Portugal study site experiment 2: SUCCESSION SYSTEMS FOR IMPROVING SOIL HEALTH

The problem

In Portugal, grain corn comprises 56% of total cereal yield. It is grown in intensive monoculture cropping systems that result in soil organic matter losses and therefore the sustainability of production. The intensive use of mineral fertilizer to maintain high levels of production also lead to a high risk of nutrient leaching during the winter.

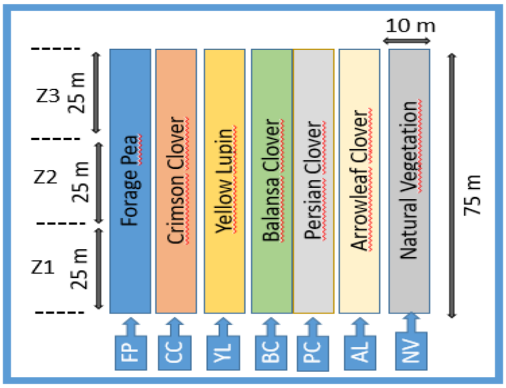
The proposed solution

A promising management practice to mitigate soil degradation is to grow a winter cover crop used as green manure for the principal crop. This may lead to the following benefits:
- mitigation of nutrient leaching: the biomass produced my result in uptake and immobilization of nutrients during the winter
- Improved nutrient recycling: by providing a source of nutrients to the principal leading to a reduction of the use of mineral fertilizer.
- Improved weed control: legumes will compete with weeds, thus resulting in less need for pesticides.
- Increased soil organic matter content

The capacity of six species of legume cover crops (LCC) was examined to determine whether they provide agro-ecological services in grain corn systems, and their suitability for use in the Mediterranean region. The study was performed at the “Loreto” Baixo Mondego Experimental Center, an agricultural station managed by the Regional Directorate of Agriculture and Fisheries of the Central Region of Portugal. It covered two autumn to spring periods of cover crop cultivation, and assessed changes in soil fertility (organic matter, total nitrogen, available phosphorus, available potassium), dry biomass yield of legumes and weeds, and their associated nutrient content (total nitrogen-phosphorus-potassium).

Experimental design

Treatment : 3 replications for each plot (Z1, Z2, Z3)	SICs?	Samples per campaign (0-30cm)
Maize in succession with Forage Pea	Y	12
Maize in succession with Crimson clover	Y	12
Maize in succession with Yellow Lupin	Y	12
Maize in succession with Balansa clover	Y	12
Maize in succession with Persian clover	Y	12
Maize in succession with Arrowleaf clover	Y	12
Maize in succession with Fallow	Control	12



Factors measured within the study site:
Physical factors: Erodibility, existing limitation rooting, bulk density, penetration resistance
Chemical factors: Available P and K, Exchangeable K, Ca, Na, Mg, total N, soil organic carbon, pH
Biological factors: pest burdens, root diseases, weed disease, cover crop assessment, crop yield
Socio-economic factors: Socio-cultural dimension, costs and benefits.

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Results

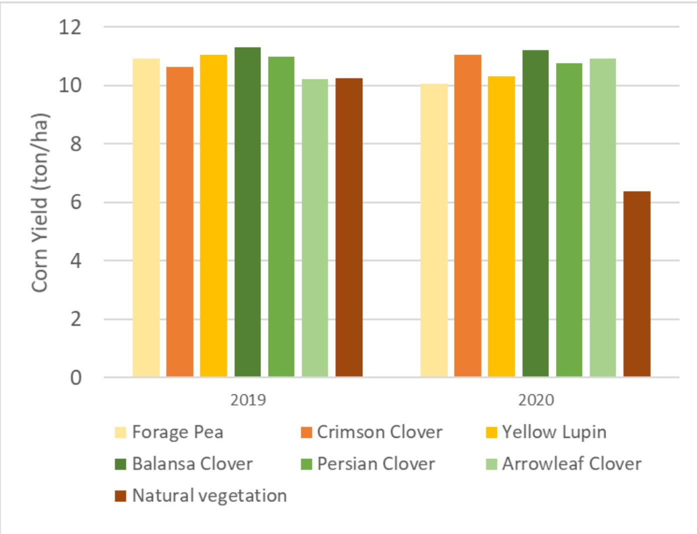

Figure 1. Corn yield
By 2020, crop yield was higher under treatment plots with legume winter cover crops than under control plot in fallow with natural vegetation.

