POLICY BRIEF

Variability of wheat responses to nitrogen and water across Europe

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This policy brief provides an overview of wheat crop response to nitrogen fertiliser across Europe, gives insights into how this response is impacted by climate change and offers recommendations on how to address the impacts of climate change on the response to nitrogen fertiliser.

- Nitrogen management in wheat differs from north to south in Europe since wheat response to nitrogen is highly dependent on water availability.
- A regionally-adapted nitrogen fertiliser strategy has the potential to increase yields and quality of wheat while minimising nitrogen pollution to air and water.
- Seasonal weather forecasting can allow farmers to take advantage of seasons with greater rainfall.

Introduction: Adapting wheat management to address water and nutrient limitations

In the face of climate change, the management of wheat, Europe's most widely grown crop, needs to adapt to changing environmental conditions. In the next 20-30 years, wheat will be exposed to more frequent water and temperature stresses. While this has regional components, by researching combined challenges relating to water and nutrients we can discover how cropping systems respond to different levels of fertiliser inputs under stress. With an increasingly variable climate, long-term weather forecasts will become more and more important in guiding farmers and advisors in selecting a suitable strategy for crop management.

In this policy brief, we focus on the evidence showing how wheat yield is impacted by nitrogen and water across Europe using existing data to provide insights into potential future management systems.

Background: Understanding current climate trend effects on wheat

In the past three decades (1981-2018), the wheat growing season in Northern Europe was characterised by a drier and warmer pattern as opposed to Southern Europe, which was characterised by increased variability with a long-term trend toward wetter and warmer weather. These climate trends are likely to continue and intensify (Cammarano et al., 2019).

Understanding the nitrogen response of wheat yield

There are opportunities to address the challenges posed by climatic variability by understanding how nitrogen fertilisation affects wheat yield, particularly under different rainfall conditions. Understanding the response can help optimise future applications of nitrogen, based on regional climatic zones.

Better use of nitrogen fertiliser can reduce pollution and promote sustainability

Nitrogen fertilisers are one of the biggest costs to farmers and over-application leads to increased air and water pollution. The latter contributes to ammonia and greenhouse gas emissions in the form of nitrous oxides, as well as to the eutrophication of water bodies in the form of nitrate. Better use of nitrogen fertiliser in wheat across Europe has the potential to profoundly advance the sustainability of both rural communities and the environment (Sutton et al., 2011). Initiatives like the EU Nitrates Directive (EEC, 1991) limit the amount and timing of nitrogen fertiliser in Nitrate Vulnerable Zones (NVZs). While these regulations are certainly valuable, the 'vulnerability' of land areas will change in response to changes in climatic variability. Therefore there should be a more nuanced approach to fertilisation in these zones which takes account of predicted variability in seasonal rainfall and therefore optimises the benefit to both agriculture and the environment.

Research Methods

The results of the study described here (Cammarano et al., 2019) are based on initial data collection using existing information from a literature review and past EU-funded and national projects conducted by SolACE project partners. A total of 80 manuscripts, covering the main EU climatic zones (Figure 1), were selected. Grain yield and nitrogen application were the main targets, with information on the following indicators extracted from the material collected:

- Soil texture and organic carbon
- Sowing dates and density
- Key growth stages: anthesis (flowering) and grain maturity
- Growing season rainfall
- Crop management: nitrogen fertiliser rates/timing and irrigation rates/timing

