



**System for Environmental and Agricultural Modelling;
Linking European Science and Society**

**Agricultural Production and Externalities
Simulator (APES) prototype to be used in
Prototype 1 of SEAMLESS-IF**

Donatelli, M, van Evert, F.K., Rutgers, B., Trevisan, M., Ewert, F.,
et al.

Partners involved: CIRAD, CRA, IAMM, INRA, PRI, UNIABDN, WU



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SEAMLESS integrated project aims at developing an integrated framework that allows ex-ante assessment of agricultural and environmental policies and technological innovations. The framework will have multi-scale capabilities ranging from field and farm to the EU25 and globe; it will be generic, modular and open and using state-of-the-art software. The project is carried out by a consortium of 30 partners, led by Wageningen University (NL).

Email: seamless.office@wur.nl
Internet: www.seamless-ip.org

Authors of this report and contact details

Name: Marcello Donatelli
Address: Via di Corticella 133, 40128 Bologna, Italy
E-mail: m.donatelli@isci.it
Partner acronym: CRA-ISCI

Name: Frits van Evert, Ben Rutgers
Address: Wageningen, The Netherlands
E-mail: frits.vanevert@wur.nl
Partner acronym: PRI

For the AgroManagement component:

Name: Marcello Donatelli
Address: Via di Corticella, 133 – 40128 Bologna, Italy
E-mail: m.donatelli@isci.it
Partner acronym: CRA-ISCI

For the AgroChemicals component:

Name: Marco Trevisan, Andrea Sorce, Matteo Balderacchi, Andrea Di Guardo
Address: Piacenza, Italy
E-mail: marco.trevisan@unicatt.it
Partner acronym: CRA-UNICATT

For the Crop component:

Name: Frank Ewert, Peter Leffelaar, Eelco Meuter, Myriam Adam
Address: Wageningen, The Netherlands
E-mail: frank.ewert@wur.nl
Partner acronym: WUR-PPS

For the Soil Carbon and Nitrogen component:

Name: Jo Smith, Pia Gottschalk
Address: Aberdeen, UK
E-mail: jo.smith@abdn.ac.uk
Partner acronym: UNIABDN

For the Soil Water and Runoff components:

Name: Marco Acutis, Patrizia Trevisiol, Antonella Gentile
Address: Milano, Italy
E-mail: marco.acutis@unimi.it
Partner acronym: CRA-UNIMI

For the Weather components:

Name: Marcello Donatelli, Gianni Bellocchi, Laura Carlini
Address: Bologna, Italy
E-mail: m.donatelli@isci.it
Partner acronym: CRA-ISCI

For the Grasses component:

Name: Michel Duru, Pablo Cruz, Myriam Adam Partner acronym: INRA
Address: Toulouse, France
E-mail: michel.duru@toulouse.inra.fr

For the Vineyards/Orchards components:

Name: Christian Gary, Kamal Kansou, Jacques Wery Partner acronym: INRA
Address: Montpellier, France
E-mail: christian.gary@cirad.fr

For the Agroforestry component:

Name: Christian Dupraz, Kamal Kansou Partner acronym: INRA
Address: Toulouse, France
E-mail: dupraz@ensam.inra.fr

For the Soil Water 2 component:

Name: Erik Braudeau Partner acronym: CIHEAM-IRD
Address: Montpellier, France
E-mail: erik.braudeau@ird.fr

Name: Pierre Martin Partner acronym: CIHEAM-CIRAD
Address: Montpellier, France
E-mail: pierre.martin@cirad.fr

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General part

Objective within the project

Make available a flexible software simulation system to estimate agricultural production and system externalities in response to technical management, in specific weather-soil conditions.

General Information

Task(s) and Activity code(s):	T3.2-A3.2.9
Input from (Task and Activity codes):	T3.2-A3.2.1/2/3/5/7
Output to (Task and Activity codes):	T6.4-A6.4.3, T3.3-A3.3.3/4/5
Related milestones:	M3.2.2

Executive summary

Several simulation tools allow studying the impact of agricultural management on production activities in specific environments. Such tools are specialized, to different extents, to specific production activities: arable crops/cropping systems, grassland, orchards, agroforestry, livestock etc. Also, their focus includes to various degrees the estimate of system externalities which may have a negative environmental impact. Furthermore, the structure of such tools does neither allow an easy plug-in of modules for different agricultural production activities, nor the use of different approaches for the simulation of processes via alternate components. Finally, such systems are proprietary systems of either research groups or projects.

