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

The problem

In Portugal, grain corn is grown in intensive monoculture cropping systems that may have negative effects on soil quality, affecting long-term fertility (specially in term of soil organic matter content) and productivity and therefore the sustainability of production. The intensive use of mineral fertilizer to maintain high level of production also lead to a high risk of nutrient leaching during the winter.

The proposed solution

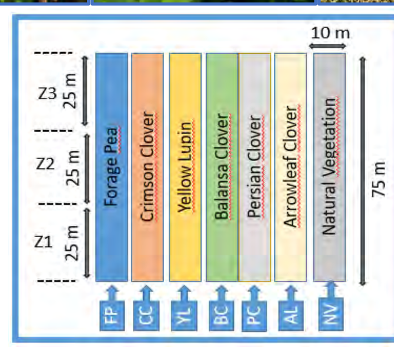
Winter cover crops used as green manure were hypothesized to tackle the soil threats outlined above through:

- Reducing nutrient leaching by producing a high amount of biomass which uptakes nutrients and prevents their immobilization during the winter
- Improving nutrient recycling by providing a source of nutrients, leading to a reduction of the use of mineral fertilizer.
- Providing weed control
- Increasing soil organic matter content

The capacity of six legume cover crops (LCC) for providing agro-ecological services in grain corn systems and their suitability for use in the Mediterranean region was examined. The study was performed at the "Loreto" Baixo Mondego Experimental Center, managed by the Regional Directorate of Agriculture and Fisheries in central Portugal. This experiment 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
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

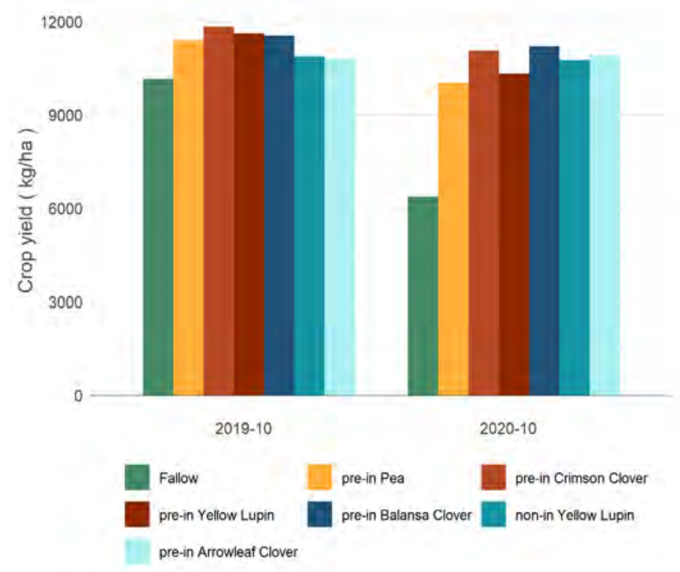

Figure 1. Crop yield versus treatment. By 2020, crop yield was higher in treatment plots than in the control plot (fallow).

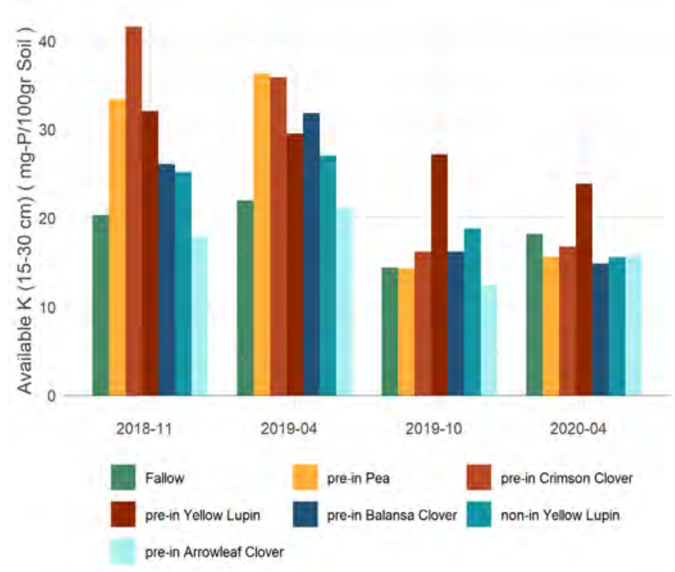

Figure 2. Available potassium (K) versus treatment. Availability evolution was not significantly different between treatment.