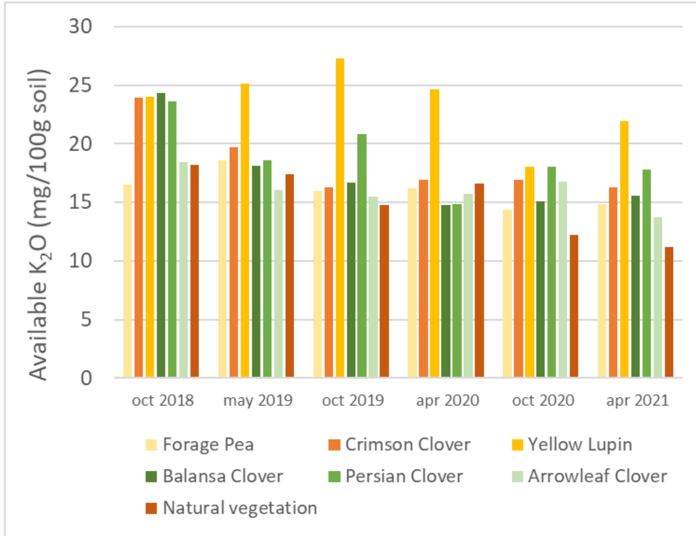

Figure 2. Available potassium (K_2O)
Available potassium evolution was not significantly different between treatments and control.

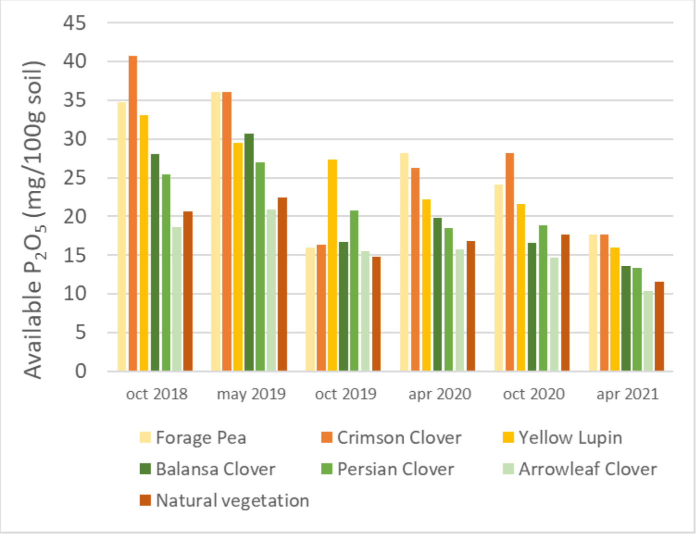

Figure 3. Available phosphorus P_2O_5
Available phosphorus was not significantly different between treatments and control.

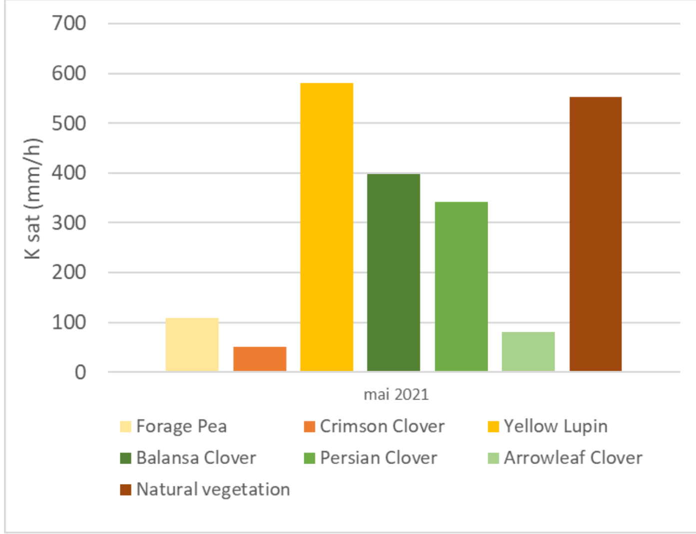

Figure 4. Ksat.
Yellow Lupin field and control present the highest K-sat, nevertheless it can not be attributed to the treatment effect but rather to soil heterogeneity.

