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THE ISSUES OF ENERGY AND CARBON CYCLE: NEW PERSPECTIVES FOR ASSESSING THE ENVIRONMENTAL IMPACT OF ANIMAL WASTE UTILIZATION

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ABSTRACT

This paper addresses relationships among efficient use of animal waste resources and reduction of fossil energy use and CO_2 emission for industrial production of fertilizers. An effective use of animal waste resources might provide important contributions in alleviating environmental change. In particular: the fulfillment of nutrient requirements of crop plants growing in non-limiting conditions and thus sequestrating atmospheric CO_2 at potential level; the chance of diminishing use of fossil energy, and related CO_2 emissions, necessary for manufacturing of industrial fertilizers; the possibility of enhancing carbon sequestration in agricultural soils by application of farmyard manure to optimized cropping systems.

INTRODUCTION

All intensive livestock systems determine serious problems of waste utilization. Begon et al. (1996) defined these problems as being among the most intractable that any ecologist can face. Until now, the overwhelming environmental concerns regarding animal waste utilization were focused on nutrient accumulation in arable soil profile, contamination of surface and groundwater, and ammonia emission in the atmosphere. Yet, during the last decade, there was a growing concern about the environmental effects of the massive use of fossil energy and the related rise of the CO_2 concentration in the atmosphere. The Inter-governmental Panel on Climate Change (IPCC, 1996) indicated that the risks of climate change induced by greenhouse gases are so serious to justify immediate action. In order to meet the challenge of reducing use of fossil energy, and consequently reducing CO_2 emission, any human activity should be analysed in order to identify possible gains of efficiency. The agricultural sector can play a crucial role in mitigating global climate change, and an efficient use of animal wastes might have a contributing role. The scope of this paper is to highlight some interrelations among waste utilization within agricultural systems and use of fossil energy and carbon cycle. The following environmental issues are addressed:

- The positive impact of an effective use of manure in reducing fossil energy consumption and CO2 emission for industrial production of fertilizers;
- The negative impact of drying and/or transporting manure using fossil energy in order to reduce accumulation of nutrients in areas surrounding the livestock activities;
- The capacity of well managed crops in sequestering atmospheric carbon, whilst utilizing nutrients, making use of the sun energy.

THE POSITIVE IMPACT OF AN EFFECTIVE USE OF MANURE IN REDUCING USE OF FOSSIL ENERGY AND CO_2 EMISSION FOR INDUSTRIAL PRODUCTION OF FERTILIZERS

In his speech at the last RAMIRAN workshop, Sangiorgi (2000) emphasized the potential role of manure for saving the fossil energy required in industrial production of mineral fertilizers. This aspect has been neglected since fossil energy was abundantly available at low cost and the concern for greenhouse gases emissions was limited. The present concerns for global climate chance should stimulate research solutions, and policy actions, for reducing use of industrial fertilizers by an increased use efficiency of manure. Helsen (1992) reported that 76.3 MJ per kg N are required to produce urea, which is the most energy-demanding but also the most widely used N fertilizer. When 300 kg of N are applied to 1 ha of maize crop, the energy cost is 22890 MJ. With an energy content of 38.66 MJ per L of diesel fuel (Pimentel, 1992), about 592 L of diesel fuel are needed solely for N fertilization. In addition, the production of granulated superphosphate requires about 8.6 MJ per kg of P_2O_5, and about 6.4 MJ per kg of K_2O. Therefore, when 100 kg of P_2O_5 and 100 kg of K_2O are also applied, other 38 L of diesel fuel are used, and a total amount of 630 L (i.e. 492 kg) should be considered. The use of 1 kg of diesel fuel determines the emissions of 3.56 kg CO_2, 5.2 g CH_4, and 0.7 g N_2O, including the energy required to the extraction and delivery of the unit of energy (Kramer et al., 1999). The overall emissions can be expressed in terms of CO_2 (the reference gas) be multiplying CO_2 for 1, CH_4 for 21, and N_2O for 310 (IPCC, 1996). This transformation takes into account the greenhouse effect of each individual gas. This lead to a total of 3.89 kg CO_2 per kg of diesel fuel. Thus, 492 L of fossil fuel determines an emission of about 1914 kg CO_2.

Since livestock manure is a by-product of a strictly useful process (i.e. meat and milk production) its nutrient content appears to have a "substitution value" with respect to the energy-demanding industrial fertilizers.

THE NEGATIVE IMPACT OF DRYING AND/OR TRANSPORTING MANURE USING FOSSIL ENERGY IN ORDER TO REDUCE ACCUMULATION OF NUTRIENTS IN AREAS SURROUNDING THE LIVESTOCK ACTIVITIES

One important condition need to be accomplished in order to make the above statement valid. The energy necessary to deliver nutrients to the recycling crops should be limited. Nowadays, technology is available to separate manure into clean water, N-P-K concentrate, and dry matter. Nevertheless, this requires about 180 MJ per cubic meter of treated slurry. If we consider a pig manure with N content of 3 kg per cubic meter, the energy cost for processing one kg of N (i.e. 90 MJ) is higher that the one necessary for producing one kg of industrial N in form of urea.