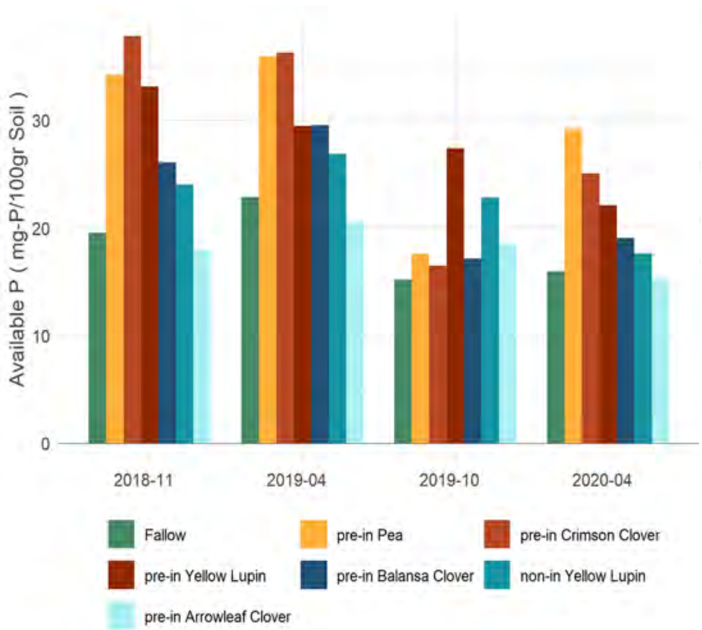

Figure 3. Available P versus treatment. Availability evolution was not significantly different between treatments.

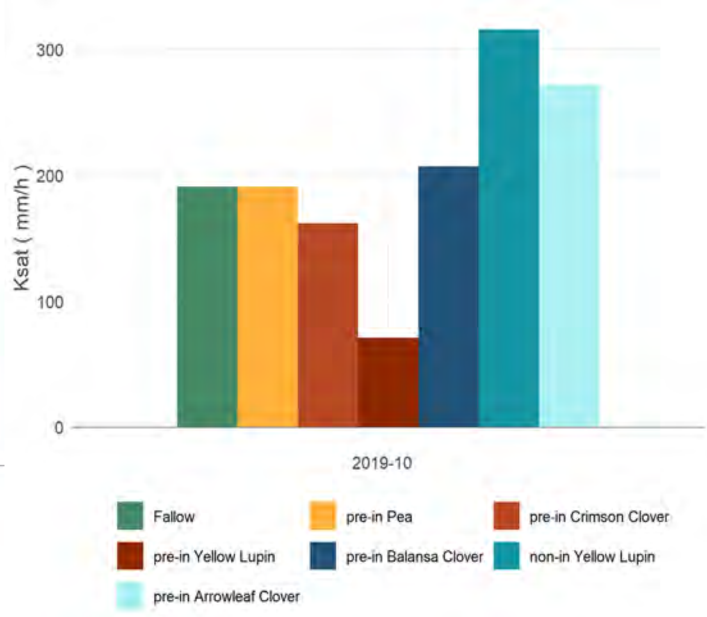

Figure 4. Ksat versus treatment. Yellow Lupin resulted in the highest K-sat, nevertheless can not be attributed to the treatment effect but to soil heterogeneity.

