Optimising nitrogen efficiency through improved biological management

Aguilera, E., Lassaletta, L., Sanz-Cobena, A., Garnier, J., & Vallejo, A. (2013). The potential of organic fertilizers and water management to reduce N2O emissions in Mediterranean climate cropping systems. A review. *Agriculture, Ecosystems & Environment*, *164*, 32-52.

Abstract

Environmental problems related to the use of synthetic fertilizers and to organic waste management have led to increased interest in the use of organic materials as an alternative source of nutrients for crops, but this is also associated with N_2O emissions. There has been an increasing amount of research into the effects of using different types of fertilization on N_2O emissions under Mediterranean climatic conditions, but the findings have sometimes been rather contradictory. Available information also suggests that water management could exert a high influence on N_2O emissions. In this context, we have reviewed the current scientific knowledge, including an analysis of the effect of fertilizer type and water management on direct N_2O emissions.

A meta-analysis of compliant reviewed experiments revealed significantly lower N_2O emissions for organic as opposed to synthetic fertilizers (23% reduction). When organic materials were segregated in solid and liquid, only solid organic fertilizer emissions were significantly lower than those of synthetic fertilizers (28% reduction in cumulative emissions). The EF is similar to the IPCC factor in conventionally irrigated systems (0.98% N_2O-N N applied^{-1}), but one order of magnitude lower in rainfed systems (0.08%). Drip irrigation produces intermediate emission levels (0.66%). Differences are driven by Mediterranean agro-climatic characteristics, which include low soil organic matter (SOM) content and a distinctive rainfall and temperature pattern. Interactions between environmental and management factors and the microbial processes involved in N_2O emissions are discussed in detail.

Indirect emissions have not been fully accounted for, but when organic fertilizers are applied at similar N rates to synthetic fertilizers, they generally make smaller contributions to the leached NO_3^- pool. The most promising practices for reducing N_2O through organic fertilization include: (i) minimizing water applications; (ii) minimizing bare soil; (iii) improving waste management; and (iv) tightening N cycling through N immobilization. The mitigation potential may be limited by: (i) residual effect; (ii) the long-term effects of fertilizers on SOM; (iii) lower yield-scaled performance; and (iv) total N availability from organic sources. Knowledge gaps identified in the review included: (i) insufficient sampling periods; (ii) high background emissions; (iii) the need to provide N_2O EF and yield-scaled EF; (iv) the need for more research on specific cropping systems; and (v) the need for full GHG balances.

Asghari HR, Cavagnaro TR (2012) Arbuscular mycorrhizas reduce nitrogen loss via leaching. *PLoS ONE* 7, e29825

Abstract

The capacity of mycorrhizal and non-mycorrhizal root systems to reduce nitrate (NO_3^-) and ammonium (NH_4^+) loss from soils via leaching was investigated in a microcosm-based study. A mycorrhiza defective tomato mutant and its mycorrhizal wildtype progenitor were used in this experiment in order to avoid the indirect effects of establishing non-mycorrhizal control treatments on soil nitrogen cycling and the wider soil biota. Mycorrhizal root systems dramatically reduced nitrate loss (almost 40 times less) via leaching, compared to their non-mycorrhizal counterparts, following a pulse application of ammonium nitrate to experimental microcosms. The capacity of AM to reduce nutrient loss via leaching has received relatively little attention, but as demonstrated here, can be significant. Taken together, these data highlight the need to consider the potential benefits of AM beyond improvements in plant nutrition alone.

Bender, S.F. (1,2) & van Der Heijden, M.G.A. (1,2,3) Soil biota enhance agricultural sustainability by improving crop yield, nutrient uptake and reducing nitrogen leaching losses

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Abstract

Summary

1. Efficient resource use is a key factor for sustainable production and a necessity for meeting future global food demands. However, the factors that control resource use efficiency in agro-ecosystems are only partly understood.

2. We investigated the influence of soil biota on nutrient leaching, nutrient-use efficiency and plant performance in outdoor, open-top lysimeters comprising a volume of 230 L. The lysimeters were filled with sterilized soil in two horizons and inoculated with a reduced soil-life inoculum (soil biota ≤11 lm, microbially dominated) and an enriched soil-life inoculum [soil organisms ≤2 mm, also containing arbuscular mycorrhizal fungi (AMF)]. A crop rotation was planted, and nutrient leaching losses, plant biomass and nutrient contents were assessed over a period of almost 2 years.

3. In the first year of the experiment, enriched soil life increased crop yield (+22%), N uptake (+29%) and P uptake (+110%) of maize and strongly reduced leaching losses of N (_51%, corresponding to a reduction of 76 kg N ha _1). In the second year, wheat biomass (+17%) and P contents (+80%) were significantly increased by enriched soil life, but the differences were lower than in the first year.

4. Enriched soil life also increased P mobilization from soil (+112%) and significantly reduced relative P leaching losses (_25%), defined as g P leached per kg P plant uptake, as well as relative N leaching losses (_36%), defined as kg N leached per kg N plant uptake, demonstrating that nutrient-use efficiency was increased in the enriched soil-life treatment.

5. Synthesis and applications. Soil biota are a key factor determining resource efficiency in agriculture. The results suggest that applying farming practices, which favour a rich and abundant soil life (e.g. reduced tillage, organic farming, crop rotation), can reduce environmental impacts, enhance crop yield and result in a more sustainable agricultural system. However, this needs to be confirmed in field situations. Enhanced nutrient-use efficiency obtained through farming practices which exert positive effects on soil biota could result in reduced amounts of fertilisers needed for agricultural production and reduced nutrient losses to the environment, providing benefits of such practices beyond positive effects on biodiversity

Bhandral, Rita, et al. "Transformation of nitrogen and nitrous oxide emission from grassland soils as affected by compaction." *Soil and Tillage Research* 94.2 (2007): 482-492.

Abstract

Animal trampling is one of the main factors responsible for soil compaction under grazed pastures. Soil compaction is known to change the physical properties of the soil thereby affecting the transformation of nitrogen (N) and the subsequent of release of N as nitrous oxide (N_2O). The form of N source added to these compacted soils further affects N emissions. Here we determine the interactive effects of soil compaction and form of N sources (*cattle* urine and ammonium, *nitrate* and urea *fertilizers*) on the loss of N through N_2O emission from *grassland* soil. Overall, soil compaction caused a seven-fold increase in the N_2O flux, the total N_2O fluxes for the entire experimental period ranged from 2.62 to 61.74 kg N_2O-N ha^{-1} for the compacted soil and 1.12 to 4.37 kg N_2O-N ha^{-1} for the uncompacted soil. Among the N sources, the highest emissions were measured with nitrate application, emissions being 10 times more than those from other N sources for compacted soil, suggesting that the choice of N fertilizer can go a long way in mitigating N_2O emissions in compacted grasslands.

Burger, M., & Jackson, L. E. (2003). Microbial immobilization of ammonium and nitrate in relation to ammonification and nitrification rates in organic and conventional cropping systems. *Soil Biology and Biochemistry*, *35*(1), 29-36.

