CHAIRS' SUMMARY PAPER: Nutrient Cycling

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NUTRIENT CYCLING IN WORLD GRASSLANDS

One of the most resonating statements of this Congress, that "productive pastures are no longer regarded as environmentally benign, especially where high stocking rates are employed and the storage and disposal of large amounts of farm wastes are necessary" introduced the invited paper by Scholefield and Oenema. Of the nutrients supplied on intensive dairy farms, only 20-30% are exported in product while the remainder is lost to the environment, accumulated in the soil, or cannot be accounted for. Nitrogen is lost by leaching of nitrate, by run-off of ammonium, volatilization of ammonia, and denitrifcation. Indeed, denitrification after manure application by injection may produce more of the potent greenhouse gas N_2O than N_2 (Scholefield et al. Paper # 300).

Current strategies for improving nutrient cycling include tactical fertilizer application with the aid of *in situ* soil tests and simulation models. But the subtleties of each system must be understood. For example, in the UK, twice as much N may be lost after a hot dry summer than after a cool wet one, regardless of management practices. How far we are still from detailed, quantitative knowledge of each farming region!

The problem of nutrient loss in tropical pastures, discussed by Fisher, Rao, and Thomas, is primarily one of conserving scarce nutrients in low input systems, rather than one of environmental impact. Nutrient losses follow the same routes as in temperate pastures, but immobilization of nutrients by below-ground biomass plays a greater role in the tropics. As tropical pastures usually receive little input, and the grasses have poor palatability, more nutrients are recycled through leaf litter than through animal waste. Nutrient release from litter in the soil is hampered by the large C:N ratios and concentrations of lignin in tropical grasses, and possibly high levels of condensed tannins in legumes. Heterogeneous deposition of urine and faeces by grazing livestock is a significant factor contributing to the quantities of nutrients lost in both temperate and tropical pastures.

Fisher et al. discussed the tendency for tropical grasses to conserve nutrients within the plant without cycling them through the soil. The nutrients are transferred out of senescent tissue to new tillers, so that in effect nutrients are passed on from generation to generation without release into the environment. Hence tropical pastures, as temperate pastures, become degraded unless nutrients are released from soil organic matter by renovation, or additional nutrients are applied. Declining nutrient status is a problem also for low-input ley farming systems in Sweden (Fagerberg).

The principal nutrient deficiency of tropical pastures is N, although it is P that is supplied more often . Nitrogen input comes mainly from biological nitrogen fixation. Legumes such as *Desmodium ovalifolium* can supply significant quantities, but a sward content of 30% is needed to exceed the high rates of immobilization. Degradation of pastures is in part caused by nutrient deficiency but also contributes to it. Endophytic N-fixers have recently been discovered that can potentially fix 180 kg N ha^{-1} yr^{-1} in sugarcane, although 40 kg N ha^{-1} yr^{-1} may be more typical in grasses. This newly discovered association offers a new opportunity for nutrient enhancement by researchers.

Several poster presentations described nutrient cycling in semi-arid temperate grasslands. These grasslands typically receive smaller nutrient loadings than the high rainfall areas of Western Europe. The problem of gaseous losses is considered less immediate compared to leaching and run-off of nutrients into confined aquifers and surface waterways. Significant leaching occurs from dairy pastures receiving 220kg N/ha in Pennsylvania. (Stout *et al*.). No nitrate leaching from pastures grazed by lactating dairy cows where most of the N inputs came from feed supplements rather than fertilizer in Minnesota and Wisconsin (Russelle *et al.*). These authors caution that leaching may occur on coarse-textured soils. In south Australia, leaching of P from rain-fed pastures due to preferential flow was reported for some soil conditions (Cox *et al*.). Movement of S but not N was reported for perennial and degraded pastures in southern Australia (Wen *et al.*).

DEFINING EFFICIENCY

Scholefield and Oenema point out that there are different ways to measure nutrient efficiency. So, also, there are different attitudes towards efficiency in different part of the world. In the Netherlands regulations set limits on nutrient inputs relative to exports to minimize all possible losses to the environment. In contrast, in areas with high livestock concentrations in North America, there is greater concern over runoff and leaching of nutrients into water bodies than over gaseous losses to the atmosphere. In fact nitrogen losses to the atmosphere are implicitly encouraged in order to reduce loading of waterways. This may change if President Clinton passes new 'green-house gas' legislation.

SOCIAL CONTEXT OF MANAGING NUTRIENTS

The XVII International Congress devoted time to issues of rural society (Session 30). Unfortunately, there was no recognition of the sociological and psychological impact on farmers of having to respond to ever tightening environmental regulations. Traditionally, the most law-abiding of citizens, farmers must now see themselves portrayed as eco-outlaws. Everywhere farmers are feeling targeted, isolated and financially threatened especially as there is so little government support available. Perhaps farmers can mitigate their sense of isolation by sharing their concerns with others around the globe, through an electronic bulletin board. It is logical that farmers will respond to changes best when they feel less threatened.

