



HAL
open science

Modelling potential nitrogen losses in oil palm plantations with IN-Palm, an agri-environmental indicator

Lenaïc Pardon, Christian Bockstaller, Raphaël Marichal, Ribka Sionita, Paul Nelson, Benoit Gabrielle, Jean-Paul Laclau, Jean-Pierre Caliman, Cécile Bessou

► To cite this version:

Lenaïc Pardon, Christian Bockstaller, Raphaël Marichal, Ribka Sionita, Paul Nelson, et al.. Modelling potential nitrogen losses in oil palm plantations with IN-Palm, an agri-environmental indicator. 8. International Congress on Environmental Modelling and Software, International Environmental Modelling and Software Society (iEMSs). FRA., 2016, Toulouse, France. hal-01578857

HAL Id: hal-01578857

<https://hal.science/hal-01578857v1>

Submitted on 29 Aug 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Copyright

-

Modelling potential nitrogen losses in oil palm plantations with IN-Palm, an agri-environmental indicator

**Pardon Lénaïc^a, Bockstaller Christian^b, Marichal Raphaël^{a,c}, Sionita Ribka^c, Nelson Paul^d,
Gabrielle Benoit^e, Jean-Paul Laclau^f, Caliman Jean-Pierre^{a,c}, Bessou Cécile^a**

^a CIRAD, UPR Systèmes de pérennes, F-34398 Montpellier, France

^b LAE, INRA, Université de Lorraine, 68021 Colmar, France

^c SMART Research Institute, Jl. Tengku Umar 19, Pekanbaru 28112, Indonesia

^d College of Science and Engineering, James Cook University, Cairns, Australia

^e AgroParisTech, INRA, UMR EcoSys, 78850 Thiverval-Grignon, France

^f CIRAD, UMR ECO&SOLS, Montpellier, France

Oil palm cultivation area is expected to increase until at least 2050. This expansion raises environmental concerns, not only regarding land-use change and its consequences, but also concerning potential impacts of losses of nitrogen such as ammonia volatilisation, nitrous oxide emission and nitrate leaching and runoff. The prerequisite to any work on the reduction of losses and identification of best practices is the development of an assessment tool. However, the available knowledge regarding nitrogen losses is limited for oil palm, which leads to high uncertainty in environmental assessment.

In this context, we chose to develop an agri-environmental indicator, IN-Palm, which aims at estimating the risk of nitrogen losses in oil palm plantations, using the INDIGO® method. This kind of operational model is built to assess environmental risks as well as being used as a decision support tool. The development of indicators is particularly relevant in such contexts of data scarcity, as it allows for harnessing the most of readily accessible data from a whole range of sources, i.e. measured or modelled, qualitative or quantitative, empirical or expert knowledge.

We adapted the indicator to characteristics of the oil palm system, such as the tropical climate, the long growth cycle of about 25 years and the high production of biomass. We designed it to be easily implementable with available data on climate and soil conditions, and sensitive to practices such as fertiliser application (type, rate and timing), legume cover establishment, and residue management. Future work will include a sensitivity analysis, a validation against experimental data of losses in Sumatra, and a validation by end-users in a plantation in Sumatra.

Keywords: oil palm; nitrogen losses; agri-environmental indicator; modelling; INDIGO®; IN-Palm, environmental impact assessment

1 INTRODUCTION

Oil palm is an important crop for global production of vegetable oil and for the economies of tropical countries. The area of land under oil palm cultivation, currently approximately 19 Mha, has been rising at 660,000 ha year⁻¹ over the 2005-2014 period (FAOSTAT 2014) and is likely to continue rising until 2050 (Corley, 2009). This expansion raises environmental concerns, not only regarding land-use change and its consequences, but also concerning potential impacts of losses of nitrogen (N) from fields. Addition of N via fertilisers and biological fixation (by legume cover crops) is a common practice to achieve the yield potential of the crop. However, this addition is associated with potential risks of N losses into the hydrosphere and atmosphere. For instance, during the cultivation period, 48.7 % of the greenhouse gases emitted to produce 1 t of oil palm fruit are due to the addition of N fertiliser (Choo et al., 2011).

In order to reduce N losses, we must be able to assess the risk of losses and to identify best management practices. We hence chose to develop an agri-environmental indicator, IN-Palm, using the INDIGO® method (Bockstaller and Girardin, 2008). This method has the advantage of being suitable for situations in which knowledge is limited, as is the case for the N cycle and N losses in oil palm (Pardon et al., 2016). Compared to process-based models, agri-environmental indicators use a limited number of input variables, while harnessing the most of readily accessible data from a whole range of sources, i.e. measured or modelled, qualitative or quantitative, empirical or expert knowledge (Girardin et al., 1999). Another advantage of this method is that it is designed to be sensitive to practices. Therefore, even if the estimation of a loss made using an indicator is less precise than one made using a process-based model, it is sufficient to assess the environmental risk and to support decisions based on site-specific practice levers.

IN-Palm is being designed for managers of oil palm plantations in order to answer the question: "what are the best practices to implement in this field, this year, to reduce N losses, given the environmental conditions, the characteristics of the field, and long term consequences of previous practices?". This indicator is adapted to characteristics of the oil palm system, such as the tropical climate, the long growth cycle of about 25 years and the high production of biomass. It is calibrated to an oil palm plantation in Sumatra, Indonesia. We designed it to be easily implementable with readily available climate and soil condition data and sensitive to practices such as fertiliser application (type, rate and timing), legume cover establishment, and residue management. Here, we present first the INDIGO® method conceptual baseline, the previous versions of the indicator and some suggested improvement tracks. Then, we present the new oil palm-adapted structure of the indicator following these tracks, and we discuss the next steps to finalise the indicator, i.e. sensitivity analysis and validation.