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Results

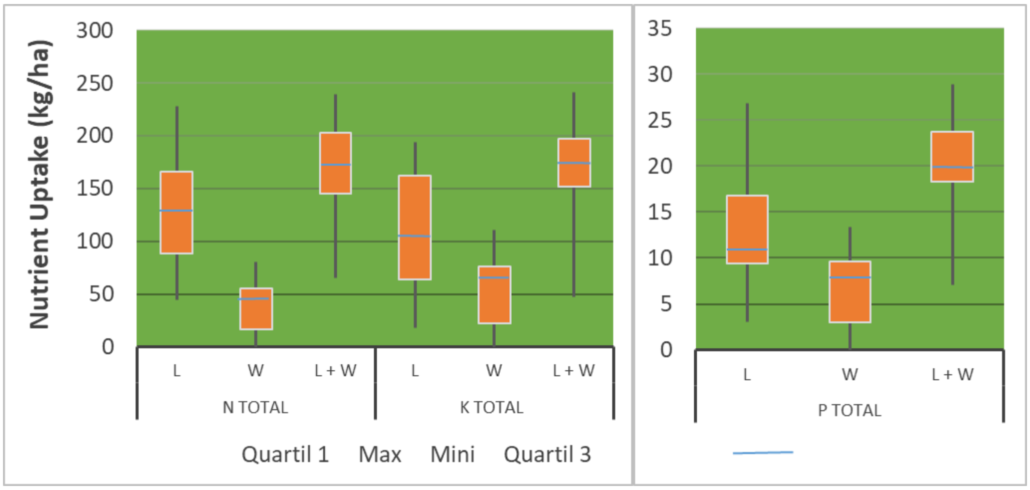

Figure 5. Median uptake of nitrogen (N), phosphorus (P), and potassium (K) for the six legume cover crops (L: legumes; W: weeds; L+W: legumes and weeds) during the 2 study years. The median N-P-K nutrient uptake (legume + weeds) is 176-20-172 kg/ha.

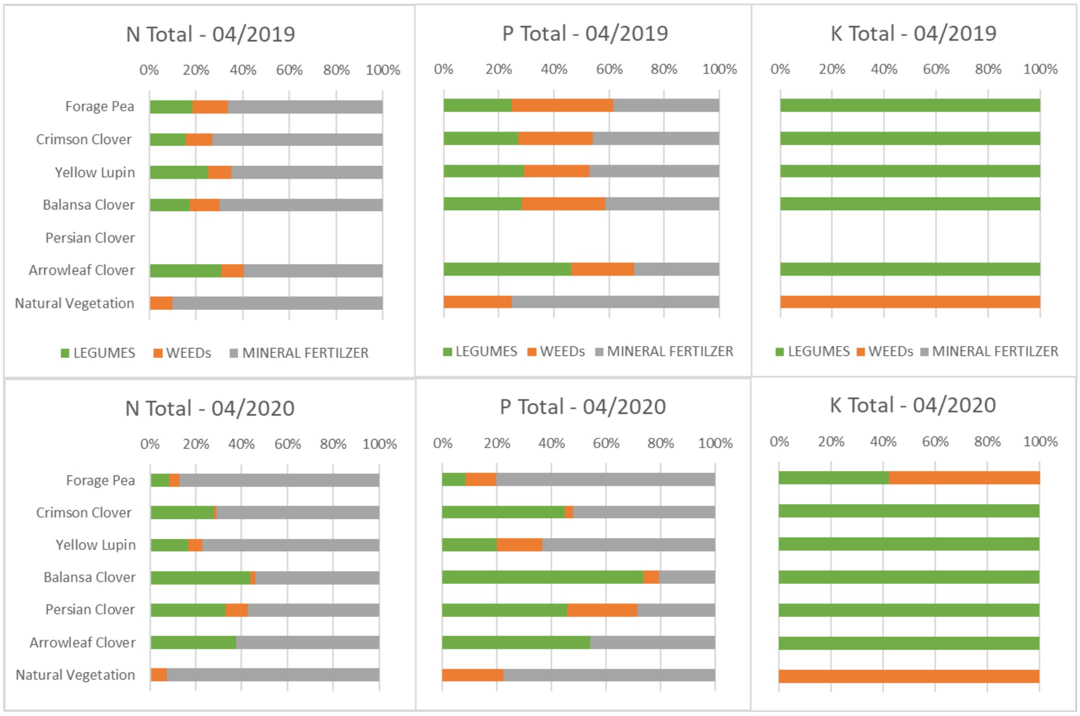

Figure 6. Percentage of macronutrients (NPK) provided to the main crop (grain corn) by the legume cover crops (legumes and weeds) used as green manure and complementary mineral fertilizer needs. Legume cover crops used as green manure enabled a reduction of about 35% of N, 50% of P, and 100% of K supplied generally by mineral fertilizers for a grain corn production of 12t/ha.