Abstract

Agricultural systems that receive high or low organic matter (OM) inputs would be expected to differ in soil nitrogen (N) transformation rates and fates of ammonium (NH_4^+) and nitrate (NO_3^-). To compare NH_4^+ availability, competition between nitrifiers and heterotrophic microorganisms for NH_4^+, and microbial NO_3^- assimilation in an organic vs. a conventional irrigated cropping system in the California Central Valley, chemical and biological soil assays, ^{15}N isotope pool dilution and ^{15}N tracer techniques were used. Potentially mineralizable N (PMN) and hot minus cold KCl-extracted NH_4^+ as indicators of soil N supplying capacity were measured five times during the tomato growing season. At mid-season, rates of gross ammonification and gross nitrification after rewetting dry soil were measured in microcosms. Microbial immobilization of NO_3^- and NH_4^+ was estimated

based on the uptake of ^{15}N and gross consumption rates. Gross ammonification, PMN, and hot minus cold KCl-extracted NH_4^+ were approximately twice as high in the organically than the conventionally managed soil. Net estimated microbial NO_3^- assimilation rates were between 32 and 35% of gross nitrification rates in the conventional and between 37 and 46% in the organic system. In both soils, microbes assimilated more NO_3^- than NH_4^+. Heterotrophic microbes assimilated less NH_4^+ than NO_3^- probably because NH_4^+ concentrations were low and competition by nitrifiers was apparently strong. The high OM input organic system released NH_4^+ in a gradual manner and, compared to the low OM input conventional system, supported a more active microbial biomass with greater N demand that was met mainly by NO_3^- immobilization.

Calderon, Francisco J., et al. "Short-term dynamics of nitrogen, microbial activity, and phospholipid fatty acids after tillage." *Soil Science Society of America Journal* 65.1 (2001): 118-126.

Abstract

Little is known about the short-term effects (hours to days) of tillage on labile pools of C and N, or microbial activity and community composition. We examined the effects of rototillage on microbial biomass C (MBC) and N (MBN), respiration (i.e., soil CO_2 production in 1-h incubations), CO_2 efflux from the soil surface, inorganic N, nitrification potential, denitrification rate, and phospholipid fatty acids (PLFA). A fallow silt loam soil was rototilled in the field and soil cores were immediately obtained from tilled and adjacent control soils. The soil cores were then incubated at constant temperature and sampled throughout a 2-wk period. Tilled soil had higher CO_2 efflux than the control soil. This increase occurred immediately after tillage and lasted for 4 d. Respiration was similar in both soils until the fourth day after tillage, and then declined in the tilled soil. Tilled soil showed increases in MBN, nitrate, and denitrification rates, suggesting that tillage makes available previously protected organic N. The overall reduction in respiration together with the lack of response in MBC, however, suggests that tillage did not make available significant amounts of readily decomposable C. These combined C and N dynamics suggest that low C/N ratio compounds may have been mineralized following tillage. Denitrification rates increased in the tilled soil even though the bulk of the soil had reduced respiration and bulk density. Tillage caused temporary changes in PLFA profiles, suggesting changes in soil microbial community structure. Phospholipid fatty acid 18:1 ω7t, which marks the presence of eubacteria, decreased in the tilled soil. In contrast, 19:0 cy, a marker for anaerobic eubacteria, increased in the tilled soil. Our results show that tillage causes short-term changes in nutrient dynamics that may potentially result in N losses through denitrification and nitrate leaching, as well as C losses through degassing of dissolved CO_2 These changes are accompanied by concomitant shifts in microbial community structure, suggesting a possible relationship between microbial composition and ecosystem function.

Chivenge, Pauline, Bernard Vanlauwe, and Johan Six. "Does the combined application of organic and mineral nutrient sources influence maize productivity? A meta-analysis." *Plant and Soil* 342.1-2 (2011): 1-30.

Abstract

The combined application of organic resources (ORs) and mineral fertilizers is increasingly gaining recognition as a viable approach to address soil fertility decline in sub-Saharan Africa (SSA). We conducted a meta-analysis to provide a comprehensive and quantitative synthesis of conditions under which ORs, N fertilizers, and combined ORs with N fertilizers positively or negatively influence *Zea mays* (maize) yields, agronomic N use efficiency and soil organic C (SOC) in SSA. Four OR quality classes were assessed; classes I (high quality) and II (intermediate quality) had >2.5% N while classes III (intermediate quality) and IV (low quality) had <2.5% N and classes I and III had <4% polyphenol and <15% lignin. On the average, yield responses over the control were 60%, 84% and 114% following the addition of ORs, N fertilizers and ORs + N fertilizers, respectively. There was a general increase in yield responses with increasing OR quality and OR-N quantity, both when ORs were added alone or with N fertilizers. Surprisingly, greater OR residual effects were observed with high quality ORs and declined with decreasing OR quality. The greater yield responses with ORs + N fertilizers than either resource alone were mostly due to extra N added and not improved N utilization efficiency because negative interactive effects were, most often, observed when combining ORs with N fertilizers. Additionally, their agronomic N use efficiency was not different from sole added ORs but lower than N fertilizers added alone. Nevertheless, positive interactive effects were observed in sandy soils with low quality ORs whereas agronomic use efficiency was greater when smaller quantities of N were added in all soils. Compared to sole added ORs, yield responses for the combined treatment increased with decreasing OR quality and greater yield increases were observed in sandy (68%) than clayey soils (25%). While ORs and ORs + N fertilizer additions increased SOC by at least 12% compared to the control, N fertilizer additions were not different from control suggesting that ORs are needed to increase SOC. Thus, the addition of ORs will likely improve nutrient storage while crop yields are increased and more so for high quality ORs. Furthermore, interactive effects are seldom occurring, but agronomic N use efficiency of ORs + N fertilizers were greater with low quantities of N added, offering potential for increasing crop productivity.

Constantin, J., Mary, B., Laurent, F., Aubrion, G., Fontaine, A., Kerveillant, P. and Beaudoin, N. (2010) Effects of catch crops, no till and reduced nitrogen fertilization on nitrogen leaching and balance in three long-term experiments. Agric Ecosyst Environ 135:268–278

Abstract
Improved agricultural practices are encouraged to reduce nitrate leaching and greenhouse gas emissions. However, the effects of these practices are often studied at annual or rotation scale without considering their long-term impacts. We have evaluated the effects of catch crops (CC), no-till (NT) and reduced nitrogen fertilization (N−) on nitrogen fate in soil–plant system during 13–17 years in three experiments in Northern France. CC were present in all sites whereas tillage treatment and N fertilization rate were tested separately at one site. Crop biomass, N uptake and N leaching were monitored during the whole period. The N balance, i.e. the difference between N inputs and crop exportations, was only affected by fertilization rate whereas leached N varied with all techniques. CC was the most efficient technique to decrease N leaching (from 36 to 62%) and remained efficient on the long term. NT and N− had a positive but smaller impact. N storage in soil organic matter was markedly increased by CC (by 10–24 kg ha^{-1} yr^{-1}), decreased by N− (−7.3 kg ha^{-1} yr^{-1}) and not significantly affected by NT. The differences in gaseous N losses (denitrification + volatilization) between treatments were assessed by nitrogen mass balance. CC establishment had no significant effect on N gaseous emissions while NT increased them by 3.6 ± 0.9 kg N ha^{-1} yr^{-1} and N− reduced them by 13.6 ± 4.6 kg N ha^{-1} yr^{-1}. Catch crops appear as a win/win technique with respect to nitrate leaching and C and N sequestration in soil.

Denef, K., Roobroeck, D., Wadu, M. C. M., Lootens, P., & Boeckx, P. (2009). Microbial community composition and rhizodeposit-carbon assimilation in differently managed temperate grassland soils. *Soil Biology and Biochemistry*, *41*(1), 144-153.