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Results

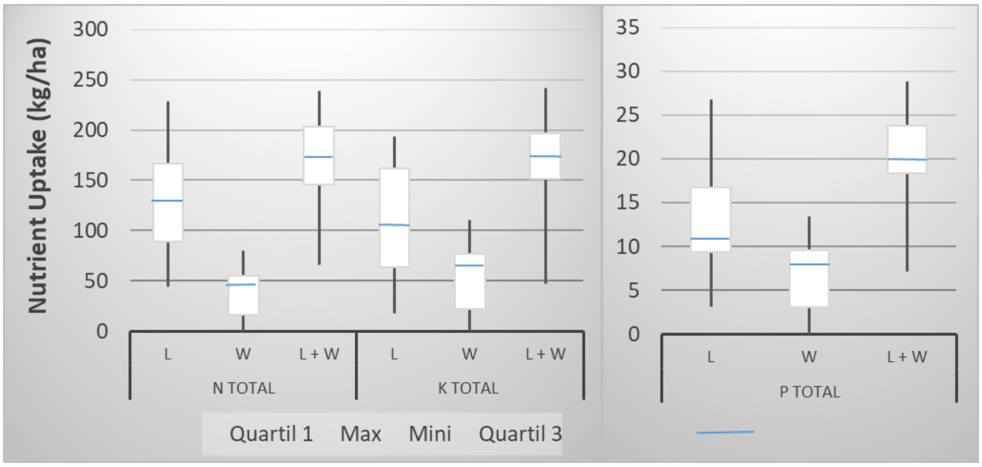

Figure 5. Median uptake of nitrogen (N), phosphorus (P), and potassium (K) for the six legume cover crops (L: legumes; W: weeds; L+W: legumes and weeds) during the 2 study years. The median N-P-K nutrient uptake (legume + weeds) is 176-20-172 kg/ha.

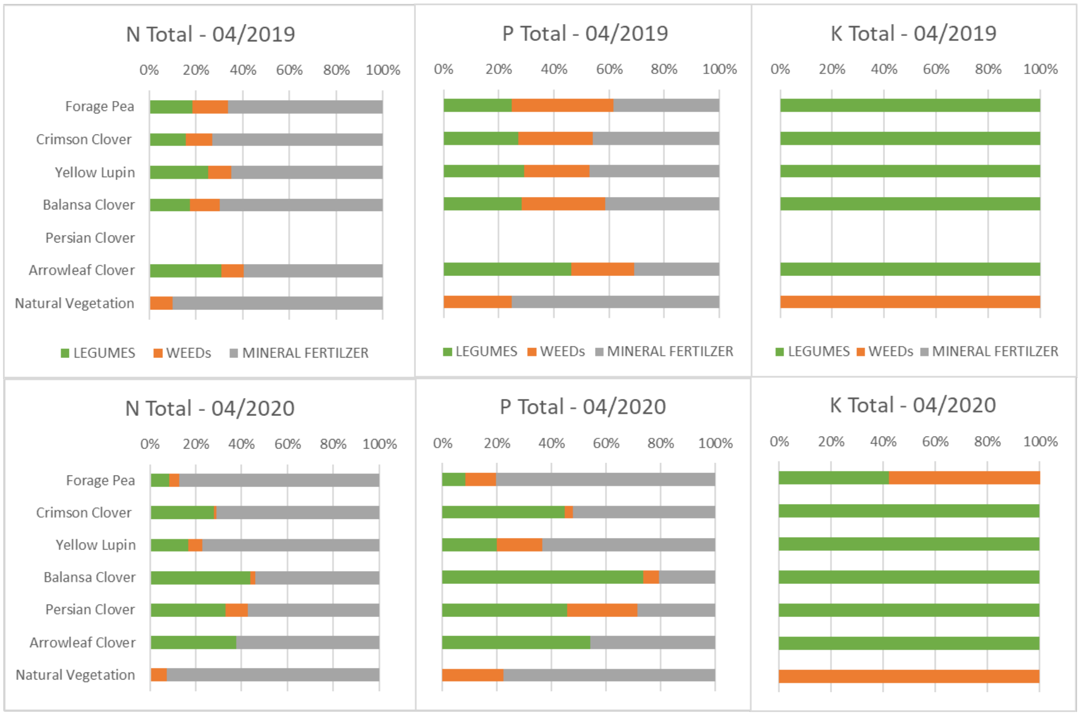

Figure 6. Percentage of macronutrients (NPK) provided to the main crop (grain corn) by the legume cover crops (legumes and weeds) used as green manure and complementary mineral fertilizer needs. Legume cover crops used as green manure enabled a reduction of about 35% of N, 50% of P, and 100% of K supplied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

