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Review

First 20 years of DNDC (DeNitrification DeComposition): Model evolution

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ABSTRACT

Mathematical models, such as the DNDC (DeNitrification DeComposition) model, are powerful tools that are increasingly being used to examine the potential impacts of management and climate change in agriculture. DNDC can simulate the processes responsible for production, consumption and transport of nitrous oxide (N_2O). During the last 20 years DNDC has been modified and adapted by various research groups around the world to suit specific purposes and circumstances. In this paper we review the different versions of the DNDC model including models developed for different ecosystems, e.g. Forest-DNDC, Forest-DNDC-Tropica, regionalised for different areas of the world, e.g. NZ-DNDC, UK-DNDC, modified to suit specific crops, e.g. DNDC-Rice, DNDC-CSW or modularised e.g. Mobile-DNDC, Landscape-DNDC. A 'family tree' and chronological history of the DNDC model is presented, outlining the main features of each version. A literature search was conducted and a survey sent out to *c.* 1500 model users worldwide to obtain information on the use and development of DNDC. Survey results highlight the many strengths of DNDC including the comparative ease with which the DNDC model can be used and the attractiveness of the graphical user interface. Identified weaknesses could be rectified by providing a more comprehensive user manual, version control and increasing model transparency in collaboration with the Global Research Alliance Modelling Platform (GRAMP), which has much to offer the DNDC user community in terms of promoting the use of DNDC and addressing the deficiencies in the present arrangements for the models' stewardship.

Contents

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1. Introduction

Nitrous oxide (N_2O) is a powerful greenhouse gas (GHG) and is also implicated in depletion of the stratospheric ozone layer. Globally, agriculture contributes 60% of the total N_2O emissions (Smith et al., 2007, 2008). Agricultural soils are known to be an important source of N_2O through the processes of nitrification and denitrification and are estimated to contribute 6.1% to anthropogenic global warming (IPCC, 2007). Nitrification is the aerobic microbial oxidation of ammonium (NH_4^+) to nitrite (NO_2^-) and then nitrate (NO_3^-). Denitrification is the anaerobic microbial reduction of NO_3^- to NO_2^- and then to the gases nitric oxide (NO), N_2O and dinitrogen (N_2).

Mathematical models are powerful tools that are increasingly being used to examine the potential impacts of management and climate change in agriculture. Models can simulate the processes responsible for production, consumption and transport of N_2O (Williams et al., 1992). Models used to establish emissions under current management practices can also be used to compare alternative management scenarios intended to reduce emissions; this capability being more pertinent in a changing climate (Shepherd et al., 2011). Where measurements of emissions cannot easily be obtained, models may be used at the site-scale to interpolate and for nations to extrapolate measurement information, both spatially and temporally, for use in GHG inventories.

The DNDC (DeNitrification DeComposition) model was first described by Li et al. (1992) as a rain event-driven process-orientated simulation model for N_2O, CO_2 and N_2 emissions from agricultural soils in the U.S. The DNDC field scale model coupled decomposition and denitrification processes, as influenced by the soil environment, to predict carbon (C) and nitrogen (N) turnover in agricultural soils. During the past 20 years the original DNDC model, used by researchers throughout the world, has been modified and adapted to include different scenarios and other ecosystems, e.g. forests, wetlands, rice paddies.

Today, the differences and similarities between different DNDC models or versions are neither well-documented nor widely understood, either by the research community or by potential users. To rectify this, the UK has initiated the Global Research Alliance Modelling Platform (GRAMP, (2014); www.gramp.org.uk), using DNDC as a pilot model, with the aim of developing a meaningful, credible model web platform with existing data and prior knowledge. In consort with end-users, every stage will be open to critical review and revision to improve the predictions of soil C and N cycling in the context of climate change. The purpose of this paper is to review the state of the DNDC model to address the issues discussed above by, (1) exploring and describing the main features of different DNDC versions and how they have evolved and are related to each other, (2) assessing information on model use and how the model has been developed to answer questions in ecosystem modelling, and (3) highlighting strengths, weaknesses and potential improvements for the model.

2. Methods

2.1. Literature review of existing DNDC versions and family tree

As part of GRAMP, DNDC model versions have been documented and a model 'family tree' constructed. During this process, model versions were identified using a series of 'biopics'. The biopics were produced as a set of searchable 'card' records summarising versions of the DNDC model that can be used in the DNDC modelling portal as part of the GRAMP system. Using the citations for key papers identified from the biopics, a literature review was carried out and a review of the DNDC family members documented. This information was used to create a 'family tree' and document the chronological development of the DNDC model versions.

2.2. Survey on model use and development

To gather information on important changes to the model and compile information on model use and development, a survey was developed using the online software Quest Back. The survey was circulated to *c.* 1500 individuals registered to the DNDC Biogeochemistry Model website and global DNDC network. The survey gathered information regarding record keeping of model version