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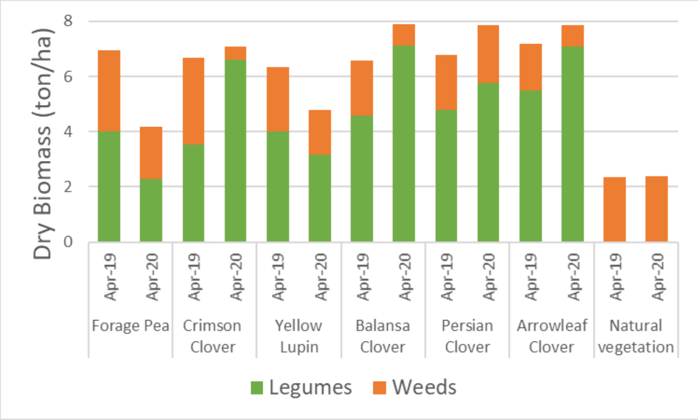

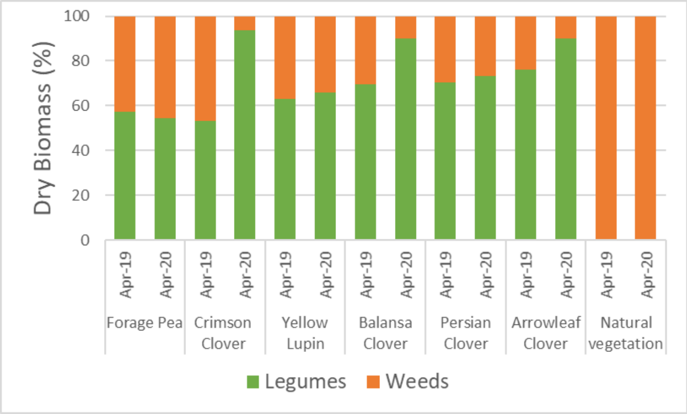

Figure 7a. Dry biomass production of weeds and legumes by weight in ton/ha.

Figure 7b. Dry biomass production of weeds and legumes in percentage in relation to overall biomass within the plot.

Legume cover crops are able to control weeds only in the second year of the study. Crimson, balansa, arrowleaf performed best in terms of weed control.

