3.2 DEVELOPMENT OF A MODULAR AND CUSTOMISABLE SUIT OF MODELS FOCUSSING ON THE IDM FARMING UNIT

Background and key outcomes

Building an overarching structure for individual decision-making models (IDM) at farm level is a declared objective of the MIND STEP project. The general idea is to create a framework that permits coupling existing and newly developed models in a flexible manner, such that a variety of research questions can be addressed. One example would be the usage of empirical findings on risk behaviour of farmers in a simulation model to assess how novel risk-management instruments would be of interest for a risk-averse farmer.

The conceptual work on the design of such a modular system that permits flexible integration of empirical work and new features of simulation models had started right at the beginning of the project. The most important aspects of modularity in the context of farm-level modelling have been discussed in Britz at al. 2021, including the importance to select a core model, to which new modules may be linked. This also implies that a clear definition of obligatory inputs and outputs (interfaces) is necessary to ensure that the equations in the module can be executed, e.g. by providing default values for all parameters. The technical documentation of core model and modules, and the development of protocols for contributor should receive particular attention from the very beginning if model development and maintenance is to be distributed across multiple teams. Definition of inputs and outputs, protocols for module development, and general aspects of quality management have been put forward in MIND STEP Deliverable 3.1 on “Specification of model requirements: Protocols for code and data” (Müller at al., 2021). Building on the conceptual work by Britz at al. (2021) and Müller et al. (2021), MIND STEP Deliverable 3.2. “An overarching IDM model structure: Interfaces within the MIND STEP model toolbox” outlines how an overarching structure for the integration of the farm-level simulation model FarmDyn (Britz et al. 2026) with new modules and empirical work within MIND STEP has been realized.

Methodological developments

Overall, the idea of an overarching model is here neither strictly interpreted as one single operational stand-alone IDM model, i.e. a one model fits all approach, nor solely as a conceptual idea without concrete implementation steps. Rather, a modular structure in which different IDM models present in MIND STEP become more flexible, modular and general is proposed, facilitating two-way loose links between the different IDM models, including FarmDyn, covering the possibility to apply IDM models more easily to different farm samples. The focus of Deliverable 3.2. is on the interactions of methods and results developed in tasks within MIND STEP work package 3 (WP3), titled “Development of modular and customisable suit of models focussing on the IDM farming unit”. These tasks apply a wide range of methods, including micro-econometric analyses of crop-management choices, behavioural aspects of technology adoption, or risk-preferences, as well as the usage of farm-level simulation models for ex-ante impact assessment of policy and technology options. Integrating these approaches requires a conceptual structure that defines the interfaces between them and exploits the exchanges of data and methods as much as possible. An important conceptual decision was to select the FarmDyn model as the integrative core of the overarching framework and to

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develop interfaces to empirical and methodological works accordingly. The decision for FarmDyn is justified by the fact that it comes already equipped with a modular and flexible template structure, where modules are turned on and off depending on the needs of the user. The user has the possibility to adjust specific details of model with respect to different farming systems (dairy/mother cows, arable farming, etc.). Further, it comprises multiple options with regard to time dynamics and offers an annual and sub-annual temporal resolution for manuy decision variables. The farmer's behaviour is based on an optimization approach, either maximizing the net present value (NPV) of returns to farm assets (including working off-farm) or using stochastic dynamic programming to maximizes the expected NPV. The latter approach can be extended to cover risk behaviour based on different options. In addition, FarmDyn comprises a wider range of environmental indicators including N and P balances, GHG emissions, a nitrate leaching indicator, different protein and calories indicators, partly also considering emissions from up-stream industries in bought inputs.
Making use of these characteristics, new models developed within WP3 that represent farmers' behaviour regarding adoption of GHG mitigation options, alternative cropping systems, or risk management are coupled to FarmDyn in a modular fashion.

