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Effects of measures to reduce nutrient losses on the overall environmental impact of the Swiss farming sector

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Abstract
We analyzed the effect of different measures to control nitrogen and phosphorus pollution on the overall environmental impact of the Swiss agricultural sector, including imports and exports. Our results show that it is possible to reduce the environmental burden of the agricultural sector within Switzerland, but only at the expense of shifting environmental impacts abroad. In order to reduce the overall environmental impact of a country's agri-food sector, small-scale local factors such as site-adapted tillage practices have to be considered in combination with a global perspective.

Keywords: *environmental impact; agricultural sector analysis; water pollution control measures*

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1. Introduction

In many European countries, nitrogen and phosphorus pollution of water caused by agriculture is considered too high. In order to achieve policy goals for pollution control, broad reduction measures are necessary. Such measures, however, have far-reaching impacts on the whole agricultural sector. For example, lower productivity due to extensification leads to more imports, causing environmental impacts elsewhere. Therefore, when defining pollution control measures, their effect on the total agricultural sector has to be considered. Commissioned by the Swiss Federal Office for Agriculture, we analyzed the effect of different measures to control nitrogen and phosphorus pollution of water on the overall environmental impact of the agricultural sector, including exports and imports. The results have been published in a report (Bystricky et al., 2017).

2. Methodology

Using direct payments and trade policy as leverage to change agricultural production, we defined four scenarios, with 2010 as baseline and 2025 as target year (see Möhring et al., 2016):

- Reference scenario (REF): A forward projection of the Swiss 2014-2017 Agricultural Policy.
- 'Extensification' scenario (EXT): Extensification of field- and forage-crop production through 10 % annual increase in direct payments for extensified land use.
- 'Tariffs' scenario (ZOLL): Reduction in domestic production of crops prone to nutrient leaching and erosion through lowering the in-quota tariffs for potatoes, resulting in lower import prices; lowering producer price for vegetables; lowering the duty levied for compulsory stocks of sugar; increasing the entry price for feed (all changes 10 % per year).
- 'Grassland scenario' (GRAS): Forcing the conversion of arable land to grassland or non-agricultural uses (5 % per year) while prohibiting an increase in livestock numbers.

Assuming a stable per-capita food consumption and 10% population growth, land use and livestock production developments were calculated with an agent-based sector model (SWISSland) for the base year and each scenario (Möhring et al., 2016). The system boundaries for the life cycle assessment of the agricultural sector in this paper contained all products considered in the SWISSland sector model. These were: milk; cheese; veal; beef; pork; poultry; eggs; live sheep, goats and horses; bread grains; rapeseed; sugar; potatoes; fruit; berries; grapes; and fresh vegetables. The sum of domestic production and import of these products, minus exports, constituted a 'basket of products', which formed the functional unit for comparing the environmental impacts.
We then added up individual life cycle inventories from several LCA databases for all products included in the basket of products. We calculated the overall environmental impacts using the SALCA method (Swiss Agricultural Life Cycle Assessment; Gaillard and Nemecek, 2009).

3. Results and Discussion

Table 1 gives an overview of the environmental impacts in the base year and in the scenarios, broken down into domestic production and imports. The environmental impacts for 2025 were almost always higher than in the 2010 base year. This rise was for the most part due to the growing population, which, as the diet remained the same, required correspondingly more food. We found that within Switzerland, the scenarios indeed reduced nitrogen and phosphorus eutrophication and at the same time affected most LCA results of agricultural production favorably. In the EXT and ZOLL scenarios, the environmental impacts of domestic production were very similar to those of the reference scenario. The GRAS scenario had the strongest effects on domestic production; here, the environmental impacts were consistently lower than in the reference scenario. The greatest reductions were for aquatic eutrophication caused by nitrogen, and for terrestrial and aquatic ecotoxicity. The cultivation of cereals and grain maize as well as temporary leys and pasture land contributed heavily to changes in nitrogen eutrophication, while the spreading of farmyard manure on grassland was decisive for aquatic eutrophication with phosphorus. Terrestrial and aquatic ecotoxicity was mostly influenced by the cultivation of cereals, maize, and potatoes.

