

It is widely understood that global food systems need to be transformed to reduce their substantial adverse environmental impacts, e.g., methane emission from livestock and N<sub>2</sub>O emissions from fertilizer use at crops (Campbell et al., 2017). In this study we will investigate how increased European grain legume (i.e., faba bean, pea, soybean) production, through either Scenario 1 or 2, could contribute to greater supply of plant-based protein and substitution of consumption of meat-based proteins, together with impacts on their land footprint and GHG emissions. As a consequence, we devise two scenarios to increase grain legume production, (1.) narrowing the yield gap, i.e., the difference between what farmers actually produce ( $Y_a$ ) and the potential yield ( $Y_p$ ) in irrigated systems or the water-limited potential yield ( $Y_w$ ) in rainfed systems; and (2.) expanding the areas of grain legumes at current yield levels. Faba bean (*Vicia faba* L.), pea (*Pisum sativum* L.) and soybean (*Glycine max* (L.) Merr.) are, by far, the three most widely grown grain legumes in Europe (Eurostat, 2023; Kezeya Sepngang et al., 2020). At the same time, there is currently increased interest in plant-based proteins, due to awareness that a protein transition from animal-to plant-based would enhance healthy and sustainable diets (Aiking and de Boer, 2020; Willett et al., 2019). Initial estimations for soybean suggest relatively low production efficiency of grain legumes (51% of potential yields) in comparison to cereals (58% of potentials) in Europe (Schils et al., 2018; van Ittersum et al., 2023; Watson et al., 2017). Yet, current harvested areas of those legumes are small, only ~2% of the European cropland is used for soybean cultivation and ~1% for pea and faba bean jointly (FAO (2023), average 2015–2020). Currently, European demand for grain legumes, specifically soybean, is high and the European Union together with the UK imports about 14 million tonnes (Mt) of soy beans and 18 Mt of soy meal (Eurostat, 2023; FAO, 2023). The European Commission (2020) is promoting EU-grown plant proteins within the Farm to Fork strategy as part of the European Green Deal in recognition of the environmental and health benefits associated with production and consumption of plant protein. At the same time, area expansion of legumes will lead to more diverse cropping systems, which is advocated by many (Francis and Clegg, 2020; Nemecek et al., 2008; Preissel et al., 2015). Additionally, due to climate change, significant areas may become more suitable for soybean production in the future due to climate change (Fodor et al., 2017; Nendel et al., 2023). It is estimated that European consumers would be willing to replace around a quarter of the meat consumption with grain legumes (Henn et al., 2022). Over 95% of the imported soybean is used for animal feed, and this is considered unsustainable from an environmental perspective because of the conversion inefficiency involved in animal production and because of (in)direct land use change in the soybean exporting countries. Intensification of current production has the advantage that it will not lead to competition for land use with the production of other food crops (although legumes can also be grown on marginal land (Gogoi et al., 2018)) nor to expansion into natural ecosystems. The production of meat-sourced proteins is of particular concern, as their environmental impact is around ten times greater on a mass basis and has CO<sub>2</sub> emissions around 30 times more than those of plant-based proteins (Poore and Nemecek, 2018). Sufficient internal European production of grain legume crops is amongst the first steps in the protein transition. Grain legumes are protein-rich and a good source of nutrients (Curran, 2012; Erbersdobler et al., 2017). For the purposes of this analysis, we consider Europe to be all European countries west of Russia and Turkey. This is in sharp contrast to cereals which cover 46% of

the European cropland (FAO (2023), average 2015–2020). Increased European legume production could be realised by both intensification and/or area expansion. Domestic production of grain legumes should .(therefore in- crease (Zander et al., 2016