Mitigating nitrous oxide emission in tropical agriculture: Myths and realities

A great deal of evidence has accumulated showing that agricultural activities, especially application of fertilizers have resulted in an increased emission of N_2O to the atmosphere[1]. The reasons why we should care about this are that N_2O is one of the so-called greenhouse gases, constituting 6% of anthropogenic greenhouse effect[1], and also contributing to the depletion of stratospheric ozone. Fertilized agriculture is the single most important anthropogenic source of N_2O, accounting for over 70% of the sources[2]. From 1980 to 1994, global agricultural N_2O emissions increased by ca. 15% (ref. 3). Agricultural lands in tropical countries are potentially large emitters of N_2O, due to favourable moisture, temperature and high rates of N fertilizer use[4]. It is estimated that the rate of N_2O emission in cultivated soils of the tropics is double the rate of temperate soils[5]. There is an urgent need therefore to find out feasible methods for mitigating N_2O emission in the tropics. Strategies to mitigate N_2O emission from agricultural soils of the world have been identified[6,7]. They include (1) matching N supply with crop demand; (2) optimizing irrigation, drainage and tillage; (3) use of advanced fertilization techniques and 4) tightening N flow cycles. Estimated decrease in the global emissions from agricultural soils by the proposed strategies is ca. 20% (ref. 7). It is hoped that if implemented, they are more likely to increase crop productivity. Strategies consist of a number of specific methods to be applied under field conditions. They are (1) optimizing spilt application schemes of fertilizers to match crop demands; (2) minimizing fallow periods to limit mineral N accumulation in the soil; (3) minimizing drying and rewetting cycles in agricultural soils; and (4) tilling before rains (as revealed from ref. 8).

Feasibility of employing them in tropical agriculture is rather doubtful, because they are not applicable under rainfed agriculture, which prevails in most of the tropics, and which provides about two thirds of the global food production[9]. Fertilizer application should be adhered to the soil moisture level that is determined by rainfall in the rainfed areas. Hence it is difficult to match fertilization with crop demands by the split application. Moreover, increased number of fertilizer application times contributes to an additional cost of labour in the crop production, which should translate to a benefit in terms of increased yields. In rainfed agriculture, the length of fallow period depends on the availability of rain water to start tillage for cropping. As proposed, one cannot therefore arbitrarily change fallow periods. Drying and rewetting cycles are also determined by rewetting of soils with the rainfall, which is out of human control. Tilling before rains is a difficult task due to soil compaction and crust formation, particularly in clay soils.

Among other options, the use of soil/plant testing to determine fertilizer needs, and match fertilizer types to seasonal precipitation have been proposed. Successful applications of these are also doubtful because of the vast spatial variability of soil fertility and the temporal variability of seasonal rainfall in the tropics. There should be extensive soil/plant testing programmes for almost all the sites, if fertilizer needs are to be accurately ascertained. Advanced fertilizer techniques such as controlled released fertilizers, foliar application of fertilizers, urease and nitrification inhibitors and placing fertilizers below the soil surface are being tested to control the N_2O emission. However, these are economically non-viable, due to their high cost and labour-intensive operations involved. Poverty in many developing countries in the tropics prohibits the use of high cost, advanced technologies. The use of urease and nitrification inhibitors has problems related to environmental safety, which could influence social acceptability.

Plant residue management on croplands has been recommended and is practiced to some extent in tropical agriculture, in order to (1) conserve soil moisture; (2) control weeds; (3) contribute to soil organic matter after decomposition; and (4) synchronize between nutrient release and plant demand for efficient nutrient use, reducing losses. Different parts of specific plant species like neem (*Azadirachta indica* L.) and karanja (*Pongamia glabra* Vent.) contain nitrification inhibitors and biocidal compounds such as polyphenols, as natural products that can inhibit nitrification and other N transformations. For example, neem and karanja seed extracts can retard nitrification by ca. 60–70% (ref. 10). Karanjin, a furano flavonoid extracted from karanja seeds can increase rice grain yield by ca. 50% and grain protein by ca. 15%, by retarding nitrification[10]. Such substances can be mixed with fertilizer formulations in designing economically-viable fertilizer techniques for the tropics. Soil surface mulch application with plant residues cuts down soil N_2O emission considerably in the tropics[11]. Retaining N_2O for prolonged periods in the soil by the mulch acting as a gas diffusion barrier, allows the complete reduction of it into N_2 (G. Seneviratne, in manuscripts). Dissolution of N_2O in moisture contained in the mulch and subsequent microbial and possibly chemical reductions are also attributed to this mitigation effect.

It is a clear fact that we should give priority immediately to boost food production, if the forthcoming world food crisis in the year 2005 is to be successfully faced. In this context, promoting organic material recycling is urgently needed to maintain ever depleting soil organic matter in the tropics. The N_2O mitigating options related to the organic material recycling are therefore the most feasible, realistic and immediately applicable options for the tropics. If we can optimize the residue management in order to sustain and improve crop production and at the same time to mitigate N_2O emission, that should provide the best agronomic, economic and environment-friendly options for tropical agriculture.

