Species mixtures for redesigning European cropping systems

## About ReMIX

The goal of the ReMIX project, funded by the EU's Horizon 2020 Programme, is to exploit the benefits of intercropping to design more diverse and resilient arable cropping systems. Together with farmers, ReMIX has designed productive, diversified, resilient and environmentally friendly cropping systems that are less dependent on external inputs. Intercropping delivers high quality food and sustainable returns to the farmer.

**POLICY BRIEF** / APRIL 2021

# Improved support for intercropping will reduce fertiliser inputs and nutrient losses

European agriculture needs to reduce fertiliser inputs to avoid environmentally harmful nutrient losses, as highlighted both in research on planetary boundaries and in the new Biodiversity and Farm to Fork strategies of the European Union. Intercropping, also known as species mixtures, is the practice of growing two or more crops in the same field and harvesting them together. Intercropping contributes to reaching this goal.

- In intercrops, beneficial plant-plant interactions contribute to ecological intensification of the production, with increased reliance on ecosystem services and more efficient resource use, thereby reducing the need for fertiliser inputs and lowering nutrient losses compared to sole crops.
- Intercropping of grain legumes and cereals is of particular interest in terms of nitrogen (N) use, since it combines legumes' inputs of symbiotically fixed N with cereals' high capacity for soil mineral N acquisition.
- Increased communication about the benefits of intercropping and implementing policies that support this practice will help to reach the EU's goals of 20% reduction in fertiliser inputs and 50% reduction of nutrient losses.

# Policy challenges

In intercrops with grain legumes and cereals, competitive and complementary interactions enhance legume reliance on symbiotic $N_2$ fixation and lead to more efficient use of soil mineral N than in grain legume sole crops. The photo shows an intercrop of lentils and oats with intimate mixture of plants, in a field experiment in Sweden.

Photos by Georg Carlsson

## 1 Current practices are shaped by goals to maximise productivity

The vast majority of European agriculture is based on sole crops (single species grown without any companion crop) which depend on inputs of fertilisers and pesticides or mechanical weed control measures to ensure high yields. This is the result of a tradition that dates back to the launch of the Common Agricultural Policy in 1962, when goals were set to increase agriculture's productivity and secure the supply of affordable food. Policies and investments in the agri-food sector have continuously manifested the goal to increase yields of commodity crops, which has made it difficult to shift towards crop diversification and reduction of inputs.

## 2 High dependency on nitrogen (N) and phosphorus (P) fertilisers

Many of the commodity crops that dominate European agriculture, *e.g.* cereals, maize, oilseeds, sugar beets, require large inputs of N fertilisers to achieve the high yields. These inputs cause several environmental problems: the energy-consuming production of N fertilisers and losses of the greenhouse gas nitrous oxide from fertilised fields contribute directly to climate change, and N leaching to ground waters and P losses via surface water run-off cause eutrophication.

## 3 Intercropping is a relatively un-adopted practice in Europe.

There is limited understanding about the capacity of intercropping to reduce nutrient inputs and losses in conventional arable cropping systems. Consequently, intercropping requires more attention from policy and advisory services in order to facilitate its adoption in Europe.

## 4 Lack of specific support for intercropping

While there is growing awareness about the benefits of crop diversification in general, and policies in place to support the diversity of crop rotations and the integration of cover crops, specific support for intercropping is mostly absent in national agricultural policies in Europe. There are even examples when intercropping is directly or indirectly discouraged, *e.g.* by premiums for protein crops but only when grown as sole crops.

# Solutions offered by intercropping

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1

## Complementarity between species

Intercropping of different species (*e.g.* cereals or grasses, legumes, oilseeds) by combining different plant traits such as growth rate in different parts of the season, rooting patterns, canopy structure, and symbiotic interactions with soil microorganisms (notably $N_2$-fixing bacteria and mycorrhizal fungi) provides good performances to produce grains and forages. A successful combination of complementary plant traits often increases the efficiency of use of plant growth resources such as light, water and nutrients.

2

## Efficient use of N and land in grain legume-cereal intercrops

Intercropping of grain legumes and cereals has been widely studied, and there is abundant research-based evidence of improved resource use efficiency in low input systems. In this system, the legume is nearly self-sustaining via symbiotic $N_2$ fixation. Also, relatively more soil N is available to the intercropped cereal than when grown as a sole crop fertilised at the same level, leading to higher cereal protein contents. This complementarity in N acquisition leads to more efficient use of soil mineral N than in grain legume sole crops. As a consequence, around one fourth of the global N fertiliser inputs could be saved if all grain legume crops worldwide would be grown as intercrops with cereals instead of as sole crops (Jensen et al. 2020). Such a large saving of the N fertiliser requirement is in line with (even exceeding) the EU's goal to reduce fertiliser inputs by 20%, and underlines that intercropping is a key for reaching the ambitious goals of a more environment-friendly agriculture.

Even though the precise effects of intercropping on N losses vary between crops, geographic context and the management of the sole crop to which the comparison is made, there is a clear potential that nitrous oxide emissions and nitrate leaching can be reduced in grain legume-cereal intercrops. A life cycle assessment indicated that intercropping can lead to impact reductions ranging from 35 to 50% for climate change and 25 to 35% for eutrophication (Naudin et al. 2014). Furthermore, with low and moderate levels of N fertilisation, the total yield of intercrops often exceeds the sum of each crop grown as a sole crop on the same area, with corresponding increases in land use efficiency of around 30 to 40%.

