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Modifying the yield factor based on more efficient use of fertilizer—The environmental impacts of intensive and extensive agricultural practices

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ABSTRACT

The aim of this article is to draw attention to calculations on the environmental effects of agriculture and to the definition of marginal agricultural yield. When calculating the environmental impacts of agricultural activities, the real environmental load generated by agriculture is not revealed properly through ecological footprint indicators, as the type of agricultural farming (thus the nature of the pollution it creates) is not incorporated in the calculation. It is commonly known that extensive farming uses relatively small amounts of labor and capital. It produces a lower yield per unit of land and thus requires more land than intensive farming practices to produce similar yields, so it has a larger crop and grazing footprint. However, intensive farms, to achieve higher yields, apply fertilizers, insecticides, herbicides, etc., and cultivation and harvesting are often mechanized. In this study, the focus is on highlighting the differences in the environmental impacts of extensive and intensive farming practices through a statistical analysis of the factors determining agricultural yield. A marginal function is constructed for the relation between chemical fertilizer use and yield per unit fertilizer input. Furthermore, a proposal is presented for how calculation of the yield factor could possibly be improved. The yield factor used in the calculation of biocapacity is not the marginal yield for a given area, but is calculated from the real and actual yields, and this way biocapacity and the ecological footprint for cropland are equivalent. Calculations for cropland biocapacity do not show the area needed for sustainable production, but rather the actual land area used for agricultural production.

The proposal the authors present is a modification of the yield factor and also the changed biocapacity is calculated. The results of statistical analyses reveal the need for a clarification of the methodology for calculating marginal yield, which could clearly contribute to assessing the real environmental impacts of agriculture.

1. Introduction

One of the greatest challenges to mankind is how to meet basic food needs for a growing population. The question arises how it is possible to increase agricultural production and minimize the detrimental impacts of agriculture at the same time. This question has clear practical significance, and it highlights a conflict between neoclassical economic theory and the ‘ecological’ approach, which takes into account the biophysical limits of production.

Agriculture creates significant negative externalities on the environment through impacting soil, water, air, biodiversity and landscape. The introduction of a sustainable approach to agricultural practices would be the most effective solution. The goal of such an approach is maximization of the net societal benefits from the production of food and fiber and from ecosystem services (Tilman et al., 2002).

The major areas of agricultural environmental impacts are connected to the effective management of fertilizer use and ecosystem services; namely nutrient-use, water-use, maintaining soil fertility and sustainable livestock production.

The harmful environmental impacts of agriculture basically stem from the transformation of natural habitats to agricultural areas. Agricultural practices can change whole ecosystems through conversion of the landscape and the usage of fertilizers and pesticides. Due to the increase in the use of agrochemicals cereal production has doubled in the past 40–50 years (FAO Database, 2010), in order to satisfy increasing demand for food – the consequence of a growing population and income level. On the positive side, the use of agrochemicals has saved natural habitats from conversion to agricultural land. However, fertilizers and pesticides (fungicides, herbicides, insecticides, etc.) are mostly nitrogen-(NO_x, ammonium), phosphorus- or potassium-based and their use and overuse causes leaching into the soil and resultant soil degradation

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and groundwater pollution. Nitrate loading of lakes and rivers induces over-enrichment and eutrophication endangering freshwater ecosystems. Crops can take up only 30–50% of nitrogen in forms of nitrate (NO_3^-) and ammonium (NH_4^+) and approximately 45% of phosphorus fertilizers, thus a great amount of the applied components are lost in the soil where they pollute groundwater.

Groundwater is the key element of freshwater purification and the main problem is that it can spread both nutrients and pollutants over a great expanse and load lakes and rivers over large distances, as well as increasing health risks for animal species, livestock and human beings. The health risk for mammals depends mainly on the dose–effect and dose–response relationships, the physical state of the product (fertilizer, pesticide), and exposure type (oral, dermal, etc.) (WHO, 1990). Through altering the terrestrial habitats of species fertilizer and pesticides affect ecosystems by decreasing biodiversity.

Sustainable agriculture posits an alternative, which can provide increased crop yields through more effective fertilizer, pesticide, and water use and ecologically conscious practices in soil maintenance and livestock production (Tilman et al., 2002).

In this article we compare intensive and extensive agricultural practices and their environmental impacts using data from two countries: the Netherlands and Hungary. We analyze the relation between agricultural yield and its determining factors in order to reveal the impacts of agricultural practices in the quest to define the efficient use of fertilizer which would lead to more sustainable farming practices. Furthermore, a proposal is presented for how the calculation of the yield factor and biocapacity, taking into account the long term impacts of fertilizer overuse, could possibly be changed.