The SEAMLESS project aims at providing a tool to integrate analyses of impacts on a wide range of aspects of sustainability and multi-functionality of agriculture. This requires evaluating agricultural production and system externalities for most, if not all, types of agricultural production systems. It also requires the availability of a simulation framework which can be extended and updated by research teams with possibly different expertise, which allows a manageable transfer of research results to operational tools, and which is transparent with respect to its contents and its functionality.

The Agricultural Production and Externalities Simulator is a modular simulation system targeted at estimating the biophysical behaviour of agricultural production systems in response to the interaction of soil-weather and different options of agro-technical management. APES is currently meant to be used at field scale, simulating 1-D fluxes (future version will also use 2-D fluxes to account for multiple cropping). All modules of this release are first prototypes linked to test the hypothesis on the component based structure and to evaluate consequent modelling and technical issues; outputs should not be analyzed to evaluate model performance at this stage.

APES is an application which uses several components being developed to offer simulation options for different processes of relevance in agricultural production systems. Models are described in the associated help files of components, and a shared ontology is being built on

the web. Such components, which are designed to be inherently re-usable, that is, not targeted specifically to a given modelling framework, are also meant to be a concrete option to share modelling knowledge with other projects and the scientific community.

This report presents a description of the current state of development of APES (release 0.3; June 2006).

Scientific and societal relevance

The APES systems aims at providing a simulation system to allow an integrated biophysical evaluation of agricultural production and system externalities. Its design allows for extension and comparison of modelling approaches, it provides a framework for multi-team work, and it has auto-documenting features. Goals of the system are providing an easier transfer from research to operational use. The scientific relevance is then in the progress, in terms of flexibility, comprehensiveness, transparency, envisioned as the result of the development of operational tools to be made available for integrated evaluation of agricultural systems.

The societal relevance is placed in making available a tool which aims at providing a more integrated evaluation, compared to the tools available, of agricultural systems, thus allowing a better awareness of possible environmental impacts of production systems.

Specific part

1 Introduction

Several simulation tools allow studying the impact of agricultural management on production activities in specific environments. Such tools are specialized, to different extents, to specific production activities: arable crops/cropping systems, grassland, orchards, agroforestry, livestock etc. Also, their focus includes to various degrees the estimate of system externalities which may have a negative environmental impact. The structure of such systems does neither allow an easy plug-in of modules for different agricultural production activities, nor the use of different approaches for the simulation of processes via alternate components. Furthermore, documentation of such tools is often out of date, and it follows various standards which make it difficult to access information. Finally, such systems are proprietary systems of either research groups or projects.

The advent of component-based programming has enabled the development of scalable, robust, large-scale applications in a variety of domains, including agro-ecological modelling.

The SEAMLESS project aims at providing a tool to integrate analyses of impacts on a wide range of aspects of sustainability and multi-functionality. This requires evaluating agricultural production and system externalities for most relevant types of agricultural production systems. Whether some indicators of system performance can be derived using static models built on existing database, estimating system behaviour for innovative techniques requires process based simulation. Also, even for known system, some of the externalities due to agricultural production are not available as observational data except for a very limited number of experimental sites. The analysis of the biophysical components of agricultural systems thus requires the availability of a simulation framework which can be extended and updated by research teams and which allows a manageable transfer of research results to operational tools, and which is transparent with respect to its contents and its functionality.

The features outlined in the previous paragraph have been at the basis of the design of the Agricultural Production and Externalities Simulator. The first release of APES (to Work Package 6 – Test Cases), which is the topic of this report, is provided to get feedback for further development.

2 Agricultural Production and Externalities Simulator

The Agricultural Production and Externalities Simulator is a modular simulation model system targeted at estimating the biophysical behaviour of agricultural production systems in response to the interaction of weather and different options of agro-technical management. Although a specific, limited set of components is available in the first release, the system is being built to incorporate, at a later time, other modules which might be needed to simulate processes not accounted in the first version.