Unlike with domestic production, the environmental impacts of the imports for the most part increased strongly in the scenarios. The reference scenario already resulted in a significant rise vis-à-vis the base year. The differences recorded between the EXT and reference scenarios were relatively minor. Owing to its incentives to facilitate the import of intensive field crops, the ZOLL scenario brought about a further increase in the environmental impacts of imported products compared to the reference scenario. This was even more the case in the GRAS scenario. In all scenarios, the environmental impacts of imported food and feed changed far more strongly than those from domestic production. Imported products of animal origin had a strong influence on the majority of environmental impacts, while imported food and feed of plant origin was important just for some impacts (energy demand, water use, aquatic eutrophication with nitrogen). With imported meat, not only were import quantities important for the performance of the scenarios, but so too was the origin of the meat, depending on the environmental impact.

Looking at the sum of domestic production and imports, the EXT scenario caused the least change overall vis-à-vis the reference scenario, whilst nearly all environmental impacts increased moderately in the ZOLL scenario. The differences were greatest in the GRAS scenario. For some environmental impacts, its overall performance was similar to the reference scenario, while deforestation, land competition and water use had the highest values and aquatic ecotoxicity the lowest value of all scenarios.

Accordingly, the water-pollution control measures on which the scenarios were based had different degrees of impact on the LCA results for agricultural production in Switzerland. A larger percentage of low-intensity crops and grassland did not play a decisive role in the overall assessment. Reduced cultivation of potatoes and vegetables in the ZOLL scenario primarily affected energy demand and toxicity in domestic production. These crops accounted for a comparatively low share of most of the environmental impacts, and neither was there a significant change in the scenario. Aquatic eutrophication due to nitrogen and phosphorus – the primary targets of the water-pollution control measures – were most strongly influenced by cereals, temporary leys and grasslands, since these all occupied a large share of the Swiss agricultural land. This influencing factor became particularly apparent in the GRAS scenario, in which arable land and temporary leys were significantly reduced.

In our study (Bystricky et al., 2017; Prasuhn et al., 2016 and 2017), we also found that site conditions could strongly influence the effect of agricultural production on aquatic eutrophication – either favourably or unfavourably, depending on site parameters. Reduced tillage also had a positive effect on most environmental impacts.

4. Conclusions

Our results show that it is possible to reduce the environmental burden of the agricultural sector within a country. Drastic measures, such as converting a considerable share of arable land to grassland, were more promising than extensification of the existing cropping systems. However, reducing the environmental burden within Switzerland led to a stagnation or reduction of domestic food production. At the same time, the overall demand for foodstuffs in Switzerland is steadily increasing due to population growth, which was a fundamental influencing factor for the results of the scenarios, as the increasing amounts of imported food and feed led to a shifting of environmental impacts abroad.

Table 1: Environmental impacts of domestic production and imports in the base year and the percentage changes with the scenarios, with reference to the functional unit ‘basket of products’.

