheat generally increases wheat yields (Mazzilli and Ernst, 2019) and could supplement nutrients in the soil (Raboanatahiry et al., 2021). Coriander (Coriandrum sativum L.) is one of the most important essential oil crops on a global scale (Harizanova et al., 2022). It is one of the most useful essential oil-bearing spices as well as medicinal plants, belonging to the family Umbelliferae/Apiaceae. The leaves and seeds of the plant are widely used in folk medicine in addition to their use as a seasoning in food preparation (Mandal and Mandal, 2015).

On the same rotating plots cultivated in the AgrEcoMed demonstration farm, part of the surface will be used to test and grow medicinal plants (Figure 11) such as Coriandrum sativum L. (C. sativum) with 20 kg/ha, Rapeseed (cv. SY Harnas) with 3.5 kg/ha, and Mugworts (cv. Artemisia) with seedling rates 22.7 seedling/ha and 44.5 seedlings/ha. The AgrEcoMed will study the feasibility of medicinal crops in rotation with wheat and grain legumes and evaluate their potential to improve yields, economic profitability, and the sustainable protection of field crops. Nitrogen fertilizer (with vs. without nitrogen), nitrogen management (high vs. VRT), and crop yield will be evaluated for understanding the synergistic effects of medicinal plants. The cultivation process of oilseed rape Brassica Napus involved nitrogen fertilizer application at 103 kg N/ha, phosphorus fertilizer at 54 kg P_2O_5/ha, utilizing plant protection products at a rate of 2.43 kg/ha, using diesel machinery at 116.6 liters per hectare, and using human labor input at 120.1 h/ha. In the cultivation process of Coriander, nitrogen fertilizer is applied at 78 kg N/ha, phosphorus fertilizer at 32 kg P_2O_5/ha, diesel machinery is used at 36.8 liters per hectare, and human labor input is at 61.9 h/ha.

Table 14. Crop yield and resource inputs for medicinal crop cultivation at Genzano di Lucania, Basilicata region, Southern Italy.

Data	Colza	Coriander	Mugwort
Parcel	Medicinal	Medicinal	Medicinal
Crop name	Colza	Coriander	Mugwort
Variety	cv. SY Harnas	Coriandrum Sativum	cv. Artemisia Vulgaris
Area (ha)	1.5	1	1
Date of sowing crop (dd.mm.yyyy)	20/10/2022	22/12/2022	28/04/2023
Date of harvest crop (dd.mm.yyyy)	8/7/2023	23/07/2023	23/07/2023
Crop yield (t/ha)	3.53	1.82	0.77/0.56
Protein content (%)	-	-	-
Gluten content (%)	-	-	-
Colour	-	-	-
Protein content (%)	-	-	-
Specific weight	-	-	-
Seeds rate (kg/ha)	3.5	20	22.7/44.5
Nitrogen fertilizer (kg N/ha)	103	78	-
P_2O_5 fertilizer (kg P_2O_5/ha)	54	32	-
Pesticide rate (kg/ha)	2.3	-	-
Active ingredient (kg A.S/ha)	0.41	-	-
Diesel machinery (l/ha)	116.6	36.8	-
Tractor hours (hour/ha)	13.1	4.1	-
Human labor (h/ha)	120.1	61.9	-

3. Experimental site in Morocco

P6-ENAM, which handles similar activities in the project, is also involved in the same WP1 task1. Experiment designs for the WP1 treatment have also been implemented in Morocco to compare conventional and agroecological practices. The experimental work was conducted in the Sefrou region, at Agricultural Domain. The Sefrou region is known for its diverse agricultural production. Farmers cultivate a range of crops, including cereals like wheat and barley, fruits such as apples, pears, and olives, and vegetables like tomatoes, peppers, and onions. The farm is situated in the northeastern part of the Middle Atlas, with an elevation ranging from 400 to 770 meters. It is 97 kilometers from ENA. The farm encompasses a total area of 3,227 hectares, with 393 ha allocated for horticulture crop, and 2345 ha to other annuals crops production. The prevailing climate in this region is semi-arid, characterized by hot summers and notably mild to cold winters. This area occasionally experiences adverse climatic events that can negatively impact agricultural production, including hailstorms, frosts, and chergui wind episodes. The average annual temperature is 14.7 °C (Table 16). Annually, approximately 660 mm of precipitation descends. The month characterized by the lowest precipitation levels is July, exhibiting a mere 14 mm. The maximum quantity of rainfall is observed during the month of April, exhibiting an average value of 83 mm.