The processes are simulated in APES with deterministic approaches which are mostly based on mechanistic representations of biophysical processes. The criteria to select modelling approaches is based on the need of: 1) accounting for specific processes to simulate soil-land use interactions, 2) input data to run simulations, which may be a constraint at EU scale, 3) simulation of agricultural production activities of interest (e.g. crops, grasses, orchards, agroforestry), and 4) simulation of agro-management implementation and its impact on the system.

A basic assumption of any biophysical model is its capability to simulate the processes which influence noticeably the behaviour of a system, and given the purpose of the modelling action. An example to clarify this concept can be that, if the intended use of the model is to study water-limited agriculture, the model cannot be restricted to potential production. This example, however, is at “high” level, meaning that simulating water-limited production may require: 1) the simulation of a different number of approaches, and 2) even different approaches for the simulation of the same process, once environmental conditions change. As an example of point 1, studying the impact of mulching requires soil evaporation models which react to soil cover beyond that given by canopy cover, and the fate of the mulching material must also be simulated. An example of point 2 can be simulating the water budget in environmental conditions of typical peak evapotranspiration of say 5 mm day^{-1} on a deep soil vs. conditions where the peak evapotranspiration can be 12 mm day^{-1} on a shallow, cracking soil. The former case can likely be simulated with simpler (and yet perfectly adequate, thus to be chosen) approaches compared to the latter. Moreover, different approaches for process simulation may demand for different inputs, not necessarily available when making operational use of the model. Also, peer reviewed sources may propose alternative options for modelling processes with the same assumptions, thus requiring testing in operational conditions to assess performance and reliability. Finally, simulation of biophysical system, no matter what level of simplification is chosen to simulate the behaviour of a given system, requires expertise in different domains, demanding for a multi-team effort to address system analysis and model development. As a concluding remark, the discussion of this paragraph is meant to summarize the reasoning behind the need for a flexible and modular simulation system, hence having an impact on the requirements of the simulation system being developed in APES.

2.1 APES component based structure

APES architecture is an ongoing attempt to meet the following requirements for the simulation system:

- Capability for easy implementation of modelling approaches to account for simulating new processes or to provide alternative models;

- Transparency of models implemented: documentation and explicit definition of variables;
- Capability for multi-team development;
- Separation of data, models, and user interfaces to allow for re-use/multiple use of components developed.

APES is available as a modelling engine (simulation engine + model components), which has two uses:

- In SeamFrame, encapsulated in one application (“APES wrapper”) which links the modelling engine to the shell FSSIM-AM (applications Production Enterprise Generator, Production Technique Generator, Technical Coefficients Generator);
- As a stand alone application, in which the modelling engine is coupled to a graphical user interface.

