DIVERFARMING

Crop diversification and low-input farming across Europe: from practitioners' engagement and ecosystems services to increased revenues and value chain organisation

DESCRIPTION OF DIVERFARMING DIVERSIFIED CROPPING SYSTEMS

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Document summary	
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Executive Summary

Over the past 60 years, the dramatic change in agricultural practices has led to an increase in yields throughout Europe. However, there has been significant side effects, with implications for long term sustainability of agricultural systems and environmental quality. Thus, agribusiness models need to be changed to ensure real sustainability, being crop diversification and efficient strategy to enhance farmer revenues while promoting the delivery of ecosystem services such as land productivity, biodiversity, carbon sequestration or soil fertility and quality. However, to achieve adoption of crop diversification, all sectors and actors in the value chain have to be integrated and considered as a whole, from farmers to consumers. Alternatives to current cropping systems and agricultural practices have mainly been conceived by researchers with little consideration of the behavioural, social and cultural changes necessary for wide-spread take-up across the rural communities. Farmers need sound data about the benefits of diversified cropping systems with sustainable agricultural practices to encourage their adoption, while their particular needs and problems have to be taken into consideration when addressing new systems and agribusiness models.

As a result, in this document we report the experimental design for the different Case Studies used in Diverfarming to assess real benefits and drawbacks/barriers of implementation of diversified cropping systems along the EU geography. We had in mind that greater productivity and sustainability could be only achieved by selecting suitable cropping systems that are defined by a range of regionally adapted crop associations, agricultural practices and technologies tailored to each particular value chain under a specific pedoclimatic region. For this purpose, we defined the experimental design after a thorough literature review from previous projects and publications and performance of a participatory process with value chain actors and stakeholders with different backgrounds and interests, valuing the different alternatives under technical, economic, social, cultural, and environmental perspectives. The selected diversified cropping systems have been tailored to achieve social acceptance, increase farm productivity, increase economic benefits, reduce production and environmental costs, facilitate the easy adaptation of the value chain, reduce the incidence of pests and diseases, increase soil quality and fertility, C sequestration and biodiversity, decrease soil and water pollution, GHG emissions and erosion rates. Furthermore, the diversified cropping systems selected have at their heart the rational use of natural resources (soil and water) and decreased use of external inputs (fertilisers, pesticides, energy, machinery).

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CASE STUDY NUM 1

Rainfed perennial crops (almonds) in Spain

CASE STUDY NUM. 1	
Partners involved	CSIC, UPCT, ASAJA, DML
Authors	Elvira Díaz-Pereira, María Martínez-Mena, Carolina Boix-Fayos, Joris de Vente, Jose A. Pascual, Margarita Ros (CSIC) Raul Zornoza, Virginia Sánchez-Navarro, Juan A. Fernández, Josefina Contreras, José María de la Rosa, Abdelmalek Temnani, Alejandro Pérez-Pastor, Silvia Martínez-Martínez, Jose A. Acosta (UPCT) Fuensanta López, Elizabeth Torrecillas, Alfonso Gálvez (ASAJA)
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Case study 1: rainfed almond

- Pedoclimatic región: MEDITERRANEAN SOUTH
- Country: SPAIN
- Location: MURCIA (REGION OF MURCIA)
- Geographical coordinates: 37° 57‘ 31“ N 0° 56‘ 17“ W
- Mean annual temperature: 17.5 ºC
- Mean annual precipitation: 231 mm
- Annual potential evapotranspiration: 1300 mm

Case study 1: Main characteristics

- Farm extension: 2.63 ha
- Diverfarming experimentation area: 0.19 ha (54 trees)
- Current crop: Almond (*Prunus dulcis*)
- Crop final use: food
- Current cropping system: rainfed conventional monocrop (7 m x 7 m pattern)
- Harvest time: August–September (blossom in January-February)
- Current management practices:
  - reduced tillage
- Current value chain:
  - Producer
  - Wholesaler
  - Supermarket

Case study 1: Main environmental problems

- Low below and aboveground biodiversity
- Erosion (sheet, rills, gullies)
- Low soil quality
- Low soil organic matter content
- Landscape homogeneity, high connectivity of water and sediment fluxes
- Low resilience and adaptability
- Infra-optimization of ecosystem services related to soil and vegetation

Case study 1: Diversified cropping systems

A. **Almond monocrop** (MA)
B. **Diversification 1** (D1): almond intercropped with *Capparis spinosa* for food (April-September), during 2018, 2019 and 2020.
C. **Diversification 2** (D2): almond intercropped with *Thymus hyemalis for* essential oils *(*November-March*)* and food (April-June), during 2018, 2019, 2020.

Case study 1: Intercropping

Perennial crops will be cultivated between the almond tree rows, which are separated 7 m.

Case study 1: Low input management practices

1. Integrated pest control
2. No tillage
3. Rainfed
4. Organic system (no fertilization)

Case study 1: Experimental design

- **Factor of study**: Crop diversification
- **Experimental design**: Strip-plot in diversification blocks.
- **Replications**: Three field replicated plots.
- **Plot size**: 217 m^2.
- **Crop monitoring and sampling**: at harvest for every crop and plot. Only the central four trees from the central row will be monitored and sampled in each plot. Annual crops will be monitored and sampled in both alleys between the tree rows.
- **Soil sampling**:
  - Time and frequency: every early November during three crop cycles
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: three composite samples per plot (nine samples per treatment) in WP5. For WP4, five out of the nine samples per treatment will be selected.
- **Greenhouse gas emission measures**: 25 measures per year in the plots where soil is sampled.
- **Erosion measures**: general field characterization at the starting of the experiment at agricultural field scale and event-based in all the treatments.

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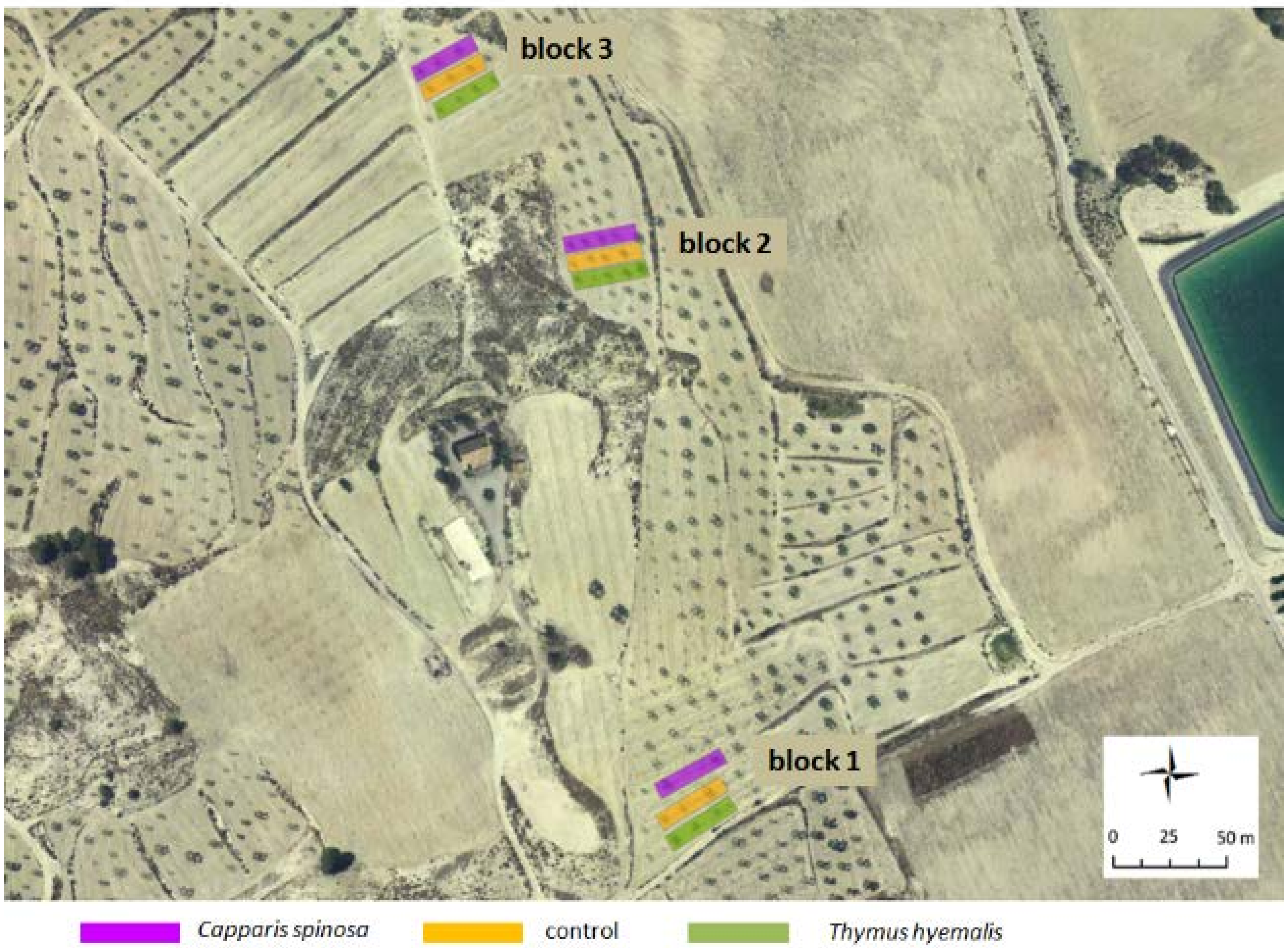
Case study 1: Experimental layout



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Case study 1: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

Case study 1: Crop properties

1. **Crop growth**
   - Crop establishment and above-ground biomass in perennial intercrops.
   - Tree height, trunk cross-sectional area, leaf area index, net assimilation rate, stem water potential, maximum daily trunk shrinkage, NVDI.
2. **Pests and diseases incidence**
   - Plants affected by pests/diseases, pest population, damage proportion and disease incidence.
3. **Crop yield**
   - Crop yield in perennial crops, marketable yield.
   - Land equivalent ratio and land productivity.
4. **Crop quality**
   - Fruit weight and size distribution.
5. **Nutritional evaluation**
   - None

Case study 1: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
    - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
    - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsusfatase activities.
    - Potential nitrification.
    - Transcriptome of active microbial populations by qPCR and RNA sequencing.
3. **Earthworms**
    - Species identification, density and mass.
    - Density and mass by ecological groups.
    - Total density and mass.
    - Only measured at the beginning and the end of the experimental period.

Case study 1: Vegetal biodiversity properties

1. **Plant species**
    - Identification and richness.
2. **Vegetation**
    - Cover.
    - Similarity index.
    - Overall spatial distribution by UAV-based optical assessment.
3. **Carbon sequestration by woody crops**
    - Net photosynthesis rate, transpiration rate, stomatal conductance, leaf area, leaf C/N ratio.

Case study 1: Soil physicochemical properties

1. **Soil fertility and pollutants**
   - Total N, ammonium, nitrate and available P, K, Ca, Mg, Fe, Mn, Cu, Zn and B.
   - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
   - Bulk density, soil water content at wilting point and field capacity, actual field moisture, texture, total organic carbon, carbonates, organic carbon functional fractions, aggregates stability, aggregates size distribution.
3. **Erosion rates**
   - Basic characterization of erosion processes and rates and event-based measures on interrill erosion, rill erosion, gully erosion, runoff generation. Rainfall simulation only when no events.
   - Measurement of nutrient and organic carbon losses.
4. **Greenhouse gas emissions**
   - Soil CO_2, N_2O and CH_4.
   - Overall emissions by Life Cycle Assessment.

CASE STUDY NUM. 1 COORDINATORS

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CASE STUDY NUM 2

Irrigated perennial crops (citrus) in Spain

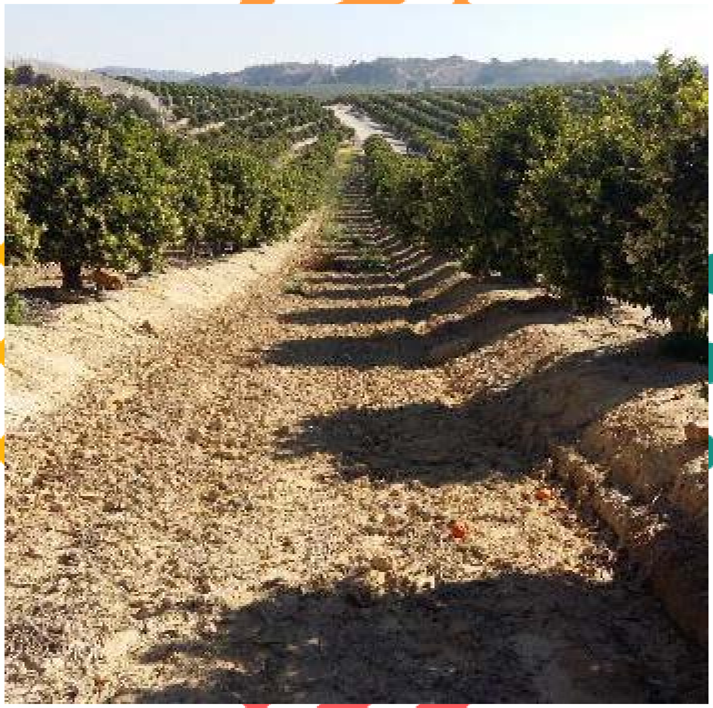
CASE STUDY NUM. 2	
Partners involved	UPCT, CSIC, ASAJA, DML
Authors	Raul Zornoza, Virginia Sánchez-Navarro, Juan A. Fernández, Josefina Contreras, José María de la Rosa, Abdel Malek Temnani, Alejandro Pérez-Pastor, Silvia Martínez-Martínez, Jose A. Acosta (UPCT) María Martínez-Mena, Elvira Díaz-Pereira, Carolina Boix-Fayos, Joris de Vente, Jose A. Pascual, Margarita Ros (CSIC) Fuensanta López, Elizabeth Torrecillas, Alfonso Gálvez (ASAJA)
E-mail of principal author	raul.zornoza@upct.es

Case study 2: irrigated citrus

- Pedoclimatic región: MEDITERRANEAN SOUTH
- Country: SPAIN
- Location: MURCIA (REGION OF MURCIA)
- Geographical coordinates: 37° 57‘ 31“ N 0° 56‘ 17“ W
- Mean annual temperature: 17.5 ºC
- Mean annual precipitation: 231 mm
- Annual potential evapotranspiration: 1300 mm

Case study 2: Main characteristics

- Farm extension: 206 ha
- Diverfarming experimentation area: 2.3 ha (1100 trees)
- Current crop: Mandarines (*Citrus reticulata* var. Clemenvilla)
- Crop final use: food
- Current cropping system: irrigated conventional permanent monocrop (6 m x 4 m pattern)
- Harvest time: January–February (blossom in March-April)
- Current management practices:
  - Intense tillage
  - Mineral fertilizer
  - Pesticides (from May to September)
  - Herbicides
- Current value chain:
  - Producer
  - Quality and certification
  - Wholesaler
  - Supermarket



Case study 2: Main environmental problems

- Low below and aboveground biodiversity
- Erosion
- Low soil quality
- Low soil organic matter content
- Soil and water pollution
- Soil salinization
- Landscape simplification

Case study 2: Diversified cropping systems

A. **Mandarin monocrop** (MC)

B. **Diversification 1** (D1): mandarin intercropped with multiple cropping of vetch/barley (*Vicia sativa/Hordeum vulgare*) for feed (February-July) and fava bean (*Vicia faba*) for food (September-January), during 2018, 2019 and 2020.

C. **Diversification 2** (D2): mandarin intercropped with rotations of:

- 2018: multiple cropping of vetch/barley/oat (*Vicia sativa/Hordeum vulgare*) for feed (February-July) and fava bean (*Vicia faba*) for food (September-January).
- 2019: multiple cropping of bladder campion (*Silene vulgaris*) for food (February-April), purslane (*Portulaca oleracea*) for food (May-July) and cardoon (*Cynara cardunculus* var. cardunculus) for food (October-December).
- 2020: multiple cropping of cowpea (*Vigna unguiculata*) for food (May-August) and rocket (*Eruca sativa*) for food (October-January).

Case study 2: Intercropping

Annual crops will be cultivated between the mandarin tree rows, which are separated 6 m.

