

# Nitrogen dynamics in flooded soil systems: an overview on concepts and performance of models

Khairudin Nurulhuda,<sup>a,b</sup> Donald S Gaydon,<sup>c</sup> Qi Jing,<sup>d</sup> Mohamad P Zakaria,<sup>e</sup> Paul C Struik<sup>f</sup> and Karel J Keesman<sup>b\*</sup>



## Abstract

Extensive modelling studies on nitrogen (N) dynamics in flooded soil systems have been published. Consequently, many N dynamics models are available for users to select from. With the current research trend, inclined towards multidisciplinary research, and with substantial progress in understanding of N dynamics in flooded soil systems, the objective of this paper is to provide an overview of the modelling concepts and performance of 14 models developed to simulate N dynamics in flooded soil systems. This overview provides breadth of knowledge on the models, and, therefore, is valuable as a first step in the selection of an appropriate model for a specific application.

© 2017 The Authors. *Journal of the Science of Food and Agriculture* published by John Wiley & Sons Ltd on behalf of Society of Chemical Industry.

Supporting information may be found in the online version of this article.

**Keywords:** nitrogen; dynamic model; flooded soil; flooded rice

## INTRODUCTION

Nitrogen (N) fertiliser is applied in flooded rice systems to increase grain production, but not all applied N will be absorbed by the rice crop.<sup>1</sup> The total N loss in fertilised and flooded rice systems can reach up to 50% of the total N applied, and may occur through several pathways, such as ammonia (NH<sub>3</sub>) volatilisation, nitrogen oxides (NO<sub>x</sub>) emissions from simultaneous nitrification and denitrification, and N leaching.<sup>2–5</sup> Although our aim is to increase grain production, it is also equally important to minimise total N loss from fertilised and flooded rice systems to reduce production costs and negative environmental outcomes.<sup>6,7</sup>

As an alternative to a conventional experimental approach, many semi-physical N dynamics models for simulating N dynamics in flooded soil systems have been developed over the last 30 years.<sup>5,8–16</sup> Simulations of system behaviour by these models under different conditions provide insights into the underlying mechanisms, and are useful in evaluating management practices to reduce N losses and increase grain production. However, the interactive, non-linear and time-varying N processes in flooded soil systems have resulted in models of different complexities. Consequently, model selection for a specific research application is challenging.

Jayaweera and Mikkelsen<sup>17</sup> reviewed the concepts and performance of physically based models developed for the estimation of NH<sub>3</sub> volatilisation in flooded soil systems without a rice crop and in the absence of other N processes; for example, models of Bouwmeester and Vlek,<sup>18</sup> Moeller and Vlek,<sup>19</sup> and Jayaweera

and Mikkelsen.<sup>9</sup> Benbi and Richter<sup>20</sup> reviewed the objectives and capabilities of about 20 soil N dynamics models, but the reviewed models were not applied to simulate N dynamics in flooded rice systems. Nieder and Benbi<sup>21</sup> reviewed models of carbon (C) and N dynamics in a soil–plant–atmosphere system, but few models were selected to illustrate different modelling concepts. Giltrap *et al.*<sup>22</sup> and Gilhespy *et al.*<sup>23</sup> specifically reviewed the development and performances of DeNitrification–DeComposition (DNDC) variants, while Keating *et al.*<sup>24</sup> provided an overview on the Agricultural Production Systems Simulator (APSIM).

\* Correspondence to: KJ Keesman, Biobased Chemistry and Technology, Wageningen University, PO Box 17, 6700 AA Wageningen, Netherlands. E-mail: karel.keesman@wur.nl

a Biological and Agricultural Engineering, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

b Biobased Chemistry and Technology, Wageningen University, Wageningen, Netherlands

c CSIRO Agriculture and Food, Brisbane, Australia

d Ottawa Research and Development Centre, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada

e Institute of Ocean and Earth Sciences, University of Malaya, 16310 Bachok, Kelantan, Malaysia

f Centre for Crop Systems Analysis, Wageningen University, Wageningen, Netherlands