The main components of APES are shown in Fig. 1

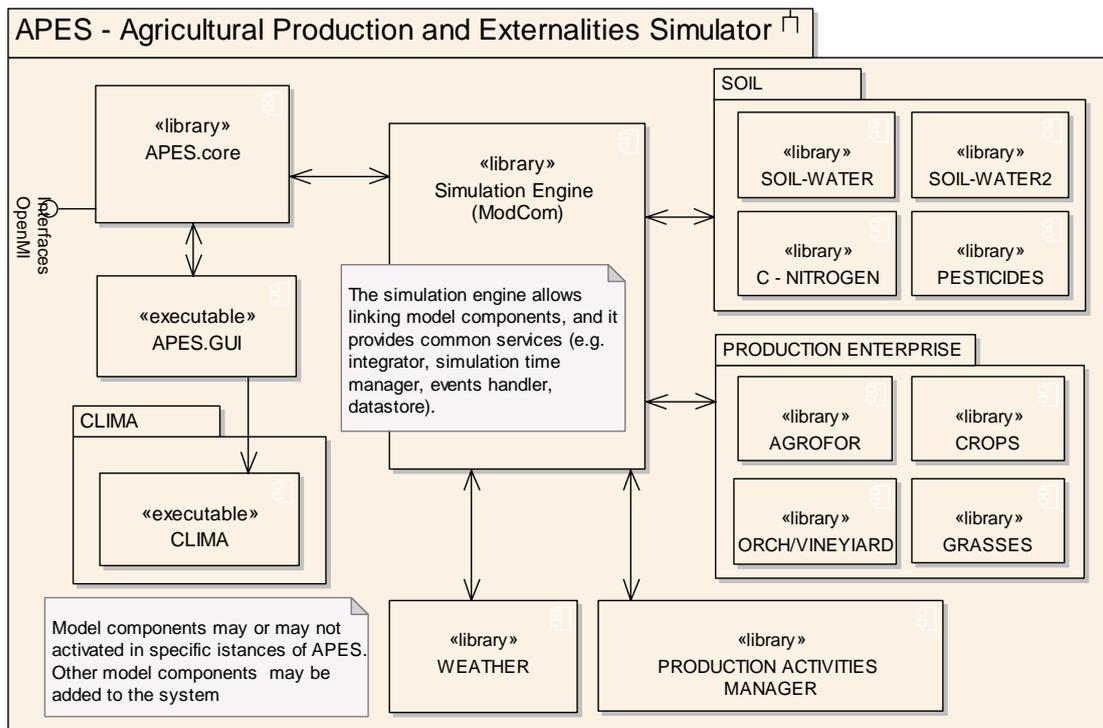


Fig. 1 APES component diagram. APES is composed of three main groups of software units: the graphical user interface and the core services component to run Modcom; the simulation engine Modcom, and the model components. Model components can be grouped as soil components, production enterprise components, weather and agricultural management. See text for details. Note that an alternate option for simulating soil water (SOIL WATER 2) is being developed to provide a first test for components interchangeability.

2.2 Models implemented

The model components included in the current release of APES are:

- AgroManagement;

- AgrochemicalsFate;
- Crop;
- Soil Water;
- Soil Erosion;
- Soil Carbon and Nitrogen;
- Weather.

Models implemented are quite comprehensive, and their full description is available in the help files, referenced in the appendix A. Such help files are in general divided in two sections: “models”, which contain model description, targeted to model users, and “design and use” which contain component information, targeted to developers. The components released to public also include a specific code documentation file.

All models use a daily time step for integration and communication across modules. Given that each component contains several models to simulate different processes, each from peer reviewed sources, the relevant references are listed in the documentation of each component (see appendix A). A summary reference per component is available in the reference section of this report for the component which were presented in a published peer reviewed paper. A summary description follows.

The AgroManagement component is designed to implement management events. It formalizes the decision making process via models called rules, and it formalizes the drivers of the implementation of the impact on the biophysical system via set of parameters encapsulated in data-types called impacts. The component is easily extendable for both rules and impacts, so that the implementation of management allows using different modelling approaches. Furthermore, the information on the biophysical system is passed via a data-type called states, which can also be extended. This is important as the current data-type includes the information needed by the rules currently implemented; newly implemented rules might require further variables which can then be added. The output drivers in terms of management actions to be applied as resulting from rules evaluated at run-time, to provide a simulation output (e.g. to output to a text file, to an XML file, and to a database, all currently available) can be fully customized by the user as well by adding new ones without recompiling the component.

The AgrochemicalsFate component allows estimating the fate of agrochemicals in the environment. The soil compartment is divided in two parts, the first represents the process over the soil surface, the second describes the soil profile. The applied pesticide may be deposited on soil surface, lost by drift, or intercepted by the crop canopy. Pesticides on the crop canopy can be volatilized or degraded, penetrate into the leaves, or can be washed off to the ground by rainfall or irrigation. From the surface, the chemical may enter the soil system transported by infiltrating water and constantly partitioned between the gas, liquid and solid phases of the soil. Chemicals are degraded in the soil profile by chemical, photochemical and microbial processes and might be taken up by plant roots.

The Crop Component is implemented as LINTUL model, a crop model that describes the biomass production as a function of intercepted radiation and its conversion efficiency. The crop growth is limited by two factors, the water stress and the nitrogen limitation. Water stress is modelled via the ratio between actual and potential transpiration; when a water stress event occurs, the simulated crop allocates more biomass to the roots and less to the shoot in order to increase the potential access the soil water. The simulation of nitrogen stress follows the growth dilution concept as implemented in the crop model CropSyst. Radiation use

efficiency is reduced by a fraction when the available percentage of nitrogen is between the minimum nitrogen requirement and the critical nitrogen requirement.