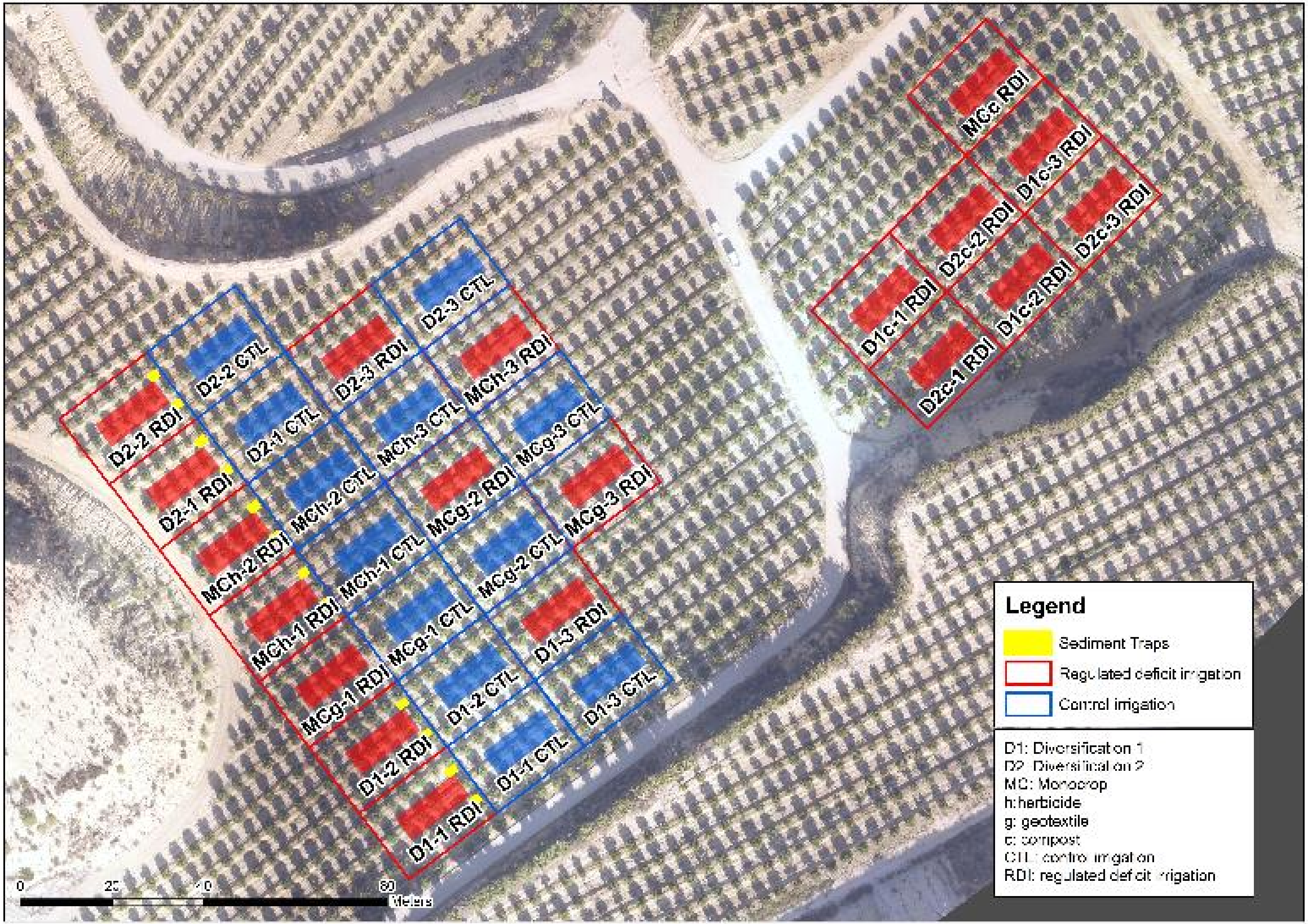
Case study 2: Low input management practices

1. Addition of compost
2. Green manure
3. Integrated pest control
4. Reduced tillage
5. Cover crops (in the tree rows)
6. Regulated deficit irrigation

Case study 2: Experimental design

- **Factors of study**: 1. Crop diversification, 2. Irrigation, 3. Addition of compost.
- **Experimental design**: Strip-plot in diversification blocks.
- **Replications**: Three field replicated plots.
- **Plot size**: three rows of six trees, 288 m^2.
- **Crop monitoring and sampling**: at harvest for every crop and plot. Only the central four trees from the central row will be monitored and sampled in each plot. Annual crops will be monitored and sampled in both alleys between the tree rows.
- **Soil sampling**:
  - Time and frequency: every early November during three crop cycles, only in the alleys of the plots with regulated deficit irrigation and no addition of compost.
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: three composite samples per plot (nine samples per treatment) in WP5. For WP4, five out of the nine samples per treatment will be selected.
- **Greenhouse gas emission measures**: 25 measures per year in the plots where soil is sampled.
- **Erosion measures**: event base in the treatments with deficit irrigation and absence of compost addition.

Case study 2: Experimental layout



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Case study 2: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

Case study 2: Crop properties

1. **Crop growth**
    - Crop establishment and above-ground biomass in annual intercrops.
    - Tree height, trunk cross-sectional area, leaf area index, net assimilation rate, stem water potential, maximum daily trunk shrinkage, NVDI.
2. **Pests and diseases incidence**
    - Plants affected by pests/diseases, pest population, damage proportion and disease incidence.
3. **Crop yield**
    - Crop yield in annual and perennial crops, marketable yield.
    - Land equivalent ratio and land productivity.
4. **Crop quality**
    - Fruit weight and size distribution.
    - Soluble solids, juice pH and tritable acidity in mandarines.
5. **Nutritional evaluation**
    - None

Case study 2: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
    - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
    - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsusfatase activities.
    - Potential nitrification.
    - Transcriptome of active microbial populations by qPCR and RNA sequencing.
3. **Earthworms**
    - Species identification, density and mass.
    - Density and mass by ecological groups.
    - Total density and mass.
    - Only measured at the beginning and the end of the experimental period.

Case study 2: Vegetal biodiversity properties

1. **Plant species**
   - Identification and richness.
2. **Vegetation**
   - Cover.
   - Similarity index.
   - Overall spatial distribution by UAV-based optical assessment.
3. **Carbon sequestration by woody crops**
   - Net photosynthesis rate, transpiration rate, stomatal conductance, leaf area, leaf C/N ratio.

Case study 2: Soil physicochemical properties

1. **Soil fertility and pollutants**
    - Total N, ammonium, nitrate and available P, K, Ca, Mg, Fe, Mn, Cu, Zn and B.
    - Total pesticides
    - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
    - Bulk density, soil water content at wilting point and field capacity, actual field moisture, rock fragments and gravels, texture, total organic carbon, carbonates, organic carbon functional fractions, aggregates stability, aggregates size distribution.
3. **Erosion rates**
    - Basic characterization of erosion processes and rates and event-based measures on interrill erosion, rill erosion, gully erosion, runoff generation. Rainfall simulation only when no events.
    - Measurement of nutrient and organic carbon losses.
4. **Greenhouse gas emissions**
    - Soil CO_2, N_2O and CH_4.
    - Overall emissions by Life Cycle Assessment.

Case study Num. 2 Coordinator

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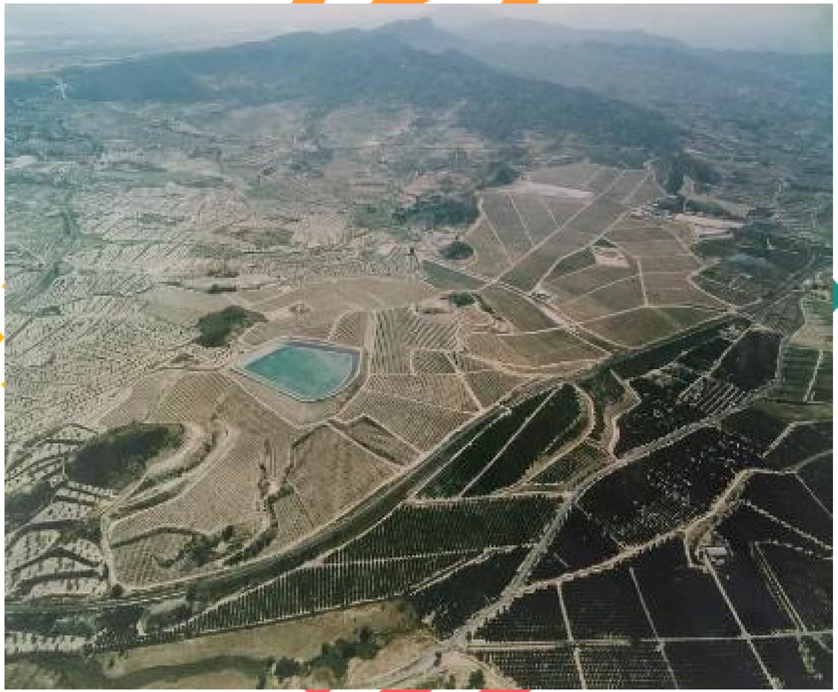

CASE STUDY NUM 3

Irrigated and rainfed field crops in Spain

CASE STUDY NUM. 3	
Partners involved	CSIC, ARENTO
Authors	Jorge Álvaro-Fuentes, José Luis Arrúe, Carmen Castañeda (CSIC) Eduardo López Gomollón (ARENTO)
E-mail of principal author	jorgeaf@eead.csic.es

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Case study 3: field crops

- Pedoclimatic región: MEDITERRANEAN SOUTH
- Country: SPAIN
- Location: Zaragoza (REGION OF ARAGON)
- Geographical coordinates: 41º 43′ 25″ N, 0º 48′ 50″ W
- Mean annual temperature: 14.8 ºC
- Mean annual precipitation: 340 mm

Zaragoza

Rainfed case study

Irrigated case study

Case study 3: Main characteristics rainfed

- Farm extension: 100 ha
- Diverfarming experimentation area: 1 ha
- Current crop: rainfed winter cereal
- Crop final use: Food and feed
- Current cropping system: conventional monocropping
- Harvest time: July
- Current management practices:
    - Intense tillage
    - Mineral fertilizers
    - Pesticides
    - Herbicides
- Current value chain:
    - Producer
    - Distribution
    - Agro-industry
    - Wholesaler
    - Supermarket

Case study 3: Main characteristics irrigated

- Farm extension: 40 ha
- Diverfarming experimentation area: 1 ha
- Current crop: Maize (*Zea mays* L.)
- Crop final use: Food and feed
- Current cropping system: monocropping
- Irrigation system: Flood
- Harvest time: October
- Current management practices:
  - Intense tillage
  - Mineral fertilizer
  - Pesticides
  - Herbicides
- Current value chain:
  - Producer
  - Distribution
  - Agro-industry
  - Wholesaler
  - Supermarket

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Case study 3: Main environmental problems

- Low soil biodiversity
- Low soil organic matter content
- Weak soil structure
- Soil, air and water pollution

Case study 3: Diversified cropping systems in rainfed

A. **Monoculture** (M): Wheat *(Triticum durum)* monocrop

B. **Diversification** (D): wheat – barley (*Hordeum vulgare*) – vetch (*Vicia sativa*) rotation for food (wheat) and feed (barley and vetch) during 2018, 2019 and 2020. All the three phases of the rotation will be present each experimental year.

Case study 3: Diversified cropping systems in irrigated

A. **Maize *(Zea mays)* monocrop** (MC)
B. **Diversification 1** (D1): barley – maize multiple cropping for food (maize) and feed (barley) during 2018, 2019 and 2020.
C. **Diversification 2** (D2): pea – maize multiple cropping for food (maize) and feed (pea) during 2018, 2019 and 2020.

Case study 3: Low input management practices

In rainfed conditions:

- Reduction in tillage intensity

In irrigated conditions:

- N fertilization optimization

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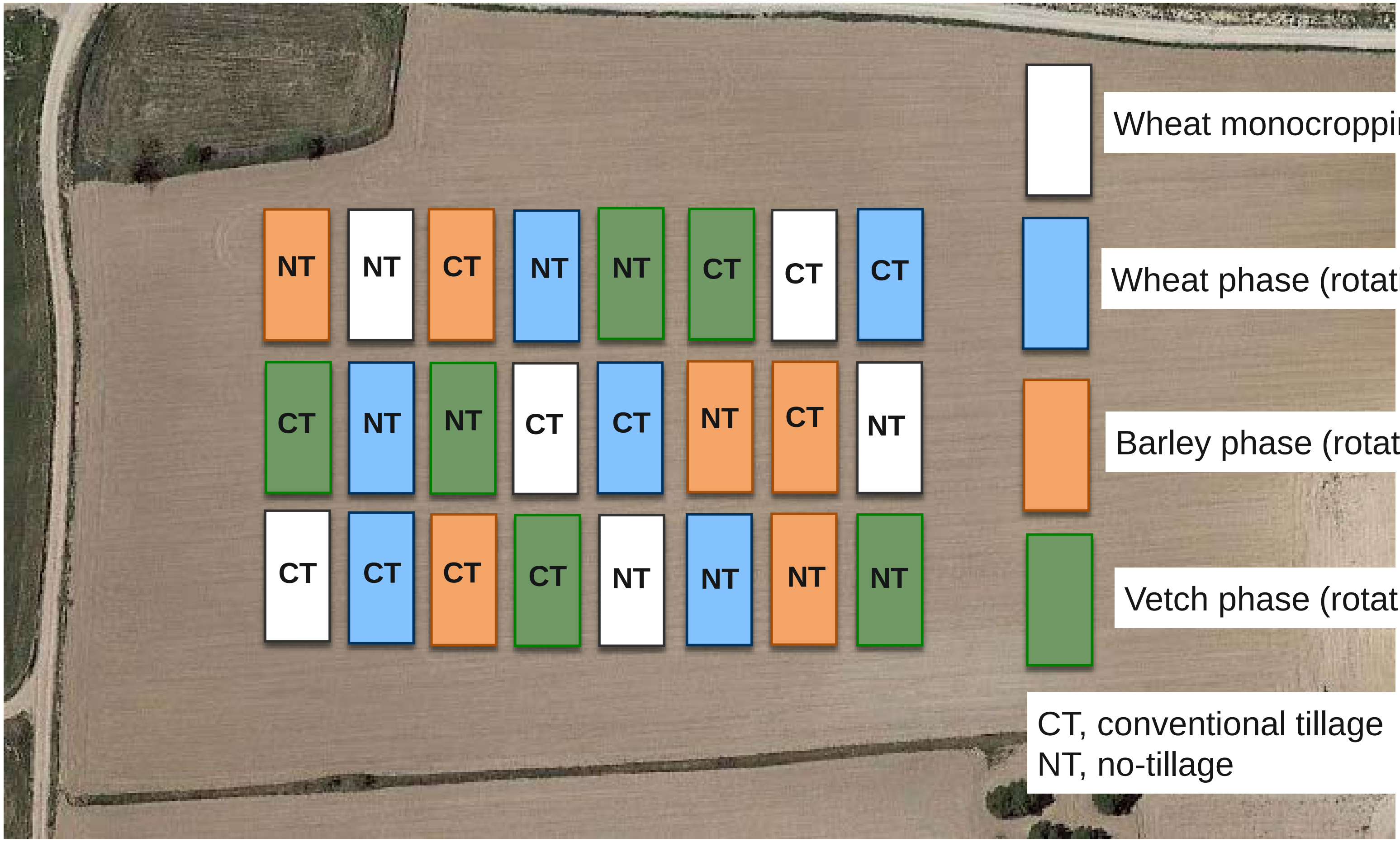
Case study 3: Experimental design in rainfed

- **Factors of study**: 1. Crop diversification, 2. Tillage
- **Experimental design**: Randomized complete block design
- **Replications**: Three field replicated plots.
- **Plot size**: 6 x 40 m, 240 m^2.
- **Crop monitoring and sampling**: at harvest for every crop and plot. Three samples per plot will be taken.
- **Soil sampling**:
  - Time and frequency: every October during three crop cycles.
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: three composite samples per plot (nine samples per treatment) in WP5. For WP4, five out of the nine samples per treatment will be selected.

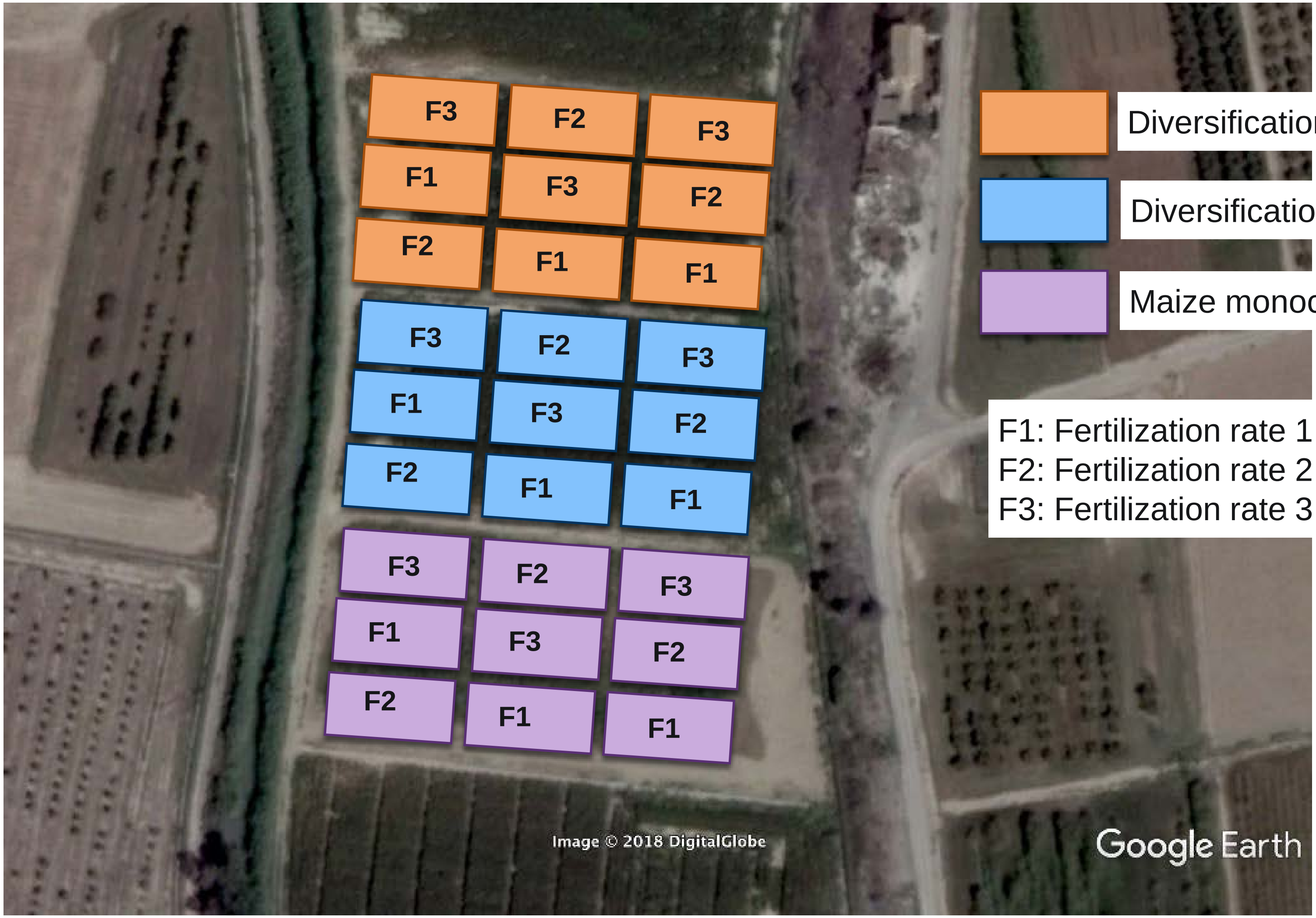
Case study 3: Experimental design in irrigated

- **Factors of study**: 1. Crop diversification, 2. Optimization of fertilization
- **Experimental design**: Randomized complete block design
- **Replications**: Three field replicated plots.
- **Plot size**: 6 x 30 m, 180 m^2.
- **Crop monitoring and sampling**: at harvest for every crop and plot. Three samples per plot will be taken.
- **Soil sampling**:
  - Time and frequency: every October during three crop cycles.
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: three composite samples per plot (nine samples per treatment) in WP5. For WP4, five out of the nine samples per treatment will be selected.
- **Greenhouse gas emission measures**: 25 measures per year in the plots where soil is sampled.