Abstract
Rhizodeposit-carbon provides a major energy source for microbial growth in the rhizosphere of grassland soils. However, little is known about the microbial communities that mediate the rhizosphere carbon dynamics, especially how their activity is influenced by changes in soil management. We combined a $^{13}CO_2$ pulse-labeling experiment with phospholipid fatty acid (PLFA) analysis in differently managed Belgian grasslands to identify the active rhizodeposit-C assimilating microbial communities in these grasslands and to evaluate their response to management practices. Experimental treatments consisted of three mineral N fertilization levels (0, 225 and 450 kg N ha^{-1} y^{-1}) and two mowing frequencies (3 and 5 times y^{-1}). In the non-fertilized treatment, the greatest ^{13}C enrichment was seen in all fungal biomarker PLFAs (C16:1ω5, C18:1ω9, C18:2ω6,9 and C18:3ω3,6,9), which demonstrates a prominent contribution of fungi in the processing of new photosynthate-C in non-fertilized grassland soils. In all treatments, the lowest ^{13}C enrichment was found in gram-positive bacterial and actinomycetes biomarker PLFAs. Fungal biomarker PLFAs had significantly lower ^{13}C enrichment in the fertilized compared to non-fertilized treatments in BU soil (C16:1ω5, C18:1ω9) as well as RA soil (all fungal biomarkers). While these observations clearly indicated a negative effect of N fertilization on fungal assimilation of plant-derived C, the effect of N fertilization on fungal abundance could only be detected for the arbuscular mycorrhizal fungal (AMF) PLFA (C16:1ω5). On the other hand, increases in the relative abundance of gram-positive bacterial PLFAs with N fertilization were found without concomitant increases in ^{13}C enrichment following pulse-labeling. We conclude that *in situ* ^{13}C pulse-labeling of PLFAs is an effective tool to detect functional changes of those microbial communities that are dominantly involved in the immediate processing of new rhizosphere-C.

De Vries, F. T., Hoffland, E., van Eekeren, N., Brussaard, L., & Bloem, J. (2006). Fungal/bacterial ratios in grasslands with contrasting nitrogen management. *Soil Biology and Biochemistry*, *38*(8), 2092-2103.

Abstract
It is frequently hypothesised that high soil fungal/bacterial ratios are indicative for more sustainable agricultural systems. Increased F / B F/B ratios have been reported in extensively managed grasslands. To determine the shifts in fungal/bacterial biomass ratio as influenced by grassland management and to find relations with nitrogen leaching potential, we sampled a two-year-old field experiment at an organic experimental farm in the eastern part of The Netherlands. The effect of crop (grass and grass-clover), N application rate (0, 40, 80,) and manure type (no manure, farm yard manure and slurry) on the F / B F/B ratio within three growing seasons was tested, as well as relations with soil and crop characteristics, nitrate leaching and partial N balance. Biomass of fungi and bacteria was calculated after direct counts using epifluorescence microscopy. Fungal and bacterial biomass and the F / B F/B ratio were higher in grass than in grass-clover. The F / B F/B ratio decreased with increasing N application rate and multiple regression analysis revealed a negative relationship with pH. Bacterial activity (measured as incorporation of [^{3}H]thymidine and [^{14}C]leucine into bacterial DNA and proteins) showed the exact opposite: an increase with N application rate and pH. Leaching

increased with N application rate and was higher in grass-clover than in grass. Partial N balance was more positive at a higher N application rate and showed an inverse relationship with fungal biomass and F / B F/B ratio. We conclude that the fungal/bacterial biomass ratio quickly responded to changes in management. Grasslands with higher N input showed lower F / B F/B ratios. Grass-clover had a smaller fungal biomass and higher N leaching than grass. In general, a higher fungal biomass indicated a lower nitrogen leaching and a more negative partial N balance (or smaller N surplus), but more observations are needed to confirm the relationship between F / B F/B ratio and sustainability.

De Vries, F. T., Liiri, M. E., Bjørnlund, L., Bowker, M. A., Christensen, S., Setälä, H. M., & Bardgett, R. D. (2012). Land use alters the resistance and resilience of soil food webs to drought. *Nature Climate Change*, *2*(4), 276-280

Abstract

Soils deliver several ecosystem services including carbon sequestration and nutrient cycling, which are of central importance to climate mitigation and sustainable food production. Soil biota play an important role in carbon and nitrogen cycling, and, although the effects of land use on soil food webs are well documented, the consequences for their resistance and resilience to climate change are not known. We compared the resistance and resilience to drought—which is predicted to increase under climate change[2, 7]—of soil food webs of two common land-use systems: intensively managed wheat with a bacterial-based soil food web and extensively managed grassland with a fungal-based soil food web. We found that the fungal-based food web, and the processes of C and N loss it governs, of grassland soil was more resistant, although not resilient, and better able to adapt to drought than the bacterial-based food web of wheat soil. Structural equation modelling revealed that fungal-based soil food webs and greater microbial evenness mitigated C and N loss. Our findings show that land use strongly affects the resistance and resilience of soil food webs to climate change, and that extensively managed grassland promotes more resistant, and adaptable, fungal-based soil food webs.

Deurer, M., Grinev, D., Young, I., Clothier, B.E. and Müller, K. (2009). The impact of soil carbon management on soil macropore structure: a comparison of two apple orchard systems in New Zealand. *European Journal of Soil Science* Volume 60, Issue 6, pages 945–955

Summary

We analysed the long-term effect of the addition of organic carbon (C) on the macropore structure of topsoils. For this purpose we compared the top 50 mm in the tree rows of an organic apple orchard with those in an adjacent conventional orchard with the same soil type, texture and previous land-use history in New Zealand. After 12 years the topsoils of the organic orchard had 32% more soil organic carbon (SOC) sequestered than those of the conventional, integrated orchard because of regular compost applications and grass coverage. We quantified the macropore structure (macropores = pores > 0.3 mm) of nine undisturbed soil columns (43 mm long, 20 × 17 mm in the plane) within each orchard using 3D X-ray computed tomography. The macroporosity (7.5 ± 2.1%) of the organic orchard soil was significantly greater than that of the integrated orchard (2.4 ± 0.5%). The mean macropore radius was similar in the organic and integrated systems, with 0.41 ± 0.02 mm and 0.39 ± 0.01 mm, respectively. The connectivity of macropores tended to be greater in the organic than in the integrated system, but this was not statistically significant. The pronounced soil C management in the organic orchard increased both the formation of macropores by roots and a larger fresh weight of anecic earthworms, and the stabilization of the macropore structure was increased by a larger aggregate stability and microbial biomass compared with those of the integrated orchard. We simulated the diffusion through the measured pore structures of segments of the soil columns. The segments had the length of the mean aggregate size of the soils. The relative diffusion coefficients at this aggregate scale were significantly greater in the organic (0.024 ± 0.0009) than in the integrated (0.0056 ± 0.008) orchard. In a regression analysis with both the porosity and connectivity of macropores as significant variables, 76% of the variability of the relative diffusion coefficients was explained in the integrated, and, with the porosity as the only significant factor, 71% of the variability in the organic orchard. We hypothesize that a greater relative diffusion coefficient at the aggregate scale would reduce nitrous oxide (N_2O) production and emission in a wet soil and suggest that soil C management combats climate change directly by sequestering C and indirectly in the form of a reduction of N_2O emissions, by creating more macropores.

Fonte, S. J., Yeboah, E., Ofori, P., Quansah, G. W., Vanlauwe, B., & Six, J. (2009). Fertilizer and residue quality effects on organic matter stabilization in soil aggregates. *Soil Science Society of America Journal*, *73*(3), 961-966.

Abstract

This study examined the influence of organic residue quality and N fertilizer on aggregate-associated soil organic matter (SOM) in maize (*Zea mays* L.) cropping systems of southern Ghana. Six residue treatments of differing quality [*Crotalaria juncea* L., *Leucaena leucocephala* (Lam.) de Wit, maize stover, sawdust, cattle manure, and a control with no residues added] were applied at 4 Mg C ha^{-1} yr^{-1} both with and without fertilizer N additions (120 kg N ha^{-1} $season^{-1}$). Soils (0–15 cm) were sampled 3 yr after study implementation and wet sieved into four aggregate size classes (8000–2000, 2000–250, 250–53, and <53 µm). Small macroaggregates (2000–250 µm) were further separated into coarse particulate organic matter (>250 µm), microaggregates within macroaggregates (53–250 µm), and macroaggregate-occluded silt and clay (<53 µm). Nitrogen fertilizer additions reduced aggregate stability, as was evident from a 40% increase in the weight of the silt and clay fraction ($P = 0.014$) as well as a decrease in microaggregates across all residue types ($P = 0.019$). Fertilizer similarly affected C and N storage within these aggregate fractions, while the effects of residue quality were largely insignificant. Our results suggest that fertilizer effects on soil aggregation may have important implications for long-term SOM dynamics.