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Results

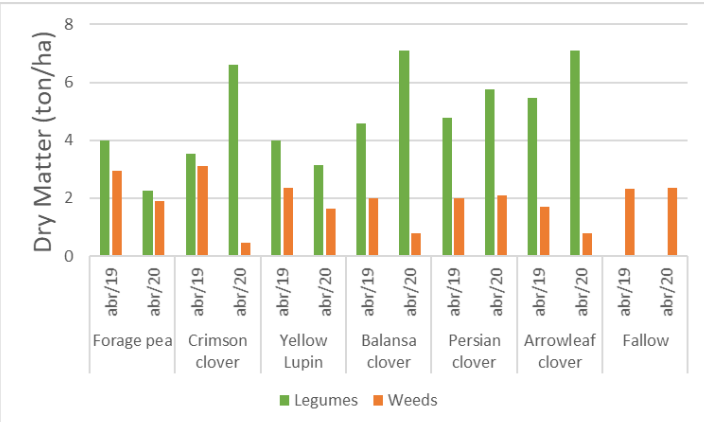

Figure 7a. Dry biomass production of weeds and legumes by weight in ton/ha.

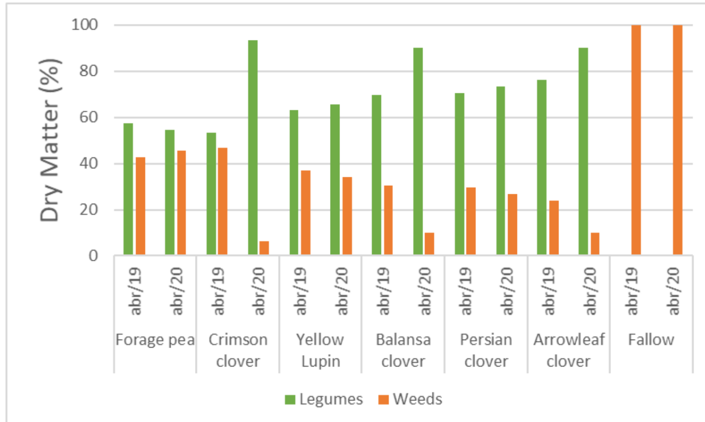

Figure 7b. Dry biomass production of weeds and legumes in percentage in relation to overall biomass within the plot.

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.