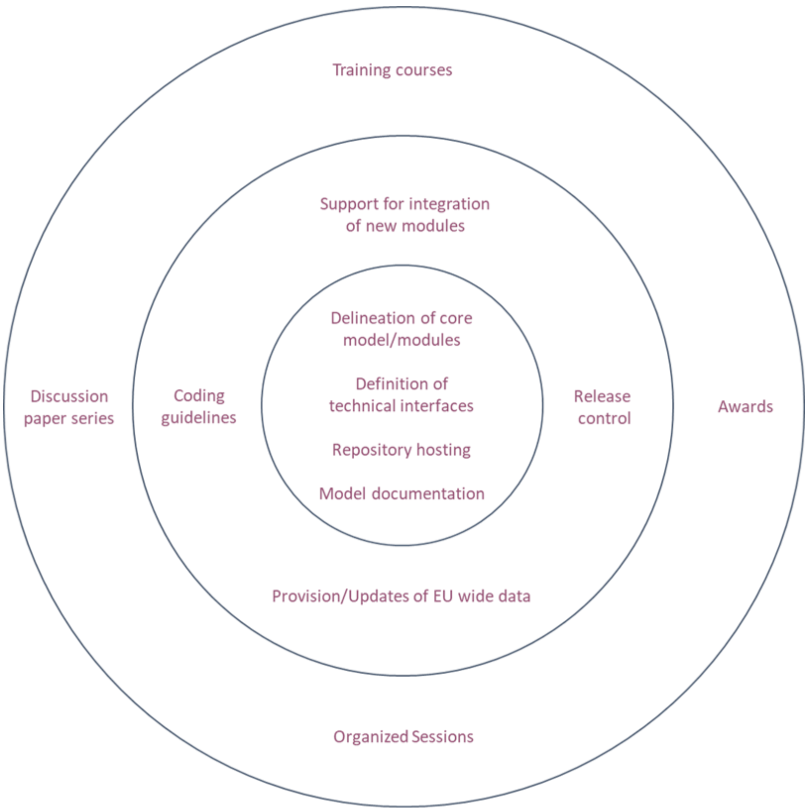
Collaborative activities

MIND STEP, together with the sister projects AGRICORE and BESTMAP, form the AgriModels Cluster, which aims at better understanding the impact of individual decision making in agriculture on the uptake of policies and technologies. Since inception, the three project have interacted closely with regard to data acquisition and dissemination of results. As an outcome of jointly organized sessions during past seminars, for instance a simulation model from the AGRICORE project became part of the combined modelling activities in MIND STEP.

Summary and outlook

Deliverable 3.2 provides an overview on conceptual considerations and implementations related to an overarching model structure at farm level in the MIND STEP project. It builds on the in-depth review of four applied models by Britz at al. (2021) and their proposed design principles for a generic, flexible, and modular bio-economic farm-level model, that can be extended and co-developed by a network of researchers.
The enhancements of FarmDyn led to a number of interesting applications within MIND STEP and improved the collaboration among the different teams of developers within MIND STEP and the AGriModels cluster projects, but also caused a range of new challenges. Increased flexibility and modularity also means increased complexity, with severe implications for model co-development, testing, and comparison of results between applications among the working groups. Comparison of model results, for instance, is only possible if all model settings are aligned, but this is already not feasible if, for instance, country-specific fertilizer ordinance modules have to be included. Good coding practices, separation of code from data, version control, the usage of test cases, and so on, greatly facilitate the exchange of modules, but their application in a new context could be impaired by conflicting settings in other modules. An example is the extended grassland module, which was developed in combination with Dutch dairy farms under Dutch fertilizer restrictions. Applying this for a German case study may cause conflicts with the German fertilizer restrictions unless the provided default data are adjusted. Such content-related problems are difficult to address by pre-defined protocols and can best

be solved by direct communication between the involved developers. Ensuring the continued use of the newly developed modules and data processing routines calls for establishing a network of developers and users, that remains in existence beyond the duration of a single project like MIND STEP. On this topic, Britz et al. (2021) conclude, that such a network would be essential for ensuring longevity and usability of a modelling framework centred around a bio-economic model like FarmDyn. The composition of the MIND STEP consortium and the distribution of the development work has already certain characteristics of a network as proposed by Britz et al. (2021). The developer teams are hosted mainly in public research institutions, i.e., governmental research institutions, European organisations or universities. FarmDyn is developed at the University of Bonn, where the main repository is located. It was adjusted for Dutch conditions by Wageningen Economic Research in close cooperation with the team in Bonn. New GHG mitigation options were also first implemented by the team in Bonn, then tested and re-parameterized in an iterative process with Wageningen Economic Research. The new risk module was also developed in Bonn (Britz, 2022) and then applied at other partner organisations. The involved teams form already a core network of developers and users as envisaged by Britz et al. (2021). Following their hierarchy of actions for establishing a network (Source: *Britz et al. (2021)*
Figure 1), the delineation of core model and modules, the definition of technical interfaces was conceptualized in deliverable 3.1 and subsequently implemented as described in this report. The repository for FarmDyn is hosted by the Bonn team, which also provides detailed model documentation. New modules as developed in MIND STEP can be shared via the repository hosted at IIASA (see MIND STEP deliverable 7.4.)



Source: Britz et al. (2021)

Figure 1 Hierarchy of actions to build a network of model users and developers

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Some general problems remain: research organizations and universities rely on third-part funding and usually have a high turnover of staff, such that individual knowledge may be lost for a network partner. If the network is sufficiently established, this could be compensated by taking over certain development responsibility by other partners and inclusion of new partners into the network. Training courses, organized sessions during conferences, or even discussion paper series can provide incentives for new partners to join the network and provide support. In this sense, the activities in MIND STEP can be seen as a first step towards a functioning model network to ensure the longevity of the overarching model structure proposed here.

The outlook is that a version of FarmDyn as the overarching farm model with the high level of detail regarding farm inputs and outputs would already be a valuable addition to the set of models used by the EU commission for policy evaluation and design. As the overarching farm model, it could serve as coefficient generator for the market models and it could give insights into the heterogeneous impacts of policies and events on farm level.

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