Case study 3: Experimental layout (rainfed)



Case study 3: Experimental layout (irrigated)



Case study 3: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

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Case study 3: Crop properties

1. **Crop growth**
   - Crop establishment.
   - Above-ground biomass.
2. **Pests and diseases incidence**
   - Damage proportion.
3. **Crop yield**
   - Crop yield.
4. **Crop quality**
   - Thousand kernel weight, specific kernel weight, grain humidity.
   - Protein, gluten (wheat).
5. **Nutritional evaluation**
   - None

Case study 3: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
   - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
   - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsusfatase activities.
   - Potential nitrification.
   - Transcriptome of active microbial populations by qPCR and RNA sequencing.
3. **Earthworms**
   - Species identification, density and mass.
   - Density and mass by ecological groups.
   - Total density and mass.
   - Only measured at the beginning and the end of the experimental period.

Case study 3: Soil physicochemical properties

1. **Soil fertility and pollutants**
   - Total N, ammonium, nitrate and available P, K, Ca, Mg.
   - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
   - Bulk density, soil water content at wilting point and field capacity, actual field moisture, texture, total organic carbon, carbonates, organic carbon functional fractions, aggregates stability, aggregates size distribution.
3. **Greenhouse gas emissions** (for the irrigated case study)
   - Soil CO_2, N_2O and CH_4.
   - Overall emissions by Life Cycle Assessment.

Case study Num. 3 Coordinator

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CASE STUDY NUM 4

Rainfed perennial crops (olive grove) in Spain

CASE STUDY NUM. 4	
Partners involved	UCO, ASAJA, DFM,
Authors	Luis Parras, Beatriz Lozano, Eloisa Agüera, Purificación de la Haba, Elena Lázaro, Manuel Parras, Francisco José Torres Ruiz, Manuela Vega Zamora, Manuel González (UCO)
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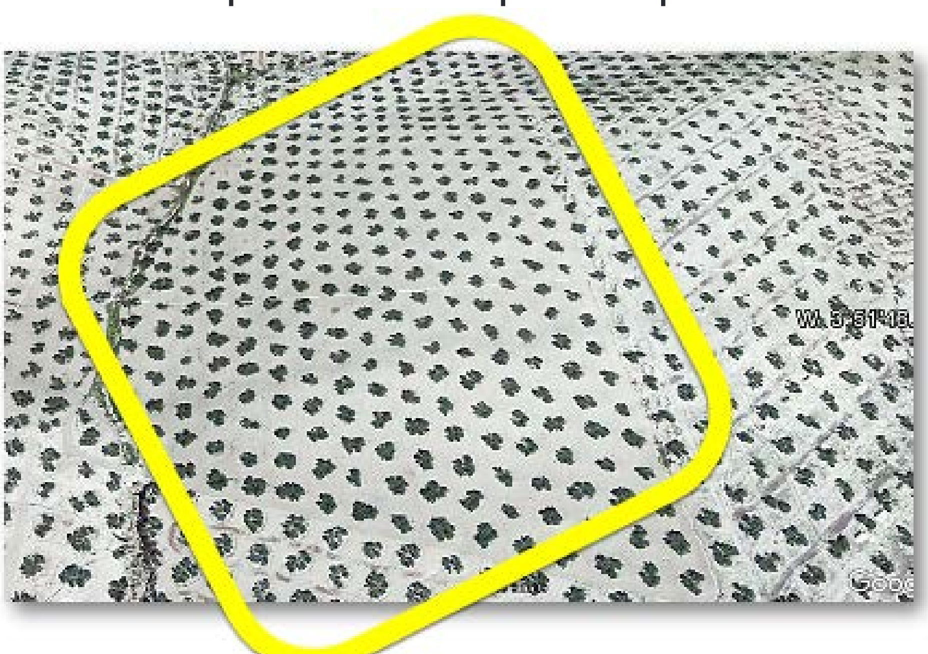
Case study 4: Unirrigated olive grove

- Pedoclimatic región: MEDITERRANEAN SOUTH
- Country: SPAIN
- Location: TORREDELCAMPO-JAEN (REGION OF ANDALUCÍA)
- Geographical coordinates: 37° 46‘ 26“ N 3° 54‘’41.5“ W
- Mean annual temperature: 17 ºC
- Mean annual precipitation: 645.7 mm
- Annual potential evapotranspiration: 916 mm

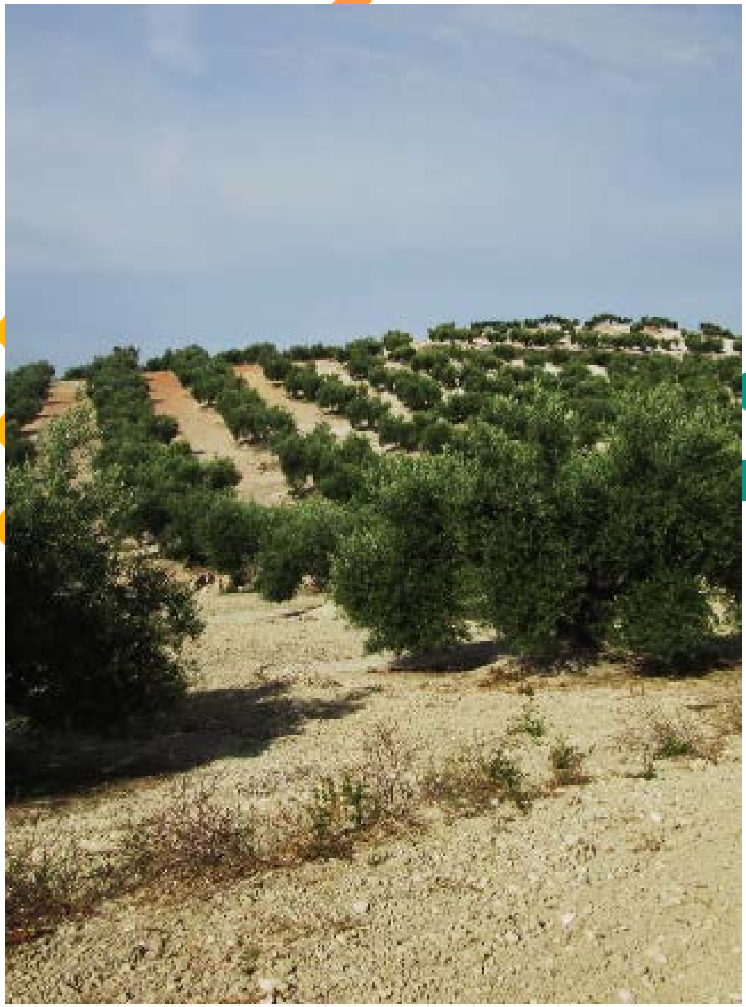


Case study 4: Main characteristics

- Farm extension: 6 ha
- Diverfarming experimentation area:3 ha (200 trees)
- Current crop: Olive (Olea europaea var. picual)
- Crop final use: food
- Current cropping system: unirrigated conventional permanent monocrop (12 m x 12 m pattern)
- Harvest time: December–February (blossom in April-May)
- Current management practices:
  - Intense tillage(annual passes with a disk harrow and cultivator in spring, followed by a tine harrow in summer)
  - Mineral fertilizer (urea, 46%N) is applied in alternate years during winter, just after the harvest.
  - Pesticides
  - Herbicides (a broad-spectrum herbicide is added in autumn to control weeds under trees)
  - Pruning residues 6Mg ha^{-1} each 2 years.
- Current value chain: (Bulk or Bottled)

1.Producer, agro-industry, direct marketing

2.Producer, agro-industry, distribution, quality and certification, exporter, retailer, supermarket



Case study 4: Main environmental problems

- Low below and aboveground biodiversity
- Water Erosion
- Low soil quality
- Low soil organic matter content



Case study 4: Diversified cropping systems

A. **Olive monocrop** (MC)

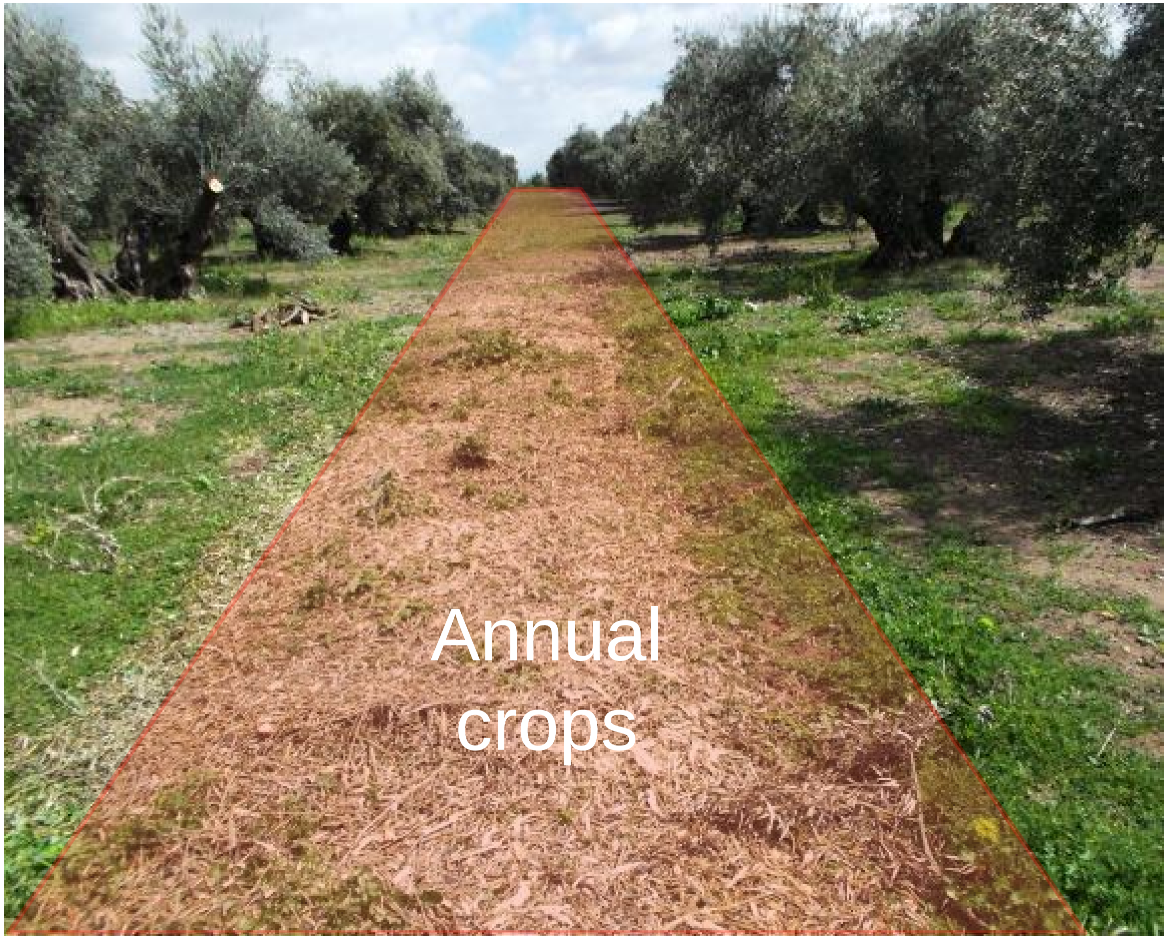
B. **Diversification 1** (D1): olives intercropped with oats and vetch (*Avena sativa and Vicia sativa*) for feed (January-May), during 2018, 2019 and 2020.

C. **Diversification 2** (D2): olives intercropped with rotations of:

- 2018-2020: cropping of saffron (*Crocus sativus*) for food (September-October).
- 2018-2020: cropping of caper (*Capparis spinosa*) for food (May – September).

Case study 4: Intercropping

Annual crops will be cultivated between the olive tree rows, which are separated 5 m.



Case study 4: Low input management practices

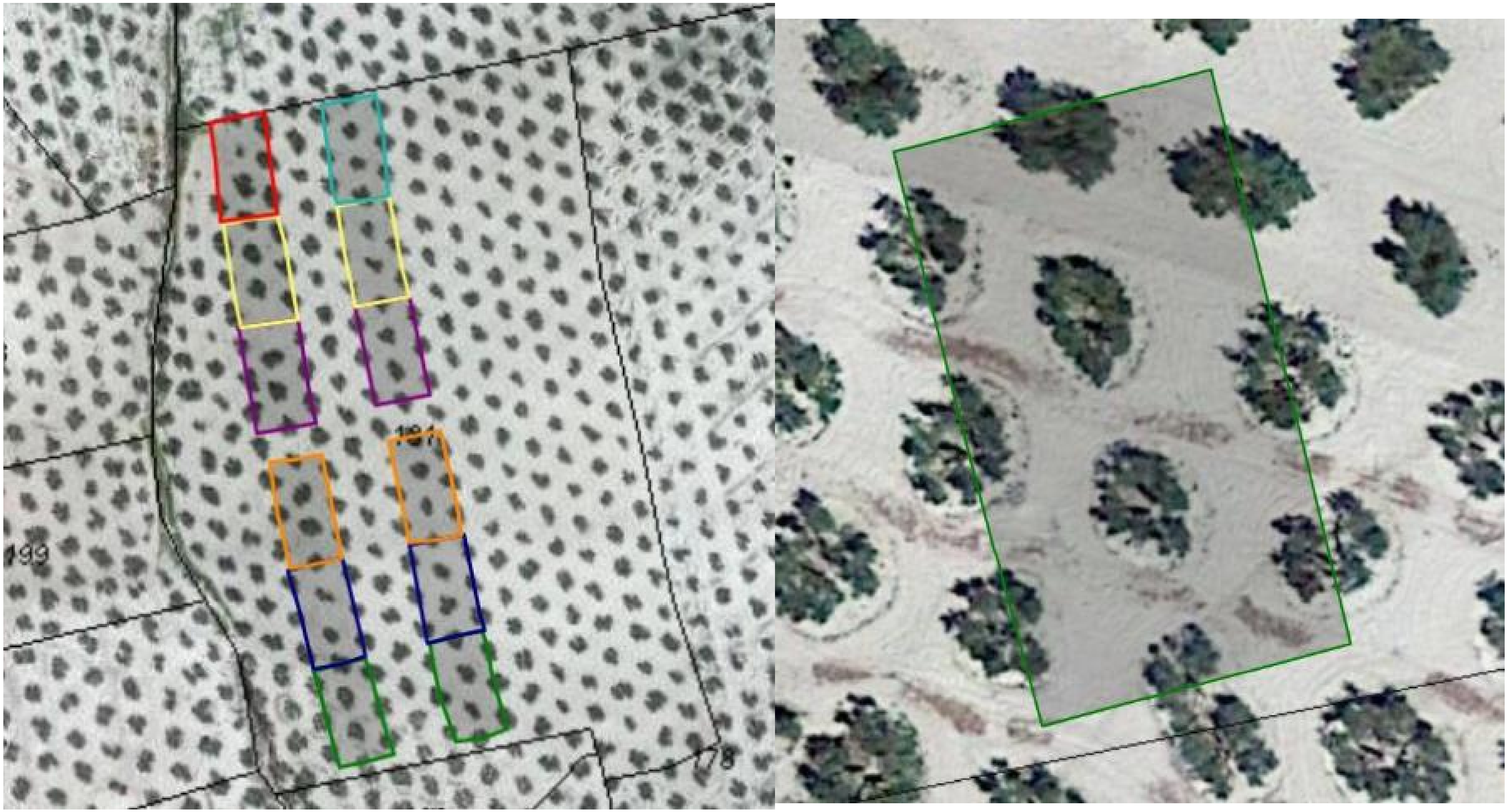
1. **Cero tillage.**
2. **Cover crops (in the tree rows).**
3. **Mulching with crushed offcuts from pruning.**

Case study 4: Experimental design

- **Factors of study**: 1. Crop diversification, 2. Crushed offcuts from pruning, 3. Cover crops.
- **Experimental design**: Strip-plot in diversification blocks.
- **Replications**: Three field replicated plots.
- **Plot size**: three rows of eight trees, 800 m^2.
- **Crop monitoring and sampling**: at harvest for every crop and plot. Only the central two trees from the central row will be monitored and sampled in each plot. Annual crops will be monitored and sampled in both alleys between the tree rows.
- **Soil sampling**:
- Time and frequency: every early November during three crop cycles, only in the alleys of the plots.
- Soil depth: arable layer (0-10 and 10-30 cm).
- Number of samples: three composite samples per plot (nine samples per treatment) in WP5. For WP4, five out of the nine samples per treatment will be selected.
- **Greenhouse gas emission measures**: 25 measures per year in the plots where soil is sampled.
- **Erosion measures**: event base in the treatments with deficit irrigation.