Gourley, C. J., Dougherty, W., Aarons, S., & Kelly, K. Improving nitrogen use efficiency: from plant to dairy paddock. www.massey.ac.nz/~flrc/workshops/14/Manuscripts/Paper_Gourley_2014.pdf

Abstract

At a global scale, human activity has increased the flux of N two-fold (Vitousek *et al*. 1997), particularly driven by large scale fertiliser manufacturing (Fowler et al. 2013). Additionally, the ability to transport inputs and outputs cheaply and extensively has led to substantial growth in agricultural production over the past 50 years with an accompanying 40% increase in world population and extensive urbanisation. However, this has also lead to a spatial disconnection between nitrogen flows required for agricultural production systems and reduced incentives to capture and recycle nitrogen at the farm scale. Moreover, agricultural production systems are inherently in efficiency at capturing nitrogen, with excess nitrogen dissipated into the broader environment. Of the total N applied to agricultural land worldwide only 5–15% is eventually transformed into human food (Erisman *et al*., 2012). In cropping systems nitrogen use efficiency (NUE) will often range between 35 – 65%, while in more intensive animal systems such as dairy production, NUE will typically range from 15 – 35% (Powell *et al.* 2010). Major pathways of agricultural N loss to the environment are gaseous emission of ammonia and nitrous oxide, and the leaching of nitrate through soil, with various transformations causing a cascade of potential environmental problems (Galloway *et al.* 2008). In the past decade, measuring losses for nitrous oxide and the effectiveness of mitigation strategies have received considerable attention due to a policy focus on greenhouse gas emissions. In contrast, grazing based dairy farms in Australia and New Zealand have been encouraged to increase production through greater reliance on imported feed and fertiliser (Thorold and Doyle 2007), with likely greater nitrogen losses per ha. Growing societal expectations for air and water quality, stricter standards from international markets, and increasing costs for purchased nitrogen will mean that improving NUE and reducing nutrient losses will be a necessary part of agricultural production systems. This is likely to require difficult choices to better balance production and environmental goals, particularly for intensive livestock industries such as dairy production.

Griffiths, B. S. (1994). Microbial-feeding nematodes and protozoa in soil: Their effects on microbial activity and nitrogen mineralization in decomposition hotspots and the rhizosphere. *Plant and Soil*, *164*(1), 25-33.

Abstract

Food web studies from a range of ecosystems have demonstrated that the fauna contributes about 30% of total net nitrogen mineralization. This results mainly from the activities of microbial-feeding microfauna (nematodes and protozoa). Microbial and microfaunal activity is concentrated at spatially discrete and heterogeneously distributed organic substrates, including the rhizosphere. The dynamics of microfauna and their effect on nutrient cycling and microbial processes at these sites is reviewed. The potential manipulation of microfauna, either as an experimental tool to further understand soil microbial ecology or as a practical means of managing nutrient flows in agroecosystems, is discussed.

Hernández-Hernández, R. M., & D. López-Hernández. "Microbial biomass, mineral nitrogen and carbon content in savanna soil aggregates under conventional and no-tillage." *Soil Biology and Biochemistry* 34.11 (2002): 1563-1570.

Abstract

In the Tropics, few studies have considered the size and quality of the active compartment of the soil organic matter (SOM) associated with soil aggregates and the concomitant changes induced by tillage management. The main objectives of this study were firstly to determine the distribution of nitrogen (N) and carbon (C) of the microbial biomass (MB) in the aggregates of savanna soils under conventional tillage (CT) and no-tillage (NT). Secondly, to examine the importance of MB in the maintenance of water stable aggregates in savanna derived soils during the two contrasting climatic seasons. Samples taken at a depth of 0–5 and 5–10 cm were collected from a cultivated ultisol under CT for 13 years and another under CT for 8 years followed by 5 years under NT. A native savanna (NS) was used as control. Sampling was in April and September corresponding to the dry and rainy seasons, respectively. A drastic decrease in water stable macroaggregates was observed in the cultivated soils compared to NS. The decrease was more accentuated in the case of CT vs NS during the rainy season (92.3 vs 38.8%), whereas it was of lesser extent in the case of NT (92.3 vs 64.5%). Savanna and NT soils had a higher proportion of macroaggregates than microaggregates, but a reverse situation occurred in the soil under CT. Microbial C and N contents were consistently higher in the macroaggregates than in the microaggregates. Soil aggregates under CT did not show changes in MB in both seasons. Within microaggregates, microbial and mineral N was not significantly affected by intensity of tillage, whereas in macroaggregates variation in MB was affected by both the tillage and the season in the NT soil. The use of NT in degraded savanna ecosystems under intensive cereal cropping and subjected to strong wet–dry changes caused by the two season climate seems to be promising since it improves the SOM and increases the structural stability which are crucial aspects of the agroecosystem's functioning.

Huber, D.M. Emeritus Professor, Purdue University. Ag Chemical and Crop Nutrient Interactions-current update. *Proc. Fluid Fert Forum, Scottsdale, AZ* Vol. 27.2010

Abstract

Micronutrients are regulators, inhibitors and activators of physiological processes, and plants provide a primary dietary source of these elements for animals and people. Micronutrient deficiency symptoms are often indistinct (“hidden hunger”) and commonly ascribed to other causes such as drought, extreme temperatures, soil pH, etc. The sporadic nature of distinct visual symptoms, except under severe deficiency conditions, has resulted in a reluctance of many producers to remediate micronutrient deficiency. Lost yield, reduced quality, and increased disease are the unfortunate consequences of untreated micronutrient deficiency.

The shift to less tillage, herbicide resistant crops and extensive application of glyphosate has significantly changed nutrient availability and plant efficiency for a number of essential plant nutrients. Some of these changes are through direct toxicity of glyphosate while others are more indirect through changes in soil organisms important for nutrient access, availability, or plant uptake. Compensation for these effects on nutrition can maintain optimum crop production efficiency, maximize yield, improve disease resistance, increase nutritional value, and insure food and feed safety.

Humphreys, J., O’connell, K., & Casey, I. A. (2008). Nitrogen flows and balances in four grassland-based systems of dairy production on a clay-loam soil in a moist temperate climate. *Grass and Forage Science*, *63*(4), 467-480.

Abstract

This study examined productivity, nitrogen (N) flows and N balances in grassland-based systems of dairy production in Ireland. There were four stocking densities of dairy cows on grass/white clover pastures and four inputs of N as fertilizers, concentrates and biological fixation over 2 years; 2001 and 2002. Annual stocking densities were 1·75, 2·10, 2·50 and 2·50 cows ha^{-1}. Associated N inputs were 205, 230, 300 and 400 kg ha^{-1} respectively. There were eighteen cows per system. Cows calved within a 12-week interval in spring with a mean calving date of 28 February and lactation extended until mid-December in each year. There were no differences in annual milk yield (6337 kg cow^{-1}; s.e.m. 106·1), live weight or body condition score. Pre-grazing N concentrations in herbage increased ($P < 0{\cdot}001$) with increasing N input, whereas there were no differences in N concentrations in silage reflecting optimum N inputs for silage production. Grazed herbage accounted for 0·64, silage 0·26 and concentrates 0·10 of annual dry matter consumed by the cows. Annual intakes of N ranged from 144 to 158 kg cow^{-1} and were mostly influenced by N concentration in grazed herbage. Annual output of N in milk and liveweight change was 38 kg cow^{-1} and was not different between systems. Annual N surpluses increased with increasing N inputs from 137 to 307 kg ha^{-1}, whereas the proportion of N inputs recovered in products declined from 0·34 to 0·24. More efficient N use was associated with lower N inputs and in particular lower N concentrations in grazed herbage.