Table 15. Climatic parameters for Sefrou region, Morocco.

Month	Precipitation (mm/month)	Wet days	Tmp. min. (°C)	Tmp. max. (°C)	Tmp. mean. (°C)	Rel. Hum. (%)	Sunshine (%)	Wind (2m) (m/s)
Jan	59	9.2	1.6	12	6.8	70.3	59.1	2.5
Feb	68	10	2.8	13.2	8	70.3	57.6	2.9
Mar	62	9.7	3.9	15.3	9.6	67.7	61.6	3.1
Apr	67	10.4	5.6	16.8	11.2	70	58.8	2.9
May	43	8.4	8.5	21.1	14.8	64.9	64.2	2.7
Jun	20	4.7	12	26.2	19.1	58.1	70	2.5
Jul	5	2.4	15.7	31.9	23.8	44.2	76.3	2.5
Aug	6	2.8	16	31.9	23.9	44.1	75	2.5
Sep	18	4.9	13.4	27.8	20.6	51.7	69.9	2.4
Oct	39	7.3	9.4	21.6	15.5	61.3	65.8	2.4
Nov	63	9.4	5.5	15.9	10.7	68.8	59.3	2.5
Dec	70	9.1	2.5	12.4	7.4	71.7	59.9	2.5

Soil samples meticulously extracted from the experimental fields have been diligently gathered and subjected to comprehensive analysis, as detailed in Table 17. The results of this analysis reveal that the soil in these fields falls within the classification of clay loam, as visually depicted in Figure 12. This classification provides valuable insights into the soil's composition, texture, and properties, which are pivotal for understanding its suitability for various agricultural endeavors and can serve as a foundational reference for future research and farming practices.

Table 16. Soil data for experimental site at Sefrou region, Morocco.

Soil data	0-30 cm	30-60cm
Clay (%)	36	42
Fine silt (%)	22	21,5
Coarse silt (%)	21,6	17,28
Fine sand (%)	13,5	13,4
Coarse sand (%)	5,1	6,1
Lime total (% de CaCo3)	44,5	65,2
Lime actif (%)	17,3	16,5
Organic matter (%)	2,5	1,11
Total nitrogen (%)	0,170	0,086
Rapport C/N	8	7,1
Chloruides Cl (mg/kg)	42,3	138,9
Conductivity (à 25°C, Extrait 1/5, mS/cm)	0,21	0,25
Potassium K2O mg/kg	190	103
MgO mg/kg	1195	747
P2O5	26	12
pH eau	8,71	8,7

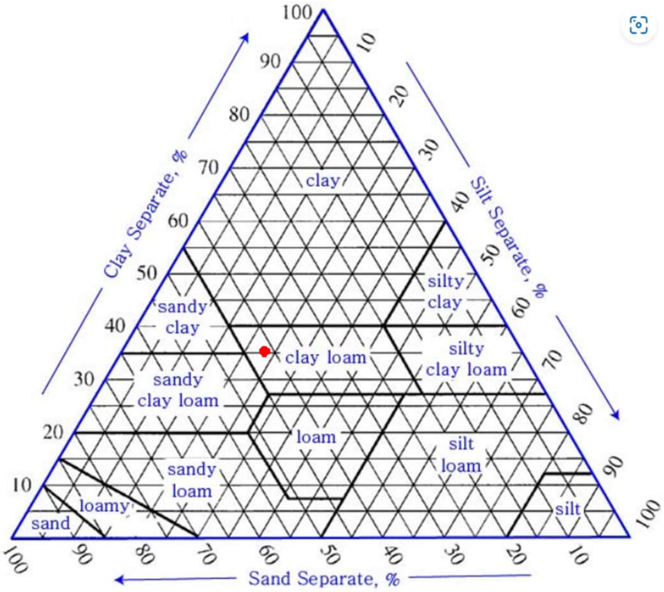

Figure 12. The triangular diagram of the basic soil textural classes of the study area.