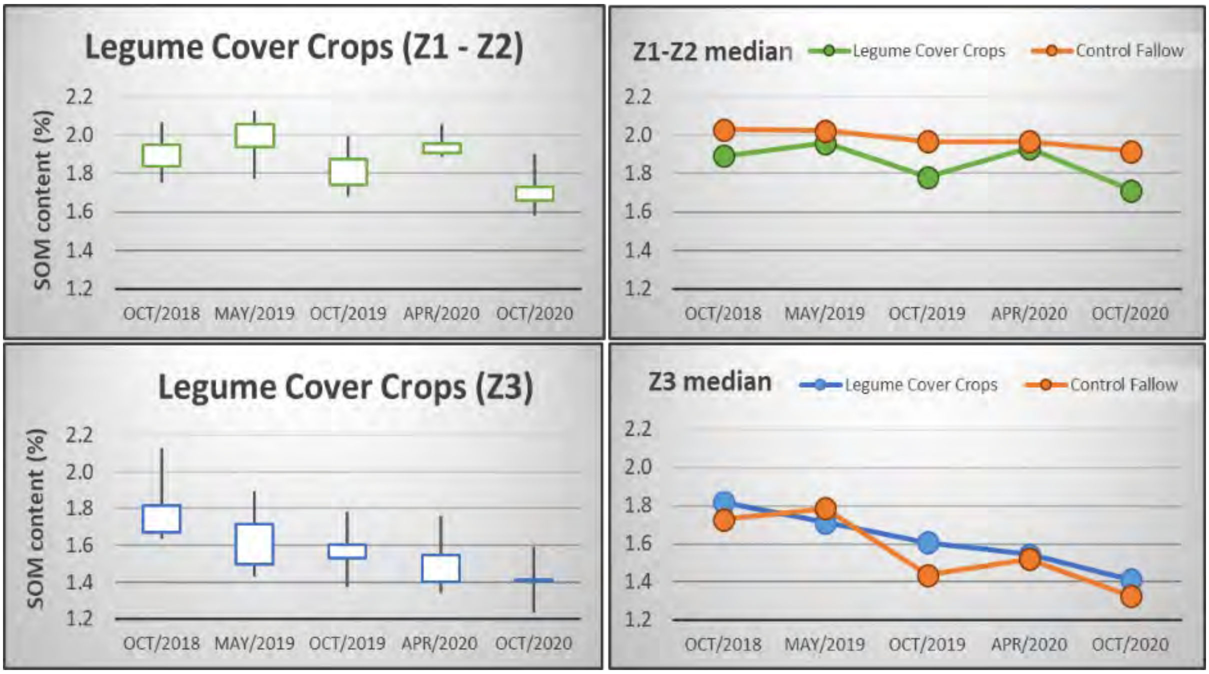

Figure 8. Overall Soil Organic Matter content evolution of LCC plots for the more fertile subplots Z1/Z2 and the less fertile subplots Z3. A slight depletion of the soil organic matter content was more severe for the less fertile soils.

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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 was 176-20-172 kg/ha across all species, with clover species performing best.
- 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.
- LCC incorporation into the soil led to a slight depletion in soil organic matter content. This was generally more severe in 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+, Mg2+,Na+,ca2+), soil compatibility, infiltration capacity, or biodiversity (earthworm).

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Conclusions

The introduction of winter legume cover crop used as green manure in the rotation provided interesting agro-ecological services despite not resulting in significant improvements in soil quality during this 2-year study.

The six LCC species produced high amounts of biomass as they survived to the winter and presented an important growing phase in spring before to be cut. Nevertheless, the variability of the results inter and intra species was very high due to the influence of many parameters.

In terms of nutrient leaching mitigation, legumes and weeds increased the uptake of nutrients from the soil, contributing to mitigate the leaching of nutrients. This mostly occurred during Spring rather than in Winter, the most critical period in term of nutrient leaching. As a result, we recommend carefully considering when cover crops should be sown.

Under an expected grain corn yield of 12t/ha, it was expected that incorporating green manures would reduce the amount of NPK mineral fertilizer required would be 35%, 50% and 100% corresponding to saving 85, 25 and 180 kg/ha of N, P2O5, K2O.

In term of weed control, LCC efficiency was 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. Weed control capacity was 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.

In term of soil organic content improvement capacity, the LCC failed during the 2 first years. This may, in part, be due to the fast decomposition characteristics of legumes combined with optimal weather conditions (warm and humid through the irrigation system). These factors led to an extremely fast mineralization of the biomass in the soil and then 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 could have led to microbial community growth, providing enough energy to mineralize more stable organic matter and leading to a decrease in soil organic matter content. In the future, it is important to plan trial fields with management practices able to mitigate this negative effect on soil organic matter content, like the use of mix seeds (legumes, crucifers, gramineous) in order to increase the C/N and slow the MO decomposition; direct sowing of the LCC seeds and also the no burring of the LCC biomass in the soil in order to limit the tillage operations and avoid the massive input of biomass in the soil.

Fact sheet authors

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