2 MATERIAL AND METHOD

2.1 INDIGO® method

The development of the INDIGO® method started in the 90's (Bockstaller et al., 1997) and remains one of the most comprehensive approaches to assess the environmental impacts of agricultural systems by combining quantitative and qualitative data based on expert knowledge (Girardin et al., 1999). Moreover, its structure is easily adaptable to new cropping systems, allowing for the accounting of context-specific practices. The original version of the INDIGO® indicator of N losses for annual crops in temperate areas (Bockstaller and Girardin, 2008, Bockstaller et al., 2008) was adapted for perennial crops in temperate areas, e.g. for vine (Thiollet, 2003). A preliminary version of IN-Palm was then developed for oil palm in tropical context, based on the adaptation for vine (Carcasses, 2004, Caliman et al., 2007). We further based our work on the preliminary version of IN-Palm.

We followed the five steps identified by Girardin et al. (1999) in the development of an indicator: (1) the definition of the objectives and the identification of the end-users, (2) the construction of the indicator, (3) the selection reference values, (4) the sensitivity analysis, and (5) the validation. The construction of the indicator is a compromise between the available information (quality and reliability), the current state of scientific knowledge, and the requirement of the users for simplicity. The reference values represent minimum values of the indicator output for which the agroecosystem is considered to be sustainable (Bockstaller et al., 1997). As the indicator must be readily understandable by non-expert farmers, it was proposed that the outputs be expressed not in physical units, but in dimensionless scores on a scale between 0 and 10, calculated with respect to the reference values (Bockstaller et al., 1997). The sensitivity analysis aims to estimate the influence of an input variable or a parameter on the indicator output. Finally, the validation, as discussed by Addiscott et al. (1995), aims to evaluate if the indicator "is well founded and achieves the overall objectives or produces the intended effects". As indicators differ from simulation models in different aspects, validation procedures commonly used in modelling have to be adapted and three steps of validation were proposed by Bockstaller and Girardin (2003): the design validation by a panel of experts, the validation of the soundness of the indicator outputs, and the end-use validation by end-users.

2.2 Previous versions of IN, the INDIGO® indicator for N losses

The version of the indicator designed for vine, IN-Vine, was adapted from the original IN in the early 2000's (Thiollet, 2003). It consists of three risk modules (R) related to the N losses assessed: R-NH₃, R-NO₃ and R-N₂O. Each module is calculated for one field and for one specific year. Modules are calculated in a certain order because the N lost through one flux is assumed not to be any longer available for others loss processes. First, the R-NH₃ module is calculated, for each application of fertiliser, as the volatilisation occurs quickly in the days following the application. Second, the R-NO₃ module assesses N losses through leaching with two different calculations. The first calculation estimates the N leached from fertiliser inputs after applications at the end of winter and end of spring. The second calculation estimates the N leached from the mineral N stock in the soil during the drainage period in the autumn-winter period. Third, the R-N₂O module calculates the emissions of N₂O over the whole year, as a portion of the N inputs from fertilisers remaining after volatilisation.

For R-NH₃, an emission factor is determined by expert knowledge for each fertiliser application, depending on influential conditions associated with the application, such as temperature, fertiliser type, soil calcium carbonates content, and mode of application. For R-NO₃, the losses are determined for each application in spring with an emission factor calculated with a simplified version of the Burns' model (1976), depending mainly on the timing of the application with respect to the peak of absorption of N by the vine. In winter, the leaching loss is determined as a portion of the remaining stock of N in the soil, depending on fertiliser surplus, nitrogen mineralisation from soil organic matter and crop residues, vine N uptake, and deep drainage during this period. Finally, for R-N₂O, the losses are determined with an emission factor corrected by factors associated with tillage, placement (burying) and soil type, from Bouwman (1996).

For each of the three modules, the value of N loss is transformed into a score between 0 and 10, with 7 being the score equal to the reference value, which is defined as the sustainable threshold. For R-NH₃, the reference value is 20 kg N ha⁻¹ yr⁻¹, which corresponds to the level of atmospheric N depositions above which effects such as soil acidification are observed (Bobbink and Roelofs, 1995). For R-NO₃, the reference value corresponds to the European legal limit of 50 mg of NO₃ l⁻¹. Finally, for R-N₂O, the reference value is 3 kg N ha⁻¹ yr⁻¹, i.e. about one third of the maximal emissions measured by Bouwman (1996).

In 2004, IN-Vine was adapted to oil palm by Carcasses (2004). This adaptation aimed at accounting for peculiarities of the oil palm system (see section 2.3), although not all oil palm-specific parameters could be added in this preliminary version. The three modules, their order of calculation, and their reference values were kept unchanged compared to the version of Thiollet (2003). As it was done for one specific year of a mature plantation (>7-year-old), this version is not suitable for young plantations. Only the mode of calculation of each module was modified in this version to be relevant for oil palm.

For R-NH₃, the emission factors were adapted by expert knowledge to tropical conditions and practices in oil palm. Emission factors were modified according to the likelihood of having rainy days just after the time of the application, placement of the fertiliser (surface or buried), and texture and compactness of soil. For R-NO₃, the mode of calculation is based on a N budget approach, coupled with a simple water budget using the estimated monthly drainage as an input. The values of N contents of plant residues and palm uptake, necessary for the N budget, were updated with measured data for oil palm. For R-N₂O, the method remained the same, but it was less sensitive to actual practices than for annual temperate crops, as in general there is no soil tillage in oil palm.