The soil carbon and nitrogen dynamics are described in the routines of the SoilCarbonNitrogen component, in which the SUNDIAL models are implemented. In SUNDIAL, the microbial processes of carbon and nitrogen turnover are described together with mineralization and immobilisation occurring during decomposition of soil organic matter. Furthermore, the bypass flow following addition of fertiliser, the nitrification of ammonium to nitrate, and the nitrogen losses by denitrification are also represented in detail.

The SoilWater component has the purpose of simulating the water dynamics in soil. This component describes the infiltration and redistribution among soil layers, the changes of water content, fluxes among layers, the effective plant transpiration and soil evaporation, the drainage if pipe drains are present. At the actual development stage, all the previous variables are simulated with daily time step, but algorithms and software structure are ready to work with an hourly or shorter time step.

The SoilErosionRunoff component has the purpose of simulating dynamically the water runoff and the soil erosion. In detail, it simulates the runoff volume, the amount of soil eroded, the interception by vegetation, and the water available for infiltration. This component has been structured in a hierarchical way with the Water component, but has its own data-type and related interfaces. As for the Water component, all the previous variables are simulated using a daily time step, but the algorithms and software structure are already designed to work with an hourly or shorter time step.

The Weather component has two functions: 1) to provide an estimate for missing weather data, and 2) to provide access at run time to location, weather, and soil data. Soil data loading is specific to location (as weather data) and to cumulate in one component many of the initialization procedures, soil data loading is a functionality included, so far, in the weather component. An associated application provided as a tool allows estimating weather variables via a rich library of alternate models implemented in five separate components: AirTemperature, Evapotranspiration, SolarRadiation, Rainfall, and Wind

Although weather and scheduled agro-management are inputs of APES simulation, specific components are needed into APES to load data and/or implement what relevant to such inputs.

2.3 APES intended use

APES' intended use of the current release is primarily the evaluation of its adequacy in terms of:

- Model framework, aiming at evaluating the possibility to link operationally different model constructs to develop a simulation tool. Such evaluation includes conceptual evaluation (criteria and needs to combine models implemented in discrete units), and technical evaluation (adequacy of modelling framework to link components);
- Graphical user interfaces, aiming at getting a feed-back from APES users on the stand alone application. Users of the integrated framework, if with a biophysical background, may want to build confidence on APES via a more detailed use as doable with a specialized user interface.

The current version of APES allows simulating rotations of crops (wheat, sunflower, maize, sugarbeet, potatoes) under water- and nitrogen-limited conditions. The system allows simulating water, nitrogen, and pesticides dynamics in response to agro-management in

combinations of soil-weather, at field scale, and, so far, simulating one dimension fluxes. The choice made for the spatial scale has been a direct consequence of the goals of the simulation: estimate production and system externalities in response to detailed agricultural management applied in specific soil-weather combinations. Modelling approaches selected and implemented in APES are mostly from peer reviewed sources on modelling approaches developed at field scale. Simulation outputs at field scale have been used in the literature as a base information at larger scales, when model tools are at times linked to geographical information systems. In such cases the more frequent recommendation is to use simulation outputs in relative comparison terms when evaluating say different agro-management options. Other options use simulation outputs at field scale as “cell” data to be integrated in spatially explicit models, as for some watershed models (in the latter case, in general the increased number of inputs needed is a limiting factor for use of such models beyond case studies). All uses at different than field scale add also at times strong assumptions to the ones made explicit for model use at field scale. Moving across scales is being addressed in SEAMLESS with specific actions.

The temporal scale is somehow still controversial, as different opinions exist in terms of possible drift in multi-year simulation without the re-initialization of state variables. However, this use is both a given and implicit in the simulation of crop rotations (multi-year), and accepted as in available peer reviewed sources on the use of tools very similar to this initial development of APES. The appropriate temporal scale will be assessed using sound procedures, to be formalized.