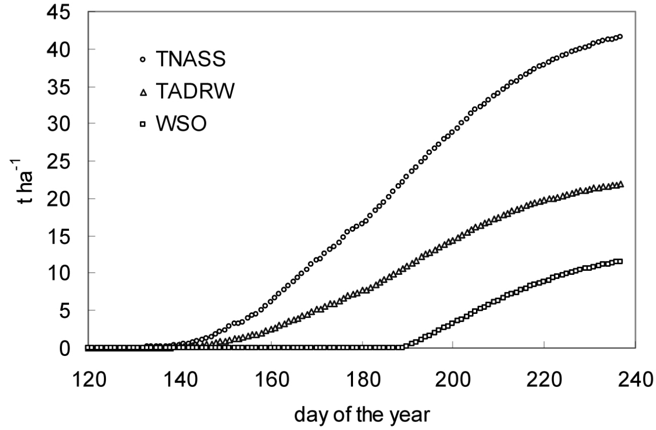
In principle, some solution for drying manure might be possible if we could make an effective use of the solar energy that is currently dissipated on the livestock roofs. In fact, under the prevailing conditions of Po Valley, an amount of 4840 MJ m^{-2} $year^{-1}$ (Modena, Lat. 44° 38', average for the years 1993-1997) is incoming for free as global solar radiation, with daily values of 20-25 MJ m^{-2} day^{-1} in June and July.

Manure transportation appears to offer more viable options. Transportation by truck of 1 ton requires 3.47 MJ per km (Pimentel, 1992). Referring to a pig manure kg with 3 kg N m^{-3}, and bearing in mind the energy required for 1 kg N in form of urea (i.e. 76.3 MJ), the equivalent energy expense is required for a transportation of about 66 km.

THE CAPACITY OF WELL MANAGED CROPS TO SEQUESTER ATMOSPHERIC CO_2, WHILST UTILIZING NUTRIENTS, MAKING USE OF THE SUN ENERGY

A field crop growing with full availability of water and nutrients is the ideal situation for efficient animal waste utilization. This is also true for atmospheric CO_2 sequestration in plant biomass. A maize crop, growing under non-limiting conditions, has a daily net assimilation of about 500 kg CO_2 ha^{-1} d^{-1}, equivalent to all the CO_2 of 100 m height of air (Loomis and Amthor,1999). This can be easily verified by considering that 300 kg of biomass with 44% of C are equivalent to 132 kg C, the ratio C/CO_2 is 12/44=0.27, and 132/0.27= 484 CO_2 ha^{-1}. By integrating daily net CO_2 assimilation throughout the growing season with a simulation model, we can assess the "sequestering C service" of a well managed crop. The example shown in figure 1 refers to a maize crop in the Po Valley. A maize crop, with a grain yield of 11.5 t ha^{-1}, and total aboveground biomass of 21.9 t ha^{-1}, has a total net CO_2 assimilation of 41.5 t ha^{-1}. Indeed, the CO_2 sequestration of the crop largely overtakes the emissions necessary for production of mineral fertilizers used to sustain its growth. Nevertheless, the role of manure in gaining efficiency on the carbon balance is crucial. In fact, most of the nutrient requirements could be fulfilled by manure, allowing high levels of crop CO_2 sequestration on the one side, and diminishing the CO_2 emissions due to production of industrial fertilizer on the other side.

Figure 1. Simulated time course of a maize crop in the Po Valley. TNASS = total net CO_2 assimilation; TADRW = total aboveground biomass; WSO = weight of storage organs. Simulation was performed with the model Sucros 97 (van Laar et al., 1997), after calibration with locally collected data.



The Kyoto protocol (cited by Izaurralde et al., 2001), introduces the concept of credit for C sinks, and recognize credits for afforestation but not for other agricultural land use. However, in the article 3.4 of the protocol is mentioned the possibility for future inclusion for other agricultural activities (Izaurralde et al., 2001). The objection against inclusion of agricultural activities was due to the difficulties in assessing the amount of C that can actually be sequestered in agricultural soils.

In effect, young and fast growing forests can act as effective C sinks by accumulating carbon both in vegetation and soil (World Resources 2000-2001). Nevertheless, recent studies raised serious doubts about the real efficiency of forests in CO_2 sequestration.

Oren et al. (2001) pointed out that forests are usually relegated to soil with poor fertility, therefore tree growth is often limited by nutrients and/or water availability. Conversely, it is important to note that a well managed crop does not suffer these limitation, and in case of maize, can take advantage of the C_4 pathway that assures one third more production efficiency.
Moreover, Schlesinger and Lichter (2001) reported that half of the carbon uptake of the forest is allocated on short lived tissues (i.e. leaves), and that carbon accumulation in deeper soil layers is absent. On the contrary, farmyard manure application, selected crop rotation and conservation tillage offer excellent opportunities for carbon sequestration in agricultural soils (Lal, 2001, 2002).
Magette (2002) pointed out that the "polluters pay" principle is a well established guideline in the EU legislation. If this principle would be applied extensively, a trade could be established by transferring payments from CO_2 polluters to "CO_2 sequesters". This would strongly encourage the adoption of good land use practices by the farmers.

CONCLUDING REMARKS

Agricultural systems provide many important services for people and society. An important challenge for agro-ecological research is to recognize and measure the value of ecosystem services, in particular carbon sequestration and nutrient recycling. In this framework, an effective use of animal waste resources might provide important contributions in alleviating environmental change:

- the fulfillment of nutrient requirements of crop plants growing in non-limiting conditions and thus sequestrating atmospheric CO_2 at potential level;
- the chance of diminishing use of fossil energy, and related CO_2 emissions, necessary for manufacturing of industrial fertilizers;
- the possibility of enhancing carbon sequestration in agricultural soils by application of farmyard manure to optimized cropping systems.

The future success of agro-ecosystems in providing these services will depend on changes of economic relations among agriculture and other production sectors. These changes can be only be achieved with a changed societal perceiving of the links between agro-ecosystems services and global environmental change.

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