Modelling the nitrogen balance of tropical perennial crops: state of the art and challenges for oil palm plantations

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1. Introduction

While a number of models exist to estimate nitrogen (N) losses from agricultural fields, they mostly pertain to temperate climate conditions and annual crops. Few models are available for tropical crops [1], [2], and even fewer for perennial crops [3], [4]. The lack of robust N-flux inventories is particularly critical for LCA of perennial and tropical crops.

Oil palm is the most rapidly expanding tropical perennial crop, which raises environmental concerns. Beside land-use change and peatland, oil palm agricultural production impacts the environment mainly through the use of synthetic fertilisers, particularly nitrogen [5], [6]. The latter is associated with pollution risks of ground and surface water, and emissions of greenhouse gases. Accurate estimation of N losses is critical to assess the environmental impacts of palm plantations.

2. Materials and methods

In this study, we reviewed some currently-available models for oil palm cultivation, and appraised their capacity to assess the N balances of oil palm agro-ecosystems. We identified various operational models that could be applied to oil palm, although most of them were not specifically adapted for tropical perennial crops. To our knowledge, APSIM is the only available process-based model of oil palm cultivation that includes N losses [7], but the accuracy of its N loss estimates was untested. Appraised models were based on statistical models [8]–[10] or other approaches [11]–[13]. For all models, we (i) set up mineral and organic fertilisers as 130 and 20 kN/ha.yr, respectively; (ii) used an uptake of 150 kgN/ha.yr; (iii) considered the same type of mineral soil when soil characteristics were needed by the models.

3. Results and discussion

Nitrogen balance assessments showed important uncertainties (Figure 1). These uncertainties are due to a lack of understanding of processes, which are numerous and may interact or counteract in variable ways depending on local conditions and managements. Moreover, it is difficult to study and understand N dynamics over the whole lifespan of oil palm crops (20-25 years) and to account for varying agricultural practices along the cycle and across various systems. None of the used statistical models allow for differentiating development stages. One proposed specific parameters for oil palm, another one accounted for tropical conditions.

Estimates of N_2O and NO_3^- rely on very uncertain and sensitive parameters, such as the clay content for instance with the SQCB-NO3 model [13]. Classes used for the statistical models may create distortion due to uneven proportions of tested conditions in the baseline data sets. This may explain the high sensitivity of some parameters and the lack of consistency in cases not in line with the defined classes, either because of the non relevancy of some parameters or class delimitations (*e.g.* soil drainage: poor or good).

4. Conclusions

Further research is required to develop a procedure that provides a robust assessment of the environmental impact of N management in oil palm cultivation. Particularly, this procedure should have the capacity to account for a range of soils, climates, and management practices over the whole cycle. One track to be pursued is the development of an agro-ecological indicator based on Indigo© concept [14], [15]. In particular, the use of the fuzzy logic may reduce the uncertainty linked to the class definition. Such an indicator could help to reduce uncertainties in LCA of tropical perennial crops.

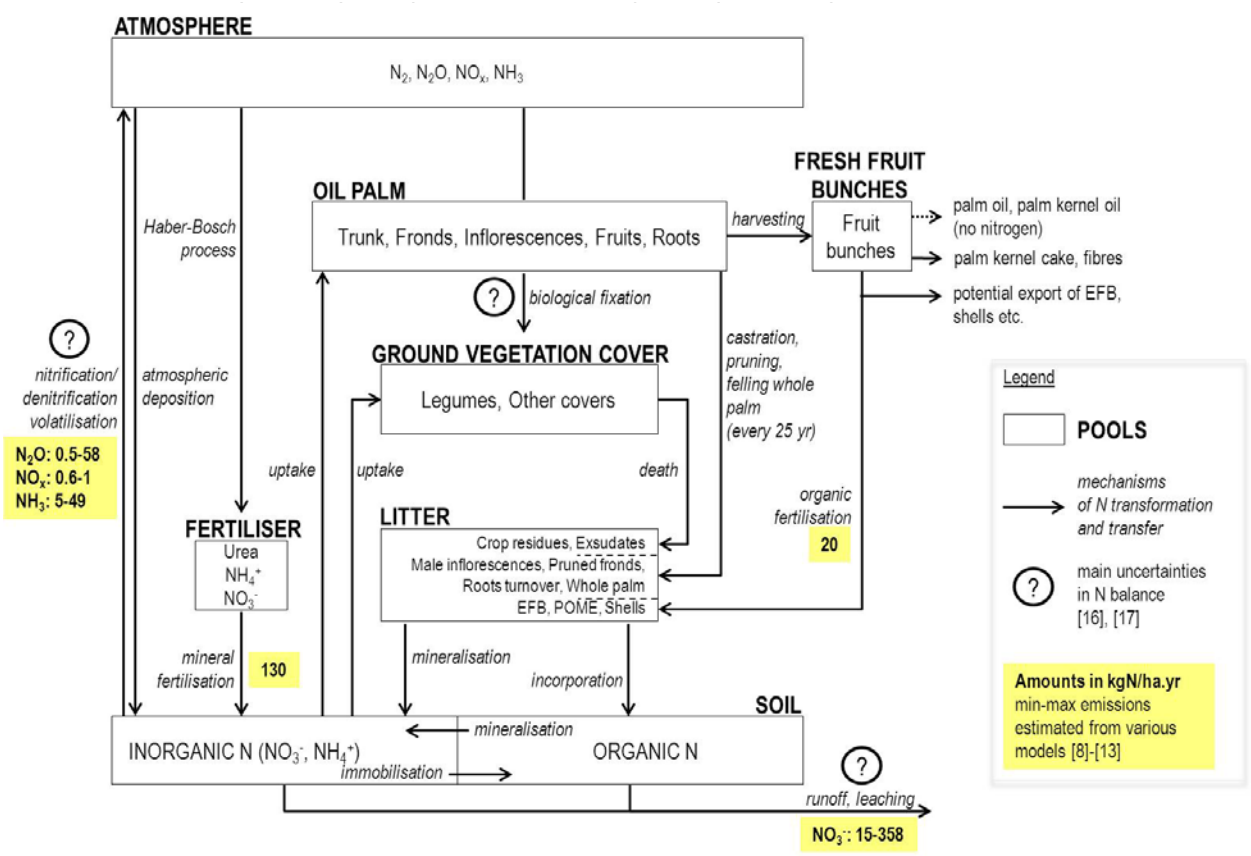

Figure 1: The nitrogen balance in oil palm plantations, highlighting the main uncertainties

5. References

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