Whether the simulation tool is developed with a focus on modularity, APES versions including different modelling engines will be made available as “closed” modelling solutions to be used under the assumptions made available by their developers (modellers). A set of options may be made accessible (e.g. simulate reference evapotranspiration using this or this other model), but APES users will not access model composition (in their role of model users). However, an open system is being developed hence, the same individual, with a different role, may access model building, in this case taking the responsibility of choices made; this will also require the use of specific tools being developed into SEAMLESS.

Simulations can be run using long series of either generated or observational weather data, to account for the stochastic variability of weather. Outputs can be evaluated as means and associated measures of variability.

2.4 APES inputs

Whenever alternate options are available to simulate a given process, and such options perform almost equally well, the lesser demanding model in terms of parameters and inputs should be selected. However, even including option for estimating variables/parameters from readily available data, data availability (as data values and quality) cannot be the leading force in implementing model capabilities when it forbids achieving the goals of the simulations in SEAMLESS. In other terms, APES releases must minimize data requirements, and its application will highlight what data might be not available, although needed, at EU scale (both in absolute terms and in specific areas/countries). Such an analysis can be considered a side-product of the APES development action, but of specific importance. For instance, the formalization of agro-management using a common framework for current conditions is a need which goes beyond the needed use in APES.

2.4.1 Site specific variables

The lists below show the minimum site-specific data set required to run APES version 0.3 simulations. Full description of variables, including optional inputs, is provided in the help file of the component weather (see appendix A). Optional variables, when missing, are estimated as detailed in the documentation. In general terms, a missing weather variable can be estimated, but it requires dedicated parameters for the purpose (e.g. global solar radiation requires the availability of the *b* parameter of Bristow-Campbell model; reference evapotranspiration can be estimated with the method Hargreaves, which is the less demanding in terms of inputs among the methods available, but then the *intercept* and *slope* parameters of the calibration vs. the Penman-Monteith estimates are required). Whether default values for such parameters are provided, the use of the simulation tool in a wide range of environmental condition would then require site specific parameters to be made available. In other words, flexibility is implemented to overcome missing data, but making full use of it using default values minimizes the site specificity of estimates. The conclusive remarks from an operational perspective then are:

- even if the weather component can supply estimates of weather variables to integrate the minimum required, the estimate of missing weather variables such as global solar radiation and reference evapotranspiration should be made using tools which offer a greater flexibility than the ones built into APES (see 1.4.4)
- the use of the tools mentioned above requires, to maximize the specificity of estimates with respect to sites, further observational data even if for a limited number of years (e.g. observed global solar radiation to derive parameters to estimate it, observational global solar radiation and wind speed to estimate reference evapotranspiration according to the Penman-Monteith model and then calibrate Hargreaves vs. Penman-Monteith, estimating the *intercept* and *slope* parameters as in the example mentioned above).

Location (site)

<i>albedo</i> :	ratio between reflected and incoming radiation
<i>clearSkyTransmissivity</i> :	fraction of clear sky global solar radiation at ground level over extra-terrestrial global solar radiation
<i>latitude</i> :	latitude of the site

Soil (by soil horizon, up to 5 horizons)

<i>thickness</i> :	horizon thickness
<i>clay</i> :	percentage of clay
<i>sand</i> :	percentage of sand
<i>silt</i> :	percentage of silt
<i>organicCarbon</i> :	percentage of organic carbon
<i>bulkDensity*</i> :	dry bulk density

Weather (daily values)

<i>date</i> :	day, month, year
<i>rain</i> :	daily precipitation amount
<i>airTemperatureMax</i> :	daily maximum air temperature
<i>airTemperatureMin</i> :	daily minimum air temperature

* variables which are now required but which will be estimated in future releases if missing

2.4.2 Planned agricultural management

The planned agricultural management to be evaluated via simulations is an input to APES. Specific management events can be scheduled related to crops/orchards/grasses/agroforestry as “rules” (see Fig. 2). A rule may be triggered by dates or within a date windows, and, more often, also by the state of the system (e.g. irrigate from June 20 to August 10 if soil plant available water is below 1/3). Moreover, a rule can be triggered by a phenological stage. Once a specific rule is evaluated as true during simulation, the specific management is applied (e.g. irrigate, use a sprinkler, amount 45 mm) via making available to model components an instance data-types called “impacts”.

