Paper/Poster Title	Integrating a Crop diversity Index to Technical Efficiency Measurement for Cropland Farms in Sweden

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Abstract	*200 words max*
This paper integrates crop diversity to the production function in investigating the dynamic effects of crop diversity on Eco-efficiency for cropland farms in Sweden. An unbalanced panel of data of 937 farms from the Swedish Farm Accounting Data Network (FADN) for the period 2009-2021 is analyzed using the spatial directional distance function. A crop diversity index (CDI) and an index of crop diversity loss, the Herfindahl index (HI), are introduced as an input and an undesirable output, respectively. The average Eco-efficiency is estimated to be 0.876. CDI in previous years is estimated to significantly positively contribute to Eco-efficiency of crop production. Findings presented here are thus useful for understanding how agriculture can become more sustainable in this respect, and for understanding the need for policy interventions to push agriculture towards more sustainable practices.	

Keywords	Spatial directional distance function, Eco-efficiency, FADN data, Herfindal index
JEL Code	C11, C23, D22, D24, Q12 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	*100 – 250 words*
There is an agreement that higher crop diversity contributes to increasing the productivity of ecosystems and that it is therefore beneficial for sustainable crop production (Cardinale et al. 2012). This is broadly acknowledged in the ecological perspective for “sampling effect” and “complementarity effect”. Sampling effect means that growing more diverse crop species will increase the probability of growing the best-adapted species, for example, different crop species have different root systems and therefore improve the efficiency in soil nutrient up taking (Tilman, Polasky and Lehman 2005; Clark and Tilman 2017). Complementarity effect can be interpreted as crop diversity can facilitate the management of different crop species planted by using the different characteristics (Loreau and Hector 2001), for example, different crops require different management and therefore production inputs such as labour and technical factors are optimized. Furthermore, crop diversity supports farm resilience by diversifying the biological risk in farms; in this way pests and diseases are easier to control because different planting seasoning. Crop diversity can also enhance the farm ability for maintain the production under climate change (Di Falco and Chavas 2008; Di Falco and Chavas 2006). However, earlier research has also showed that changes in crop diversification can decrease the income (e.g. Louhichi et al., 2017, Cimino et al., 2015, Cortignani and Dono, 2015). The above described effects of crop diversity in crop production motivates us to incorporate measure of crop diversity to the measurement of the Eco-efficiency for cropland farms.	

Data and Methodology	*100 – 250 words*
The empirical data used here is an unbalanced panel of data for 861 individual farms and a total of 4,951 observations of cropland farms (specialist cereals, oilseeds and protein crops, general field cropping, and mixed cropping) obtained from the Swedish farm accounting data network (FADN) for the period 2009-2016[1] (Table 1). The economic output (y) is the total revenue of agricultural products from the arable land, measured in Swedish Kronor (SEK). The classic economic inputs of the production function are: arable land area size (x_1), in ha; labor	

[1] The crop diversity index in the past two years was calculated using data from 2007 to 2014.

(x_2), in working hours per year; fixed cost (x_3), measuring fixed asset input in the agricultural production, in SEK; intermediate cost (x_4), representing the variable cost excluding the cost for chemical inputs i.e. fertilizer and pesticide, in SEK; and cost of chemicals (x_5) in SEK. All variables represent the economic output and the inputs for the production function were calculated based on standard FADN definitions (European Commission, 2018). The arable land for agricultural production is located mainly in the South and North Sweden, thus we use the arable land located in the South and North with region code 710 and 730 in FADN database. Following Chambers et al. (1998; 2002) and Färe et al. (2005), we build the output oriented spatial directional distance function. The advantage of the output oriented directional distance function is that it allows us to expand the desirable output of agricultural revenue while contracting the undesirable output HI holding inputs unchanged.

Results	***100 – 250 words***

The elasticity of eco-inefficiency w.r.t. land area size (x_1) and fixed cost (x_3) are found negative, which implies that there are positive relationships between ECO-E and these two inputs, suggesting that increasing the inputs farmland and fixed cost will increase potential higher ECO-E . Does this also mean the larger farms have higher ECO-E potential? The literature has pointed to that there are arguments that small scale farms have higher ECO-E in agricultural production (Zhong et al. 2020; Stępień et al., 2021). There is also argument that small and labor-intensive farms are associated with a higher degree of ECO-E compared to capital-intensive farms (Grzelak et al. 2019). In light of our finding of the relationship between farmland size and ECO-E, we suggest that the EU CAP should consider multiple factors related to ECO-E instead of applying one-size-fit-all policy. The elasticity of eco-inefficiency w.r.t. labor (x_2), intermediate cost without chemicals (x_4), cost of chemicals (x_5) and CDI two years lagged (x_6) are found to be positive, which means there are negative relationships between these inputs and ECO-E. The largest elasticity of the eco-inefficiency w.r.t. inputs is associated with the intermediate cost without chemicals (x_4), estimated at 0.640 at the sample mean. This implies that greater intermediate cost excluding chemicals (x_4) would be correlated with higher eco-inefficiency. The elasticity of eco-inefficiency w.r.t. CDI_{t-2} (x_6) is estimated at 0.063 at the sample mean, implying a 1% decrease of CDI_{t-2} would decrease the potential ECO-E by 6.3% on average. According to the finding of Di Falco and Chavas (2008), crop diversity is positively related with production in lagged effects, which indicates that maintaining a diverse crop pattern would enhance agricultural productivity in the long run.

The average estimated ECO-E is 0.876, which indicates that on average, cropland farmers can improve ECO-E by 12.4% in terms of expanding agricultural products revenue and reducing HI given unchanged inputs. The average ECO-E in Southern Sweden is 0.875, while the average ECO-E in Northern Sweden is 0.879. Although there is no significant regional difference between the average ECO-E in Southern and Northern Sweden, the minimum ECO-E in Southern Sweden (0.273) is much lower than the minimum ECO-E in Northern Sweden (0.609). This is expected because farming in Southern Sweden is comparatively more intensive, more fertilizer and pesticide are used in agricultural production, which therefore leads to less environmentally friendly production and a lower ECO-E in Southern Sweden. The ECO-E for conventional farming, organic certificated farming, and mixed or transitional organic farming are 0.876, 0.886, and 0.845 respectively.

Discussion and Conclusion	***100 – 250 words***

Our results show that the crop diversification is a burden on the farm economy, and is related with the regional economic and environmental characteristics. The new CAP 2021-2027 is aiming at better targeting for securing stable economic incomes and intensifying the environmental and climate actions, with increased focus on biodiversity (European Commission, 2021). Given our results, to achieve the goals, policy compensation schemes should take into consideration the income forgone, given the regional potential, both in terms of agricultural production and environmental endowments.