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Potential impact of CAP's Ecological Focus Areas on soil fertility

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An indicator of soil fertility is the content of organic matter measured by the share of carbon in the soil, which is negatively affected by many conventional land management practices. As those heavily depend on individual land use decisions, the agent-based model of regional structural change AgriPoliS is applied to assess carbon losses resulting from behaviors and interactions of individual farms. The extended model now considers nitrogen input and the development in soil's carbon content. Three scenarios are implemented where farms have either to use 7%, 15% or 25% of their land as ecological focus area (EFA). Results show that although carbon losses continue at a slower pace under the 7%-scenario, 25% of the land is to be set aside to stop them completely. However this implies short-term income losses for farmers but better plant resistance and improved soil productivity in the long-run if soil organic matter can be maintained.

Keywords: soil organic carbon, CAP, agent-based modelling.

JEL codes: Q24, Q18, C63, Q57.

1. Introduction

Soil organic matter and associated soil biodiversity is difficult to renew if degraded. Simultaneously, associated soil processes and functions are vital for production of food and biomass as well as storage, filtration and transformation of many substances, e.g. water and carbon. Human utilization of soils causes erosion, loss of organic matter, compaction, salinization, landslides, contamination and surface-sealing (DG Environment, 2012). Those problems are well-known in agriculture and widely discussed in Germany (BMELV, 2012). Less attention is given, though, to the decline in organic matter due to agricultural utilization of soil (Andrén et al., 2004).

Long-term experiments have shown that the percentage of organic matter is essential for soil productivity. Brady et al. (2012) estimated production functions for the research regions Scania (South Sweden) and Rothamsted (South East England) to quantify the economic consequences of the decline in organic matter. Production functions were subsequently implemented in the agent-based model AgriPoliS (Agricultural Policy Simulator). Integration of soil-carbon based production functions into an agent-based agro-economic model is reasonable as the content of organic matter in soil depends on individual farmers' soil management choices. This means that the content of organic matter and thus soil fertility may fluctuate substantially from farm to farm, which in turn has an influence on the incomes of individual farms.

Measures aimed at conserving or increasing soil organic matter, however, must be implemented periodically over a long span. Typically such actions are slow to take effect, i.e. productivity increases are only detected over time (Belcher et al., 2003). Therefore in the short term, conservation measures generate additional costs for farmers but only measurable benefits in the future. Hence, there is likely to be a low private-economic incentive to implement such measures. Intentions to conserve soil organic matter and thus soil fertility raise the question for political incentives. Ecological Focus Areas (EFA) to be provided under the Common Agricultural Policy after 2014 could be seen as such an intervention (EU, 2013). Fallowing arable land (grass fallow) or at least more extensive management could have a positive effect on the content of organic matter in soils. The objective of this paper is to extend knowledge related

to the actual impacts of the implementation of an important feature of the future CAP, i.e., EFA, by considering farmers' individual production decisions. The paper is structured as follows. After a brief description of the agent-based model AgriPoliS, section 2 describes the simulation experiments carried out for the regions of Scania (Sweden) and South East England. The aim of those experiments is to quantify impacts of the creation of ecological focus areas (in the following simply referred to as 'grass fallow'). Section 3 presents the main results of the three scenarios tested with the model and their impacts on organic matter in soil as well as economic implications for farms in the regions. Section 4 provides concluding remarks on the simulation exercise as well as general consideration on soil conserving measures.

2. Model and scenarios

The agent-based model AgriPoliS (Happe et al. 2006; Kellermann et al. 2008; Sahrbacher et al. 2012) allows for mapping of regional agricultural structures and their development. To model an agricultural region in AgriPoliS, 10 to 30 farms are selected and weighted by applying a mathematical programming approach. The sum total of individual features of selected and weighted farms (arable land, grassland, livestock, legal form, etc.) represents the manifestation of such features at regional level. In AgriPoliS individual farms are 'cloned' according to their weight and individualized in terms of age of farm manager, vintage of machinery and buildings, spatial location and management capabilities of the farm manager. Production and investment decisions are made by farms in order to maximize profits by means of a mixed-integer programming model (Hazell and Norton, 1986). At the end of a production period (one year), farms compare their anticipated income for the next year with the potential income that could be generated after quitting agriculture to take a full-time employment off-farm, leasing own land and interest income from equity. If the potential non-agricultural income is higher than the anticipated agricultural income, farms exit agriculture as do farms that become insolvent. Land made available by closing farms or expiring lease contracts is auctioned to new lessees.