Khan, S. A., Mulvaney, R. L., Ellsworth, T. R., & Boast, C. W. (2007). The myth of nitrogen fertilization for soil carbon sequestration. *Journal of Environmental Quality*, *36*(6), 1821-1832.

Abstract

Intensive use of N fertilizers in modern agriculture is motivated by the economic value of high grain yields and is generally perceived to sequester soil organic C by increasing the input of crop residues. This perception is at odds with a century of soil organic C data reported herein for the Morrow Plots, the world's oldest experimental site under continuous corn (*Zea mays* L.). After 40 to 50 yr of synthetic fertilization that exceeded grain N removal by 60 to 190%, a net decline occurred in soil C despite increasingly massive residue C incorporation, the decline being more extensive for a corn–soybean (*Glycine max* L. Merr.) or corn–oats (*Avena sativa* L.)–hay rotation than for continuous corn and of greater intensity for the profile (0–46 cm) than the surface soil. These findings implicate fertilizer N in promoting the decomposition of crop residues and soil organic matter and are consistent with data from numerous cropping experiments involving synthetic N fertilization in the USA Corn Belt and elsewhere, although not with the interpretation usually provided. There are important implications for soil C sequestration because the yield-based input of fertilizer N has commonly exceeded grain N removal for corn production on fertile soils since the 1960s. To mitigate the ongoing consequences of soil deterioration, atmospheric CO_2 enrichment, and NO_3^- pollution of ground and surface waters, N fertilization should be managed by site-specific assessment of soil N availability. Current fertilizer N management practices, if combined with corn stover removal for bioenergy production, exacerbate soil C loss.

Kong, A. Y., Fonte, S. J., van Kessel, C., & Six, J. (2007). Soil aggregates control N cycling efficiency in long-term conventional and alternative cropping systems. *Nutrient Cycling in Agroecosystems*, *79*(1), 45-58.

Abstract

This paper presents novel data illustrating how soil aggregates control nitrogen (N) dynamics within conventional and alternative Mediterranean cropping systems. An experiment with ^{15}N-labeled cover crop residue and synthetic fertilizer was conducted in long-term (11 years) maize–tomato rotations: conventional (synthetic N only), low-input (reduced synthetic and cover crop-N), and organic (composted manure- and cover crop-N). Soil and nitrous oxide (N_2O) samples were collected throughout the maize growing season. Soil samples were separated into three aggregate size classes. We observed a trend of shorter mean residence times in the silt-and-clay fraction than macro- (>250 μm) and microaggregate fractions (53–250 μm). The majority of synthetic fertilizer-derived ^{15}N in the conventional system was associated with the silt-and-clay fraction (<53 μm), which showed shorter mean residence times (2.6 months) than cover crop-derived ^{15}N in the silt-and-clay fractions in the low-input (14.5 months) and organic systems (18.3 months). This, combined with greater N_2O fluxes and low fertilizer-N recoveries in both the soil and the crop, suggest that rapid aggregate-N turnover induced greater N losses and reduced the retention of synthetic fertilizer-N in the conventional system. The organic system, which received 11 years of organic amendments, sequestered soil organic carbon (SOC) and soil N, whereas the conventional and low-input systems merely maintained SOC and soil N levels. Nevertheless, the low-input system showed the highest yield per unit of N applied. Our data suggests that the alternating application of cover crop-N and synthetic fertilizer-N in the low-input system accelerates aggregate-N turnover in comparison to the organic system, thereby, leading to tradeoffs among N loss, benefits of organic amendments to SOC and soil N sequestration, and N availability for plant uptake.

Korsaeth, A. & Eltun, R. (2000) Nitrogen mass balances in conventional, integrated and ecological cropping systems and the relationship between balance calculations and nitrogen runoff in an 8-year field experiment in Norway. Agriculture, Ecosystems & Environment Volume 79, Issues 2–3, Pages 199–214

Abstract

For a cropping system to be sustainable, should not only the soil nitrogen (N) content be preserved but also the N runoff be minimised. Finding a simple but robust way to estimate N runoff would thus be a great advantage when evaluating cropping systems. In this study all major N flows in six different cropping systems, each covering 0.18 ha of a separately pipe drained field lysimeter, located in southeast Norway, were either measured or estimated over a period of 8-years. The effect of the cropping system on the soil N content was evaluated using mass balances of total N, and the usefulness of such N balances to predict N runoff (total N losses via drainage and surface water) was investigated. The experiment included systems with conventional arable cropping (CON-A), integrated arable-cropping (INT-A), ecological arable cropping (ECO-A), conventional forage cropping (CON-F), integrated forage cropping (INT-F), and ecological forage cropping (ECO-F). All the arable cropping systems resulted in a net reduction in the calculated soil N pool, and the reduction increased with decreasing N input. The only system, which did not

alter the soil N content, was CON-F. The largest net reduction was estimated for ECO-A and ECO-F, which averaged 45 and 43 kg N ha^{-1} per year, respectively. The N runoff from the systems was in the range of 18–35 kg N ha^{-1} per year, with highest losses from the two conventional and lowest from the two ecological systems and INT-F. The forage systems had lower N runoff than the arable systems. The INT-F system appeared to be the most favourable system in terms of both soil N balance and N runoff.
The annual precipitation and the precipitation from the previous year were used as predictors in a linear regression model, 87 and 65% of the variation in N runoff could be explained from the arable and forage cropping systems, respectively. The average N balance calculated for all years, on its own predicted 86% of the variation in N runoff from the arable systems. Mass N balances were thus found to be a useful tool for predicting N runoff, especially in systems with mainly arable crops.

Kramer, A. W., Doane, T. A., Horwath, W. R., & Kessel, C. V. (2002). Combining fertilizer and organic inputs to synchronize N supply in alternative cropping systems in California. *Agriculture, ecosystems & environment*, *91*(1), 233-243.

Abstract

One of the principal aims of alternative cropping systems is to minimize excessive loss of N while maximizing N use efficiency and meeting crop N requirements. Many such cropping systems substitute intensive application of synthetic fertilizer with organic inputs, such as N2-fixing legumes. The effectiveness of legume residues as a N source for subsequent crops depends heavily on temporal N release from the residue during the growing season. A field experiment with ^{15}N-labeled fertilizer and ^{15}N-labeled vetch residue was conducted to determine the temporal pattern of N release from both sources in conventional and alternative cropping systems in California. The experiment was conducted within conventional (fertilizer), low-input (fertilizer and organic N), and organic (organic N only) cropping systems established 9 year previously. Availability of N from the labeled inputs was determined based on uptake by maize (Zeamays L.). Uptake of total N and $^{15}N$by maize in each cropping system was monitored at 10 day intervals from 50 to 90 days after seeding for determination of uptake rates. Uptake of N from fertilizer in the conventional system was greater than uptake of N from vetch in the low-input and organic systems. Uptake of N from vetch was delayed, but with a sustained availability later in the season. Uptake rates of N from fertilizer peaked at 4.3 kg N ha−1 per day between 70 and 80 days while those from vetch residue reached a maximum of 0.6 kg N ha−1 per day during the same time period. Grain and N yield at harvest did not differ between cropping systems despite different temporal and quantitative availability of N from organic and inorganic N inputs. This demonstrates that optimum yields can be achieved under management which uses alternative sources of N and can successfully match N availability with crop uptake.