DIVERFARMING

Case study 4: Experimental layout



Case study 4: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

DIVERFARMING

Case study 4: Crop properties

1. **Crop growth**
   - Above-ground biomass in annual intercrops.
   - Tree height, trunk cross-sectional area, leaf area index, net assimilation rate.
2. **Pests and diseases incidence**
   - Plants affected by pests/diseases, pest population, damage proportion and disease incidence.
3. **Crop yield**
   - Crop yield in annual and perennial crops, marketable yield.
   - Land equivalent ratio and land productivity.
4. **Crop quality**
   - Specific weight, grain humidity, protein, gluten, extensometer, baking score, fat content, thousand kernel weight.
   - Fruit weight and size distribution.
   - Grain and biomass weight.
   - Soluble solids, degree of acidity and quality of fatty matter in olives.
5. **Nutritional evaluation**
   - None

Case study 4: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
   - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
   - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsusfatase activities.
   - Potential nitrification.
   - Transcriptome of active microbial populations by qPCR and RNA sequencing.
3. **Earthworms**
   - Species identification, density and mass.
   - Density and mass by ecological groups.
   - Total density and mass.
   - Only measured at the beginning and the end of the experimental period.

Case study 4: Vegetal biodiversity properties

1. **Plant species**
    - Identification and richness.
2. **Vegetation**
    - Cover.
    - Similarity index.
    - Overall spatial distribution by UAV-based optical assessment.
3. **Carbon sequestration by woody crops**
    - Net photosynthesis rate, transpiration rate, stomatal conductance, leaf area, leaf C/N ratio.

Case study 4: Soil physicochemical properties

1. **Soil fertility and pollutants**
   - Total N, ammonium, nitrate and available P, K, Ca, Mg, Fe, Mn, Cu and Zn .
   - Total pesticides
   - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
   - Bulk density, soil water content at wilting point and field capacity, actual field moisture, texture, total organic carbon, carbonates, organic carbon functional fractions, aggregates stability, aggregates size distribution, saturated hydraulic condivity, water infiltration.
3. **Erosion rates**
   - Basic characterization of erosion processes and rates and event-based measures on interrill erosion, rill erosion, gully erosion, runoff generation. Rainfall simulation only when no events.
   - Measurement of nutrient and organic carbon losses.
4. **Greenhouse gas emissions**
   - Soil CO_2, N_2O and CH_4.

Case study Num. 4 Coordinator

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CASE STUDY
NUM 5

Arable Land
Diversified annual crop rotations in Italy

CASE STUDY NUM. 5	
Partners involved	CCP, UT, CREA, Barilla
Authors	Davide Rocca (CCP), Emanuele Blasi (UT), Roberta Farina (CREA)
E-mail of principal author	roberta.farina@crea.gov.it

Case study 5: Intensive arable DW and TO

- Pedoclimatic región MEDITERRANEAN NORTH
- Country: ITALY
- Location: Padania Valley – Lombardia Region - Mantova Province
- Geographical coordinates: 45° 16.529’ N, 10° 30.855’ E
- Mean annual temperature: 13.2 ºC
- Mean annual precipitation: 684 mm

Case study 5: Main characteristics

- Farms extension: 131 ha
- Diverfarming experimentation area: 18.2 ha
- Current crop: durum wheat and tomato
- Crop final use: food
- Current cropping system – two years rotation
  → rainfed (*Triticum durum Desf.*)
  → irrigated (*Solanum lycopersicum L.*)
- Harvest time: late spring - summer
- Current management practices:
  - Intense tillage
  - Mineral fertilizer
  - Integrated Pest Management
- Current value chain:
  - Producer
  - Quality and certification
  - Wholesaler and processer
  - Supermarket

Case study 5: Main environmental problems

- Low soil organic matter
- Soil compaction and low aggregate stability
- Risk of water irrigation shortage
- Soil and water pollution
- Nitrate management
- Landscape simplification

Case study 5: Diversified cropping systems

A. **Tomato-Wheat** (T-W): current situation

B. **Diversification 1** (D1): introduction of a leguminous crop in the rotation (pea for food)

C. **Diversification 2** (D2): introduction of tomato as second crop in the rotation after pea (Multiple crops)

Case study 5:

new crop in rotation and organic fertilizer

Case study 5: Low input management practices

1. Use of organic fertilizer (pig slurry/two doses)
2. Reduced tillage
3. Integrated irrigation, pest and fertilizers control (use of DSS in durum wheat cultivation)

Case study 5: Experimental design

- **Exp. Factors**: 1. Farms (Block), 2. Crop diversification, 3. Fertilization management (pig slurry dose)
- **Experimental design**: Randomized block considering all case studies as blocks (CS5, CS6, CS7). Split plot design in each farm.
- **Replications**: Within the farm, main plot is the crop (3 replicates x 3 crops + control) and sub-plot (3 replicates) is the dose of pig slurry (2 doses)
- **Plot size**: main plot 5 ha, subplot approximately 1/2 of main plot
- **Crop monitoring and sampling**: monitoring at specific phenological stages for tomato and durum wheat, at harvest for every crop, plots and sub-plots. Quality assessment
- **Soil sampling**:
  - Time and frequency: every year according to crops cycle or growing season (3 samples for each subplot).
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: 3 composite samples per plot in WP5 (3 crops + control X 2 doses x 2 depth X 3 replicates= 48 samples). For WP4, 4 out of 9 samples per treatment (crop) will be selected + 1 for the control.
- **Greenhouse gas emission measures**: 25 measures per year per farm (around 300 samples).

DIVERFARMING

Case study 5: Experimental layout

Case study 5: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

Case study 5: Crop properties

1. **Crop growth**
   - Crop biomass
   - Crop establishment (plant/m^2)
2. **Pests and diseases incidence**
   - Plants affected by pests/diseases, pest population, damage proportion and disease incidence.
3. **Crop yield**
   - Crop yield, marketable yield.
   - Land productivity.
4. **Crop quality**
   - Tomato quality (brix degrees, lycopene, physical properties).
   - Wheat quality (thousand kernel weight, grain humidity, protein, gluten index).
5. **Nutritional evaluation**
   - None

Case study 5: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
   - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
   - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsusfatase activities.
   - Potential nitrification.
   - Transcriptome of active microbial populations by qPCR and RNA sequencing.
3. **Earthworms**
   - Total density and mass.
   - Only measured at the beginning and the end of the experimental period.

Case study 5: Vegetal biodiversity properties

1. **Plant species**
   - Identification and richness.
2. **Vegetation**
   - Cover.
   - Similarity index.

Case study 5: Soil physico-chemical properties

1. **Soil fertility and pollutants**
    - Total N, ammonium, nitrate and available P, K, Ca, Mg, Fe, Mn, Cu, Zn and B.
    - Cd, Pb, Ni, Cr, As, Al
    - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
    - Bulk density (beginning/end), soil water content at wilting point and field capacity (only once), actual field moisture (at sampling), texture (only once), total organic carbon, carbonates, aggregates stability (beginning/end), aggregates size distribution (beginning/end).
4. **Greenhouse gas emissions**
    - Soil CO_2, N_2O.
    - Overall emissions by modeling

Case study Num. 5 Coordinator

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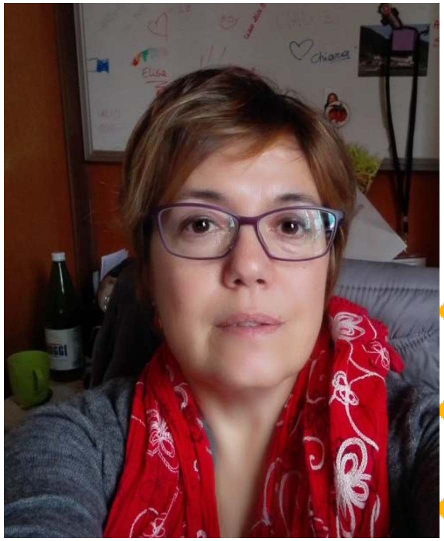

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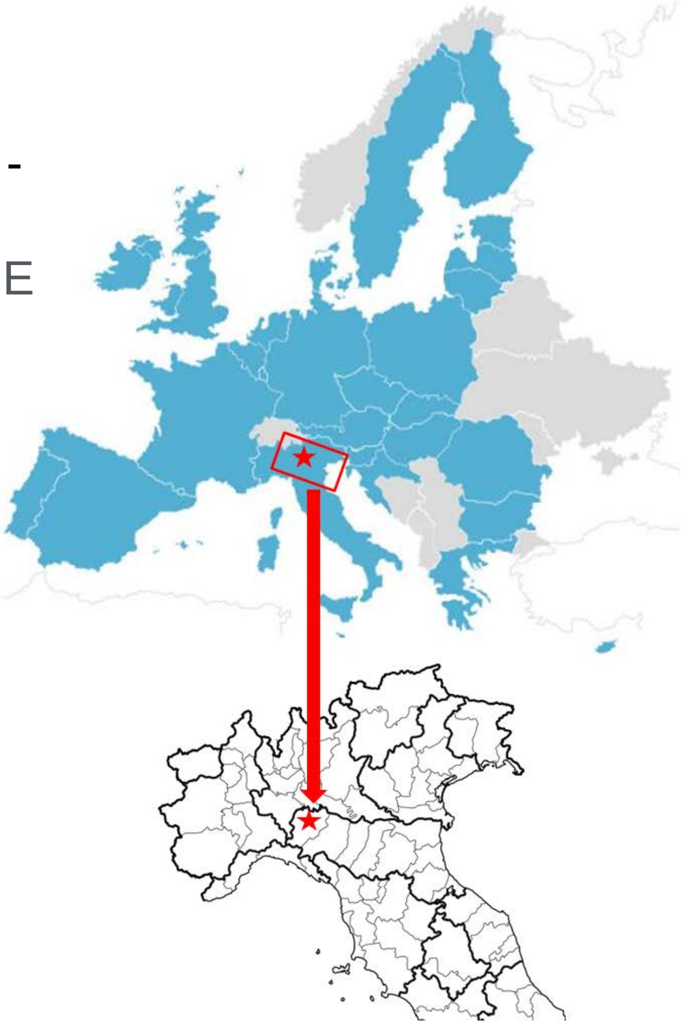
CASE STUDY NUM 6

Arable Land
Diversified annual crop rotations in Italy

CASE STUDY NUM. 6	
Partners involved	CCP, UTu, CREA, Barilla
Authors	Davide Rocca (CCP), Emanuele Blasi (UTu), Roberta Farina (CREA)
E-mail of principal author	roberta.farina@crea.gov.it

Case study 6: Intensive arable DW and TO

- Pedoclimatic región MEDITERRANEAN NORTH
- Country: ITALY
- Location: Padania Valley – Emilia Romagna Region - Piacenza Province
- Geographical coordinates: 44°55.740’ N, 9°48.754’ E
- Mean annual temperature: 11.8 ºC
- Mean annual precipitation: 836 mm



Case study 6: Main characteristics

- Farm extension: 48 ha
- Diverfarming experimentation area: 18 ha
- Current crops: durum wheat or tomato
- Crop final use: food
- Current cropping system – two years rotation:
  - rainfed wheat (Triticum durum) -irrigated tomato (Solanum lycopersicum)
- Harvest time: late spring - summer
- Current management practices:
  -Intense tillage
  -Mineral fertilizer
  -Integrated Pest Management
- Current value chain:
  -Producer
  -Quality and certification
  -Wholesaler and processer
  -Supermarket

Case study 6: Main environmental problems

- Low soil organic matter
- Soil compaction and low aggregate stability
- Risk of water irrigation shortage
- Soil and water pollution
- Nitrate management
- Landscape simplification

Case study 6: Diversified cropping systems

A. **Tomato-Wheat** (T-W): current situation
B. **Diversification 1** (D1): introduction of a leguminous crop in the rotation (pea for food)
C. **Diversification 2** (D2): introduction of tomato as second crop in the rotation after pea (Multiple crops)

Case study 6: crop rotation and use of digestate

Digestate is the by-product from biogas anaerobic digestion process. Availability of digestate is very large in the area and it is almost available for free. It could represent a feasible alternative to mineral fertilizers. There is the need to assess the effect on the soil-crop-water system.

Case study 6: Low input management practices

1. **Use of organic fertilizer (digestate/two doses)**
2. **Reduced tillage (for wheat)**
3. **Integrated irrigation, pest and fertilizers control (use of DSS in durum wheat cultivation)**

Case study 6: Experimental design

- **Exp. Factors**: 1. Farms (Block), 2. Crop diversification, 3. Fertilization management (digestate dose)
- **Experimental design**: Randomized block considering all case studies as blocks (CS5, CS6, CS7). Split plot design in each farm.
- **Replications**: Within the farm, main plot is the crop (3 replicates x 3 crops + control) and sub-plot (3 replicates) is the dose of digestate (2 doses)
- **Plot size**: main plot 5 ha, subplot approximately 1/2 of main plot
- **Crop monitoring and sampling**: monitoring at specific phenological stages for tomato and durum wheat, at harvest for every crop, plots and sub-plots. Quality assessment
- **Soil sampling**:
  - Time and frequency: every year according to crops cycle or growing season (3 samples for each subplot).
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: 3 composite samples per plot in WP5 ((3 crops + control) X 2 doses x 2 depth X 3 replicates= 48 samples). For WP4, 4 out of 9 samples per treatment (crop) will be selected + 1 for the control.
- **Greenhouse gas emission measures**: 25 measures per year per farm (around 300 samples).

Case study 6: Experimental layout

Case study 6: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

DIVERFARMING

Case study 6: Crop properties

1. **Crop growth**
   - Crop biomass
   - Crop establishment (plant/m^2)
2. **Pests and diseases incidence**
   - Plants affected by pests/diseases, pest population, damage proportion and disease incidence.
3. **Crop yield**
   - Crop yield, marketable yield.
   - Land productivity.
4. **Crop quality**
   - Tomato quality (brix degrees, lycopene, physical properties).
   - Wheat quality (thousand kernel weight, grain humidity, protein, gluten index) .
5. **Nutritional evaluation**
   - None

Case study 6: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
   - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
   - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsulfatase activities.
   - Potential nitrification.
   - Transcriptome of active microbial populations by qPCR and RNA sequencing.
3. **Earthworms**
   - Total density and mass.
   - Only measured at the beginning and the end of the experimental period.

DIVERFARMING

Case study 6: Vegetal biodiversity properties

1. **Plant species**
    - Identification and richness.
2. **Vegetation**
    - Cover.
    - Similarity index.

Case study 6: Soil physicochemical properties

1. **Soil fertility and pollutants**
   - Total N, ammonium, nitrate and available P, K, Ca, Mg, Fe, Mn, Cu, Zn and B.
   - Cd, Pb, Ni, Cr, As, Al
   - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
   - Bulk density (beginning/end), soil water content at wilting point and field capacity (only once), actual field moisture (at sampling), texture (only once), total organic carbon, carbonates, aggregates stability (beginning/end), aggregates size distribution (beginning/end).
4. **Greenhouse gas emissions**
   - Soil CO_2, N_2O.
   - Overall emissions by modeling

Case study Num. 6 Coordinators

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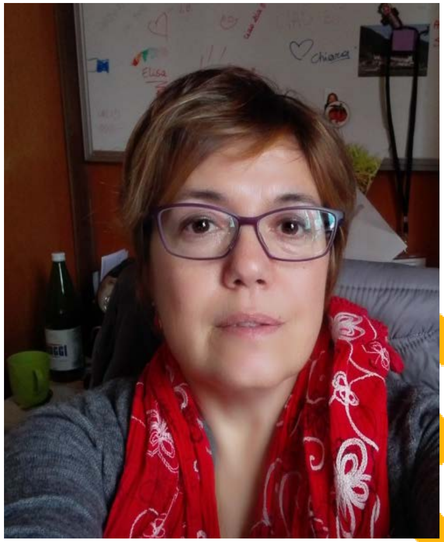

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CASE STUDY
NUM 7

Arable Land
Diversified annual crop rotations in Italy

CASE STUDY NUM. 7	
Partners involved	CCP, UTu, CREA, Barilla
Authors	Davide Rocca (CCP), Emanuele Blasi (UTu), Roberta Farina (CREA)
E-mail of principal author	roberta.farina@crea.gov.it

Case study 7: Intensive arable DW and TO

- Pedoclimatic región: MEDITERRANEAN NORTH
- Country: ITALY
- Location: Padania Valley – Lombardia Region - Cremona Province
- Soil texture: loamy soil
- Geographical coordinates 7: 45° 4.997’ N, 10° 26.048’ E
- Mean annual temperature: 13,2 °C
- Mean annual precipitation: 760 mm

Case study 7: Main characteristics

- Farms extensions: 84.3 ha
- Diverfarming experimentation area: 18.1 ha
- Current crop: durum wheat or tomato
- Crop final use: food
- Current cropping system – two years rotation
  → rainfed (*Triticum durum Desf.*)
  → irrigated (*Solanum lycopersicum L.*)
- Harvest time: late spring - summer
- Current management practices:
  - Intense tillage
  - Mineral fertilizer
  - Integrated Pest Management
- Current value chain:
  - Producer
  - Quality and certification
  - Wholesaler and processer
  - Supermarket

Case study 7: Main environmental problems

- Low soil organic matter
- Soil compaction and low aggregate stability
- Risk of water irrigation shortage
- Soil and water pollution
- Nitrate management
- Landscape simplification

DIVERFARMING

Case study 7: Diversified cropping systems

A. **Tomato-Wheat** (T-W): current situation
B. **Diversification 1** (D1): introduction of a leguminous crop in the rotation (pea for food)
C. **Diversification 2** (D2): introduction of tomato as second crop in the rotation after pea (Multiple crops)

Case study 7: crop rotation and use of digestate

Digestate is the by-product from biogas anaerobic digestion process. Availability of digestate is very large in the area and it is almost available for free. It could represent a feasible alternative to mineral fertilizers. There is the need to assess the effect on the soil-crop-water system.