Modeling the development of the content of organic matter in soils starts by initializing the initial distribution of the organic matter content for a given area. Carbon content in soil (Soil Organic Carbon = SOC) is used as yardstick for the content of organic matter in soil. To this end, average SOCs are assigned to farms modeled in AgriPoliS. This assignment is based on yields

shown in farms' accounts and their production functions estimated from long-term experiments. In addition, a standard deviation is assigned to each farm; SOC of different plots (fields) of a farm fluctuates normally distributed around the average value.

A further step is implementing a general quadratic production function in AgriPoliS. The parameters of the production function are crop type-specific and are imported in AgriPoliS. The inputs of the production function are nitrogen application and average carbon content in the land of a given farm. Optimization of production based on the production function required an extension of the mixed-integer programming model. Previously aggregated production activities, such as production of one hectare wheat or sugar beets, had to be disaggregated. This means that the application of inputs such as nitrogen, phosphorus, potassium, pesticides and energy as well as sales of wheat or sugar beets, have to be considered and modeled as distinct production activities. Optimal nitrogen application depends on the sales price of individual crop types and the purchase price of yield related inputs. The underlying assumption is that application of phosphorus, potassium and pesticides is a proportionate function of nitrogen application and that energy demand is a function of the yield of individual crop types. Changes in the sales price of individual crop types or in the purchase price of variable inputs thus cause changes in yields and input levels.

Changes in the carbon content of soil are resulting from production decisions made by farms. The underlying assumption is that all farms are managed conventionally and do not carry out any special measures to retain organic matter in soil. Thus, organic matter is assumed to decrease annually by 0.5% relative to previous-year carbon content when considering intensive crop production activities (Table 1). Accumulation of organic matter by 1% can be achieved through one-year grass fallow and other extensive production activities such as grass silage and arable pasture (Alvarez 2005; Blair et al. 2006; Luo et al. 2010; Thomsen and Christensen 2004).

Quantification of effects of 'grass fallow' on soil fertility and agricultural income initially requires calculation of a reference scenario (0%) without 'grass fallow'. Modeled on the initial proposal by the EU Commission for the reform of the CAP for the programming period 2014-2020, a second scenario includes 'grass fallow' on 7% of the UAA (EU Commission, 2011).[1] Further calculations are made to establish the impact of a 'grass fallow' doubling to 15% and that

[1] UAA. Utilized Agricultural Area.

of a 'grass fallow' increase to 25%. The latter percentage is the equivalent demand for green fertilization in zero-livestock organic production. Grass fallow percentages in all scenarios are integrated into the crop rotation and there is no permanent grass fallow of individual areas which would only improve soil fertility in non-used land. Impacts of technical progress are neglected in order to better illustrate how loss of organic matter influences soil fertility and yields. The reason is that technical progress has a clearly stronger effect on yields than reductions in yields caused by loss of organic matter.

3. Results

In the reference scenario without 'grass fallow' (0%), the relative reduction in organic matter content in Scania is 10% over a period of 20 years (Table 2). The decline in South East England is somewhat lower (8%) because ca. 5% of land was voluntarily used as grass fallow or used as one-year grassland for fodder production. Losses of organic matter are reduced with an increasing share of 'grass fallow' in crop rotation. Thus, losses are brought down at a share of 25% 'grass fallow' by one third to 3% over 20 years. What can be noted is that the obligation to use land as 'grass fallow' 7% of arable land would hardly have any impact in South East England because farms are already using parts of their land extensively without this requirement. The effect of such measure therefore depends on the initial production structure of the region considered.

Yield losses caused by loss of organic matter are lower as organic-matter losses can be partially compensated by increased nitrogen fertilization (Table 3). For instance, wheat in Scania requires ca. 6% (9 kg/ha) and in South East England some 2% (5 kg/ha) more nitrogen (Table 5). Yield losses are also crop type-specific. Yield losses for wheat in Sweden without measures to retain organic matter are of 3%, while losses for rapeseed are of 6% and for sugar beets even of 9%. 'Setting-aside' 25% of arable land reduced yield losses for wheat in Scania to 1% and in South East England to almost 0%. And – there is only third of additional nitrogen necessary to compensate losses of organic matter.