RESEARCH PRIORITIES

Recommendations for research made at the XVII International Grassland Congress are summarized in Table 1.

Scholefield and Oenema suggested that there are two strategies to reduce leakage of nutrients from grassland systems: reducing intensification of production (i.e. reduced inputs) and development of new techniques for reducing losses.

Most of the above research priorities and approaches were addressed in the poster presentations of the Nutrient Cycling Session (Table 2)

It can be seen that the papers in the Nutrient Cycling session dealt mainly with understanding nutrient cycling, monitoring losses, and reducing reliance on fertilizer inputs. A few papers offered solutions for overcoming nutrient loss, but two examples of radically new approaches to reducing nutrient losses were identified from other sessions at the IGC. J.R.Crush (Session 8) reported that condensed tannins in forages not only improves protein utilization by ruminants but also reduces nitrification in the soil, thereby possibly reducing nitrate leaching and even nitrous oxide emission. Van Loo *et al*. (Session 4) showed that tissue protein concentrations, in excess of animal requirements, result if cropping systems maximize the yield of digestible dry matter. By selecting N-use efficient ryegrass germplasms (using hydroponics), it may be possible to obtain good yields, with more appropriate N concentrations, and using less N inputs.

An encouraging trend throughout the congress, and perhaps most significantly in the realm of nutrient cycling, is the growing acceptance, use and even reliance on simulation models. Modeling is no longer in anyone's private domain and the gradual integration of this tool into our everyday kit-bag represents a quiet revolution.

The future will be a combination of brilliant and unexpected innovation and judicious resource management. Understanding nutrient cycling is not a short-term goal, but a process with incremental improvements that will be going on for years to come. The key now, as it was four years ago, is for better integration of our knowledge of biological and chemical processes. This will certainly require computer modeling, which is likely to become a universal tool as its effectiveness increases with all the new information becoming available.

Table 1
Research requirements identified in XVII International Grassland Congress

Dry environments (Parton, p. 504)
- Study plant-soil interactions
- Evaluate how soil water and nutrients control plant competition
- Develop sustainable grazing systems
- Study spatial variabilty

Temperate environments (Edmeades, p. 522)
- Develop and use models for sensitivity analysis to examine relative importance of key factors
- Develop an understanding of the changes in components over time
- Establish good long term trials to understand temporal changes
- Develop useful systems models to understand practical consequences of managementeg erosion
- Encourage interactions over the whole range of research disciplines, i.e.consider the whole environment when developing solutions to problems

Table 2
Poster presentations in the Nutrient Cycling Session at the XVIII IGC, grouped according to principal theme

Assessing nutrient losses	
Stout et al.	Nitrate leaching from a dairy system in northeast US.
Francis et al.	Using forages to reduce nitrate leaching form cropping rotations in NZ.
Wen et al.	Nitrate and sulphur movement under degraded and perennial pastures in south Australia.
Owens et al.	Movement of non-N nutrients into groundwater from moderately fertilized pasture in Ohio.
Russelle et al.	Nitrate leaching from intensive rotational grazing (dairy cows) mid-west US.
Scholefield et al.	New methodology for measuring N_2O and N_2 losses after injection of slurry.
Porqueddu et al.	Nutrient losses by runoff/ leaching from intensive and extensive forage systems in Italy.
Cox et al.	Vertical movement of P in contrasting soils in south Australia.
Chiy et al.	Application of Na or Cd on leaching of several nutrients in UK.
Mwendera, Saleem.	Grazing pressure and degree of slope on run-off and soil loss in Ethiopia.
Nutrient flows	
Liya and Abgoola.	Role of termites, livestock, wild animals and humans in nutrient cycling in Nigeria.
Fagerberg.	N balance and crop yield of ecological and conventional ley systems in Sweden.
Oyanarte et al.	Methodology for P and K requirements using nutrient cycling of contrasting forage systems and terrains in Basque region.
Clancy et al.	Comparison of N and C dynamics in alternative and conventional farming systems relative to native prairie in N. Dakota.
Mandret, Blanfort.	Organic and inorganic N on production, organic matter decomposition and N uptake in a humid tropic grassland.
Yadava, Thoudam.	Factors affecting rate of decomposition of grass litter and nutrient release in humid grassland in India.
Practices for reducing nutrient losses	
Gerrish et al.	How location of water sources affects grazing and nutrient deposition patterns in Missouri.
Peel et al.	N and P emissions from dairy farming relative to cropping and manure use strategies in UK.
Ivers et al.	Using reed canary grass to recycle nutrients from heavy doses of dairy slurry in Midwest US.