Table 18 presents the details of crop growth and agronomic practices applied for wheat and chickpea production. Durum Wheat, variety cv. BONIDIRO, was cultivated over a 2-hectare area, with a sowing date of 20/11/2022 and a harvest date of 10/05/2023. The crop yield stood at 0.8 tons per hectare, a deviation from the normal range of 6-8 tons per hectare for a regular growing season. The seeds were sown at a rate of 200 kg per hectare. Fertilization involved the application of 300 kg of NPK (10-30-10), with 30 kg of nitrogen, 90 kg of P_2O_5, and 30 kg of K_2O. Plant protection measures were implemented before tillage when the crop was around 10 cm high, using a combination of Pallas (500 ml/ha), Pyroxsulame (45 g/l), and Cossack (7.5 g/l of mesosulfuron-methyl and 7.5 g/iodosulfuron-methyl-sodium plus 22.5 g/l of mefenpyr-diethyl). Additionally, cross-cover cropping was employed for seedbed preparation, enhancing the overall cultivation process.

Table 17. Crop yield and resource inputs for crops in Morocco site.

Data	Wheat	Chickpea
Crop name	Durum Wheat	Chickpea
Variety	cv. BONIDIRO	cv. Farihane
Area (ha)	2	3
Date of sowing crop (dd.mm.yyyy)	20/11/2022	17/03/2023
Date of harvest crop (dd.mm.yyyy)	10/05/2023	-
Crop yield (ton/ha)	0.8 compared to a normal 6-8 t/ha (normal growing season)	-
Seeds rate (kg/ha)	200	110
Fertilization	300 kg of NPK (10-30-10)	150 kg of NPK (19-38-0)
Nitrogen fertilizer (kg N/ha)	30	28.5
P_2O_5 fertilizer (kg P_2O_5/ha)	90	57
K_2O fertilizier (kg K_2O/ha)	30	0
Plant protection	Before tillage (around 10 cm heigh), Pallas (500 ml/ha , Pyroxsulame (45 g/l))+ plus cossak Cossack (7.5 g/l de mesosulfuron-methyl (mesomax) et 7.5 g/iodosulfuron-methyl-sodium+22.5 g/l de mefenpyr-diethyl).	Fungicide: Anthracnose, Botrytis traited with mancozeb at 200g/hl x 2 per cycle; Insecticide: Leaf miner, cutworm, treated with Confidor (Active ingredient: Imidacloprid at 50cc/hl); against leaf miner, cutworm treated with DIMEZYL (Dimethoate at 80 cc/hl
Soil preparation	Semi with soil preparation to a depth of 20-25 cm. Cross-cover cropping for seedbed preparation	

Chickpea, specifically cv. Farihane, was cultivated over a 3-hectare area, with a sowing date of 17/03/2023 with a seeding rate of 150 kg per hectare. Fertilization involved the application of 150 kg of NPK (19-38-0), with 28.5 kg of nitrogen, 57 kg of P_2O_5, and no K_2O. To protect the crop, a comprehensive plant protection strategy was employed. Anthracnose and Botrytis were addressed with mancozeb at a concentration of 200g/hl applied twice per cycle. Insect-related issues, specifically leaf miner and cutworm, were treated with Confidor, featuring Imidacloprid at a rate of 50cc/hl, and DIMEZYL, utilizing

Dimethoate at a concentration of 80 cc/hl, was applied against leaf miner and cutworm infestations. These measures aimed to ensure the health and productivity of the Chickpea crop throughout its growth cycle. The harvested yield reached 220 kg/ha, though it was nearly negligible due to the pervasive impact of drought across the entire field.
Table 19 presents the measurement of photosynthesis rate, chlorophyll content, and leaf area index (LAI). These measurements were carried out using a portable LICOR device, the LI-6400 for all studied crops. Net photosynthesis is expressed in µmolCO_2 m^{-2} s^{-1}, while transpiration rate is expressed in mmol H_2O m^{-2} s^{-1}. The measurements were taken on top 3 leaves x from 5 different plants x 5 repetitions.

Table 18. Crop yield and resource inputs for crops in Morocco site.

Crop details	Photosynthesis rate (µmolCO_2 m^{-2} s^{-1})	Transpiration rate (mmol H_2O m^{-2} s^{-1})	Chlorophyll content	LAI	Yield
Crop 1: Wheat					
Wheat (Tillering stage)	22.4	12.5	44 (SPAD Unit)	6.1	0.8 ton/na
Wheat (Epiaison stage)	10.2	11.60	33 (SPAD UNIT)	10.5	
Crop 2: Lentils*					
First stage	28.3	7.45	14	1.10	
Flowering	25.2	8.11	12	1.2	220 kg/ha (almost not harvested as drought impacted all the field
Pod filling	24.7	6.8	7	0.8	

The data collection process for ENAM encountered various challenges, including adverse weather conditions, budget limitations, and unforeseen circumstances. This report aims to summarize the progress made and the challenges faced in collecting this crucial data.