2.3 Identification of key features in N cycling and N losses in oil palm

Oil palm plantations are usually established for a growth cycle of approximately 25 years. In steep areas, terraces can be established before planting. Palms are planted as 1-year-old seedlings, the plantation is considered immature during the 2-3 first years, and then mature when the palm canopy closes. A legume cover, e.g. *Pueraria phaseoloides*, is generally sown in order to provide quick ground cover and fix N from the atmosphere. The legume rapidly covers the whole surface, declines as the oil palm canopy grows, and is at least partially replaced by more shade-tolerant vegetation around the 6th year when the palm canopy closes. Harvesting of fresh fruit bunches starts after about 2-3 years. For each fresh fruit bunch harvested, one or two palm fronds are pruned and left in the field, mostly in windrows in every second inter-row. The alternate inter-row is used for the harvest pathway. The natural vegetation cover in the harvest path and in the circle around the palms is controlled three

to four times a year with chemical or mechanical weeding, while in the remaining area, vegetation is left to grow. N mineral and organic fertilisers are applied. Organic fertilisers come mainly from the palm oil mill. After oil extraction, the empty fruit bunches and the palm oil mill effluent may be returned to parts of the plantation, either fresh or after co-composting. The old palms are felled and left in the field to decompose, and new seedlings are planted between them. Over the years, a spatial heterogeneity develops due to these practices. Three main zones can be differentiated: the harvesting path without vegetation cover, the weeded circles around palms with no or low vegetation, and the windrows where pruned fronds are left to decompose and covered by natural vegetation.

In oil palm plantations, internal fluxes are among the largest N fluxes (Pardon et al., 2016). They include palm N uptake, N released by residue decomposition, N fixed by the legume cover crop during the immature phase, and N released from felled palms from the previous cycle. Among N losses, N leaching and NH_3 volatilisation are the largest, but with a high variability depending on the age, the environmental conditions and management practices. Moreover, the losses through runoff and erosion are not negligible (Figure 1).

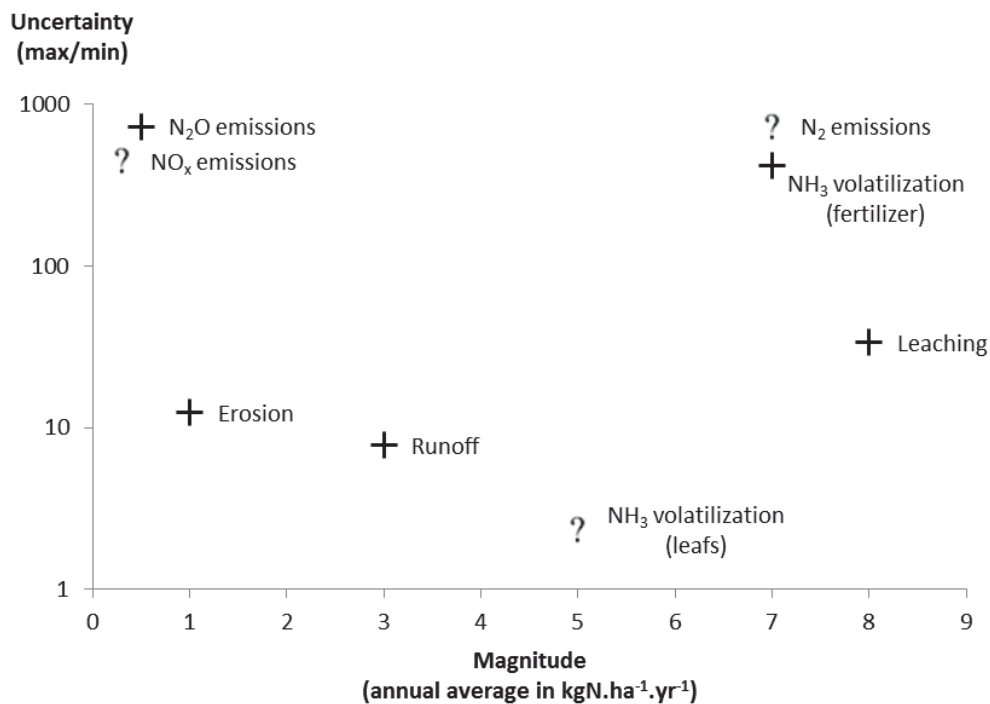


Figure 1. Uncertainty and magnitude of the N losses.

NH_3 volatilisation from fertiliser and leaching have high magnitude and high uncertainty. N_2O emissions have low magnitude but high variability. Uncertainties are calculated as the max/min ratio (logarithmic scale), and magnitudes are annual averages in $\text{kg N.ha}^{-1}.\text{yr}^{-1}$ estimated assuming an application of $100 \text{ kg N.ha}^{-1}.\text{yr}^{-1}$ of mineral N fertiliser. When no quantified estimates were available, approximations of uncertainty and magnitudes were done and are represented with “?”. Uncertainty and magnitude of NO_x and N_2 were considered to be comparable to N_2O , except for the magnitude of N_2 which must be higher. Uncertainty and magnitude of NH_3 volatilisation from leaves were considered to be comparable to NH_3 volatilization from annual crops (Andersen et al., 2001).

A comparison of 11 models to estimate N losses in oil palm plantations showed that about 80% of the modelled N loss was lost via leaching (Pardon et al., in review). The most important uncertainty across models occurred for leaching and denitrification. Moreover, a peak of emissions was modelled over the first years of the cycle, but the timing and the magnitude were very variable across models. The timing depended mainly on whether or not the process of N immobilisation in soil was considered when modelling the decomposition of residues.

A sensitivity analysis of the APSIM-Oil palm simulation model (Huth et al., 2014) showed that the most influential parameters for prediction of N_2O emissions and N leaching depended on the age of the palms (Pardon et al, in preparation). Before 7 years of age the amount of legume cover, the rate of

mineral fertiliser, and the soil organic C content were the most influential parameters. After 7 years of age the rate of mineral fertiliser and the drainage were the most influential parameters.