Environmental impact		Base year 2010	REF_2025	EXT_2025	ZOLL_2025	GRAS_2025
Energy demand	Domestic	43.3	-2%	-1%	-5%	-14%
10^9 MJ eq	Imports	14.1	42%	43%	68%	100%
	Total	***57.4***	***9%***	***10%***	***13%***	***14%***
Demand for P resources	Domestic	26.9	-3%	-4%	-3%	-13%
10^6 kg P	Imports	**5.0**	41%	44%	51%	104%
	Total	*31.9*	***4%***	***3%***	***6%***	***5%***
Demand for K resources	Domestic	**168.5**	0%	-1%	-1%	-4%
10^6 kg K	Imports	**10.8**	42%	46%	57%	105%
	Total	*179.3*	***2%***	***2%***	***3%***	***3%***
Land competition	Domestic	12.7	-2%	-2%	-2%	-11%
10^9 m^2*a	Imports	3.0	89%	89%	101%	164%
	Total	***15.6***	***16%***	***15%***	***18%***	***22%***
Deforestation	Domestic	0.4	-2%	-2%	-5%	-16%
10^6 m^2	Imports	14.7	24%	17%	32%	62%
	Total	***15.1***	***23%***	***17%***	***31%***	***60%***
Water use (WSI)	Domestic	11.7	-2%	0%	-9%	-14%
10^6 m^3	Imports	15.6	35%	41%	65%	106%
	Total	***27.3***	***19%***	***23%***	***33%***	***55%***
Global warming potential	Domestic	7.9	-3%	-2%	-3%	-13%
10^9 kg CO_2 eq	Imports	2.2	55%	52%	74%	113%
	Total	***10.0***	***9%***	***10%***	***13%***	***14%***
Ozone formation (vegetation)	Domestic	57.6	-3%	-2%	-4%	-13%
10^9 m^2*ppm*h	Imports	13.5	69%	67%	98%	136%
	Total	***71.2***	***10%***	***11%***	***16%***	***15%***
Ozone formation (human)	Domestic	5.7	-4%	-1%	-3%	-12%
10^6 person*ppm*h	Imports	1.1	89%	84%	113%	157%
	Total	***6.8***	***11%***	***13%***	***16%***	***15%***
Acidification	Domestic	1806.2	-5%	-4%	-5%	-13%
10^6 m^2	Imports	272.2	66%	65%	81%	125%
	Total	***2078.4***	***4%***	***5%***	***6%***	***5%***
Terr. eutrophication	Domestic	16.1	-5%	-4%	-5%	-12%
10^9 m^2	Imports	2.3	70%	69%	81%	128%
	Total	***18.4***	***4%***	***5%***	***6%***	***5%***
Aq. eutrophication N	Domestic	29.8	-3%	-4%	-3%	-27%
10^6 kg N	Imports	9.5	57%	62%	70%	127%
	Total	***39.3***	***11%***	***12%***	***14%***	***10%***
Aq. eutrophication P	Domestic	1185.8	-2%	-3%	-4%	-10%
10^3 kg P	Imports	331.8	73%	70%	86%	133%
	Total	***1517.6***	***14%***	***13%***	***16%***	***21%***
Human toxicity	Domestic	2585.4	-3%	-3%	-5%	-15%
10^6 kg 1,4-DB eq	Imports	1101.1	10%	6%	24%	49%
	Total	***3686.5***	***1%***	***0%***	***4%***	***4%***
Terr. ecotoxicity	Domestic	7.5	-2%	-3%	-3%	-34%
10^6 kg 1,4-DB eq	Imports	3.0	44%	45%	73%	123%
	Total	***10.6***	***11%***	***10%***	***19%***	***11%***
Aq. ecotoxicity	Domestic	218.8	-5%	-8%	1%	-32%
10^6 kg 1,4-DB eq	Imports	67.5	46%	43%	55%	109%
	Total	***286.3***	***7%***	***4%***	***13%***	***1%***

With regard to meat imports, however, not only the amount but also the country of origin was decisive, which might be considered when working out import strategies.

Our results also indicate that the potential for reducing nutrient emissions and other environmental impacts could be higher when site factors or alternative soil tillage practices are taken into account than when pollution-control measures are applied in an undifferentiated way. There is a need for research regarding site differences and tillage, which should be systematically taken into account when creating scenarios and adequately depicted in LCA results. Equally, there is a need to include further influencing factors such as technical developments and changes in eating habits in the modelling, since these factors have an appreciable influence on the environmental impact of the agriculture and food sector.

When addressing the effect of pollution control measures, global and small-scale regional approaches have to be combined in order to reduce the environmental impact of a country's agriculture and food sector.

6. Literature

Bystricky, M., Nemecek, T., Gaillard, G. 2017. Gesamt-Umweltwirkungen als Folge von Gewässerschutzmassnahmen im Schweizer Agrarsektor. Agroscope Science 50, Agroscope, Zurich.

Gaillard, G. and Nemecek, T. 2009. Swiss Agricultural Life Cycle Assessment (SALCA): An integrated environmental assessment concept for agriculture. Proceedings of the AgSAP Conference 2009. Egmond aan Zee.

Möhring, A., Ferjani, A., Mack, G., Mann, S. 2016. Nährstoffreduktion in Gewässern – Modellergebnisse SWISSland. Agroscope Science Nr. 31, Agroscope, Zurich.

Prasuhn, V., Kupferschmied, P., Spiess, E., Hürdler, J. 2016. Szenario-Berechnungen für das Projekt zur Verminderung diffuser Nährstoffeinträge in die Gewässer der Schweiz mit MODIFFUS. Bericht im Auftrag des Bundesamtes für Umwelt, Agroscope, Zurich.

Prasuhn, V., Möhring, A., Bystricky, M., Nemecek, T., Gaillard, G. 2017. Ökonomische und ökologische Beurteilung von Gewässerschutzszenarien. Agrarforschung Schweiz 8(9): 340-347.