- The data for the crude protein content in lentils is anticipated to be available soon. Efforts have been made to collect this data, but due to certain constraints, it has not yet been obtained. The delay is primarily attributed to logistical issues and sample preparation.
- Unfortunately, data related to the nutritional quality of lentils and chickpeas remains incomplete. The collection process was impeded by a series of adverse weather events, notably a drought that affected the entire field. Furthermore, the precipitation received in June exacerbated the situation, causing further delays and complications in data collection efforts. The climate conditions throughout the growing season have had a significant impact on the quality and quantity of data obtained. Nonetheless, the team remains committed to sharing the available data for mid-report assessment.
- Regrettably, the data collected from medicinal plants has proven to be inadequate. The poor quality of data in this category is primarily attributed to weather-related factors. Unpredictable weather patterns, such as extreme temperatures and irregular rainfall, have hampered the growth and development of medicinal plants, leading to insufficient data collection. Efforts are ongoing to improve the quality of data in this area, but significant challenges persist.

In summary, while progress has been made in some areas, it is important to acknowledge the setbacks caused by uncontrollable factors like climate conditions. The team remains dedicated to overcoming these challenges and ensuring the availability of comprehensive data for future assessments. Further updates and the complete dataset will be shared as soon as possible.

4. Conclusion

This report showcases the agronomic information and data acquired during the initial year of AgrEcoMed field operations in Genzano di Lucania, located in the Basilicata region of Southern Italy, as well as in the Sefrou region of Morocco. In the above-said farms, “conventional agriculture” (CA) is being compared with the proposed “agroecological approach (AA). More specifically, in Italian site the wheat (cv. Tirex) was sown in a conventional cropping system characterized by business as usual monoculture wheat being based on synthetic fertilizer and herbicide use. Within the same rotating plots under cultivation on the farm, a portion of the area was allocated for evaluating the agroecological management regime (AA). This evaluation involved the utilization of Trichoderma strains, compost-enhanced wheat, diverse wheat varieties, wheat with biostimulants and variable rate fertilization for wheat. Compost field experiments assessed winter wheat growth under nitrogen management techniques including a novel approach involving organic microgranular fertilizers with biostimulant properties. AgrEcoMed ompared the growth patterns and productivity of modern wheat varieties (Marco Aurelio, Tirex, and Svevo) with ancient varieties like Senatore Capelli enhancing the understanding of the factors influencing their growth and productivity, providing valuable insights for future agricultural practices and crop selection.

Meticulous collection and analysis of field data were conducted for all strategies and crops grown. The collected data encompassed:

i. **Soil-related data**: soil map and soil analysis and statistics, electric resistivity of soil, spatial analysis of soil physical-chemical characteristics;
ii. **Climate data**: Average annual precipitation, Number of wet days per year, Mean elevation;
iii. **Crop Information:** cultivar, crop chlorophyll content and leaf area index (LAI), Timing of soil cultivation, sowing, and harvesting, the seed rate and number of seedlings used for cultivation;
iv. **Fertilizer and Agro-Chemical Data**: Type and quantity of N-P-K fertilizers and agro-chemicals for plant protection, Fertilization maps, Soil amendment quantities;
v. **Farming Operations:** Fuel and machinery expenditures for farming activities, Human labor working hours;
vi. **Yield Data:** The yield of main products and yield by-products

The field activities planned for WP1 will provide data, information, and materials for the activities of WP2, tasks 1,2,3,4, P UNIBAS, UNIBA, CREA-PB, CBS, and ENAM. WP3, task 1,2,3,4, P UNIBAS, UNIBA, UCO, UPV. WP4, task 1,2,3 P UNIBA, UCO, WP5, and WP6. The environmental impacts and damage generated by the cultivation of the products grown in the experimental tests will be carried out using Life Cycle Assessment (LCA), by following ISO 14040-44 standards. LCA involves evaluating the environmental impacts associated with a product or process throughout its entire life cycle, from raw material extraction to disposal.

Additionally, the economic sustainability and potential economic benefits for farmers in given contexts will be explored. Economic sustainability typically involves evaluating factors such as production costs, market demand, and revenue potential.

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