Given the characteristics of oil palm system, and given the results of previous studies, several points are important in order to improve IN-Palm. The indicator should be able to assess the risks of N losses at all the ages of the 25-year cycle, as the N dynamics and drivers do not remain the same over the years. For instance, the modelling of legume crop N fixation and release is important in the immature phase. Then, the important internal N fluxes, such as the decomposition of organic matter and the concomitant immobilisation of N in soil and litter, should be considered to assess losses with more accuracy. The large amount of N in decomposing matter could enhance losses, but the immobilisation could also reduce losses by delaying the release of N. As the losses through leaching seem to be the highest, with a high variability, the indicator should model this loss pathway carefully. For instance, the most influential parameters, such as the speed of drainage, should be considered with accuracy. As the N losses have a high variability, the calculation of the modules should be sensitive to practices and spatial heterogeneity. For instance, the distribution of vegetation cover or placement of residues may affect runoff, erosion or denitrification. Finally, in terms of indicator structure, it should be important to add a module about runoff and erosion as this loss pathway is not negligible. Even if the magnitude of NO_x emission is lower, it could be taken into account as it is associated with environmental impacts. Losses should be calculated in separated modules, in R-NH₃, R-runoff-erosion, R-leaching, R-N₂O, and R-NO_x, in order to be able to calculate environmental impacts related with each of the loss pathways, and identify the combination of practices having most impact on each of them.

3 RESULTS

3.1 General structure and methods of calculation of modules

We adapted the indicator to estimate the risks of N losses for one specific year in the whole cycle of 25 years. We kept the same three modules, R-NH₃, R-leaching, R-N₂O, and we added two more modules, R-runoff-erosion and R-NO_x. The calculation of R-NH₃, R-runoff-erosion, R-N₂O and R-NO_x are done independently, because emission factors used from literature are a fraction of the input of mineral and organic fertilisers, or residues. R-leaching is calculated after the other modules, as it has a budget approach in which all the other losses are considered.

For R-NH₃, we kept the same method, with an emission factor defined by a decision-tree, but we updated the emission factors based on measured fluxes in the literature (Pardon et al., 2016). R-NH₃ is calculated for each application of mineral fertiliser and palm oil mill effluent, and separately for each of the three zones of the plantation, being the harvesting pathway, the weeded circle and the windrow. Indeed, mineral fertiliser is applied only in the weeded circle during the immature phase, but in the weeded circle and the windrow in the mature phase. The emission factor is determined for each application, depending on the fertiliser type and placement, the soil texture and compactness and the likelihood of having rainy days just after the time of the application.

For R-runoff-erosion, we used a similar approach to that of the R-NH₃ module, with an emission factor defined by a decision-tree. We set the values of emission factors based on measured fluxes in the literature (Pardon et al., 2016) and a set of data from a trial in Sumatra, Indonesia (Sionita, 2014). Calculations are done jointly for the three zones of the plantation because the available data was not specific to each zone. Calculations are done for each application of mineral fertiliser, and they also account for the portion of N contained in rainfall that is lost through runoff. The emission factor depends on the presence of terraces, the slope, the texture of soil, the ground vegetation cover density, the rainfall intensity at the time of the application, and the presence of residues with anti-erosion placement (empty fruit bunches or pruned fronds).

For R-N₂O and R-NO_x, we kept the same general method of an emission factor, with correction factors depending on environmental conditions and practices. However, we increased the sensitivity of the model using a wider set of co-factors, and we increased the reliability of the prediction using a subset of data corresponding to tropical conditions (Stehfest and Bouwman, 2006), with additions of available measurements in the literature (Pardon et al., 2016). We used the method developed by Philibert et al. (2013) to calibrate the statistical model. Calculations are done separately for the three zones of the plantation, for each application of mineral fertiliser, and also taking into account baseline emissions

from each zone. The factors taken into account are soil compactness, soil drainage, soil texture, soil C content, and annual rainfall.

For R-leaching, we used an N budget approach coupled with a simple water budget, focussing on N in the soil. Calculations are done at a monthly time step, separately for the three zones, for one specific year. The two pools considered are mineral N in soil and the N immobilised in soil and litter. The inputs to the mineral N pools are the mineral fertiliser application, the atmospheric deposition and the palm oil mill effluent application, after subtraction of losses through volatilisation, runoff-erosion, and denitrification (N_2O , NO_x , N_2). Another input is the mineralisation of organic N in soil and litter, coming from the decomposition of plant residues, empty fruit bunches, and compost. When inputs of organic matter occurred over previous years, such as empty fruit bunch application or felling of palms, their mineralisation is also taken into account. The outputs are the N taken up by plants and N leaching. For each application of organic matter (empty fruit bunches, compost) and residues (e.g. pruned fronds), the rate of immobilisation or mineralisation is estimated from the C:N ratio. Drainage is estimated through a simple water budget approach, depending on rainfall, runoff, and evapotranspiration. A portion of the soil mineral N that is not taken up by the vegetation cover is considered to be lost through drainage. As fluxes of N and water differ between the three zones, the N and water budgets are calculated independently for the three zones, in order to obtain a more accurate estimate.

3.2 Reference values and calculation of scores

One of the objectives of the indicator is to be used as a decision tool. Thus, it must clearly help to identify best practices, in order to deliver a useful message to the manager. Hence, the indicator must link the potential environmental impact of N losses to the actual practices implemented in the field. In order to qualify a set of practices as sustainable or not, it is necessary to determine a reference value of loss below which the environmental impact is considered as acceptable in terms of sustainability. The choice of the reference value must be scientifically sound regarding the environmental processes involved, but also subjective in light of potential room for improvement and distance-to-target in terms of sustainable practices.