A comparison of the development of gross margins and yield developments shows that gross margin losses are higher than the decline in yields (Table 3 and Table 4). This is due, on the one

hand, to the revenue/cost relation and, on the other, to increased fertilizer expenses for wheat and sugar beets.

The development of gross margins, however, relates only to certain crop types. Additionally, income losses at the farm level caused by 'grass fallow' have to be factored in. Thus, gross margin losses with 'grass fallow' of 25% arable land are of maximally 6% after 20 years while short-term slumps in gross margins per hectare are markedly higher in all scenarios (Figure 1). This income gap, however, is gradually closed over time in each scenario due to a decelerated decline of organic matter in soils. In the scenario with 25% 'grass fallow', the short-term income loss shows the highest reduction over time but the income gap caused by 'grass fallow' cannot be fully closed, at least not over a period of 20 years. In contrast, the income gap is reduced to zero after 20 years in the scenario with 7% 'grass fallow' and there are indications that profits after that period will be even higher than profits in the reference scenario.

4. Conclusions

Simulation experiments for the regions of Scania (Sweden) and South East England carried out with AgriPoliS illustrate the importance of maintaining soil fertility. Indeed, in Scania the annual natural yield losses in wheat are around 0.1 dt per hectare. The low natural yield loss rate, however, is owed to the fact that losses of organic matter can be partially compensated by higher nitrogen quantities – at higher expenditures. Thus, the loss of organic matter has a higher impact on revenues than on physical hectare yields. Hence, considering rising fertilizer costs, safeguarding soil fertility is increasingly gaining significance from a business management viewpoint, but is crucial for farm sustainability as well (i.e., long-run performance). At the moment farmers are not realizing the yield losses due to losses of organic matter, because annual yield variations due to different weather conditions as well as technical progress which was found to be 1 dt per hectare for wheat (Ordon, 2011) are much stronger.

The introduction of a rotational 'grass fallow' scheme of 7% arable land would only slow down but not stop losses of organic matter. Stopping those losses would require setting 25% of arable land aside. Yet, such an approach would cause severe income losses in the short-term which could not be compensated through the retention of organic matter even within 20 years. In contrast, the income level after 20 years for a 'set-aside' rate of 7% would be the same as

without any set-aside scheme; an increasing income can even be observed. It has also been shown that a high percentage of organic matter in soils helps crops overcoming adverse weather events (Cong et al., 2014), which is especially important when considering climate change. Other options for retaining organic matter would be to leave straw on the field, to cultivate intermediate crops or to apply manure. Such actions, however, have a weaker effect on the retention of organic matter. In contrast, the use of the 'grass fallow' option for the production of biomass, e.g. the cultivation of Miscanthus (Chinese grass) increases biomass content per year not only by 0.5% as in a simple 'grass fallow' scheme but by up to 1.5% (Brady et al., 2012).

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Tables and Figures

Table 1: Relative annual SOC-change of different production activities

Relative annual SOC-change [%]	Scania	South East England
-0.5	Cereals Rape seed Sugar beet	Cereals Rape seed Potatoes Forage maize
+1.0	Set aside Grass silage Arable pasture	Set aside Temporary grassland

Source: Hedlund, 2012.

Table 2: Relative change of carbon content in soils between 2012 and 2032

Region	**Ø Carbon content in 2012 in%**	**Scenario**			
		0%	**7%**	**15%**	**25%**
Scania	2.42	-10%	-8%	-5%	-3%
South East England	2.50	-8%	-8%	-6%	-3%

Source: own calculations.

Table 3: Relative change of carbon content in soils between 2012 and 2032

			Scenario			
Field crop	**Region**	**Ø Yield 2012 [dt/ha]**	**0% [%]**	**7% [%]**	**15% [%]**	**25% [%]**
			Relative yield decline by 2032			
Wheat	Scania	79	-3	-2	-2	-1
	South East England	85	-1	-1	-1	0
Rapeseed	Scania	37	-6	-5	-4	-2
	South East England	33	-6	-6	-4	-2
Sugar beets	Scania	325	-9	-6	-4	-2

Source: own calculations.