2. Research question

The ecological footprint indicator is designed to show the difference between a sustainable lifestyle and the actual or current way of life and its impacts. According to the calculation formula for the ecological footprint and for biocapacity (concerning the cropland component) the ecological footprint should not exceed biocapacity. The yield factor used in the calculation of biocapacity is not the sustainable amount of yield for a given area, but is calculated from the real and actual yields, and this way biocapacity and the ecological footprint for cropland shows the same result. Thus the cropland biocapacity indicator does not show the production area that is sustainable, but the actual land used for agricultural production.

The reason for this method of calculation is that there is no available data to indicate what the sustainable yield is. The sustainable yield would surely be lower than the present amount, thus overexploitation could be revealed by considering this factor. The importance of this research topic has already appeared in research by Wackernagel et al. (2004). They suggest taking into the calculation the productivity factor, which could be used as a time-series.

Data on optimal and sustainable production are needed to calculate the ecological footprint and to show the real overshoot. In this study we examine what the sustainable amount of yield could be and how it could be estimated. We start from the assumption that the regenerative capacity of the land should be taken into account in the calculation, therefore if (excessive) fertilizer use no longer contributes to increasing yield, then the yield production is not efficient. In a later section of this article, a detailed reasoning will be given for this.

Another problem with the calculation of the cropland footprint is that an increase is shown in biocapacity if a more efficient agricultural production technique is found – but this may not be a sustainable improvement: the overexploitation of soil through addition of chemicals and fertilizer does not appear in the calculation and results. The real environmental load generated by agriculture is not revealed properly through ecological footprint indicators, as the type of agricultural farming (thus the nature of the pollution it creates) is not incorporated in calculation processes.

The research question discussed here is additionally of critical practical importance from the viewpoint of economics, as it involves a conflict between the need for providing food for a growing population and the ecological limits of increasing crop yields. Significant increases in yield are necessary in China, South Asia and Africa, but the environmental constraints will limit this outcome. According to Harris (1996), there is a conflict between the pressure to increase yields on the demand side and the requisites of long-term sustainability. There is an ecological cost to providing food for the global population and meeting conditions for sustainability. This cost associated with expansion of supply must be considered – not only the supply capacity of world agriculture.

Neoclassical economical approaches focus on yield increases as a result of technological advances and increasing inputs. In this way biophysical limits and carrying capacity are not taken into account. Neoclassical economists reject the necessity of taking into account the focus on limits, arguing that technological advances and trading activities will solve the problem of the excessive use of agricultural land. In contrast, the ecological economics perspective is based on the environmental limits of the economic growth (Harris, 1996). Ecological economists Martinez-Alier (1991) and Gever et al. (1991) argued that agricultural production must be considered according to ecological limits and carrying capacity.

3. Intensive and extensive agricultural practices in Hungary and the Netherlands

It is very difficult to define accurately the differences between intensive and extensive agricultural practices; they are usually both utilized on similar areas, depending on the availability of resources and farming practices. However, there are some peculiarities of each method.

Extensive agriculture generally uses a larger land area in order to produce the same yields as intensive agriculture and crop yields primarily depend on the natural fertility of the soil, climate and availability of water. Contrarily, intensive agricultural practices need larger amounts of capital and the application of fertilizers and pesticides and the use of irrigation equipment, which induces greater crop yields per unit of land than extensive agriculture.

A high and increasing level of agricultural pollution is common to Europe. In the case of Hungary, the present state of agriculture is not desirable from either an ecological or a social point of view, though the country is well-endowed for agricultural production having fertile soils and a high number of hours of sunshine. Agricultural traditions are nearly a 1000 years old, and because of this and the advantageous geographic features, Hungarian agriculture can ensure good crop yields both in quality and in quantity. Hungary has a total area of 9.3 million hectares and almost two-thirds of the country's total area is under agricultural cultivation (a large amount when compared to other European countries). Only Denmark and the United Kingdom have higher proportions. 78% of this cultivable area is arable land and 17% is grassland, while kitchen gardens, orchards and vineyards take a combined share of only 5% (MARD, 2009).

Agriculture has traditionally been an important sector of the Hungarian national economy. Because of the political transition, economic changes and restructuring have taken place so Hungarian agriculture has changed much during the last 20 years. In 1989, when the changes and transition started to take place, agriculture accounted for 13.7% of GDP; 20 years later, in 2009, it was only 3.7%.