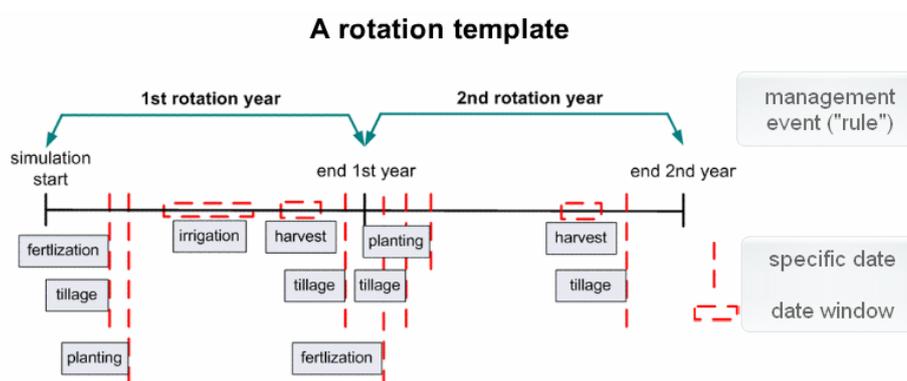


Fig. 2 Graphical representation of an example of rotation template: grey boxes are agro-management actions scheduled for a given date/date window, if other conditions based on the state of the system are matched (see text).

The rule approach implemented goes beyond that. Even the production enterprise can be driven by the state of the system (e.g. “if soil water is above a given threshold at a given date, plant this crop, if not plant this other crop”, or “implement a fallow – do nothing”). The system is hence extremely flexible.

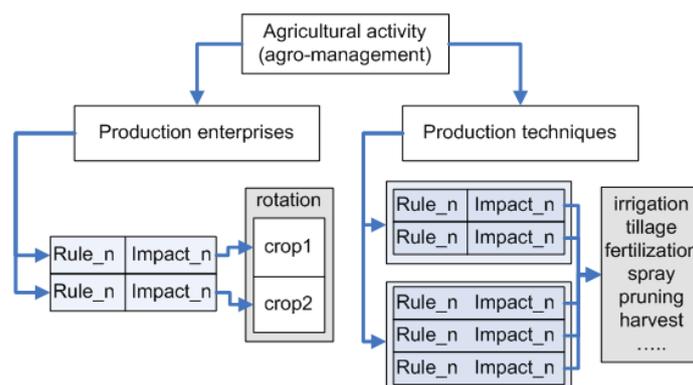


Fig.3 Diagram representing of the use of couples rule-impact to schedule and implement agricultural management both as production enterprise and as production technique.

One feature of interest is that implementing the rule approach allows formalizing what is generically referred to as “expert knowledge”. For example, expert knowledge which suggests, in a specific environment, to “plant maize at a *date* later than April 1st, if it has not rained for the *last 3 days*, and when *average air temperature* has been above 5 °C for *seven days* in a row” can be formalized and used in simulations. Words in *italic* will be the parameters of the rule to be compared to system states/exogenous variables at run-time (e.g. the condition “no rain for the last three days” is tested against the values of rain at run time

starting from April 1st as in the example above). The possible uses of such formalization are multiple, for instance to build and make persistent a quantitative database of agricultural management across Europe, to use the optimization of parameters in climate change scenarios as adaptation strategy and use such metric as part of climate change impact assessment, and to improve technical management in current conditions via rule-parameters optimization.

Currently, the management actions which can be implemented are crop operations, nitrogen fertilization (mineral and organic), tillage, irrigation, pesticides application. The software implementation is such that new agro-management typologies, and new actions within typology, can be easily added.

Scheduled agro-management is defined as files which can be used both by APES in SEAMLESS-IF and as stand alone application. In the former case they are built using some components of FSSIM-AM, in the latter via a dedicated graphical user interface.

2.4.3 Parameters

Parameters are defined as quantities which do not change value during the simulation or parts of the simulation. For instance, crop parameters change when a crop is changed during the simulation, but their values do not change during the time a given crop is simulated. A simulation system which allows for use of different modelling approaches cannot define a constant set of parameters. In fact, different simulation approaches may need to model a parameter (which then becomes a variable). For instance, a simulation system which does not model impact of tillage on soil physical properties will likely consider soil bulk density as a parameter, whereas bulk density will be modelled if the goal of simulation is estimating the impact of tillage on soil hydrological characteristics.