Table 4: Relative gross margin (GM) losses between 2012 and 2032 as a function of the 'grass fallow obligation'

			Scenario			
Field crop	**Region**	**Ø GM 2012**	**0%**	**7%**	**15%**	**25%**
			Relative GM decline by 2032			
		[€/ha]	**[%]**	**[%]**	**[%]**	**[%]**
Wheat	Scania	687	-8	-6	-4	-2
	South East England	535	-3	-3	-2	-1
Rapeseed	Scania	589	-14	-11	-8	-4
	South East England	429	-12	-11	-8	-3
Sugar beets	Scania	1194	-23	-17	-12	-6

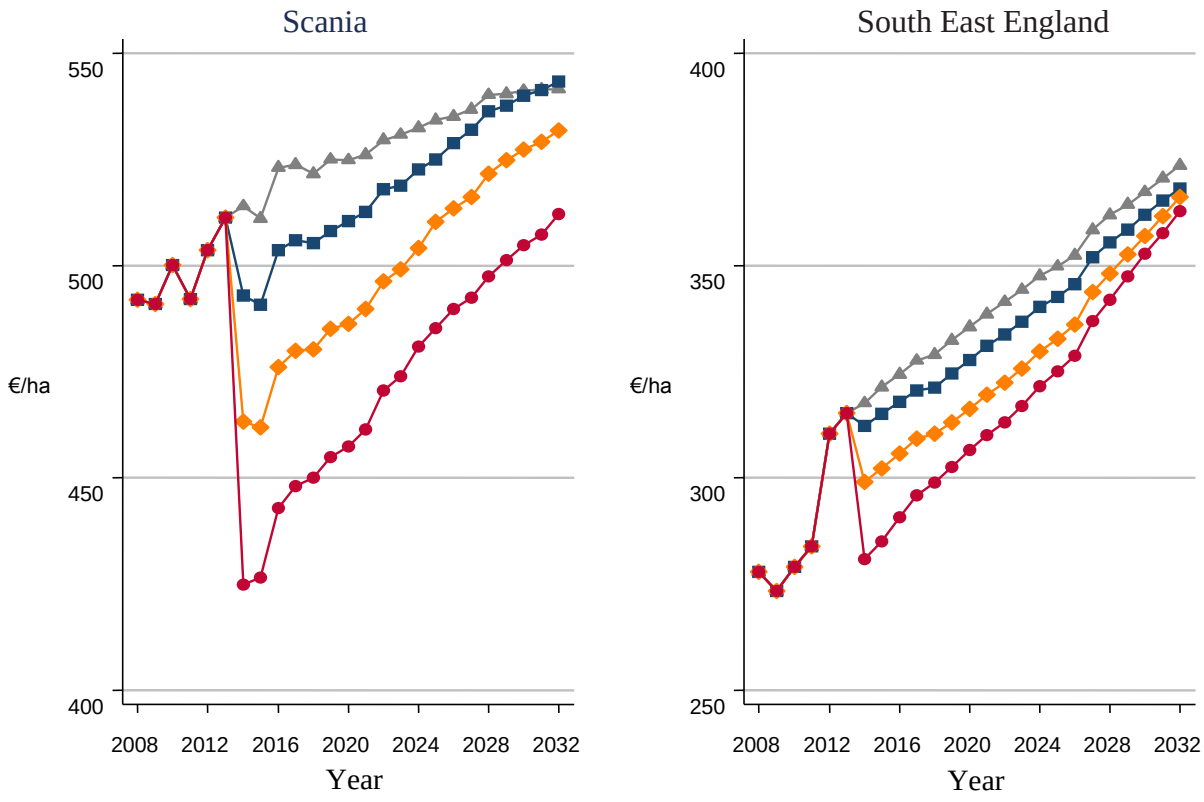
Source: own calculations.

Table 5: Increase in N-input between 2012 and 2032

			Scenario			
Field crop	**Region**	**N-input 2012**	**0%**	**7%**	**15%**	**25%**
			Increase in N-input			
		[kg/ha]	**[kg/ha]**	**[kg/ha]**	**[kg/ha]**	**[kg/ha]**
Wheat	Scania	158	+9.9	+8.3	+6.1	+3.6
	South East England	200	+1.8	+1.7	+1.2	+0.6
Rapeseed	Scania	172	-	-	-	-
	South East England	210	-	-	-	-
Sugar beets	Scania	120	+19.9	+15.3	+11.0	+5.5

Source: own calculations.

Figure 1: Development of profit per hectare in Scania and South East England



Source: own calculations.