1. Houghton, J. T. *et al.*, *Climate Change 1994: Radiative Forcing of Climate Change and an Evaluation of the IPCC*

IS92 Emission Scenarios, Cambridge University Press, Cambridge, 1995, p. 337.
2. Bouwman, A. F., Report No. 773004004, National Institute of Public Health and Environmental Protection, Bilthoven, 1994.
3. Mosier, A. and Kroeze, C., *IGBP Newsl.*, Stockholm, 1998, p. 24.
4. Bouwman, A. F., *Nature*, 1998, **392**, 866–867.
5. Mosier, A., Kroeze, C., Nevison, C., Oenema, O., Seitzinger, S. and van Cleemput, O., *Nutr. Cycl. Agroecosyst.*, 1998, **52**, 225-248.
6. Mosier, A. R., Duxbury, J. M., Freney, J. R., Heinemeyer, O. and Minami, K., *Climatic Change*, 1998, **40**, 7–38.
7. Pathak, H., *Curr. Sci.*, 1999, **77**, 359–369.
8. Ball, B. C., Scott, A. and Parker, J. P., *Soil Till. Res.*, 1999, **53**, 29–39.
9. Falkenmark, M. *et al.*, *Ambio*, 1998, **27**, 148–154.
10. Sahrawat, K. L., in *Nitrogen Economy in Tropical Soils* (ed. Ahmad, N.), Kluwer Academic Publishers, Dordrecht, 1996, pp. 379–388.
11. Seneviratne, G., *Ambio*, 1999, **28**, 378.

GAMINI SENEVIRATNE

Biological Nitrogen Fixation project, Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka
e-mail: gaminis@ifs.ac.lk

Mapping fish research in India – Missed opportunity

Jayashree and Arunachalam[1] have analysed the impact of fish research in India among the global scientific community and reported that majority of publications, particularly those from the central research laboratories, are published in non-*Science Citation Index* (*SCI*) and non-*Journal Citation Reports* (*JCR*) journals of low impact with poor visibility. They have concluded 'fish research in India appears to be mediocre in general'.

The fish production in our country increased by more than five times[2] and the contribution of fisheries to the GDP of India increased by nearly three times[3] during the last 5 decades, a growth arguably one of the highest among the food production sectors. This growth would not have been possible without an effective research support. A few examples of research-supported fish production are as follows: (i) The then Central Inland Fisheries Research Institute (Barrackpore) published the first paper on the success in induced breeding of carps in 1957 (ref. 4). Subsequently, technologies on induced breeding and larval rearing were developed for a number of species of carps, all of which were published in non-*SCI* journals. These research developments paved the way for the current annual carp production of >1 million tonnes. (ii) The Central Marine Fisheries Research Institute (CMFRI), Kochi developed the hatchery technology of penaeid shrimps in 1973 (ref. 5), and by 1978, larval rearing of several shrimps was successfully developed and documented. All these achievements were published in the Institute's non-*SCI* journals. In 1999–2000, the country has exported farmed shrimps worth US $ 0.8 billion. (iii) The CMFRI developed hatchery and mariculture technologies for the pearl oyster[6], edible oyster, mussels[7] and clams. All these technologies were, and are being documented in non-*SCI* journals since 1973. Of these, pearl culture and mussel culture have made significant impacts among the entrepreneurs and fishermen. (iv) The Bay of Bengal Programme (FAO), Chennai designed a high opening trawlnet with the help of gear experts in India. The design, which revolutionized the capture fisheries sector, was published as a BOBP working paper in 1980 (ref. 8). In two decades, all the trawlnets (150,000 in number in 1998) in the country are of high opening type. These nets now produce 1.2 million tonnes of fish/year. (v) Several special publications and bulletins of the central fisheries institutes have helped the Supreme Court, Parliamentary Standing Committees and the maritime state governments in framing several policy documents such as the Aquaculture Authority Bill, Deepsea Fishing Policy and Marine Fishing Regulation Acts, which are milestones in the development of fisheries sector in India. There are many more examples, which paved the way for, what is hailed as 'Blue revolution' in India. The growth of the fisheries sector, to a very large extent, is due to the impact of research on the fish farmers, fisherfolk, fisheries planners and managers.

The mandate of the central research institutes is to develop technology packages and transfer them to the beneficiaries to increase/sustain fish production. Publications in high impact journals will not help in meeting the objective of directly reaching the beneficiaries. The philosophy of Garfield[9] has not considered the importance of this kind of production-oriented research, which is crucial for developing countries like India. By following the methodology commonly adopted for measuring the quality of publications of physical, chemical and biological and several other disciplines of science, Jayashree and Arunachalam[1] have missed a good opportunity to evolve a specialized methodology for proper assessment of the impact of fisheries research (and for other food production researches as well). Scientometrics has to perhaps redefine and reorient its methodology and evolve a meaningful tool for quantitatively measuring the output of science and scientists.

1. Jayashree, B. and Arunachalam, S., *Curr. Sci.*, 2000, **79**, 613–620.