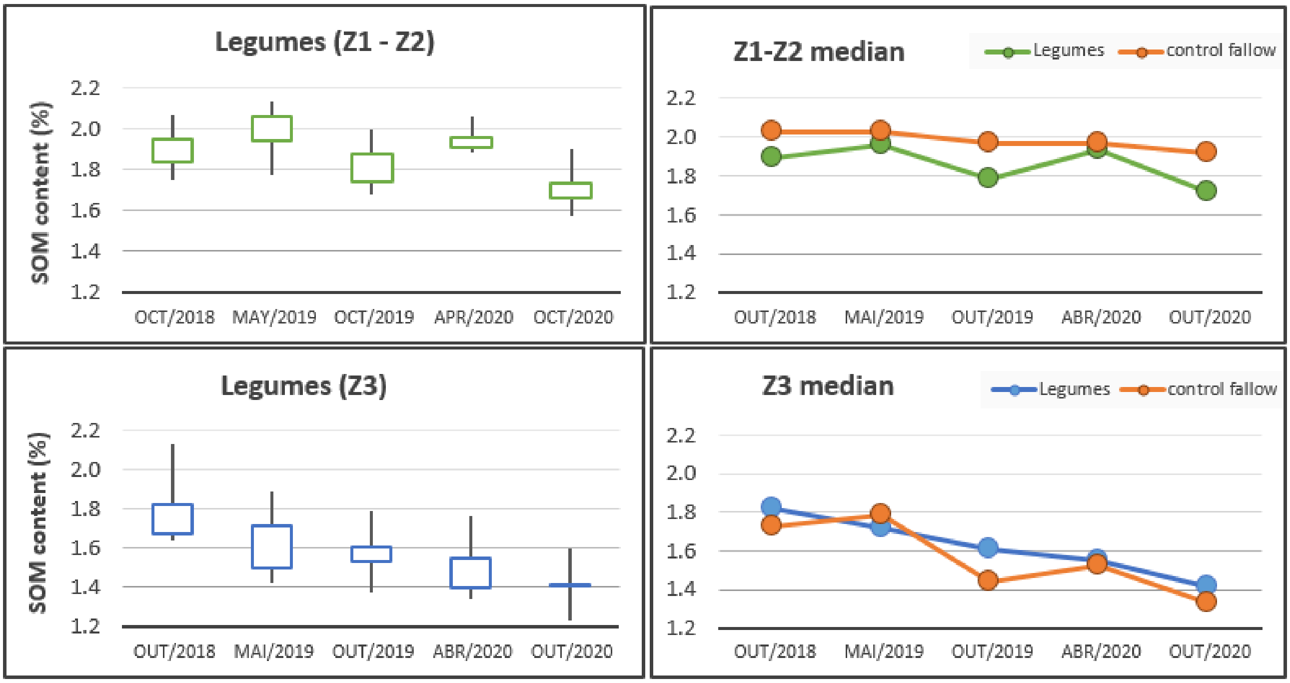

Figure 8. Overall Soil Organic Matter content evolution of legumes cover crops plots for the more fertile subplots Z1/Z2 and the less fertile subplots Z3. A slight depletion of the soil organic matter content is observed generally more severe for the less fertile soils.

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Key findings

- In general, all six LCC showed good adaptation to Mediterranean conditions, yielding large amounts of dry biomass (up to 8 ton/ha for some clovers species).
- The overall median N-P-K nutrient uptake over the 2 study years considering all the species was 176-20-172 kg/ha with clover species presenting generally the best performances.
- The capacity of the LCC to provide green manure services enabled a general reduction of about 35% of N, 50% of P, and 100% of K supplied generally by mineral fertilizers for a grain corn production of 12t/ha.
- LCC effectively controlled weeds, although only in the second year of the study. Three clover species (crimson, balansa, arrowleaf) performed best in terms of weed control due to early establishment and/or high biomass production in later growth stages, and thus continuous competition with weed species.
- LCC incorporation into the soil leaded through the two years experiment to a slight depletion of the soil organic matter content generally more severe for the less fertile soils. However, large fluctuations in soil organic matter content in LCC plots between soil sampling occasions were observed for the LCC plots, but not for the fallow control plot, reflecting important modifications in soil nutrient cycles due to incorporation of large LCC biomass with high decomposition potential.
- No differences were found between treatments and in term of pH, Nitrogen, available phosphorus and potassium or exchange base (K^+, Mg^{2+}, Na^+, ca^{2+}), soil compatibility, infiltration capacity, or biodiversity (earthworm).

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Conclusions

The introduction of Winter leguminous cover crops used as green manure provided interesting agro-ecological services. The six LCC species produced high amounts of biomass, far above the quantities registered for most studies conducted in cooler climates. Nevertheless the variability of the results inter and intra species was very high due to the influence of many parameters.

Legumes and weeds allowed an important uptake of nutrients from the soil, contributing to mitigate the leaching of nutrients during Spring. This was not, however, the case during Winter, the most critical period in term of nutrient leaching. Further research is needed to explore how sowing dates may affect this.

In terms of green manure services, this study highlights that for an expected grain corn yield of 12t/ha, that it is possible to reduce the amount of NPK mineral fertilizer of respectively (35%, 50% and 100%) corresponding to saving 85, 25 and 180 kg/ha of N, P2O5, K2O on account of the nutrient recycling provided by green manure incorporation. It is important to provide farmers with simple tools, allowing them to estimate accurately the amount of nutrients legumes are able to provide for diverse conditions and the corresponding amount of mineral fertilizer that they could save.

In term of weed control, LCC efficiency is highly variable. Three clover species (crimson, balansa, and arrowleaf clover) performed best due to early establishment and/or high biomass production in later growth stages, ensuring strong competition with weed species. In a general way, weed control capacity is strongly related to legume biomass production. The success in weed control also depends of the early stage establishment of cover crops and soil surface cover than can compensate positively the lower biomass from some species.

In term of soil organic content improvement capacity, the LCC failed. This may be due to the fast decomposition characteristics of the legumes due to their low C/N, combined with optimal weather conditions (warm and humid through the irrigation system) which led to an extremely fast mineralization of the biomass and a decline in organic matter content during the warm period. The intensification of the soil mobilizations due to the LCC cultivation could also have increased the oxygenation of the soil leading to the acceleration of the organic matter decomposition. Finally, the massive addition of biomass to the soil may have led to microbial community growth, providing enough energy to mineralize more stable organic matter and leading to a global decrease of the soil organic matter content.

Fact sheet authors

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