3

## Improved P acquisition

Intercropping delivers advantages not only for the use of N. Intercrops can also use P in the soil more efficiently than sole crops. It has been shown that intercrops can achieve the same yields as sole crops with around 20% less P fertiliser (Tang et al. 2020). This occurs because some crop species *e.g.* legumes, can mobilise P in the soil from organic form, especially in soils with limited P availability, and make it available to a companion species. Increased uptake of soil mineral P in an intercrop compared with a sole crop can also happen when the two intercrop species have different rooting patterns and rooting depths thus making more effective use of the available soil volume.

4

## Yes, it can be done!

Intercrops of grain legumes and cereals can be successfully managed with standard farm machinery in particular for sowing and application of inputs, provided that species and varieties with equal maturity times are chosen, and thus can be harvested with classical combine harvesters. However, settings of combine harvesters and sorting/cleaning facilities need to be adapted for intercrops, which calls for support that facilitate the post-harvest handling and selling of intercrops – as described in another ReMIX policy brief (Bedoussac et al. 2021).

There are good opportunities to design and implement policies that support intercropping, *e.g.* through direct subsidies or by including intercropping in a list of practices that qualify for specific subsidy schemes within the Biodiversity or Farm to Fork strategies. This will contribute to climate change mitigation by decreasing the use of N fertilisers and consequently reduce gaseous N losses from soil (nitrous oxide, ammonia). Intercropping can also be indirectly supported by policies that strengthen the communication and information about the benefits of crop diversification for improved nutrient use efficiency, *e.g.* through campaigns targeting farmers and farm advisors.

# Policy recommendations

Intercropping of grain legumes and cereals improves the use of N and P natural resources, and can thereby reduce both the need for fertiliser inputs and the risk of N and P losses in agriculture.

To realize the benefits of intercropping for reduced fertiliser inputs and losses, policies are needed to:

**1**

Support research on the soil-plant intimal functioning and its modelling in order to better understand the ecosystem services provision and optimize the management of intercrops.

**2**

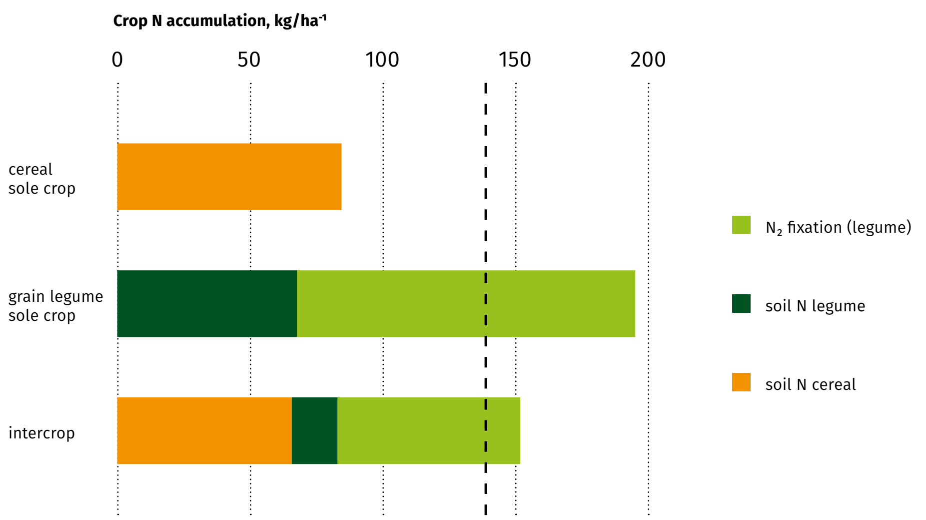
Improve the information about intercropping and associated benefits to farmers, advisors, and central actors in the food system (*e.g.* wholesale, food industry, retail). Information campaigns, *e.g.* brochures, websites, videos, should explain and illustrate intercropping in ways that are easy to understand, and clearly describe how it reduces fertiliser inputs and nutrient losses.

**3**

Directly support intercropping through targeted subsidies, via direct support for the cultivation of intercrops or by incentives for reducing fertiliser inputs.

**4**

Indirectly promote intercropping through policies for crop diversification, and in particular to increase the cultivation of grain legumes by intercropping, which will contribute to the protein autonomy of Europe. For example, intercropping can be included in a list of crop diversification practices (along with *e.g.* cover crops and diverse crop rotations), of which at least one must be used in order to comply with a certain subsidy.




Nitrogen acquisition and its accumulation in aboveground biomass of cereal and grain legume sole crops and intercrops, represented by different N sources. Soil mineral N is the sum of N derived from mineralization of soil organic matter and fertiliser inputs.

Intercrops reach higher total N acquisition than cereal sole crops, also exceeding the average of the two types of sole crops (dashed line), and the same level of soil mineral N acquisition as cereal sole crop. This means a better overall N use efficiency by intercrops than both sole crops.

The illustration is modified from Jensen et al. (2020b), based on results presented in Jensen et al. (2020a).

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