Cattle trampling reduces the risk of nitrate leaching in organic dairy rotations




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Organic dairy farming is characterized by grazing cows in contrast to Danish conventional farms where the majority of cows are kept indoors. Cattle trampling reduces the finer macroporosity in the first five to ten centimetres of the soil. This caused a low infiltration capacity at the soil surface, giving a higher probability to initiate macropore flow at the surface. Rapid water movement through macropores bypasses the soil matrix, reducing nitrate leaching.

Macropore flow depends to a large degree on hydraulic conductivity of the soil and the rain intensity. Water will only flow from the soil matrix out into the non-capillary macropores if the soil is water saturated.

This is a situation mostly occurring in the period from autumn to spring. The cattle may still be grazing in the autumn and there is a high potential for leaching of nitrate from the urine patches at this time of the year (Figure 1).

On the other hand, macropore flow can cause the rain water to bypass large parts of the bulk soil where higher concentrations of nitrate are found and therefore delay leaching. Intensive cattle trampling reduces the porosity of the first five to ten centimetres of the soil. This decreases near-saturated hydraulic conductivity, giving a higher probability to initiate macropore flow at the surface (Figure 2). At the same time, the use of semi-permanent grass-clover pastures in organic dairy crop rotations is greatly stimulating earthworm populations.

Earthworms living under the soil surface may significantly increase soil macroporosity. Moreover, deep-burrowing species, which are particularly favoured by organic farming and in pastures, creates persistent vertical burrow systems that penetrate to deep soil layers.

It means that, after some years of grazing, we may have a topsoil where the density of finer macropores have been reduced by cattle trampling, and where many permanent vertical burrows of deep-burrowing earthworms are connected to the surface.

Figure 3 presents the model we tested in the ICROFS project, OrgGrass, where we investigated how three years of cattle trampling in grass-clover fields could influence the risk of nitrate leaching in the autumn.

The experiment

The experiment was situated within the dairy crop rotation on loamy sand at the Foulum experimental farm. The dairy crop rotation, converted to organic practice in 1987, is among the oldest organic experimental areas in Denmark.

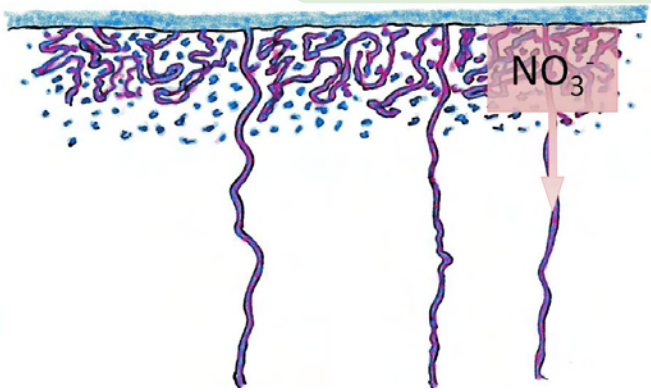

Figure 1. In this schematic situation, high rain fall occurred while the soil was close to saturation. After three years in pasture without grazing or traffic with heavy machinery, macropores (> 30 µm) will be numerous and well connected in the topsoil. Rain water will be transported slowly through a large part of the soil porosity, and will mobilize soil water containing solutes.

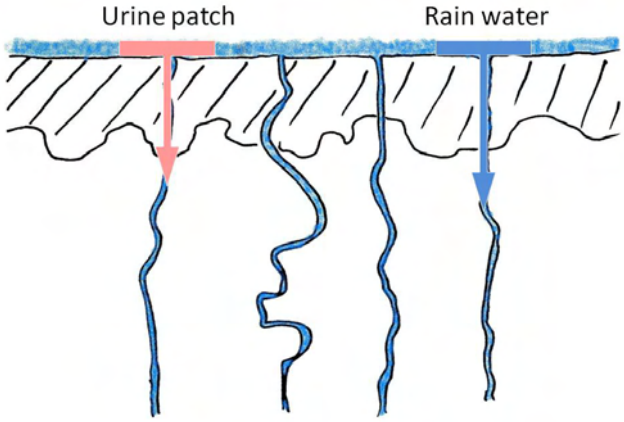

Figure 2. Here again, high rain fall occurred while the soil was close to saturation. Cattle trampling has reduced the finer macropores and increased tortuosity. Rain water will then bypass the soil matrix. This situation leads to a low risk of nitrate leaching. However, a urine patch would then be swiftly transported to the subsoil through preferential flow paths.

Irrigation experiments were performed in third year grass-clover plots with cutting regime or grazing regime (8 heifers per hectares from May to October).

Each plot was irrigated during an hour with 18.5 mm of water containing a non-reactive tracer (bromide). 24 hours after the irrigation, macropores larger than 1 mm were recorded on horizontal plan at five depths, Bromide concentration in soil was analysed at the same depths and the density of earthworm was recorded.

All field work took place in October 2008 at a soil water content corresponding

to field capacity.