Case study 7: Low input management practices

1. **Use of organic fertilizer (digestate/two doses)**
2. **Reduced tillage (for wheat)**
3. **Integrated irrigation, pest and fertilizers control (use of DSS in durum wheat cultivation)**

Case study 7: Experimental design

- **Exp. Factors**: 1. Farms (Block), 2. Crop diversification, 3. Fertilization management (digestate dose)
- **Experimental design**: Randomized block considering all case studies as blocks (CS5, CS6, CS7). Split plot design in each farm.
- **Replications**: Within the farm, main plot is the crop (3 replicates x 3 crops + control) and sub-plot (3 replicates) is the dose of digestate (2 doses)
- **Plot size**: main plot 5 ha, subplot approximately 1/2 of main plot
- **Crop monitoring and sampling**: monitoring at specific phenological stages for tomato and durum wheat, at harvest for every crop, plots and sub-plots. Quality assessment
- **Soil sampling**:
  - Time and frequency: every year according to crops cycle or growing season (3 samples for each subplot).
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: 3 composite samples per plot in WP5 ((3 crops + control) X 2 doses x 2 depth X 3 replicates= 48 samples). For WP4, 4 out of 9 samples per treatment (crop) will be selected + 1 for the control.
- **Greenhouse gas emission measures**: 25 measures per year per farm (around 300 samples).

Case study 7: Experimental layout

Case study 7: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

Case study 7: Crop properties

1. **Crop growth**
    - Crop biomass
    - Crop establishment (plant/m^2)
2. **Pests and diseases incidence**
    - Plants affected by pests/diseases, pest population, damage proportion and disease incidence.
3. **Crop yield**
    - Crop yield, marketable yield.
    - Land productivity.
4. **Crop quality**
    - Tomato quality (brix degrees, lycopene, physical properties).
    - Wheat quality (thousand kernel weight, grain humidity, protein, gluten index) .
5. **Nutritional evaluation**
    - None

Case study 7: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
   - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
   - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsulfatase activities.
   - Potential nitrification.
   - Transcriptome of active microbial populations by qPCR and RNA sequencing.
3. **Earthworms**
   - Total density and mass.
   - Only measured at the beginning and the end of the experimental period.

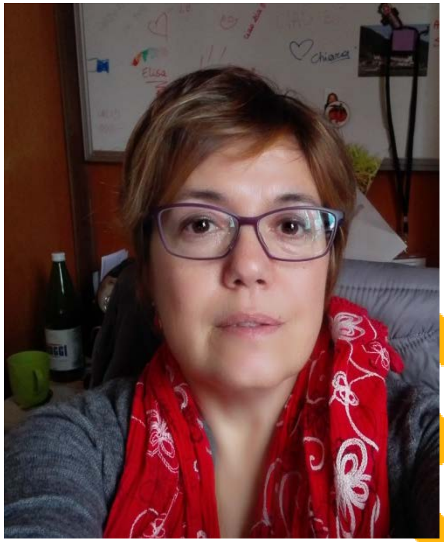
Case study 6: Vegetal biodiversity properties

1. **Plant species**
   - Identification and richness.
2. **Vegetation**
   - Cover.
   - Similarity index.

Case study 7: Soil physicochemical properties

1. **Soil fertility and pollutants**
   - Total N, ammonium, nitrate and available P, K, Ca, Mg, Fe, Mn, Cu, Zn and B.
   - Cd, Pb, Ni, Cr, As, Al
   - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
   - Bulk density (beginning/end), soil water content at wilting point and field capacity (only once), actual field moisture (at sampling), texture (only once), total organic carbon, carbonates, aggregates stability (beginning/end), aggregates size distribution (beginning/end).
4. **Greenhouse gas emissions**
   - Soil CO_2, N_2O.
   - Overall emissions by modeling

Case study Num. 7 Coordinators



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CASE STUDY NUM. 7bis

Crop Rotations
Diversified annual crop rotations in Italy

CASE STUDY NUM. 7	
Partners involved	CCP, Utu, CREA, Barilla
Authors	Davide Rocca (CCP), Emanuel Blasi (UTu), Cesare Ronchi (Barilla), Roberta Farina (CREA), Antonio Troccoli (CREA)
E-mail of principal author	antonio.troccoli@crea.gov.it roberta.farnia@crea.gov.it

Case study 7bis: Crop rotations

- Pedoclimatic region: MEDITERRANEAN SOUTH
- Country: ITALY
- Location: Foggia (APULIA REGION)
- Geographical coordinates: 41°27’57.3’’ N, 15°30’19.8’’ E
- Mean annual temperature: 15.8 ºC
- Mean annual precipitation: 529 mm
- Annual potential evapotranspiration: 734 mm

Case study 7bis: Main characteristics

- **Farm extension**: 150 ha
- **Diverfarming experimentation area**: 12 ha
- **Current crops**: durum wheat, tomato and/or bare fallow
- **Crop final use**: food (durum wheat, tomato)
- **Current cropping system**: two years rotation:
  - rainfed (Triticum durum Desf.)
  - irrigated (Lycopersicum esculentum L.)
- **Harvesti time**: summer
- **Current management practices**:
  - intense tillage
  - mineral fertilizer
  - irrigation
  - Integrated Pest Management
- **Current value chain**:
  - producer
  - quality and certification
  - wholesaler and processoer
  - supermarket

Case study 7bis: Main environmental problems

- Low soil organic matter
- Soil compaction and low aggregate stability
- Risk of water irrigation shortage
- Soil and water pollution
- Nitrate management
- Landscape simplification

Case study 7bis: Diversified cropping systems

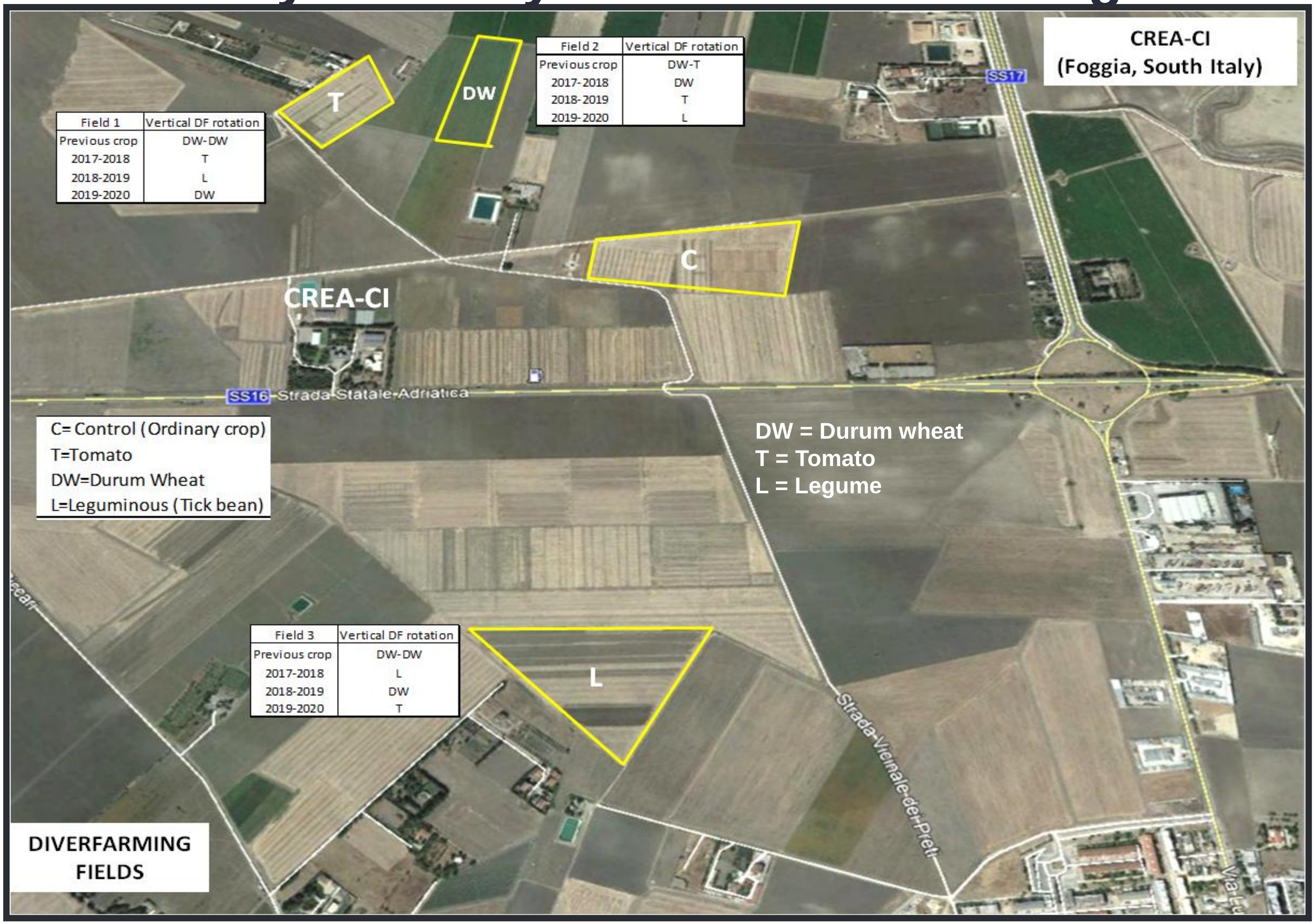
A. **Tomato-Durum Wheat (T-DW)**: current situation
B. **Diversification 1 (D1):** introduction of a leguminous crop in the rotation (tick bean for green manure)
C. **Diversification 2 (D2):** introduction of crop residues management;
D. **Diversification 3 (D3):** for tomato to apply a reduced irrigation of 20%

Case study 7bis: Experimental design

- **Factors of study**: DiverFaming (DF) rotation *vs*. Ordinary crop of the farm (C, Control)
- **Experimental design**: for each year, three fields represent the DF rotation *versus* one control field (C)
- **Replications**: three randomized replications within of each field
- **Plot size**: fields at least of 3 ha and sampling subplots of 300 m^2
- **Crop monitoring and sampling**: monitoring at specific phenological stages for crops in progress, and quality assessment for every crops.
- **Soil sampling**:
  - **Time and frequency**: every year according to crops cycle or growing season (3 samples for each subplot).
  - **Soil depth**: arable layer (0-10 and 10-30 cm).
  - **Number of samples**: 3 composite samples per plot (3 crops + control) x 2 depth x 3 replicates= 24 samples).

DIVERFARMING

Case study 7bis: layout for DiverFarming fields



Field 1	Vertical DF rotation
Previous crop	DW-DW
2017-2018	T
2018-2019	L
2019-2020	DW

Field 2	Vertical DF rotation
Previous crop	DW-T
2017-2018	DW
2018-2019	T
2019-2020	L

Field 3	Vertical DF rotation
Previous crop	DW-DW
2017-2018	L
2018-2019	DW
2019-2020	T

Case study 7bis: Environmental

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Minimum daily temperature.
- Mean daily soil temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

Case study 7bis: Crop properties

1. **Crop growth**
   - Crop biomass
   - Crop establishment (plant/m2)
2. **Pests and diseases incidence**
   - Plants affected by pests/diseases, pest population, damage proportion and disease incidence.
3. **Crop yield**
   - Crop yield, marketable yield.
   - Land productivity.
4. **Crop quality**
   - Tomato quality (brix degrees, lycopene, physical properties).
   - Wheat quality (thousand kernel weight, grain humidity, protein, gluten index).
5. **Nutritional evaluation**
   - None

Case study 7bis: Soil physicochemical properties

1. Soil fertility and pollutants

- Total N, ammonium, nitrate and available P, K, Ca, Mg, Fe, Mn, Cu, Zn and B.
- Cd, Pb, Ni, Cr, As, Al
- pH, electrical conductivity, cation exchange capacity and sum of bases.

2. Soil structure and carbon sequestration

- Bulk density (beginning/end), soil water content at wilting point and field capacity (only once), actual field moisture (at sampling), texture (only once), total organic carbon, carbonates, aggregates stability (beginning/end), aggregates size distribution (beginning/end).

Case study Num. 7bis: Coordinators

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CASE STUDY NUM 8

Fodder Crops in The Netherlands

CASE STUDY NUM. 8	
Partners involved	WU, Ben van Tilburg (Bromo, Wadden Max), Ekoboerderij de Lingehof
Stakeholders involved	SPNA, BioBakker
Authors	Coen Ritsema, Violtte Geissen, Esperanza Huerta Lwanga, Hennie Gertsen, Nicolas Beriot, Benjamin van Schothorst (WU) Ben van Tilburg, Mieke Frieters (Bromo, Wadden Max), Carina Rietema (SPNA) Jan Willem Bakker (BioBakker) Petra Derkzen (Ekoboerderij de Lingehof)
E-mail of responsable author	esperanza.huertalwanga@wur.nl

Case study 8: Fodder Crops

- Pedoclimatic region: Atlantic Central
- Country: THE NETHERLANDS
- Location: Groningen (WEST FRISIAN)
- Geographical coordinates: 53°22'52.3"N 6°19'42.2"E
- Mean annual temperature: 9.4 ºC
- Mean annual precipitation: 780 mm

Fodder crop

Potato crop

Case study 8: Main characteristics

- Farm extensions:
  - Fodder crop: 25 ha
  - Potato crop: 112 ha & 64 ha
- Diverfarming experimentation area: 0.72 ha
- Current crops: Fodder (grass) & Potatos
- Crop final use: feed and food
- Current cropping system. Fodder: Biodinamic, Potatos: Conventional monocrop and Biodinamic multiple crop
- Harvest time: Fodder: December, Potato: August
- Current management practices: Fodder: Biodinamic with rotation and tillage. Potatos: tillage, use of pesticides. Biodinamic Potatos: tillage, intercropping, multiple cropping, rotation
- Current value chain:
  - Producer
  - Quality and certification
  - Wholesaler
  - Supermarket

DIVERFARMING

Case study 8: Main environmental problems

- Low below and aboveground biodiversity
- Low soil quality
- Low soil organic matter content
- Plant diseases (Potato crops)
- Unknown pesticide residues in the soils

Case study 8: Diversified cropping systems

The experimental setting will be stablished in three sites:

1) Biodynamic fodder crop (in order to test the effect of rotations/multiple cropping vs no diversification)

2) Experimental conventional potato farm (in order to test the effect of rotation/multiple cropping vs no diversification)

3) Biodynamic potato farm (in order to test the effect of 10 years of rotation vs 20 years of rotation)

Case study 8: Diversified cropping systems

A. **Grass (fodder) & Potatos** (MC)

B. **Diversification 1 Fodder** (D1): Wheat-Peas (May-August 2018), grass (September-December 2018)

C. **Diversification 2 Fodder** (D2): Mais (May-November 2019), wheat-peas (May-Agustus 2020), grass (September-December 2020)

D. **Diversification 1 Conventional Potato** (D1): Oat (July-March 2018), Potato (April-August 2018) (In experimental Farm)

E. **Diversification 2 Conventional Potato** (D2): Solarigol DSV (green fertilizer,September-February 2019) potato (April-Agust 2019), Oat (September 2019-March 2020), Potato (April-July 2020) (In experimental Farm)

F. **Diversification 1 Biodynamic Potato**. Grass clover (January-April 2018), Coliflower (March-June 2018), Oat (July-December 2018)

G. **Diversification 2 Biodynamic Potato.** Oat (January-March 2019), Potato (April-August 2019), Phacelia/Wikke (September-December 2019), Coliflower/Japanese Oat/Alexclover (March-October 2020), Carrot or celeriac/oat (November-December 2020)

Case study 8: Intercropping

Seasonal crops will be cultivated before and after the main crop, grass for feed in the case of fodder crop, oat for food in the case of conventional potatoes, and coliflower for food in the case of biodynamic potatoes.