At this stage, we keep exploring the possibilities to define a reference value for each module, accounting for both the scientific soundness and the local peculiarities. One interesting track to pursue could be the normalisation of environmental impacts against carrying capacity of ecosystems, using the planetary boundary references from Rockström et al. (2009). Then, the score from 0 and 10 is calculated for each module, with the same method as in the previous versions of the indicator, depending on the difference between the loss estimated and the reference value.

3.3 Inputs from the user

Four groups of input data are necessary from the user: soil, climate, plants and practices. For soil, the main inputs are the slope, texture, drainage, soil organic C content and compactness. For the climate, the inputs are monthly rainfall and annual atmospheric deposition of N. For plants, the inputs are oil palm planting density and expected yield. For practices, the inputs are presence or absence of terraces, presence or absence of previous felled palms, establishment or not of a legume cover, vegetation cover density in each zone, presence or absence of pruned fronds, anti-erosion placement of residues, fertiliser type (mineral, empty fruit bunches, palm oil mill effluent, compost), and fertiliser application (rate, timing, placement).

Parameters of the indicator are based on references from the literature, but they can be modified easily by the user if more relevant values are available for specific conditions. For example, parameters include N content and C:N of palm tissues, rate of N immobilisation depending on C:N ration of residues and legume N fixation rate.

4 DISCUSSION

The future work to finalise the indicator will include a sensitivity analysis and a validation based on three steps proposed by Bockstaller and Girardin (2003).

One of the objectives of the sensitivity analysis is to check whether the outputs are sensitive to all the input variables, to be sure that the input variables are necessary and sufficient to estimate losses. Another objective is to check whether the indicator is sensitive enough to management practices. Sensitivity analysis is straightforward for quantitative variables because the effect on the output of a continuous variation of the input (e.g. amount of nitrogen fertiliser) can be evaluated. However, it is less easily carried out for qualitative variables where the input may be a class (e.g. soil texture). In the case of indicators, qualitative variables are commonly used and the method of sensitivity analysis must be adapted. One track to be pursued could be one of the three approaches proposed by Carpani et al., (2012) to perform sensitivity analysis of hierarchical qualitative models: factorial designs combined with analysis of variance, Monte-Carlo sampling and conditional probabilities. Another possibility could be to test contrasting scenarios of practices, and to compare the variation of outputs from IN-Palm to the variations of outputs from other models of N losses.

The indicator will be validated in three steps. The first step is the design validation by a panel of experts to evaluate if the structure of the indicator is scientifically founded. The second step is the output validation to assess the soundness of the indicator outputs compared to field measurement data. For the latter point, the available dataset consist of leaching measurements under mature oil palm, carried out from 2008 and 2015 in Sumatra, Indonesia. Concentrations of nitrate and ammonium in soil solution were measured at three different depths, 0.3, 1 and 3 m, in the three zones of the plantation, being the harvesting path, the weeded circle and the windrow. This dataset will be used to validate the R-leaching module, which is an important module in the indicator as it corresponds to the highest losses, with high variability. The third step is the validation by end-users. It will be done across several estates in a plantation in Sumatra, Indonesia, from where the leaching dataset comes. It will aim to evaluate the usefulness of the indicator as a decision-support tool.

5 CONCLUSION

We adapted the preliminary version of IN-Palm taking into account accurately peculiarities of oil palm system and available knowledge about N cycle and drivers of N losses in plantations. IN-Palm is hence adapted to oil palm characteristics, such as the tropical climate, the long growth cycle of about 25 years and the high production of biomass which is recycled in the field. It assesses the risk of losses through NH_3 , runoff-erosion, N_2O , NO_x , and leaching. In this context of data scarcity, the development of an indicator is an interesting option, and methods of calculation of losses are adapted to the limited knowledge about processes. The indicator is calibrated to an oil palm plantation in Sumatra, Indonesia. It is designed to be implementable with readily available input data, sensitive to practices, and useable to perform environmental impact assessments as well as to support decision-making process.

ACKNOWLEDGMENTS

The authors would like to thank the French National Research Agency (ANR) for its support within the frame of the SPOP project (<http://spop.cirad.fr/>) in Agrobiosphere program; ANR-11-AGRO-0007. We also thank Jacques Ranger, from the French National Institute for Agricultural Research in Nancy, who designed the trial of leaching measurements whose results will be used to validate the leaching module of IN-Palm.

REFERENCES

- Addiscott, T., Smith, J., Bradbury, N., 1995. Critical evaluation of models and their parameters. *J. Environ. Qual.* 24, 803–807.
- Andersen J M, H D Poulsen, C F Børsting, H B Rom, S G Sommer and N J Hutchings (2001), Ammoniakemission fra landbruget siden midten af 80'erne (English: Ammonia emission from agriculture since the mid 80ies). Faglig rapport fra DMU, nr. 353, Danmarks Miljøunder-søgelse, Miljøministeriet, Copenhagen
- Bobbink, R., Roelofs, J.G.M., 1995. Nitrogen critical loads for natural and semi-natural ecosystems: The empirical approach. *Water. Air. Soil Pollut.* 85, 2413–2418. doi:10.1007/BF01186195

