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Harmonization and translation of crop modeling data to ensure interoperability☆

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ABSTRACT

The Agricultural Model Intercomparison and Improvement Project (AgMIP) seeks to improve the capability of ecophysiological and economic models to describe the potential impacts of climate change on agricultural systems. AgMIP protocols emphasize the use of multiple models; consequently, data harmonization is essential. This interoperability was achieved by establishing a data exchange mechanism with variables defined in accordance with international standards; implementing a flexibly structured data schema to store experimental data; and designing a method to fill gaps in model-required input data. Researchers and modelers are able to use these tools to run an ensemble of models on a single, harmonized dataset. This allows them to compare models directly, leading ultimately to model improvements. An important outcome is the development of a platform that facilitates researcher collaboration from many organizations, across many countries. This would have been very difficult to achieve without the AgMIP data interoperability standards described in this paper.

Software and/or data availability

The data translation tools described herein are provided to AgMIP researchers at the AgMIP toolshed (http://tools.agmip.org/). These tools are in a continuous state of modification as translators for new models are added, new functions are included in the DOME, and known bugs are fixed. All source code for AgMIP projects, including applications described herein, is maintained under source control on GitHub. These repositories can be forked or downloaded from https://github.com/agmip and are further documented on the AgMIP research site at http://research.agmip.org/display/dev/Projects. The GitHub.com repositories relevant to this paper are:

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Acronyms

ACE	AgMIP Crop Experiment data schema
ACMO	AgMIP Crop Model Output data schema
AgMIP	Agricultural Model Intercomparison and Improvement Project
APSIM	Agricultural Production Systems sIMulator (crop model)
DOME	Data Overlay for Multi-model Export
DSSAT	Decision Support System for Agrotechnology Transfer (crop model)
EPIC	Environmental Policy Integrated Climate (crop model)
ICASA-MVL	International Consortium for Agricultural Systems Applications-Master Variable List
JSON	JavaScript Object Notation
RIA	AgMIP Regional Integrated Assessment
RRT	AgMIP Regional Research Team
RZWQM2	Root Zone Water Quality Model 2 (crop model)
SALUS	System Approach to Land Use Sustainability (crop model)
STICS	Simulateur mulTIdiscplinaire pour les Cultures Standard (crop model)
WOFOST	WOrld FOod STudies (crop model)

- Applications:
  - quadui
  - acmoui
- Libraries:
  - ACE data translators (input and output):
    - translator-apsim
    - translator-agmip
    - translator-wofost
    - translator-stics
    - translator-dist
    - translator-cropgrow
    - translator-dssat
    - translator-generic-csv
  - ACMO data translators:
    - acmo-apsim
    - acmo-dssat
    - acmo-cropgrow
  - agmip-common-functions
  - agmip-core
  - ace-core
  - ace-lookup
  - ace-translator-parent
  - agmip-parent
- Others:
  - json-translation-samples

AgMIP software tools above are made available under the BSD 3-Clause license.

1. Introduction

The Agricultural Model Intercomparison and Improvement Project (AgMIP, www.agmip.org, Rosenzweig et al., 2013a) seeks to improve the capability of biophysical and economic models to characterize the risks of hunger and food insecurity due to the increasing pressures of population, food price volatility, water scarcity, land degradation, competition for arable land, weather extremes and climate change. AgMIP promotes a consistent, long-term research approach to agricultural model testing, improvement and application across modeling disciplines, regions and scales. The project encourages use of ensemble modeling approaches with climate, biophysical and agricultural economics models.

AgMIP protocols emphasize the use of multiple models because ensembles allow better characterization of the uncertainty associated with model outputs and because ensemble means of crop responses are more accurate than outputs from single models (Asseng et al., 2013; Bassu et al., 2014); consequently, data harmonization is essential to facilitate interpretation, storage, access, interoperability and publication of data products. Similar problems of interoperability across models, scales and data sets have been researched in the past using different approaches and solutions in different domains. There has been extensive development of modeling frameworks, which allow plug-and-play use of different models (e.g., OMS, David et al., 2013; KEPLER; TIME, Argent, 2004), or in a slightly different approach the development of shared standards implemented as in OpenMI (Gregersen et al., 2007; Knapen et al., 2013). Other efforts have focused on the developments of semantic techniques based on ontologies (Janssen et al., 2011; Villa et al., 2009). Recently, attention has gone to re-developing models as components that can be plugged into existing modeling frameworks, see Donatelli et al. (2014) for an example of such a solution. Modeling frameworks and standards such as the OpenMI have advantages in aligning multiple models in the same code base and allowing re-use of the models as components in different configurations and applications. Although successful in their specific modeling domains these modeling frameworks have seen little adoption by the original model developers or others to put models to new uses. This is due to the fact that some of those frameworks are too narrow as they are tailored to specific domain needs, while others, which are of generic nature, never invested enough in community building. Knapen et al. (2013) discuss reasons for slow or no adoption of OpenMI, which is currently proposed as an OGC (Open Geospatial Consortium; OGC, 2014) standard. One of the breakthroughs of the AgMIP work is that it focused early in community building, brought together almost all major crop model developer groups, and developed tools that have been used for numerous AgMIP studies. Results presented here is an outcome of a community process.

Interoperability and exchange of data among multiple models potentially increase research efficiency, allow models to use a greater variety of datasets, and facilitate comparability and ensembles. This paper describes the AgMIP approach to achieving data interoperability across crop models, which consists of first, establishing an efficient standardized data exchange mechanism with specifications defined in accordance with international standards; second, implementing a flexibly structured data schema to store experimental datasets; and third, providing consistent procedures for filling gaps in model-required inputs.

The following section describes the technical architecture, standards and components as part of the AgMIP data solution,