Ledgard, F. F. Nitrogen cycling in low input legume-based agriculture, with emphasis on legume/grass pastures . Plant and Soil. Volume 228, Number 1 (2001), 43-59

Abstract

Low input legume-based agriculture exists in a continuum between subsistence farming and intensive arable and pastoral systems. This review covers this range, but with most emphasis on temperate legume/grass pastures under grazing by livestock. Key determinants of nitrogen (N) flows in grazed legume/grass pastures are: inputs of N from symbiotic N2 fixation which are constrained through self-regulation via grass/legume interactions; large quantities of N cycling through grazing animals with localised return in excreta; low direct conversion of pasture N into produce (typically 5–20%) but with N recycling under intensive grazing the farm efficiency of product N: fixed N can be up to 50%; and regulation of N flows by mineralisation/immobilisation reactions. Pastoral systems reliant solely on fixed N are capable of moderate-high production with modest N losses e.g. average denitrification and leaching losses from grazed pastures of 6 and 23 kg N ha–1 yr–1. Methods for improving efficiency of N cycling in legume-based cropping and legume/grass pasture systems are discussed. In legume/arable rotations, the utilisation of fixed N by crops is influenced greatly by the timing of management practices for synchrony of N supply via mineralisation and crop N uptake. In legume/grass pastures, the spatial return of excreta and the uptake of excreta N by pastures can potentially be improved through dietary manipulation and management strategies. Plant species selection and plant constituent modification also offer the potential to increase N efficiency through greater conversion into animal produce, improved N uptake from soil and manipulation of mineralisation/immobilisation/nitrification reactions.

Lipiec, J., and W. Stepniewski. "Effects of soil compaction and tillage systems on uptake and losses of nutrients." *Soil and Tillage Research* 35.1 (1995): 37-52.

Abstract

In the framework of research on the environmental consequences of soil compaction, the impact of soil compaction and tillage systems on uptake and losses of nutrients, in particular nitrogen, are discussed. Evidence is presented to indicate interactive relationships between the amount of soil compaction, root growth, soil water and soil aeration status, and nutrient supply and uptake by plants. The importance of soil structure and pore size distribution in influencing the transport of nutrients in compacted soil is illustrated. Emphasis is given to the negative effects of soil compaction on components of the environment due to nutrient leaching, surface runoff and gaseous losses to the atmosphere.

Magesan, G. G., & McFadden, G. (2012). Nutrient leaching under conventional and biological dairy farming systems. *Advanced Nutrient Management: Gains from the Past-Goals for the Future. (Eds LD Currie and C L. Christensen). http://flrc. massey. ac. nz/publications. html. Occasional Report*, (25).

Summary

Accepted modern farming practises with outcomes such as steadily increasing animal numbers, high utilisation of pastures, and heavier use of fertiliser nitrogen, often appear at odds with farmers‟ notions of a healthy farming enterprise. An increasing number of farmers are not only questioning the accepted outcomes, but also implementing practises that are aligned to biological farming principles. These farmers have observed many benefits.

However, a scientific understanding is essential to ensure that these changes are real, not short term. Obtaining reliable measurements of unsaturated water and nutrient fluxes has been difficult in the past but new devices such as drainage flux meters offer a cost effective and reliable way of obtaining such measurements (Green et al. 2010).

The preliminary results from nutrient leaching studies are promising.

Our preliminary results from two experimental sites showed that, in general, the biological farms had significantly lower nitrate concentrations than the conventional farms in both farms. In Edgecumbe site, which had biological farming for a longer period, the leaching of dissolved organic carbon was greater in the biological farm than in the conventional farm.

Mulvaney, R. L., S. A. Khan, and T. R. Ellsworth. "Synthetic nitrogen fertilizers deplete soil nitrogen: a global dilemma for sustainable cereal production." *Journal of Environmental Quality* 38.6 (2009): 2295-2314.

Abstract

Cereal production that now sustains a world population of more than 6.5 billion has tripled during the past 40 yr, concurrent with an increase from 12 to 104 Tg yr^{-1} of synthetic N applied largely in ammoniacal fertilizers. These fertilizers have been managed as a cost-effective form of insurance against low yields, without regard to the inherent effect of mineral N in promoting microbial C utilization. Such an effect is consistent with a net loss of soil organic C recently observed for the Morrow Plots, America's oldest experiment field, after 40 to 50 yr of synthetic N fertilization that substantially exceeded grain N removal. A similar decline in total soil N is reported herein for the same site and would be expected from the predominantly organic occurrence of soil N. This decline is in agreement with numerous long-term baseline data sets from chemical-based cropping systems involving a wide variety of soils, geographic regions, and tillage practices. The loss of organic N decreases soil productivity and the agronomic efficiency (kg grain kg^{-1} N) of fertilizer N and has been implicated in widespread reports of yield stagnation or even decline for grain production in Asia. A major global evaluation of current cereal production systems should be undertaken, with a view toward using scientific and technological advances to increase input efficiencies. As one aspect of this strategy, the input of ammoniacal N should be more accurately matched to crop N requirement. Long-term sustainability may require agricultural diversification involving a gradual transition from intensive synthetic N inputs to legume-based crop rotations.

Oquist, K. A., J. S. Strock, and D. J. Mulla. "Influence of alternative and conventional farming practices on subsurface drainage and water quality." *Journal of Environmental Quality* 36.4 (2007): 1194-1204.

Abstract

Agricultural runoff contributes nutrients to nonpoint-source pollution of surface waters. This study was conducted to investigate the potential use of alternative farming practices to improve water quality. The study examined the effects of both alternative and conventional farming practices on subsurface drainage and nitrogen and phosphorus loss through subsurface drainage from glacial till soils (i.e., Calciaquolls, Endoaquolls, Eutrudepts, Hapludolls) in southwest Minnesota. Alternative farming practices included organic management practices, species biodiversity, and/or practices that include reduced inputs of synthetic fertilizer and pesticides. Conventional farming practices include corn–soybean (*Zea mays* L.–*Glycine max* L., respectively) rotations and their associated recommended fertilizer rates as well as pesticide usage. Precipitation was highly variable during the 3-yr study period including a below-average year (2003), an average year (2002), and an above-average year (2004). Results indicate that alternative farming practices reduced subsurface drainage discharge by 41% compared with conventional practices. Flow-weighted mean nitrate-nitrogen (nitrate N) concentrations during tile flow were 8.2 and 17.2 mg L^{-1} under alternative and conventional farming practices, respectively. Alternative farming practices reduced nitrate N losses by between 59 and 62% in 2002 and 2004 compared with conventional practices. Ammonium-nitrogen (ammonium N), orthophosphorus, and total phosphorus losses in subsurface drainage were very low and did not pose a substantial risk of pollution. Results suggest that alternative farming practices have the potential to reduce agricultural impacts on water quality.

Palm, Cheryl A., et al. (1997) “Combined Use of Organic and Inorganic Nutrient Sources for Fertility Maintenance and Replenishment,” in Roland J. Buresh, et al., eds., Replenishing Fertility in Africa, SSSA Special Publication No. 51, Madison, Wisconsin, Soil Science Society

Abstract

The beneficial effects of combined organic and inorganic nutrients on soil fertility have been repeatedly shown, yet there are no guidelines for their management. Organic materials are not magic; many of their functions with respect to soil fertility are known.