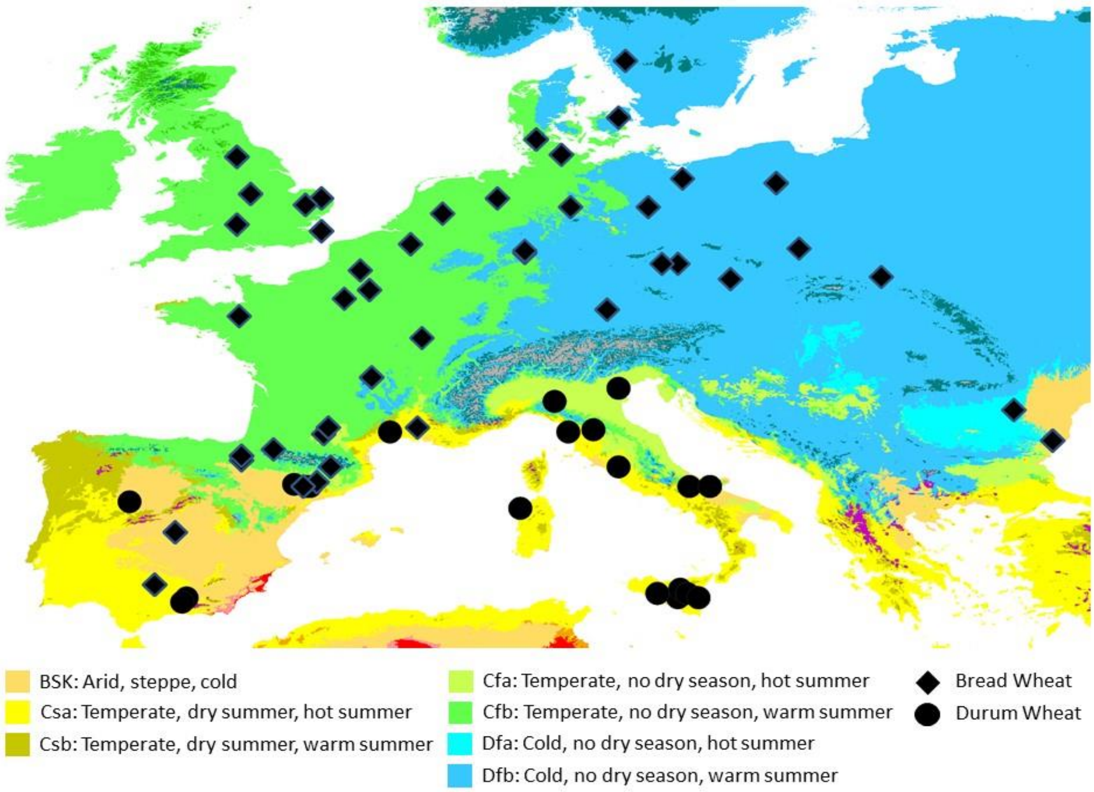

Figure 1: Climatic zones of Europe and positions of data points used in the analysis referred to in this briefing. The legend of the climatic zones refer to the areas containing data points (diamonds refer to bread wheat and circles to durum wheat). The Köppen-Geiger climate map was obtained from Beck et al. (2018).

The resulting data set has many uses and applications, but for the purposes of this policy brief, the focus is on yield response to nitrogen inputs for two wheat species, bread wheat and durum wheat, as they reflect different European regional climatic considerations.

Yield variation for bread and durum wheat

Generally, in Europe, durum wheat is grown in the Mediterranean area while bread wheat is grown in a wider range of climatic areas (Figure 1).

The data shows that wheat yield increases with increasing nitrogen input (Figure 2). On average, for durum wheat, for each kg N applied there is 16 kg/ha dry matter produced, while for bread wheat this response is 11 kg/ha per kg N fertiliser. Variations in yield between these two crops are considerable due to climatic conditions and water availability.

Higher nitrogen response in the Atlantic, Sub-Oceanic climatic zones

The nitrogen response was distinct in the different climatic zones, which also reflects the two species of wheat:

- A higher nitrogen response was observed in the Atlantic, Sub-Oceanic climatic zones (Cfa, Cfb, green on Figure 1), where bread wheat is predominantly grown.
- In the Mediterranean climatic zone (Bsk, yellow/orange on Figure 1), there was little response to higher nitrogen levels in durum wheat.

Plants in water-limited zones are unable to take advantage of greater nitrogen availability

These different nitrogen responses are likely due to differences in water availability between zones. Plants in rainfed systems in water-limited zones are unable to take advantage of greater nitrogen availability because of drought. In Southern Europe, the main issue continues to be the reliability of rainfall in non-irrigated wheat production, as the inter-annual variation in rainfall can be considerable.