- Bockstaller, C., Girardin, P., 2008. Mode de calcul des indicateurs agri-environnementaux de la méthode INDIGO. Rapprt Tech. INRA.
- Bockstaller, C., Girardin, P., 2003. How to validate environmental indicators. *Agric. Syst.* 76, 639–653. doi:10.1016/S0308-521X(02)00053-7
- Bockstaller, C., Girardin, P., van der Werf, H.M.G., 1997. Use of agro-ecological indicators for the evaluation of farming systems. *Eur. J. Agron.* 7, 261–270. doi:10.1016/S1161-0301(97)00041-5
- Bockstaller, C., Guichard, L., Makowski, D., Aveline, A., Girardin, P., Plantureux, S., 2008. Agri-environmental indicators to assess cropping and farming systems. A review. *Agron. Sustain. Dev.* 28, 139–149. doi:10.1051/agro:2007052
- Bouwman, A.F., 1996. Direct emission of nitrous oxide from agricultural soils. *Nutr. Cycl. Agroecosystems* 46, 53–70. doi:10.1007/BF00210224
- Burns, I.G., 1976. Equations to predict the leaching of nitrate uniformly incorporated to a known depth or uniformly distributed throughout a soil profile. *J. Agric. Sci.* 86, 305–313.
- Carcasses, R., 2004. Adaptation d'un indicateur agro-environnemental de pollution azotée à la culture du palmier à huile à Sumatra (Mémoire de fin d'études). DAA-ENSA Montpellier-France.
- Carpani, M., Bergez, J.-E., Monod, H., 2012. Sensitivity analysis of a hierarchical qualitative model for sustainability assessment of cropping systems. *Environ. Model. Softw.* 27–28, 15–22. doi:10.1016/j.envsoft.2011.10.002
- 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., 2009. How much palm oil do we need? *Environ. Sci. Policy* 12, 134–139. doi:10.1016/j.envsci.2008.10.011
- Girardin, P., Bockstaller, C., Werf, H.V. der, 1999. Indicators: Tools to Evaluate the Environmental Impacts of Farming Systems. *J. Sustain. Agric.* 13, 5–21. doi:10.1300/J064v13n04_03
- Huth, N.J., 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., 2016. 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., and Nelson, P. N., in review, 2016. Quantifying nitrogen losses in oil palm plantations: models and challenges, *Biogeosciences Discuss.*, doi:10.5194/bg-2016-177
- Pardon, L., Huth N., Nelson P.N., Banabas M, Gabrielle B, Bessou C, in preparation. Yield and nitrogen losses in oil palm plantations: key influential factors determined using simulation and sensitivity analysis.
- Philibert, A., Loyce, C., Makowski, D., 2013. Prediction of N₂O emission from local information with Random Forest. *Environ. Pollut.* 177, 156–163. doi:10.1016/j.envpol.2013.02.019
- Rockström, J., Steffen, W.L., Noone, K., Persson, A.S., Chapin III, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., others, 2009. Planetary boundaries: exploring the safe operating space for humanity.
- Sionita, R., 2014. Water run-off, soil erosion and nutrient losses: impact of slope and ground vegetation. Presented at the Oil Palm Cultivation: Becoming a Model for Tomorrow's Sustainable Agriculture, ICOPE, Bali, Indonesia.
- Stehfest, E., Bouwman, L., 2006. N₂O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modeling of global annual emissions. *Nutr. Cycl. Agroecosystems* 74, 207–228. doi:10.1007/s10705-006-9000-7
- Thiollet, M., 2003. Construction des indicateurs viti-environnementaux de la méthode INDIGO. INRA Colmar.

iEMSs 2016 Conference

Environmental modelling and software
for supporting a sustainable future

Draft



iEMSs 2016
Toulouse France

Proceedings | Volume 2 | Pages 351-569
**8th International Congress on Environmental
Modeling and Software (iEMSs)**

July 10-14, 2016
Toulouse, France

**Proceedings of the 8th International Congress on Environmental
Modelling and Software (iEMSs)
July 10-14, 2016, Toulouse, FRANCE.**

How to cite the full proceedings:

Sauvage, S., Sánchez-Pérez, J.M., Rizzoli, A.E. (Eds.), 2016. Proceedings of the 8th International Congress on Environmental Modelling and Software, July 10-14, Toulouse, FRANCE. ISBN: 978-88-9035-745-9

How to cite an individual paper:

Author, A., Author, B., Author, C..., 2016. This is the title of your paper. In: Sauvage, S., Sánchez-Pérez, J.M., Rizzoli, A.E. (Eds.), 2016. Proceedings of the 8th International Congress on Environmental Modelling and Software, July 10-14, Toulouse, FRANCE. ISBN: 978-88-9035-745-9

Peer Review:

Each paper has been peer reviewed by at least two independent reviewers with possible outcomes of reject, revise, and accept.