Organic materials influence nutrient availability (i) by nutrients added, (ii) through mineralization-immobilization patterns, (iii) as an energy source for microbial activities, (iv) as precursors to soil organic matter (SOM), and (v) by reducing P sorption of the soil. The challenge is to combine organics of differing quality with inorganic fertilizers to optimize nutrient availability to plants. Numerous field trials indicate both added benefits and disadvantages of combining nutrient sources. Increased nutrient recovery and residual effects are associated with combined nutrient additions compared with inorganic fertilizers applied alone. Unfortunately, for many trials there is lack of crucial information on the nutrient content and quality of the organic inputs. Trials are needed that link the quality of the organic material to its fertilizer equivalency and its effect on the longer term composition of SOM and crop yields. A systematic framework for investigating the combined use of organic and inorganic nutrient sources includes farm surveys, characterization of the quality of organic materials, assessment of the fertilizer equivalency value based on the quality of organics, and experimental designs for determining optimal combinations of nutrient sources. The desired outcome is tools that can be used by researchers, extension-ists, and farmers for assessing options of using scarce resource for maintaining soil fertility and improving crop yields.

Poudel, D.D. Horwath, W.R. Mitchell J.P, & Temple, S.R. (2001) Impacts of cropping systems on soil nitrogen storage and loss. Agric. Syst., 68 (2001), pp. 253–268

Abstract

Organic and low-input cropping systems that use more C inputs are alternatives to conventional systems for sustaining long-term soil fertility. An understanding of the impacts of these cropping systems on N balance (N applied minus N removed in harvested plant material), storage and loss is necessary to improve long-term soil fertility and minimize the risk of environmental pollution. An evaluation of 4-year rotations of organic (N from legumes and composted manures), low-input (N from legumes and reduced amounts of synthetic fertilizers), and conventional (conv-4, N from synthetic fertilizers) and a conventional 2-year rotation (conv-2, N from synthetic fertilizers) on N balance, storage and loss was conducted from 1989 to 1998. Compared to the conv-2 system, the organic and conv-4 systems showed 119 and 8% greater cumulative N balances, respectively, over the duration of the study. However, N balance in the low-input system was 19% less than in conv-2 system. After 10 years of differential management, total N in the top 15 cm of soil was 1.46 g kg^{-1} in the organic, 1.26 g kg^{-1} in the low-input, 1.13 g kg^{-1} in the conv-4, and 1.1 g kg^{-1} in the conv-2 system. Compared to the conv-2 system, cumulative N losses for the organic, low-input and conv-4 systems were lower

by 80, 92, and 10%, respectively. These findings suggest that organic and low-input cropping systems that add C to soil have the potential for storing N and making it available for future crop use, while minimizing the risk of environmental pollution.

Poudel, D. D., et al. "Comparison of soil N availability and leaching potential, crop yields and weeds in organic, low-input and conventional farming systems in northern California." *Agriculture, ecosystems & environment* 90.2 (2002): 125-137.

Abstract

Increasing dependence on off-farm inputs including, fertilizers, pesticides and energy for food and fiber production in the United States and elsewhere is of questionable sustainability resulting in environmental degradation and human health risks. The organic (no synthetic fertilizer or pesticide use), and low-input (reduced amount of synthetic fertilizer and pesticide use), farming systems are considered to be an alternative to conventional farming systems, to enhance agricultural sustainability and environmental quality. Soil N availability and leaching potential, crop yields and weeds are important factors related to agricultural sustainability and environmental quality, yet information on long-term farming system effects on these factors, especially in the organic and low-input farming systems is limited. Four farming systems: organic, low-input, conventional (synthetic fertilizer and pesticides applied at recommended rates) 4-year rotation (conv-4) and a conventional 2-year rotation (conv-2) were evaluated for soil mineral N, potentially mineralizable N (PMN), crop yields and weed biomass in irrigated processing tomatoes (*Lycopersicon esculentum* L.) and corn (*Zea mays* L.) from 1994 to 1998 in California's Sacramento Valley. Soil mineral N levels during the cropping season varied by crop, farming system, and the amount and source of N fertilization. The organic and low-input systems showed 112 and 36% greater PMN pools than the conventional systems, respectively. However, N mineralization rates of the conventional systems were 100% greater than in the organic and 28% greater than in the low-input system. Average tomato fruit yield for the 5-year period (1994–1998) was 71.0 Mg ha^{-1} and average corn grain yield was 11.6 Mg ha^{-1} and both were not significantly different among farming systems. The organic system had a greater aboveground weed biomass at harvest compared to other systems. The lower potential risk of N leaching from lower N mineralization rates in the organic and low-input farming systems appear to improve agricultural sustainability and environmental quality while maintaining similar crop yields.

Powell, J. M., et al. "Nitrogen use efficiency: A potential performance indicator and policy tool for dairy farms." *Environmental Science & Policy* 13.3 (2010): 217-228.

Abstract

Escalating fertilizer and feed costs, declining product prices, and increasing regulations to reduce environmental pollution have created new pressures to improve nutrient use in agricultural production. This study provides an overview of factors and processes that impact nitrogen use efficiency (NUE) in dairy production, identifies practices that may bridge gaps between actual-NUE obtained on commercial farms and potential-NUE obtained under experimental conditions, and explores the possibility of using NUE as a performance indicator and policy tool for dairy production. Actual feed-NUE varies from 16% to 36% and is impacted by of a range of dairy practices; manure/fertilizer-NUE varies from 16% to 77% and is very site-specific; and whole-farm NUE varies from 8% to 64% and declines as stocking rates increase. Optimal stocking rate and manure nitrogen (N) crediting can enhance NUE, increase farm profits, and reduce N loss from dairy farms. NUE could be used to further engage dairy producers in collaborative assessments of gaps between their actual N use and the biological potential of N use, to develop performance goals for N use in various production components, and to monitor and evaluate the impacts of alternative feed, manure and fertilizer management practices on N use, profitability, and environmental outcomes.

Rafique, R., Hennessy, D., & Kiely, G. (2011). Nitrous oxide emission from grazed grassland under different management systems. Ecosystems, 14(4), 563-582.

Abstract

Nitrous oxide (N_2O) emissions from grazed grasslands are estimated to be approximately 28% of global anthropogenic N_2O emissions. Estimating the N_2O flux from grassland soils is difficult because of its episodic nature. This study aimed to quantify the N_2O emissions, the annual N_2O flux and the emission factor (EF), and also to investigate the influence of environmental and soil variables controlling N_2O emissions from grazed grassland. Nitrous oxide emissions were measured using static chambers at eight different grasslands in the South of Ireland from September 2007 to August 2009. The instantaneous N_2O flux values ranged from -186 to 885.6 μg N_2O-N m^{-2} h^{-1} and the annual sum ranged from 2 ± 3.51 to 12.55 ± 2.83 kg N_2O-N ha^{-1} y^{-1} for managed sites. The emission factor ranged from 1.3 to 3.4%. The overall EF of 1.81% is about 69% higher than the Intergovernmental Panel on Climate Change (IPCC) default EF value of 1.25% which is currently used by the Irish Environmental Protection Agency (EPA) to estimate N_2O emission in Ireland. At an N applied of approximately 300 kg ha^{-1} y^{-1}, the N_2O emissions are approximately 5.0 kg

N_2O-N ha^{-1} y^{-1}, whereas the N_2O emissions double to approximately 10 kg N ha^{-1} for an N applied of 400 kg N ha^{-1} y^{-1}. The sites with higher fluxes were associated with intensive N-input and frequent cattle grazing. The N_2O flux at 17°C was five times greater than that at 5°C. Similarly, the N_2O emissions increased with increasing water filled pore space (WFPS) with maximum N_2O emissions occurring at 60–80% WFPS. We conclude that N application below 300 kg ha^{-1} y^{-1} and restricted grazing on seasonally wet soils will reduce N_2O emissions.

Schofield P.; Watt, N. and Schofield, M. (2013). Using humic compounds to improve efficiency of fertiliser nitrogen. In: Accurate and efficient use of nutrients on farms. (Eds L.D. Currie and C L. Christensen). Abstract online: http://flrc.massey.ac.nz/publications.html. Occasional Report No. 26. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 1-7 page.