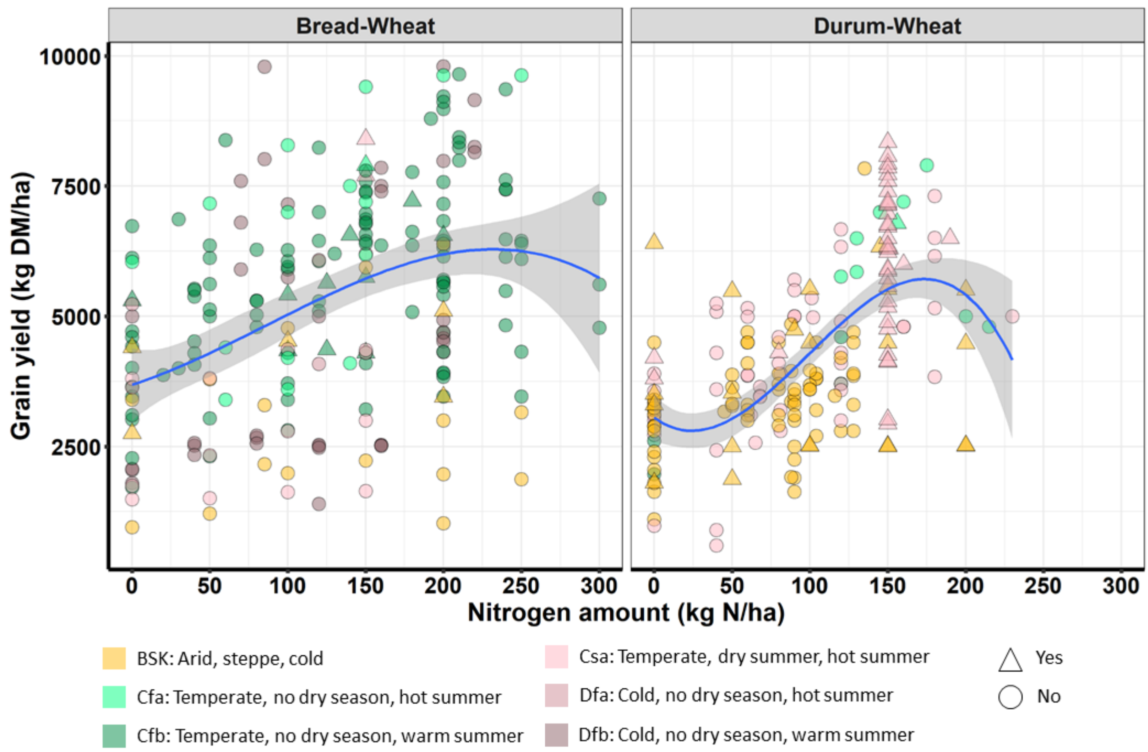

Figure 2: Grain yield response of bread and durum wheat with varying nitrogen fertiliser applications across different climatic and irrigation conditions in Europe.

Increases in rainfall during the growing season in the Mediterranean region: Is wheat becoming more responsive to nitrogen fertiliser?

However, in some Mediterranean zones (e.g. Foggia, Southeast Italy), the amount of rainfall during the growing season (defined as the period between sowing and harvesting) has increased over the last two decades, allowing wheat to be more responsive to higher nitrogen fertiliser levels. This opens up the opportunity to define new fertiliser recommendations for this climatic region specifically. However, in those regions the amount of rainfall between sowing and harvest can vary greatly between years, which is an obstacle for optimal nitrogen management (Basso et al., 2012).

Policy recommendations

This initial analysis of the dataset suggests that European policy recommendations for sustainable nitrogen use should be specific to different climatic regions. Policymakers can support nitrogen-use optimisation with mutli-disciplinary research approaches that have crop management at the centre and integrate computational models (Cammarano et al., 2021). With the specificity of regional requirements in mind, overall policy recommendations include the following:

- **Re-asses management of Nitrate Vulnerable Zones (NVZs) to make systems more environmentally and agriculturally sustainable.**

  Unpredictable weather patterns increase the risk of negative environmental impacts as farmers attempt to overcompensate for rainfall variability with excessive nitrogen application. Instead of setting limits for NVZs, adjust limits according to annual weather conditions and regional crop variability.

- **Incentivise sustainable and regionally adapted nitrogen fertiliser strategies**

  An initial pilot programme for sustainable farming payment schemes in the UK will offer payments for creating and following a nutrient management plan (DEFRA, 2021). A similar policy that incentivises a good nitrogen fertiliser strategy at the farm level can bolster the yield and quality of both bread and durum wheat. Such a strategy needs to take into account that optimising fertiliser nitrogen use can ensure high yields, quality and economic returns. Still, the optimum nitrogen application rate in a given year will vary depending on water availability. This is a major problem in dry regions of Europe. Timing, amount and type of nitrogen fertiliser are key elements for a successful fertilisation strategy.

- **Enable seasonal rainfall forecasts**

  Encourage research to enable long-term rainfall forecasts for the coming growing season. This will allow farmers to take advantage of seasons with greater rainfall through improved nitrogen yield response. At the European level it is possible to leverage the work done by the European Centre for Medium-Range Weather Forecasts (ECMWF) and the work currently being done by the Joint Research Center (JRC) MARS-crop yield forecasting (van der Velde and Nisini, 2019). As forecasting for rainfall and yield becomes more widely available, policy should seek to make this information available to farmers and encourage its use in designing fertilisation strategy.

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Project website: www.solace-eu.net

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