Nitrogen fluxes and losses in oil palm plantations: a review of available knowledge about measurements and models

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Improving palm oil production sustainability is crucial for both reducing negative environmental impacts (e.g. Carlson et al., 2012 for greenhouse gas emissions), and ensuring food security (Corley and Tinker, 2015; Rival and Levang, 2014). The application of nitrogen (N) fertilisers is a major source of environmental impacts associated with oil palm cultivation (Choo et al., 2011). Environmental assessments of palm oil production are useful to quantify impacts of N losses and identify potential improvements of management practices. However, such environmental assessments tend to be uncertain as there is no model specific to oil palm, sensitive to agricultural practices, which simulates all the N losses.

We performed three steps to synthesise the available knowledge about measurements and modelling of N fluxes and losses in oil palm plantations. The study focused on industrial oil palm plantations on mineral soils. First, we conducted a literature review of all the existing knowledge about N fluxes and losses in plantations. Second, we compared 11 existing models that may be used to predict N losses in plantations. Third, we performed an in-depth Morris's sensitivity analysis of one of these models, the APSIM-Oil palm process-based model (Huth et al., 2014).

In the literature review, we estimated the main N fluxes and N losses in oil palm plantations, we identified their drivers, and we pointed out the research gaps (Pardon et al., 2016a). In the model comparison, we identified the models ability to capture peculiarities of the oil palm system, their limits, and the main uncertainties in modelling (Pardon et al., 2016b). In the sensitivity analysis, we identified the key drivers of N losses and yield of APSIM-Oil palm model (Pardon et al., 2017).

This research constitutes a comprehensive synthesis of the available knowledge and models for N fluxes and losses in oil palm plantations. It provides useful insights for oil palm managers, experimentalists and modellers, to help identify management practices to reduce N losses in the environment, lacks of field measurements and modelling challenges. Finally, these results were used as a base for the building of IN-Palm, an agri-environmental indicator to estimate N losses in oil palm plantations.

Carlson, K.M., Curran, L.M., Asner, G.P., Pittman, A.M., Trigg, S.N., Marion Adeney, J., 2012. Carbon emissions from forest conversion by Kalimantan oil palm plantations. Nat. Clim. Change 3, 283–287. doi:10.1038/nclimate1702

Choo, Y.M., Muhamad, H., Hashim, Z., Subramaniam, V., Puah, C.W., Tan, Y., 2011. Determination of GHG contributions by subsystems in the oil palm supply chain using the LCA approach. Int. J. Life Cycle Assess. 16, 669–681. doi:10.1007/s11367-011-0303-9

Corley, R.H.V., Tinker, P.B.H., 2015. The oil palm. John Wiley & Sons.

Huth, N.I., Banabas, M., Nelson, P.N., Webb, M., 2014. Development of an oil palm cropping systems model: Lessons learned and future directions. Environ. Model. Softw. doi:10.1016/j.envsoft.2014.06.021

Pardon, L., Bessou, C., Nelson, P.N., Dubos, B., Ollivier, J., Marichal, R., Caliman, J.-P., Gabrielle, B., 2016a. Key unknowns in nitrogen budget for oil palm plantations. A review. Agron. Sustain. Dev. 36. doi:10.1007/s13593-016-0353-2

Pardon, L., Bessou, C., Saint-Geours, N., Gabrielle, B., Khasanah, N., Caliman, J.-P., Nelson, P.N., 2016b. Quantifying nitrogen losses in oil palm plantations: models and challenges. Biogeosciences 13, 5433–5452. doi:10.5194/bg-13-5433-2016

Pardon, L., Ian Huth, N., Netelenbos Nelson, P., Banabas, M., Gabrielle, B., Bessou, C., 2017. Yield and nitrogen losses in oil palm plantations: Main drivers and management trade-offs determined using simulation. Field Crops Res. 210, 20–32. doi:10.1016/j.fcr.2017.05.016

Rival, A., Levang, P., 2014. Palms of controversies: Oil palm and development challenges. CIFOR, Bogor, Indonesia.