Soane, B. D., and C. Van Ouwerkerk. "Implications of soil compaction in crop production for the quality of the environment." *Soil and Tillage Research* 35.1 (1995): 5-22.

Abstract

Evidence is presented to indicate the possible serious, widespread and long-term implications of soil compaction for the quality of the environment. Soil compaction enhances harmful physical, chemical and biological processes which, in the context of inappropriate soil management, lead to soil degradation. Soil compaction is shown to result in changes in soil properties which control the emission of greenhouse gases, the runoff of water and pollutants into surface waters, and the movement of nitrate and pesticides into ground waters. Soil compaction will also affect the amounts of fertiliser and energy used in crop production, which may have additional adverse environmental consequences. Recommendations for further research on the environmental consequences of soil compaction in crop production are made.

In conclusion, the available information suggests a potential of organic fertilizers and water-saving practices to mitigate N_2O emissions under Mediterranean climatic conditions, although further research is needed before it can be regarded as fully proven, understood and developed.

Torbert, H. A., and C. W. Wood. "Effects of soil compaction and water-filled pore space on soil microbial activity and N losses." *Communications in Soil Science & Plant Analysis* 23.11-12 (1992): 1321-1331.

Abstract

Soil compaction is a significant production problem for agriculture because of its negative impact on plant growth, which in many cases has been attributed to changes in soil N transformations. A laboratory experiment was conducted to study the effect of soil compaction and water-filled pore space on soil microbial activity and N losses. A hydraulic soil compaction device was used to evenly compress a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Kandiudults) soil into 50 mm diameter by 127 mm long cores. A factorial arrangement of three bulk density levels (1.4, 1.6, and 1.8 Mg/m^3) and four water-filled pore space levels (60, 65, 70, 75%) was used. Fertilizer application of 168 kg N/ha was made as 1.0 atom % ^{15}N as NH_4NO_3. Soil cores were incubated at 25°C for 21 d. Microbial activity decreased with both increasing water-filled pore space and soil bulk density as measured by CO_2-C entrapment. Nitrogen loss increased with increasing bulk density from 92.8 to 334.4 g N/m^3 soil at 60% water-filled pore space, for 1.4 and 1.8 Mg/m^3, respectively. These data indicate that N loss and soil microbial activity depends not only on the pore space occupied by water, but also on structure and size of soil pores which are altered by compaction.

Pimentel, D., Culliney, T. W., Buttler, I. W., Reinemann, D. J., & Beckman, K. B. (1989). Low-input sustainable agriculture using ecological management practices. *Agriculture, ecosystems & environment*, *27*(1), 3-24.

Abstract

The use of chemicals for high crop productivity and compensation for soil, water and biological resource degradation contribute to the high production costs and other problems of U.S. agriculture. This has prompted strong interest by U.S. farmers in low-input sustainable agriculture. The principles that underlie a low-input sustainable agricultural system are: (1) adapting the agricultural system to the environment of the region, including soil, water, climate and biota present at the site; (2) optimizing the use of biological and chemical/physical resources in the agroecosystem. In this investigation, it was demonstrated that high corn yields could be maintained and input costs reduced by adaptive management of soil, water, energy and biological resources. For example, soil erosion was reduced from 18 t ha^{-1} $year$ to 1 t ha^{-1} $year^{-1}$ and pest control accomplished without the use of pesticides. This reduced the costs of corn production 33% while reducing fossil energy inputs by about 50%.

Van Der Heijden, Marcel GA, Richard D. Bardgett, and Nico M. Van Straalen. "The unseen majority: soil microbes as drivers of plant diversity and productivity in terrestrial ecosystems." *Ecology letters* 11.3 (2008): 296-310.

Abstract

Microbes are the unseen majority in soil and comprise a large portion of life's genetic diversity. Despite their abundance, the impact of soil microbes on ecosystem processes is still poorly understood. Here we explore the various roles that soil microbes play in terrestrial ecosystems with special emphasis on their contribution to plant productivity and diversity. Soil microbes are important regulators of plant productivity, especially in nutrient poor ecosystems where plant symbionts are responsible for the acquisition of limiting nutrients. Mycorrhizal fungi and nitrogen- fixing bacteria are responsible for c. 5–20% (grassland and savannah) to 80% (temperate and boreal forests) of all nitrogen, and up to 75% of phosphorus, that is acquired by plants annually. Free-living microbes also strongly regulate plant productivity, through the mineralization of, and competition for, nutrients that sustain plant productivity. Soil microbes, including microbial pathogens, are also important regulators of plant community dynamics and plant diversity, determining plant abundance and, in some cases, facilitating invasion by exotic plants.
Conservative estimates suggest that c. 20 000 plant species are completely dependent on microbial symbionts for growth and survival pointing to the importance of soil microbes as regulators of plant species richness on Earth. Overall, this review shows that soil microbes must be considered as important drivers of plant diversity and productivity in terrestrial ecosystems

Van der Werff, P. A., A. Baars, and G. J. M. Oomen. "Nutrient balances and measurement of nitrogen losses on mixed ecological farms on sandy soils in the Netherlands." *Biological Agriculture & Horticulture* 11.1-4 (1995): 41-50.

Abstract

For three ecological mixed arable-dairy farms on sandy soils in the Netherlands the nutrient balances for N, P and K have been assessed on the basis of inputs and outputs of products, manure, fodder and straw. For nitrogen the assessment of N-fixation and NH_4 volatilization from deep litter stables offer new problems because of the special farming methods in ecological agriculture. The nitrogen surpluses for the organic farms are 83 kg N per ha against 444 kg N per ha for conventional extensive dairy farms on sandy soils. The average nitrogen efficiency for the three organic farms is 31%, conventionally this was 12% in 1986. The leaching of N has been estimated on the basis of soil moisture analysis for most fields of the separate farms. The average N loss by leaching was 20 kg $N*ha^{-1}$ $*yr^{-1}$. The average nitrogen content of shallow ground water was 11 mg $NT*1^{-1}$, which will be lower in deeper layers as a result of denitrification. The results of the research over three consecutive years showed possibilities for improvement in farm management that will be necessary to meet recommendations for improvement of groundwater quality in the future.

White, J. F., Chen, Q., Torres, M. S., Mattera, R., Irizarry, I., Tadych, M., & Bergen, M. (2015). Collaboration between grass seedlings and rhizobacteria to scavenge organic nitrogen in soils. *AoB plants*, *7*, plu093

Abstract

Plants require nitrogen (N) to make proteins, nucleic acids and other biological molecules. It is widely accepted that plants absorb inorganic forms of N to fill their needs. However, recently it has become clear that plants also have the capacity to absorb organic N from soils. In this paper we describe a new kind of symbiosis involving seed-vectored rhizobacteria and grasses that is targeted at enhancing acquisition of organic N from soils. Our proposal is based on results of experiments on seedlings of grass species *Festuca arundinacea* Schreb., *Lolium perenne* L. and *Poa annua* L. that suggest: (i) seed-vectored rhizobacteria colonize seedling roots and influence their development; (ii) reactive oxygen secretion by seedling roots plays a role in organic N procurement by denaturing microbial proteins in the vicinity of roots (daytime activity); and (iii) plant root and microbial proteases degrade denatured proteins prior to absorption by roots (night-time activity). This research involved the following types of studies: (i) seedling root development experiments with and without rhizobacteria on a variety of substrates in agarose media and (ii) isotopic N-tracking experiments to evaluate the absorption into seedlings of N obtained from degradation of proteins. We hypothesize that grasses, in particular, are adapted to scavenge organic N from soils through application of this 'oxidative nitrogen scavenging' symbiosis with rhizobacteria, and their soil-permeating root systems. This newly discovered symbiosis in grass species could lead to new ways to cultivate and manage grasses to enhance efficiency of N utilization and reduce applications of inorganic fertilizers.