Case study 8: Low input management practices

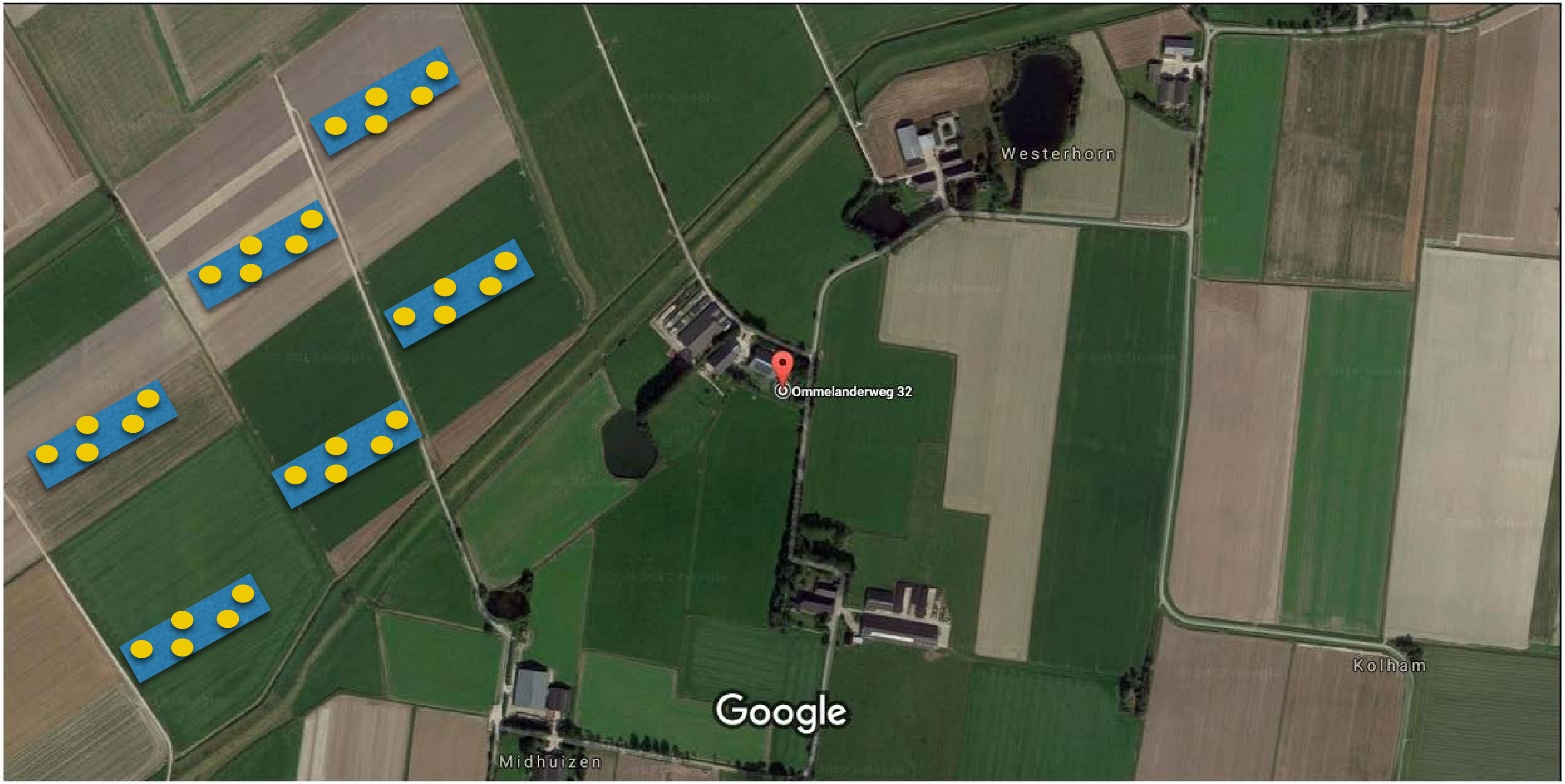
1. Addition of organic matter (/manure, compost, etc)
2. Maintenance of egetation cover (natural or cover crops)
3. Use of green manure
4. Integrated pest control
5. Use of green manure
6. Precision agriculture to optimise weed control

DIVERFARMING

Case study 8: Experimental design

- **Factors of study**: 1. Crop diversification, 2. Pest control, 3. Years of biodynamic crops (10 vs 20 years), 4. Biodynamics vs Conventional
- **Experimental design**: Strip-plot in diversification blocks.
- **Replications**: Three field replicated plots.
- **Plot size**: Fodder crop & biodynamic potatoes: 210 m^2, conventional potatoes: 200m^2
- **Crop monitoring and sampling**: at harvest for every crop and plot.
- **Soil sampling**:
  - Time and frequency: Once per year, when the weather conditions allow the best soil fertility condition (middle May)
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: 5 composite samples per plot (15 samples per treatment) in WP5. For WP4, 5 out of the 15 samples per treatment will be selected.

Case study 8: Experimental layout



Example in fodder crop

Case study 8: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

Case study 8: Crop properties

1. **Crop growth**
    - Crop establishment and above-ground biomass in annual intercrops.
2. **Pests and diseases incidence**
    - Plants affected by pests/diseases, pest population, damage proportion and disease incidence.
3. **Crop yield**
    - Crop yield in all crops.
    - Land productivity.
4. **Crop quality**
    - Thousand kernel weight, humidity and protein content for fodder.
5. **Nutritional evaluation**
    - None

Case study 8: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
   - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
   - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsusfatase activities.
   - Potential nitrification.
   - Transcriptome of active microbial populations by qPCR and RNA sequencing.
3. **Earthworms**
   - Species identification, density and mass.
   - Density and mass by ecological groups.
   - Total density and mass.
   - Only measured at the beginning and the end of the experimental period.

Case study 8: Vegetal biodiversity properties

1. **Plant species**
    - Identification and richness.
2. **Vegetation**
    - Cover.
    - Similarity index.

Case study 8: Soil physicochemical properties

1. **Soil fertility and pollutants**
    - Total N, ammonium, nitrate and available P, K, Ca, Mg, Fe, Mn, Cu, Zn and B.
    - Total pesticides
    - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
    - Bulk density, soil water content at wilting point and field capacity, actual field moisture, rock fragments and gravels, texture, total organic carbon, carbonates, organic carbon functional fractions, aggregates stability, aggregates size distribution.

CASE STUDY NUM. 8 COORDINATOR

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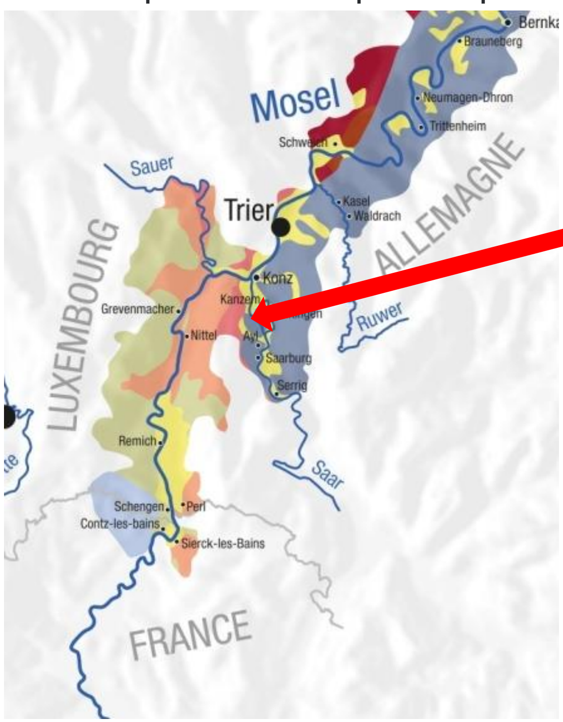
CASE STUDY NUM 9

Perennial crops (vineyards) in Germany

CASE STUDY NUM. 3	
Partners involved	UT, WDF, ETH
Authors	Sören Thiele-Bruhn, Manuel Seeger, Thomas Iserloh, Felix Dittrich (UT) Katharina Frey-Treseler, Cord-Henrich Treseler (WDF) Roman Hüppi (ETH)
E-mail of principal author	seeger@uni-trier.de

Case study 9: wine

- Pedoclimatic región: CONTINENTAL
- Country: GERMANY
- Location: WAWERN (RHEINLAND-PFALZ)
- Geographical coordinates: 49°39'23.976''N, 6°33'27.936''E
- Mean annual temperature: 11.2 ºC
- Mean annual precipitation: 727 mm
- Annual potential evapotranspiration: 672 mm



Case study 9: Main characteristics

- Farm extension: 5 ha
- Diverfarming experimentation area: 0.3 ha (1500 wine plants)
- Current crop: wine (*Vitis vinifera* L.), Riesling
- Crop final use: food consumption
- Current cropping system: organic, rainfed permanent monocrop (2 m x 1 m pattern)
- Harvest time: September to November (blossom in June)
- Current management practices:
  - Tillage / howing / mowing of natural vegetation
  - Organic pest control (May to August) and fertilization
- Current value chain:
  - Producer (certification)
  - Shops / private customer / restaurants (direct marketing)
  - Wholesaler

Case study 9: Main environmental problems

- Mechanical weed management below wine plants
  - ✓ To avoid competition on water
  - ✓ To avoid diseases (fungus infections)
- Soil erosion
- Loss of soil organic matter
- Damage on wine plants

Case study 9: Diversified cropping systems

A. **Diversification 1** (CS9a): wine intercropped with *Origanum vulgare* L. for multiple uses during 2018 (establishment), 2019 and 2020.
B. **Diversification 2** (CS9b): wine intercropped with *Thymus vulgaris* L. for multiple uses during 2018 (establishment), 2019 and 2020
C. **Diversification 3** (CS9c): wine intercropped with *Sideritis spp.* for food uses during 2018 (establishment), 2019 and 2020
D. **Wine monocrop** (CS9d)

Case study 9: Intercropping

Perennial herbs established under wine plants in row

Case study 9: Low input management practices

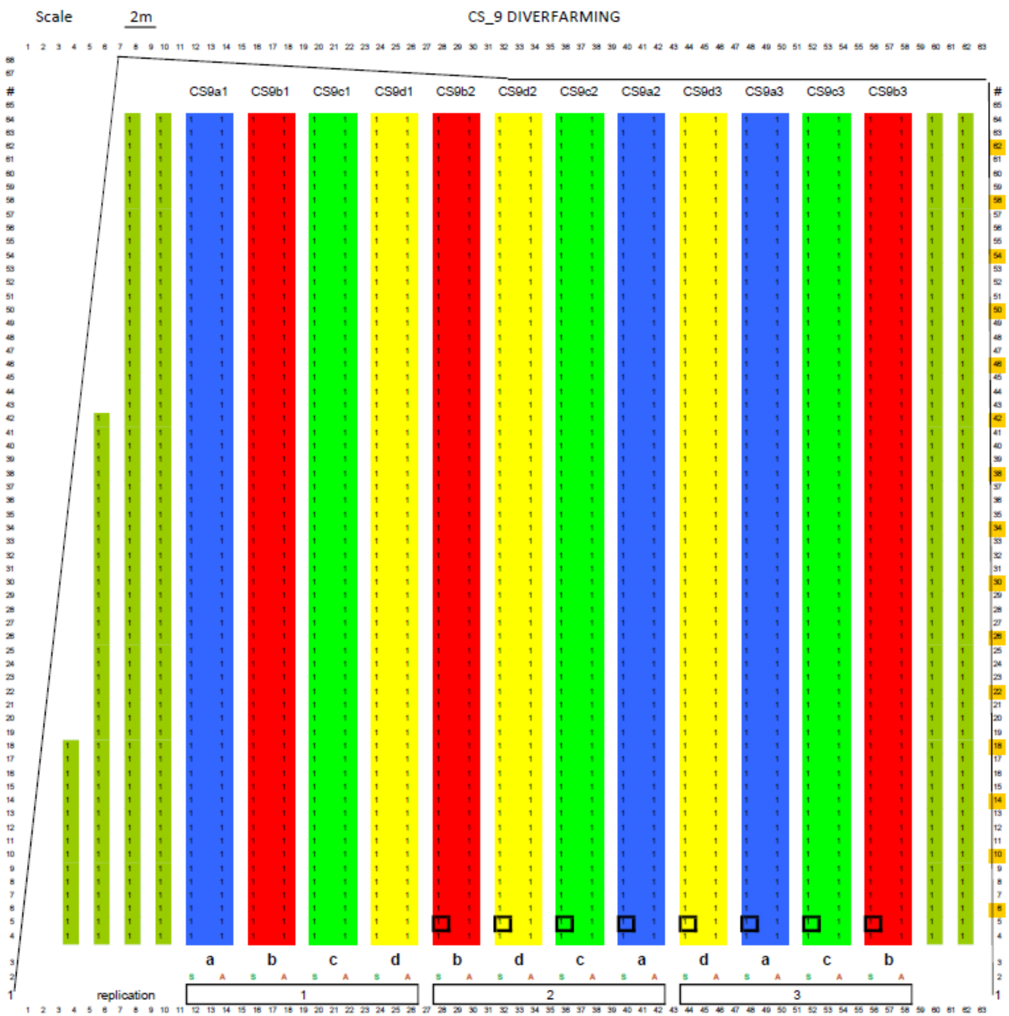
1. Organic wine production
2. Organic pest control
3. Organic fertilizer
4. Perennial cover crop in row (no till)
5. Cover vegetation (in driving space)

Case study 9: Experimental design

- **Factors of study**: 1. Crop diversification (3 herbs), 2. establishment strategy (spring and autumn planting/seeding)
- **Experimental design**: Strip-plots in diversification blocks.
- **Replications**: Three field replicated plots.
- **Plot size**: two rows of 55 wine plants, 220 m^2.
- **Crop monitoring and sampling**: weekly monitoring during vegetation time and at harvest for every crop and plot. Six wine plants will be monitored and sampled in each plot. Herbs will be monitored and sampled at similar spots.
- **Soil sampling**:
  - Time and frequency: Two times a year.
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: Three per plot (9 samples per treatment) in WP5. For WP4, five out of the nine samples per treatment will be selected..
- **Greenhouse gas emission measures**: 25 measures per year in the plots where soil is sampled.
- **Erosion measures**: Mixture of direct measurements, observations and experimental evaluation. Weekly measurements in sediment traps (each treatment in two replications), event-based monitoring (large-scale terrestrial and aerial monitoring) and rainfall and runoff experiments.

DIVERFARMING

Case study 9: Experimental layout



Variations

- a Echter Dost / Oregano (*Origanum vulgare* L.)
- b Thymian /Thyme (*Thymus vulgaris* L.)
- c Griechischer Bergtee / mountain tea (*Sideritis spp.*)
- d Control (open soil/mowing)
- S planting (Spring)
- A planting (Autumn)
- Sediment traps in rows between wine plants

Case study 9: Environmental variables

- Relief parameters.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Minimum daily temperature.
- Cumulative daily rainfall.
- Rainfall duration.
- Rainfall intensity.
- Air humidity.
- Wind speed.
- Wind direction.

Case study 9: Erosion and contamination prevention (WP5)

Assesment of:

- Effects on soil fertility and pollutants
- Improvements in soil structure, water availability and soil carbon sequestration
- Effect of crop diversification with low-input practices on carbon sequestration by biomass
- Reduction of erosion rates
- Mitigation of greenhouse gas emissions
- Benefits, drawbacks and limitations of machinery adapted to diversified cropping systems

Case study 9: Crop properties

1. **Crop growth**
   - Crop establishment and above-ground biomass in perennial intercrops (herbs).
   - Wine trunk growth (number, length, diameter), leaf area index, leaf water potential.
2. **Pests and diseases incidence**
   - Plants affected by pests/diseases, pest population, damage proportion and disease incidence.
3. **Crop yield**
   - Crop yield in perennial herbs, marketable yield.
   - Yield of wine grapes (kg) and juice (l).
   - Land equivalent ratio and land productivity.
4. **Crop quality**
   - Herbal essences and residual pollutants
   - Juice sweetness (°Oe), tritable acidity and pH.
5. **Nutritional evaluation**
   - None

Case study 9: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
   - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
   - C-, N, and P-cycle: Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsulfatase activities.
   - N-cycle: Potential nitrification; functional gene analysis with qPCR of 16S rDNA.
   - Transcriptome of active microbial populations by qPCR and DNA sequencing.
3. **Earthworms**
   - Species identification, density and mass.
   - Density and mass by ecological groups.
   - Total density and mass.
   - Only measured at the beginning and the end of the experimental period.

Case study 9: Vegetal biodiversity properties

1. **Plant species**
   - Identification and richness.
2. **Vegetation**
   - Cover.
   - Similarity index.
   - Overall spatial distribution by UAV-based optical assessment.
3. **Carbon sequestration by woody crops**
   - Net photosynthesis rate, transpiration rate, stomatal conductance, leaf area, leaf C/N ratio.

Case study 2: Soil physicochemical properties

1. **Soil fertility and pollutants**
    - Total N, ammonium, nitrate and available P, K, Ca, Mg, Fe, Mn, Cu, Zn and B.
    - Total pesticides
    - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
    - Bulk density, soil water content at wilting point and field capacity, actual field moisture, texture, total organic carbon, carbonates, organic carbon functional fractions, aggregates stability, aggregates size distribution.
3. **Erosion rates**
    - Basic characterization of erosion processes and rates and event-based measures on interrill erosion, rill erosion, gully erosion, runoff generation.
    - Measurement of nutrient and organic carbon losses.
4. **Greenhouse gas emissions**
    - Soil CO_2, N_2O and CH_4.

Case study Num. 9 Coordinator

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CASE STUDY NUM 10

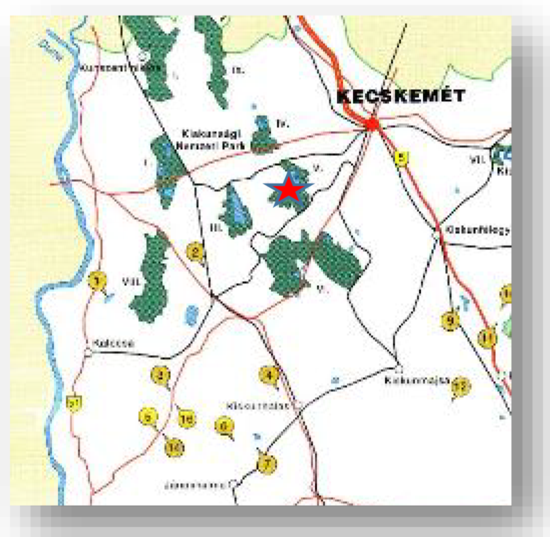
Horticulture in Hungary

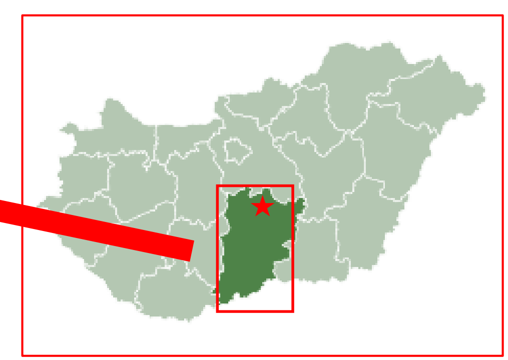
CASE STUDY NUM. 10	
Partners involved	NMT, UP, ETH, UT,
Authors	Ferenc Tarjányi, József Dezső, Dénes Lóczy, Tamás Móricz, László Horváth, Tamás Weidinger, Roman Hüppi, Johan Six, Sören Thiele-Bruhn, Manuel Seeger, Thomas Iserloch
E-mail of principal author	dejozsi@gamma.ttk.pte.hu

DIVERFARMING

Case study 10: horticulture

- Pedoclimatic region: Pannonian
- Country: Hungary
- Location: Jakabszállás (Danube-Tisza Interfluve)
- Geographical coordinates: 46°44’52.6”N 19°34’25.7”E
- Mean annual temperature: 10.8 °C
- Mean annual precipitation: 538 mm
- Annual potential evapotranspiration: 848 mm





DIVERFARMING

Case study 10: Main characteristics

- Farm extension: 280 ha
- Diverfarming experimentation area: 1.3 ha (28 rows)
- Current crop: Asparagus (*Asparagus officinalis*)
- Crop final use: food
- Current cropping system: 7-10 years monocrop (rows)
- Harvest time: April - May
- Current management practices:
  - Febr. - April: preparing ridges, covering with foil
  - June: rotation, demolition of the ridges,
  - Mineral fertilizer (2/3 of annual dose in June, 1/3 in August)
  - Integrated pest management
- Current value chain:
  - Producer
  - Quality and certification
  - Wholesaler

Case study 10: Main environmental problems

- Reduced biodiversity and landscape pattern
- Wind erosion, lack of ground cover
- Poor soil quality (skeletal sandy soil)
- Low soil organic matter content
- Water budget problems/water scarcity

Case study 10: Diversified cropping systems

A. **Asparagus monocrop**
B. **Diversification 1** (D1): interrows cropped with field pea (*Pisum sativum* L.) (March – June) for nitrogen balance
C. **Diversification 2** (D2): interrows cropped with oat (*Avena sativa*) (March – June) for organic material enhancement and/or marketable produce

Case study 10: Intercropping

Annual crops (bean, oat) will be cultivated between the asparagus rows, which are at 1.8 m intervals.