TABLE OF CONTENTS

Stream B Sessions	351
Session B1: Data assimilation techniques for uncertainty reduction	352
Quillon Harpham, Nigel Tozer, Paul Cleverley, David Wyncoll and Doug Cresswell. A Bayesian method for data assimilation in probabilistic wave forecasting	353
Andrea Kaim, Anna Cord and Martin Volk. Optimal land use?! – A review on optimization techniques used in multi-criteria decision analysis	354
Lila Collet, Lindsay Beevers and Faye Entwistle. Future flood extents: capturing the uncertainty associated with climate change	355
Nabil El Mocayd, Sophie Ricci, Nicole Goutal, Mélanie Rochoux, Sébastien Boyaval, Cédric Goeury and Didier Lucor. Uncertainty quantification with Polynomial chaos expansion in Ensemble based data assimilation framework	356
Ondřej Tichý, Václav Šmídl and Radek Hofman. Bayesian Estimation of Source Term of Atmospheric Radiation Release with Interval Prior	357
Melanie Rochoux, Cong Zhang, Didier Lucor, Sophie Ricci and Arnaud Trouve. Data-driven wildfire behaviour modelling: application of FIREFLY to field-scale grassland controlled burns	365
Sébastien Barthélémy, Sophie Ricci, Nicole Goutal, Thierry Morel and Etienne Le Pape. Multi-dimensional hydraulic coupling for flood forecasting	366
Giorgio Mannina and Alida Cosenza. A mathematical model for GHG from SB-MBR: calibration by an innovative protocol	367
Ka In Hoi, Ka Veng Yuen, Kai Meng Mok, Ana Miranda and Isabel Ribeiro. Comparison of offline and online bias correction of WRF-EURAD in Porto, Portugal	377
Inderpreet Kaur and Gianni Pagnini. Fire-spotting modelling and parametrisation for wild-land fires	384
Session B2: Advances in agricultural modelling	392
Vasileios Myrgiotis, Robert Rees, Cairistiona Topp and Mathew Williams. Simulating regional-scale soil nitrous oxide emissions in Scotland	393
Wenfeng Liu and Hong Yang. PEPIC – understanding the impacts of different PET methods on simulating global crop-water relations of maize	394
Jingyi Yang and Craig Drury. Residual Soil Nitrogen Scenario Analysis of Canadian Farmland using a Canadian Agricultural Nitrogen Budget (CANB v4.0) Model	395
Val Snow, Rogerio Cichota, Nick Hutchings and Jonas Vejlin. Implementing urine patches in a dynamic processbased	403
Khaled Brimo, Stéphanie Ouvrard, Sabine Houot, François Lafolie and Patricia Garnier. Modeling the dynamic of PAH added with composts in agricultural soils: from laboratory calibration to field evaluation	411
Francois Guerrin, Zoubida Afoutni and Remy Courdier. Agent-based Modelling: What Matters is Action	412

Jim Ascough, Nathan Lighthart, Holm Kipka, Timothy Green, Gregory McMaster and Olaf David. Advances in the Spatially Distributed AgES-W Model: Parallel Computation, Java Connection Framework (JCF) Integration, and Streamflow/Nitrogen Dynamics Assessment	420
Dean Holzworth, Hamish Brown and Neil Huth. A better way of building plant models	421
Serge Zaka, Renáta Sándor, Raphaël Martin, Gaëtan Louarn, Katja Klumpp, David Borrás and Gianni Bellocchi. The Pasture Simulation model – evaluation of plant acclimatory effects on grassland systems in France	422
Maël Ameline, Rémy Fieuzal, Julie Betbeder, Jean-François Berthoumieu and Frédéric Baup. Assimilation of SAR and optical data into an agro-meteorological model for monitoring yield of corn	429
Marcelo Carauta Montenegro Medeiros de Moraes, Affonso Amaral Dalla Libera, Anna Hampf, Evgeny Latynskiy, José Maria Ferreira Jardim Silveira and Thomas Berger. Integrated assessment of novel two-season production systems in Mato Grosso, Brazil	430
Francesca Recanati and Giorgio Guariso. Assessing Crop Portfolios: Diversification versus Monoculture for Biodiesel	438
Lénaïc Pardon, Christian Bockstaller, Raphaël Marichal, Ribka Sionita, Paul Nelson, Benoît Gabrielle, Jean-Paul Laclau, Jean-Pierre Caliman and Cécile Bessou. Modelling potential nitrogen losses in oil palm plantations with IN-Palm, an agri-environmental indicator	445
Christian Troost and Thomas Berger. Advances in probabilistic and parallel agent-based simulation: Modelling climate change adaptation in agriculture	453
Andreas Enders, Matthias Langensiepen, Holger Hoffmann, Heidi Webber, Frank Ewert and Thomas Gaiser. Balancing between performance and flexibility in the object oriented model framework SIMPLACE	461
Sara Maqrot, Simon De Givry, Gauthier Quesnel and Marc Tchamitchian. Designing mixed fruit-vegetable cropping systems by integer quadratic programming	462
Tommy Klein, Argyrios Samourkasidis, Pierluigi Calanca, Ioannis N. Athanasiadis and Gianni Bellocchi. webXTREME: a simple web tool for calculating agroclimatic indicators of extreme events	471
Oleksii Kryvobok and Oleksandr Krivoshein. <i>Comparison the performance of different modelling solutions in agricultural systems in Ukraine</i>	472
Gregory McMaster, Debora Edmunds, Nathan Lighthart, James Ascough II, Timothy Green, Robert Erskine and Holm Kipka. Modeling winter wheat phenological responses to water deficits in the Unified Plant Growth Model (UPGM) component of the spatially distributed AgroEcoSystem-Watershed (AgES-W) model	473
Session B3: Methods for visualization and analysis of high-dimensional outputs from complex simulation models (5 submissions)	474
Jordi Ferrer Savall, Pierre Barbillon, Cyril Benhamou, Marie-Luce Taupin, Patrick Durand, Hervé Monod and Jean-Louis Drouet. Spatial and dynamic sensitivity analysis of a biophysical model of nitrogen transfers and transformations at the landscape scale.	475
Veronika Novotná, Bedřich Půža and Jiří Hřebíček. Modelling socio-ecological problems with delay. Case study on environmental damage	484