Consequences of cattle trampling on water transport downward

The results of the irrigation experiment showed that the concentration of Bromide was significantly larger with the grazing regime than with the cutting regime below 30 cm depth (Figure 4). The amount of water transported downward was larger with the grazing regime, down to at least 1 m depth. The velocity of water transport was higher with the grazing regime, indicating that preferential flow through large macropores happened to a larger extend than for the cutting regime. The rain fall intensity and the soil water potential are two very important factors regarding the occurrence of preferential flow. The combination of an irrigation intensity of 18.5 mm h^{-1} and a soil water potential close to field capacity is a situation observed several times during a year in Denmark.

Density of the largest macropores

We observed equivalent macropore densities between the two treatments, both at 10 and at 30 cm in the soil profile. We have to remember that only the largest macropores were recorded (i. e. larger than 1 mm; per definition a macropore is larger than 30 μm).

The dry bulk density measured at 10 cm depth was significantly larger in the plots with the grazing regime as compared to the plots with the cutting regime (1.48 and 1.54 kg m^{-3}, respectively), indicating a reduction of the porosity at this depth for the plots subjected to cattle trampling.

Earthworm population

A slightly lower earthworm density was recorded in the plots with grazing (Figure 5). Cattle trampling reduced the density of earthworms living in the topsoil. Deep-burrowing species were not affected by cattle trampling. These results are supported by other studies. Cattle trampling affects mainly earthworm species living at the soil surface and in the topsoil (i.e. epigeic and endogeic species, respectively).

Deep-burrowing species (i.e. anecic species) are the less sensitive to cattle trampling, protected in the permanent vertical burrows they produce.

Conclusions

A tracer experiment in the field showed a deeper infiltration of water when the soil was subjected to cattle trampling. It indicates that preferential flow through large macropores occurred, and that rain water may bypass the soil matrix under similar or more extreme conditions than this experiment. We expect such hydraulic functioning to reduce the risk of leaching the nitrate contained in the soil water.

The conclusion drawn from the irrigation experiment was supported by investigations of the porosity and earthworm activity.

Three years of cattle trampling lead to a reduction of porosity in the upper topsoil but did not affect the density of macropores larger than 1 mm in diameter. These macropores are often associated with the activity of earthworms living under the soil surface, especially deep-burrowing species, which are the less sensitive to cattle trampling.

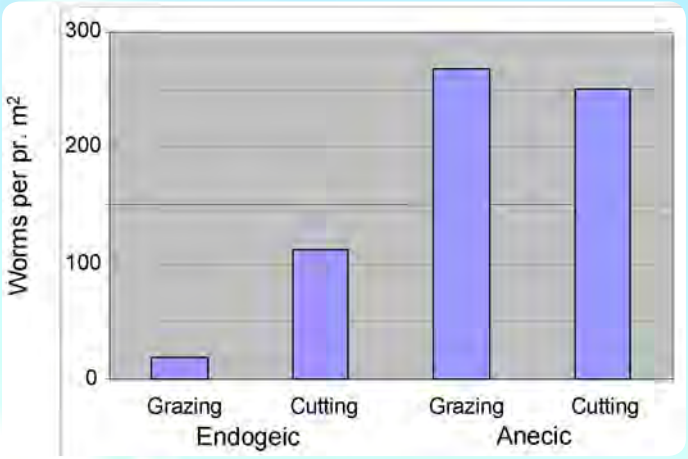

Figure 5. The density of earthworms was slightly lower for the grazing regime than for the cutting regime. Cattle trampling reduced the density of earthworms living in the topsoil. Deep-burrowing species were not affected by cattle trampling.

Read more

You can find more information about the DARCOF III research project OrgGrass on the webpage:

www.icrofs.org/Pages/Research/darcofIII_orggrass.html.

Figure 3. Our hypothesis was that three years of cattle trampling in grass-clover fields could reduce the risk of nitrate leaching in the autumn by enhancing the macropore flows.

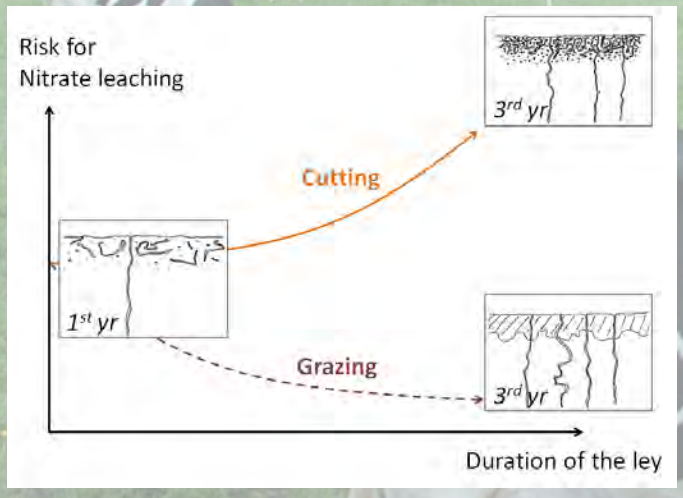

Figure 4. The concentration of Bromide in soil, which is proportional to the amount of irrigation water transported downward, was larger below 30 cm depths for the grazing regime as compared to the cutting regime. Different letters indicate significant differences between the two treatments.