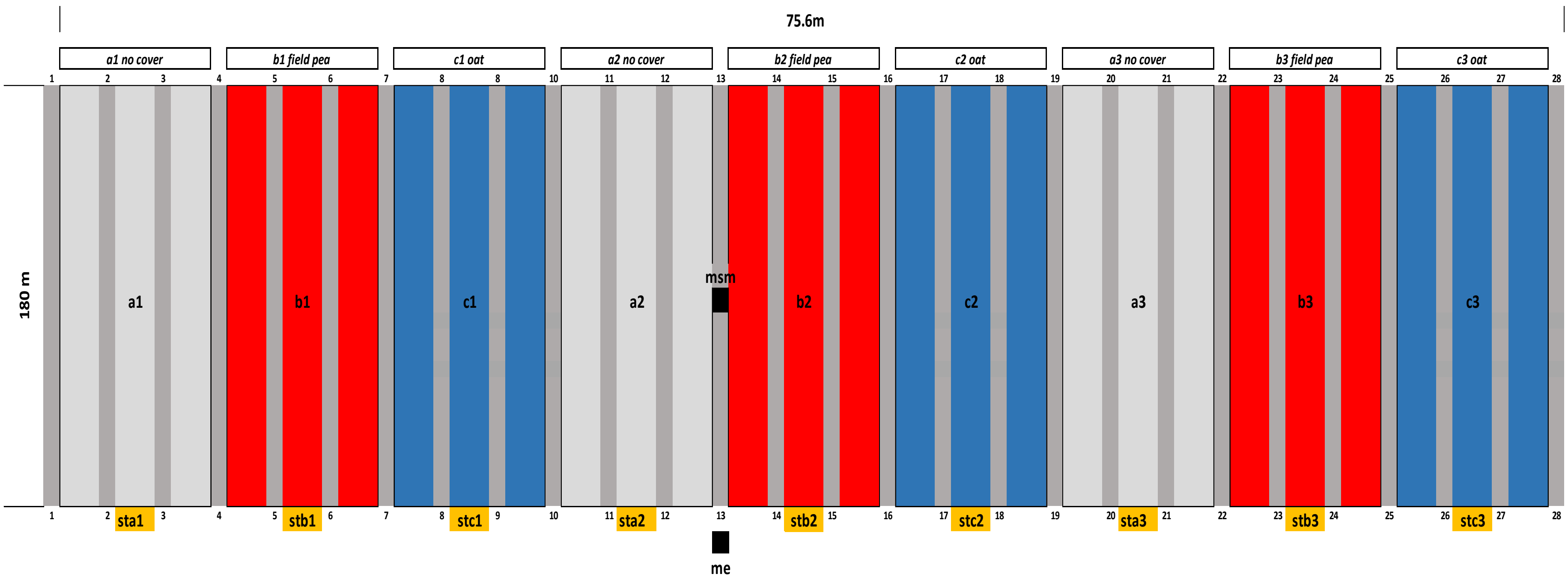
Case study 10: Low input management practices

1. Addition of “greensoil” (granulate OM mixed with mineral fertiliser)
2. Green manure
3. Integrated pest control
4. Cover crops (in the interrows)
5. Regulated irrigation
6. Cellulose-decomposing bacteria (November-March)

Case study 10: Experimental design

- **Factors of study**: 1. Intercropping, 2. Soil water budget, 3. Effect of intercrop rotation
- **Experimental design**: Strip-plot in diversification blocks.
- **Replications**: Three-field replicates.
- **Plot size**: Three rows with interrows, 160 x 8.4= 1,344 m^2
- **Crop monitoring and sampling**: at harvest for every crop and plot. Crop (asparagus) samples from the central row will be sampled in each plot.
- **Soil sampling**:
  - Time and frequency: every June during three crop cycles
  - Soil depth: ploughed layer (0-10 and 10-30 cm) and one soil pit excavation at the beginning of field experiment
  - Number of samples: three composite samples per plot (nine samples per treatment) in WP5. For WP4, five out of the nine samples per treatment will be selected.
- **Greenhouse gas emission measures**: CO_2 and N_2O, 25 measurement campaigns per year in the plots focusing on the growing season, harvest, rotation and manuring (April-July) period. In periods when rapid changes occur: using dynamic chambers
- **Erosion measurements**: in situ photogrammetric (eventbased) monitoring and sediment traps for wind deposited material at each interrow, mapping erosion features, using UAV.

Case study 10: Experimental layout



1, 2, 3, ... rows
me in situ monitoring for erosion
msm in situ monitoring for soil moisture
sta1,2,3.. sediment traps

Case study 10: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Minimum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

Case study 10: Crop properties

1. **Crop growth**
   - Crop establishment and above-ground biomass in annual intercrops (field pea, oat).
2. **Pests and diseases incidence**
   - Plants affected by pests/diseases, pest population, damage proportion and diseases incidence.
3. **Crop yield**
   - Crop yield in annual (field pea, oat) and perennial (asparagus) crops, marketable yield.
   - Land equivalent ratio and land productivity.
4. **Crop quality**
   - Asparagus weight and size distribution, mineral composition: Na, K, Ca, Mg, Fe, Cu, Zn
5. **Nutritional evaluation**
   - None

Case study 10: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
   - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
   - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsusfatase activities.
   - Potential nitrification.
   - Transcriptome of active microbial populations by qPCR and RNA sequencing.
3. **Earthworms**
   - Species identification, density and mass twice during the field experiment period (2018 and 2020)
   - Density and mass by ecological groups.
   - Total density and mass.
   - Only measured at the beginning and the end of the experimental period.

Case study 10: Vegetal biodiversity properties

1. **Plant species**
   - Identification and richness.
2. **Vegetation**
   - Percentage cover.
   - Similarity index.
   - Overall spatial distribution by UAV-based visual assessment.
3. **Carbon sequestration by woody crops**
   - None.

Case study 10: Soil physicochemical properties

1. **Soil fertility and pollutants**
    - Total N, Kjeldahl N, ammonium, nitrate, nitrite, P, K, Ca, Mg, Fe, Mn, Cu, Zn, B, Mo
    - Metals: Cu, Zn, Cd, Pb, Ni, Al,
    - Total pesticides
    - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
    - Bulk density, soil water content at wilting point and field capacity, actual field moisture, texture, total organic carbon, carbonates, organic carbon functional fractions, aggregates stability, aggregates size distribution.
3. **Erosion rates**
    - Characterization of wind dependent erosion processes and rates. Measurement of nutrient and organic carbon losses from deposited material.
4. **Greenhouse gas emissions**
    - Soil CO_2, N_2O
    - Emissions during growing season (April – July)

Case study Num. 10 Coordinator

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CASE STUDY NUM 11

Perennial crop (vineyard) in Hungary

CASE STUDY NUM. 10	
Partners involved	AKA, UP, ETH, UT,
Authors	János Werner, József Dezső, Dénes Lóczy, Tamás Móricz, László Horváth, Tamás Weidinger, Roman Hüppi, Johan Six, Sören Thiele-Bruhn, Manuel Seeger, Thomas Iserloch
E-mail of principal author	dejozsi@gamma.ttk.pte.hu

DIVERFARMING

Case study 11: vineyard

- Pedoclimatic región: PANNONIAN
- Country: HUNGARY
- Location: BARANYA (SOUTH TRANSDANUBIA)
- Geographical coordinates: 45° 51’’47.8“ N 18° 26’’39.6“ W
- Mean annual temperature: 10.7 ºC
- Mean annual precipitation: 680 mm
- Annual potential evapotranspiration: 650 mm

Case study 11: Main characteristics

- Farm extension: 70 ha
- Diverfarming experimentation area: 1.36 ha
- Current crop: vineyard
- Crop final use: food
- Current cropping system: rainfed permanent monocrop
- Harvest time: September - October (blossom in March-May)
- Current management practices:
  - Biofarming
  - Manuring, cover grass
  - Use of copper products
- Current value chain:
  - Producer
  - Quality and certification
  - Wholesaler, exporter
  - Supermarket,
  - Direct marketing

Case study 11: Main environmental problems

- Soil compaction
- Erosion by water
- Low infiltration capacity
- Lack of natural landscape elements
- Wheeltracks by overuse of tractors

Case study 11: Diversified cropping systems

A. **Vineyard monocrop**

B. **Diversification 1** (D1): interrows planted with herbs (yarrow, *Achillea millefolium*)

C. **Diversification 2** (D2): interrows cover by native grasses

Case study 11: Intercropping

Herbs will be sown between the grape rows, at 1.8 m interval

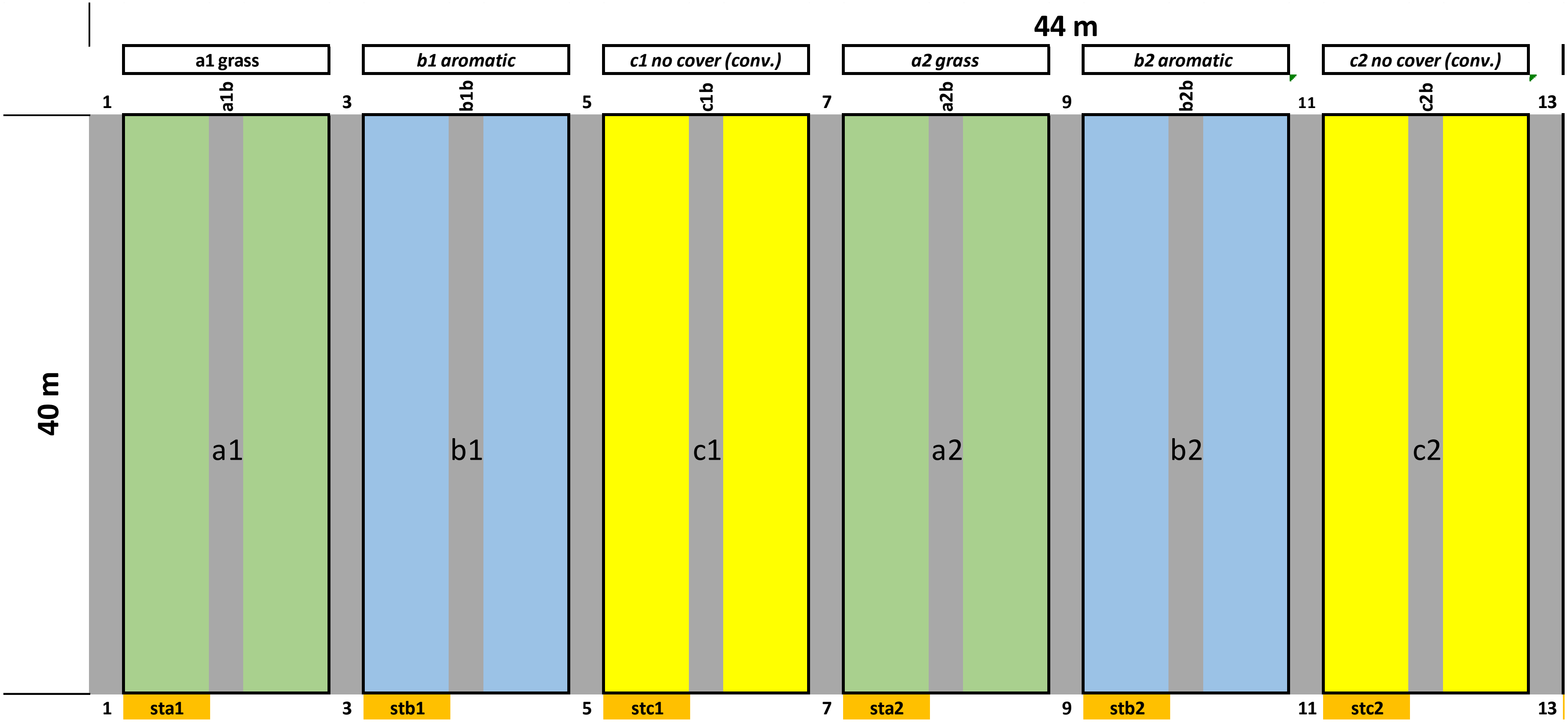
Case study 11: Low input management practices

1. Biofarming
2. Biostimulants
3. Green manure
4. Cover crops

Case study 11: Experimental design

- **Factors of study**: 1. Crop diversification with herbs, crop/herb interactions 2. Nutrient balance , 3. Erosion control
- **Experimental design**: Strip-plot in diversification blocks.
- **Replications**: Three field replicates
- **Plot size**: three rows, two interrows, 120 m^2.
- **Crop monitoring and sampling**: at harvest for every crop and plot.
- **Soil sampling**: Time and frequency: every June at peak of biological activity
  - Soil depth: ploughed layer (0-10 and 10-30 cm) and one soil pit excavation at the beginning of field experiment
  - Number of samples: three composite samples per plot (nine samples per treatment) in WP5. For WP4, five out of the nine samples per treatment will be selected.
- **Greenhouse gas emission measures**: CO_2 and N_2O, 25 measures per year during the growing season, at peak of leaf density. In periods when rapid changes occur using dynamic chamber
- **Erosion measures**: in situ photogrammetric (event-based) monitoring and sediment traps for water deposited material at each interrows, mapping erosion features, using UAV.

Case study 11: Experimental layout



1,..3,..5,..	berms
a1b, b1b, c1b...	berms lotated in the middle of the plots
sta1, stb1, stc1...	sediment traps
msm	in situ monitoring for soil moisture
me	in situ monitoring for erosion

Case study 11: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Minimum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

Case study 11: Crop properties

1. **Crop growth**
   - Crop establishment and above-ground biomass in annual intercrops.
2. **Pests and diseases incidence**
   - Plants affected by pests/diseases, pest population, damage proportion and diseases incidence.
3. **Crop yield**
   - Crop yield in grape and herbs, marketable yield.
   - Land equivalent ratio and land productivity.
4. **Crop quality**
   - Fruit weight and (berry) size distribution.
   - Soluble solids, juice pH and titritable acidity in grapes. Mineral composition: Na, K, Ca, Mg, Fe, Cu, Zn,
5. **Nutritional evaluation**
   - Sugar content

Case study 11: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
   - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
   - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, alkaline phosphatase and arylsusfatase activities.
   - Potential nitrification.
   - Transcriptome of active microbial populations by qPCR and RNA sequencing.
3. **Earthworms**
   - Species identification, density and mass.
   - Density and mass by ecological groups.
   - Total density and mass.
   - Only measured at the beginning and the end of the experimental period.