Kai G. Mertens, Iris Lorscheid and Matthias Meyer. Structural Equation Modelling for Individual-Based Simulation	364
Reza Hesani and Erik Pruyt. Hierarchical hybrid modeling	493
Romina Martin and Spencer Angus Thomas. Analyzing regime shifts in agent-based models with equation-free analysis	494
Session B4: Environmental and agricultural modelling for Ecosystem Services	503
Stephane Bourrelly, Antonino Marvuglia and Ian Vazquez-Rowe. Advanced clustering to integrate spatial socio-ecological components in decision-making: a case study on sustainable agriculture	504
Kanokwan Saswattecha, Lars Hein, Carolien Kroeze and Warit Jawjit. Land use change effects of oil palm expansion in Tapi river basin, Thailand	505
Martin-Clouaire Roger. Towards an ontology of ecosystem services for modelling and managing their flows to and from agriculture	506
Mamadou Sané, Jonathan Vayssières, Myriam Grillot, Alassane Bah and Alexandre Ickowicz. Simulating spatial changes in vegetation-livestock interactions under different landscape structures: a multi-agent system applied to agro-pastoral territories	507
Sabrina Gaba, Nathalie Peyrard, Julia Radoszycki and Régis Sabbadin. A Markov Decision Process model to compare Ecosystem Services provided by agricultural landscapes	515
Jule Schulze, Karin Frank, Joerg A. Priess and Markus A. Meyer. How can farmers' decisions and policy actions on novel bioenergy feedstocks affect the supply of ecosystem service bundles?	516
Sven Lautenbach, Anita D. Bayer and Almuth Arneith. Trade-offs between carbon storage, crop yield production and water supply at the global scale	517
Anne-Isabelle Graux, Katja Klumpp, Shaoxiu Ma, Raphaël Martin and Gianni Bellocchi. Plant trait-based assessment of the Pasture Simulation model	518
Hugo Thierry, Annie Ouin, Aude Vialatte and Claude Monteil. ATLAS: a tool to model spatial-temporal dynamics of processes influencing ecosystem services	526
Quang Bao Le. Rural Livelihood, Biodiversity and Carbon Stock in Vietnam Mountains: Agent-Based Modeling to Anticipate Trade-Offs	527
Francesca Recanati, Giorgio Guariso, Michel Saini and Sergio Vilchez Mendoza. Planning Complex Agro-Ecosystems: The Case of Analog Forestry	528
Romina Martin and Maja Schlüter. Balancing trade-offs among aquatic ecosystem services while navigating through regime shifts.	536
Session B5: Managing uncertainty	537
Baihua Fu, Joseph Guillaume, Michael Asher and Anthony Jakeman. Using scenario analysis to investigate uncertainty in water resource management	538
Evelina Trutnevyte and Philip Berntsen. New approach to interactive use of energy system models for policy support	539
Saman Razavi, Hoshin Gupta, Amin Haghnegahdar and Razi Sheikholeslami. A New Framework for Global Sensitivity Analysis for Environmental Modelling	540

Devanmini Halwatura, Alex Lechner, Neil McIntyre and Sven Arnold. Uncertainties in estimating design droughts	541
Audrey Douinot, H�el�ene Roux and Denis Dartus. Including discharge uncertainties into an adaptable objective function for rainfall - runoff model calibration and evaluation	549
Joseph Guillaume, Casey Helgeson, Sondoss Elsayah, Tony Jakeman and Matti Kummu. How modellers frame uncertainty in scientific publications: review and reflections	550
Willem Vervoort, Joseph Henry, Mana Gharun and Mark Adams. The stability and ecophysiological realism of calibrated parameters in a detailed vegetation model (WAVES)	551
Mathias Braun, Olivier Piller, Angelo Iollo, Iraj Mortazavi and Jochen Deuerlein. Uncertainty Analysis toward confidence limits to hydraulic state predictions in water distribution networks	552
Sandra Lanini and Yvan Caballero. Groundwater recharge and associated uncertainty estimation combining multi-method and multi-scale approaches	553
Jiri Nossent, Mahyar Shafii and Willy Bauwens. Evaluating model structure uncertainty by a new approach to sensitivity analysis utilizing hydrological signatures	561
Carlo Giupponi, Juliana Bernhofer and Vahid Mojtahed. Uncertainty and resilience assessment of critical infrastructures: an airport case study	562
Joerg Priess, Christian Hoyer, Greta J�ackel, Sebastian Pomm, Eva Lang and Christian Schweitzer. Land use change and agricultural production of a Central European region expected until 2050	563
Matthias Kuhnert, Jagadeesh Yeluripati, Pete Smith, Holger Hoffmann, Marcel van Oijen, Julie Constantin, Elsa Coucheney, Rene Dechow, Henrik Eckersten, Thomas Gaiser, Bal�asz Grosz, Edwin Haas, Kurt-Christian Kersebaum, Ralf Kiese, Steffen Klatt, Elisabet Lewan, Claas Nendel, Helene Raynal, Carmen Sosa, Xenia Specka, Edmar Teixeira, Enli Wang, Lutz Weiherm�uller, Gang Zhao, Zhigan Zhao, Stephen Ogle and Frank Ewert. Effects of climate data aggregation on regional net primary production modelling	564
Hannah Kosow, Sigrid Prehofer and Wolfgang Weimer-Jehle. Context scenarios: understanding societal context uncertainty in environmental modeling	565
Tadesse Alemayehu, Ann van Griensven, Willy Bauwens and Hoshin Gupta. Calibration of Hydrological Model in Data Scarce Tropical Basin	566
Carmen Kuan, Robert Curry, Gloria Degrandi-Hoffman, Kris Garber, Andrew Kanarek, Marcia Snyder and Tom Purucker. Sobol' sensitivity analysis for stressor impacts on honeybee colonies	567
Graeme Riddell, Hedwig van Delden, Holger Maier, Aaron Zecchin and Graeme Dandy. Futures of resilience and mitigation – Combining stakeholder knowledge, statistical analysis and integrated modelling to better understand and reduce disaster risk	568
Am�elie Pinet, Romain Bourget, Pierre Moreau, Nathalie Saint-Geours, Julia Radoszycki and Philippe Stoop. How weather uncertainty impacts the predicted yield in an agricultural decision support tool?	569