Case study 11: Vegetal biodiversity properties

1. **Plant species**
    - Identification and richness.
2. **Vegetation**
    - Percentage cover
    - Similarity index.
    - Overall spatial distribution by UAV-based visual assessment.
3. **Carbon sequestration by woody crops**
    - None

DIVERFARMING

Case study 11: Soil physicochemical properties

1. **Soil fertility and pollutants**
    - Total N, Kjeldhal N, ammonium, nitrate, nitrite, P, K, Ca, Mg, Fe, Mn, Cu, Zn, B, Mo
    - Metals: Cu, Zn, Cd, Pb, Ni, Al,
    - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
    - Bulk density, soil water content at wilting point and field capacity, actual field moisture, texture, total organic carbon, carbonates, organic carbon functional fractions, aggregates stability, aggregates size distribution.
3. **Erosion rates**
    - Characterization of water-dependent erosion processes and rates. Measurement of nutrient and organic carbon losses from deposited material.
4. **Greenhouse gas emissions**
    - Soil CO_2, N_2O
    - Emissions during the growing period (April – July)

Case study Num. 11 Coordinator

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CASE STUDY NUM 12

Conventional fodder crops in Finland

CASE STUDY NUM. 12	
Partners involved	Luke, PK
Authors	Kristiina Regina, Eila Turtola, Riitta Lemola, Jaakko Heikkinen, Visa Nuutinen, Hannu Fritze, Tero Tuomivirta, Heikki Lehtonen, Tuomo Purola, Terhi Latvala, Janne Artell (Luke) Maija-Liisa Paavola, Anne Paavola, Jarmo Lautamäki (PK)
E-mail of principal author	kristiina.regina@luke.fi

Case study 12: Conventional fodder crops in Finland

- Paavolan Kotijuustola
- Pedoclimatic region: BOREAL
- Country: FINLAND
- Location: KOUVOLA (SOUTHEAST FINLAND)
- Geographical coordinates: 60º 52’ N, 26º 50’’ E
- Mean annual temperature: 4.4ºC
- Mean annual precipitation: 698 mm
- Annual potential evapotranspiration: 412 mm

DIVERFARMING

Case study 12: Main characteristics

- Farm extension: 37 ha
- Diverfarming experimentation area: 2 ha
- Current crop: Feed for milk production
- Current cropping system: rain-fed conventional cereal monocropping
- Crop final use: cheese
- Harvest time: August
- Current products: cream cheese and yoghurt
- Current management practices:
    - Intense tillage
    - Mineral fertilizer
    - Pesticides
    - Herbicides
- Current value chain:
    - Milk producer
    - Farm-scale industry
    - Quality and certification
    - Distribution
    - Supermarket

Case study 12: Main environmental problems

- Milk farms concentrating on certain areas -> reduced diversity in cropping in other areas
- Arable farms have simple rotations or monocultures
- Decreasing soil organic matter content
- Erosion
- Nutrient leaching (N and P)
- Poor soil structure and low water conductivity

Case study 12: Diversified cropping systems

A. **Cereal monoculture** (past 10 years)
B. **Diversification 1** Barley amended with ryegrass catch crop during 2018, 2019 and 2020.
C. **Diversification 2** Cereal monocropping interrupted by an oilseed crop
    - 2018: spring barley, winter rapeseed sown in August/September
    - 2019: winter rapeseed
    - 2020: spring barley

Case study 12: Low input management practices

1. **Cereal monocrop, annual ploughing** (past 10 yr, otherwise 25-yr dataset available)
2. **Diversification 1** Barley in no-till management (past 10 years and during 2018, 2019 and 2020.
3. **Diversification 2** Barley-winter oilseed rape-barley rotation in no-till management ploughed once in 2018, then continued as no-till with cereals in 2019 and 2020

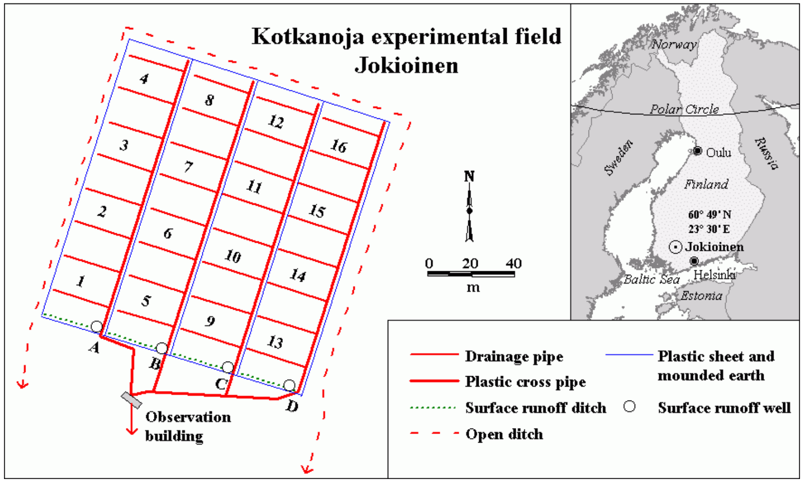
Case study 12: Experimental design

- **Factors of study**: 1. Crop rotation amendment with catch crop, 2. Crop rotation diversification 3. No-till.
- **Experimental design**: Split-plot.
- **Replications**: Four field replicated plots.
- **Plot size**: 0.11 ha (33 x 33 m)
- **Crop monitoring and sampling**: at harvest for every crop and plot.
- **Soil sampling**:
  - Time and frequency: in May 2018, then every September during three crop cycles
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: two to three composite samples per plot (nine samples per treatment) in WP5. For WP4, five out of the nine samples per treatment will be selected.
- **Greenhouse gas emission measures**: 25 measures per year in the plots where soil is sampled, one monitoring point in each plot.
- **Erosion measures**: Subsurface drainage collected continuously from each sub-plot (16). Surface runoff collected continuously from each field strip (4 sub-plots pooled).

DIVERFARMING

Case study 12: Experimental layout

Plough	No-till	Plough	No-till
4	8	12	16
3	7	11	15
2	6	10	14
1	5	9	13
o	o	o	o
A	B	C	D



A: Barley+catch crop, ploughed
B: Barley in long-term no-till
C: Barley-winter oilseed rape-barley, ploughed
D: Barley-winter oilseed rape-barley in no-till, ploughed once
O: surface runoff well

Case study 12: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

DIVERFARMING

Case study 12: Crop properties

1. **Crop growth**
   - Above-ground biomass.
2. **Pests and diseases incidence**
   - Damage proportion.
3. **Crop yield**
   - Crop yield at harvest
4. **Crop quality**
   - Thousand kernel weight, humidity and protein content.
5. **Nutritional evaluation**
   - None

Case study 12: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
    - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
    - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, acid phosphatase and arylsulfatase activities.
    - Potential nitrification.
    - qPCR of three nitrogen cycling-related transcripts.
3. **Earthworms**
    - Species identification, density and mass.
    - Density and mass by ecological groups.
    - Total density and mass.
    - Only measured at the beginning and the end of the experimental period.

Case study 12: Vegetal biodiversity properties

1. **Plant species**
    - Identification and richness.
2. **Vegetation**
    - Cover.
    - Similarity index.
3. **Carbon sequestration by woody crops**
    - None.

Case study 12: Soil physicochemical properties

1. **Soil fertility and pollutants**
    - Total N, ammonium, nitrate and available P, K, Ca and Mg.
    - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
    - Bulk density, soil water content at wilting point and field capacity, actual field moisture, texture, total organic carbon, carbonates, organic carbon functional fractions, aggregates stability, aggregates size distribution.
3. **Erosion rates**
    - Total runoff and erosion rates, continuous measurement. Measurement of nutrient and organic carbon losses.
4. **Greenhouse gas emissions**
    - Soil CO_2, N_2O and CH_4.
    - Overall emissions by Life Cycle Assessment.

CASE STUDY NUM. 12 COORDINATOR

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CASE STUDY NUM 13

Organic fodder crops in Finland




CASE STUDY NUM. 13	
Partners involved	Luke, PJ
Authors	Kristiina Regina, Eila Turtola, Riitta Lemola, Jaakko Heikkinen, Visa Nuutinen, Hannu Fritze, Tero Tuomivirta, Heikki Lehtonen, Tuomo Purola, Terhi Latvala, Janne Artell (Luke) Lasse Rainio, Taina Rainio, Jussi Heinonen (PJ)
E-mail of principal author	kristiina.regina@luke.fi

Case study 13: Organic fodder crops in Finland

- Polven Juustola
- Pedoclimatic region: BOREAL
- Country: FINLAND
- Location: KOUVOLA (SOUTHEAST FINLAND)
- Geographical coordinates: 60º 83’ N, 26º ’ 98’’ E
- Mean annual temperature: 4.4ºC
- Mean annual precipitation: 698 mm
- Annual potential evapotranspiration: 412 mm

Case study 13: Main characteristics

- Farm extension: 30 ha
- Diverfarming experimentation area: 2.6 ha
- Current crop: Feed for milk production
- Current cropping system: rain-fed conventional feed production
- Crop final use: feed for milk production
- Harvest time: June-August for ley, August-September for cereals
- Product: cheese
- Current value chain:
  - Milk producer
  - Farm-scale cheese producer
  - Quality and certification
  - Distribution
  - Supermarket
- Current management practices:
  - Intensive tillage
  - Mineral fertilizer
  - Pesticides
  - Herbicides

Case study 13: Main environmental problems

- Milk farms concentrating on certain areas -> reduced diversity in cropping in other areas
- Arable farms have more simple rotations and monocultures
- Decreasing soil organic matter content
- Erosion
- Nutrient leaching (N and P)
- Poor soil structure and low water conductivity

DIVERFARMING

Case study 13: Diversified cropping systems

A. **Simple rotations**: Barley-ley-ley-barley and barley-barley-rye-oats

B. **Diversification 1** Legume in feed rotation (Barley-clovergrass-ley-vetch+oat)

C. **Diversification 2** Legume in cereal rotation (Barley-clovergrass-rye-oats)

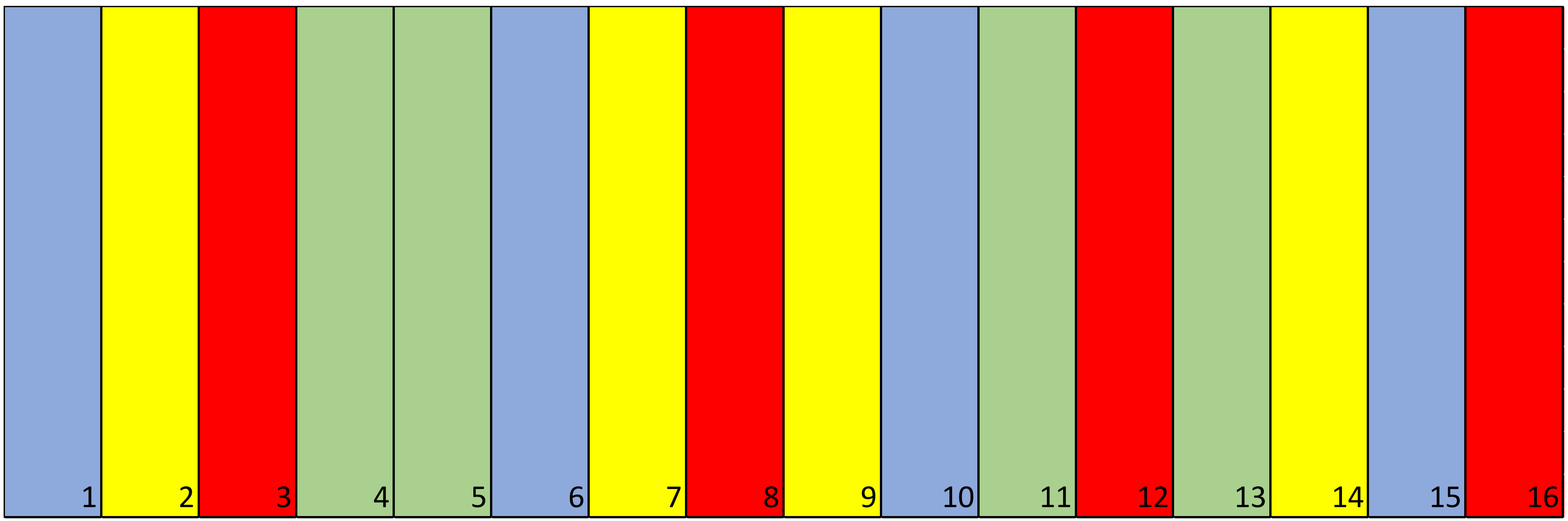
Case study 13: Low input management practices

1. **Conventional rotations**
2. **Diversification 1** Organic cereal rotation
3. **Diversification 2** Organic feed rotation

Case study 13: Experimental design

- **Factors of study**: 1. Conventional production, 2. Organic production, 3. Legume in rotation
- **Experimental design**: Randomized complete block.
- **Replications**: Four field replicated plots.
- **Plot size**: 0.16 ha (16 x 100 m)
- **Crop monitoring and sampling**: at harvest for every crop and plot.
- **Soil sampling**:
  - Time and frequency: once in 2018
  - Soil depth: arable layer (0-10 and 10-30 cm).
  - Number of samples: two to three composite samples per plot (nine samples per treatment) in WP5. For WP4, five out of the nine samples per treatment will be selected.
- **Greenhouse gas emission measures**: None, some results available from 2003-2004
- **Erosion measures**: Data available from 2001-2014

Case study 13: Experimental layout



OM	Organic milk: Barley-clover grass-ley-vetch+oat
OC	Organic cereal: Barley-ley-rye-oats
CC	Conventional cereal: barley-barley-rye-oats
CM	Conventional milk: barley-ley-ley-barley

Case study 13: Environmental variables

- Elevation.
- Mean annual temperature.
- Mean annual precipitation.
- Mean annual ETP.
- Solar radiation.
- Maximum daily temperature.
- Average daily temperature.
- Maximum daily temperature.
- Cumulative daily rainfall.
- Air humidity.
- Wind speed.

Case study 13: Crop properties

1. **Crop growth**
   - Above-ground biomass.
2. **Pests and diseases incidence**
   - Damage proportion
3. **Crop yield**
   - Crop yield at harvest
4. **Crop quality**
   - Thousand kernel weight, humidity and protein content.
5. **Nutritional evaluation**
   - None

Case study 13: Soil biological properties

1. **Microbial community structure and soil-borne diseases**
   - Soil DNA extraction, amplification and next generation sequencing.
2. **Enzyme activities and functional genes**
   - Dehydrogenase, β-glucosidase, leucine-aminopeptidase, acid phosphatase and arylsulfatase activities.
   - Potential nitrification.
   - qPCR of three nitrogen cycling-related transcripts.
3. **Earthworms**
   - Species identification, density and mass.
   - Density and mass by ecological groups.
   - Total density and mass.
   - Only measured at the beginning and the end of the experimental period.

Case study 13: Vegetal biodiversity properties

1. **Plant species**
   - Identification and richness.
2. **Vegetation**
   - Cover.
   - Similarity index.
3. **Carbon sequestration by woody crops**
   - None.

Case study 13: Soil physicochemical properties

1. **Soil fertility and pollutants**
   - Total N, ammonium, nitrate and available P, K, Ca and Mg.
   - pH, electrical conductivity, cation exchange capacity and sum of bases.
2. **Soil structure and carbon sequestration**
   - Bulk density, soil water content at wilting point and field capacity, actual field moisture, texture, total organic carbon, carbonates, organic carbon functional fractions, aggregate stability, aggregate size distribution.
3. **Erosion rates**
   - Total runoff and erosion rates, continuous measurement. Measurement of nutrient and organic carbon losses.
4. **Greenhouse gas emissions**
   - Soil CO_2, N_2O and CH_4.
   - Overall emissions by Life Cycle Assessment.

CASE STUDY NUM. 13 COORDINATOR

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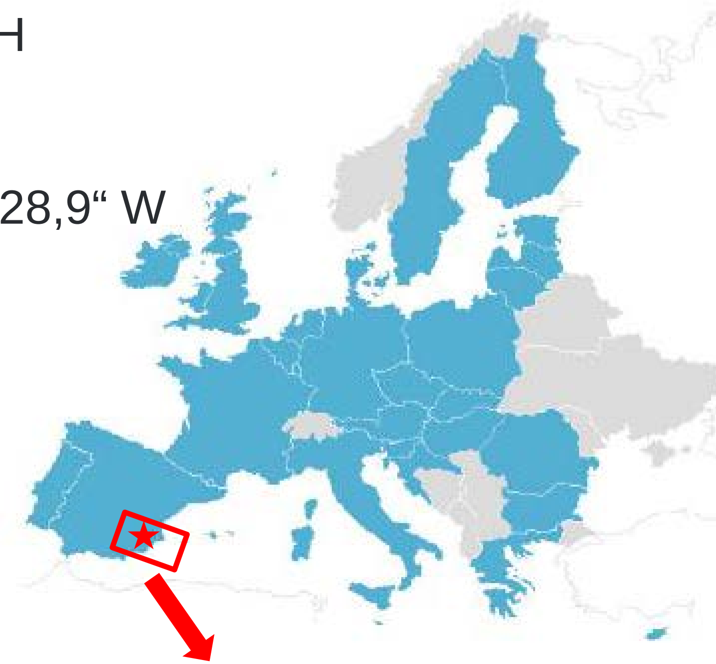
CASE STUDY NUM 14

Machinery prototype validation on woody perennial crops (vineyards) in Spain

CASE STUDY NUM. 14	
Partners involved	INDA, ASAJA, CCP, GA, NBT, WDF, AKA, NMT, PK, PJ
Authors	Francisco Jose López, Daniel Guandián (INDA) Alfonso Gálvez (ASAJA) Davide Rocca (CCP) Eduardo López (GA) Ben van Tilburg (NBT) Cord-Henrich Treseler (WDF) Attila Gere (AKA) Ferenc Tarjányi (NMT) Maija-Liisa Paavola (PK) Lasse Rainio (PJ)
E-mail of principal author	industriasdavid@industriasdavid.com

Case study 14: irrigated citrus

- Pedoclimatic región: MEDITERRANEAN SOUTH
- Country: SPAIN
- Location: YECLA (REGION OF MURCIA)
- Geographical coordinates: 38° 36‘ 17“ N, 1° 03‘’28,9“ W
- Mean annual temperature: 14.9 ºC
- Mean annual precipitation: 412 mm
- Annual potential evapotranspiration: 1270 mm



Case study 14: Main characteristics

- Farm extension: 15 ha
- Diverfarming experimentation area: 1 ha (1100 trees)
- Current crop: vineyard in trellis system (Monastrell variety)
- Crop final use: wine
- Current cropping system: Trellis system with 2.4 to 3.10 m between rows and conventional drip irrigation
- Harvest time: September-October
- Current management practices:
  - Tillage
  - Mineral fertilizer
  - Herbicides
- Current value chain:
  - Producer
  - Quality and certification
  - Winery

Case study 14: Main environmental problems

- Erosion
- Low soil quality
- Low soil organic matter content
- Low below and aboveground biodiversity
- Landscape simplification

Case study 14: Objectives

The objective of the machinery prototype is to reduce the following variables:

Labor time, fuel consumption, greenhouse gas emissions, soil disturbance and herb control

The prototype will be engineered to have a polyvalent modular configuration, capable of employing specific characteristics selectively.

It will also incorporate diverse data collecting systems, giving valuable information to the farmer while working.

Intended crops:

High-density olive trees

Vineyards

High-density orchards

Case study 14: Testing the prototype machine

Testing will be carried out in our own facilities and in the vineyard for at least 3 cycles of the crops.

The variables will be measured by having continuous feedback with farmers in the following manner:

A. **Labor time:** hours taken to work the fields by farmers
B. **Fuel consumption:** liters of diesel fuel used by farm tractors
C. **Greenhouse gas emissions:** a dependent variable of fuel consumption that will be quantified in metric tons of carbon dioxide equivalent (tCO_2e)
D. **Soil disturbance:** number of tractor passes and soil compaction (controlled with force-gauges in plow arms)
E. **Herb control:** growth and height will be controlled visually and quantified with a tape measure

Case study Num. 14 Coordinator

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