Parameters of the current version of APES are crop and soil carbon-nitrogen parameters. Crop parameters are detailed in a dedicated page of the help file attached to this report.

A general requirement to model component developers is to provide either ways to estimate needed parameters, or to provide parameter values (for instance in look-up tables). Default values are provided and are part of the definition of the parameter (as for variables), as well as minimum and maximum values.

2.4.4 Input estimating capabilities

APES estimates, if missing at run-time, daily values of:

- dayLength;
- globalSolarRadiation;
- referenceEvapotranspiration;
- vapourPressureDeficit.

Much richer estimating capabilities are available via the tool CLIMA (weather data need to be generated before running the simulation). CLIMA will be available from the APES stand alone installation (it already is, but with limited functionalities).

As for soil inputs, currently, APES allows estimating initial values of soil water content at field capacity and permanent wilting point.

2.5 APES outputs

APES makes available all daily outputs of components, which include some cumulated values computed when of interest. Summaries (e.g. yearlyNLeaching, cropYield) are extracted from such output. Daily outputs of soil are made available as vectors (one value per layer) for each variable.

All outputs are described in one of the graphical user interface display tables as minimum, maximum, and default values as defined for each variable and stored in the knowledge base being built (see Appendix A, help file of APES, tools, Model Component Explorer page): Also, a description and units are provided.

Some graphical interfaces are provided to evaluate simulation outputs in the APES stand alone release; and outputs can be saved as XML or MS Excel files. Such utilities will be further expanded to match model users requests. The graphical user interface capabilities, and the other functionalities of the current APES stand alone release are described in the APES documentation (see appendices A and B)

References

SEAMLESS papers (references about models are included in the documentation of each component)

Athanasiadis, I. N., A. E. Rizzoli, M. Donatelli, L. Carlini Enriching software model interfaces using ontology-based tools iEMSs congress, Vermont, July 2006 (accepted)

Carlini, L., G. Bellocchi, M. Donatelli, 2006. Rain, a software component to generate synthetic precipitation data. *Agronomy Journal* (in press)

Donatelli, M., F.K. van Evert, A. Di Guardo, M. Adam, K. Kansou, 2006. A component to simulate agricultural management. iEMSs congress, Vermont, July 2006 (accepted)

Donatelli, M., G. Bellocchi, and L. Carlini, 2006. A software component for estimating solar radiation. *Environmental Modelling and Software*. Vol. 21, 3:411-416

Donatelli M., G. Bellocchi, L. Carlini, . 2006. Sharing knowledge via software components: models on reference evapotranspiration. *European Journal of Agronomy* ,Vol. 24, 2:186-192

Donatelli, M., L. Carlini, G. Bellocchi, M. Colauzzi, 2005. CLIMA: a component based weather generator. In Zerger, A. and Argent, R.M. (eds) MODSIM 2005 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2005 ISBN: 0-9758400-2-9, p. 627-633

Rizzoli A.E, M. Donatelli, I. Athanasiadis, F. Villa, R. Muetzelfeldt, D. Huber, 2005. Semantic links in integrated modelling frameworks. In Zerger, A. and Argent, R.M. (eds) MODSIM 2005 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2005 ISBN: 0-9758400-2-9 p. 704-710

Villa, F., M. Donatelli, A. Rizzoli, P. Krause, S. Kralisch, F. K. van Evert Declarative modelling for architecture independence and data/model integration: a case study iEMSs congress, Vermont, July 2006 (accepted)

Glossary

<i>Component</i>	A (software) component is a discrete, binary (executable or library - no source code) unit of software. A component is a unit of composition with contractually specified interfaces and explicit context dependencies only. A software component can be deployed independently and is subject by composition by third parties. A component may implement one or more models.
<i>Model</i>	Conceptualization of a process. This is one possible definition of “model”, which is relevant for the work of developing components for biophysical simulation.
<i>Data-type</i>	Set of variables grouped to represent a domain (e.g. “soil water”) or for a specific use (e.g. parameters to implement the impact on the system of an agro-management action).

APPENDIX A: Documentation of model components

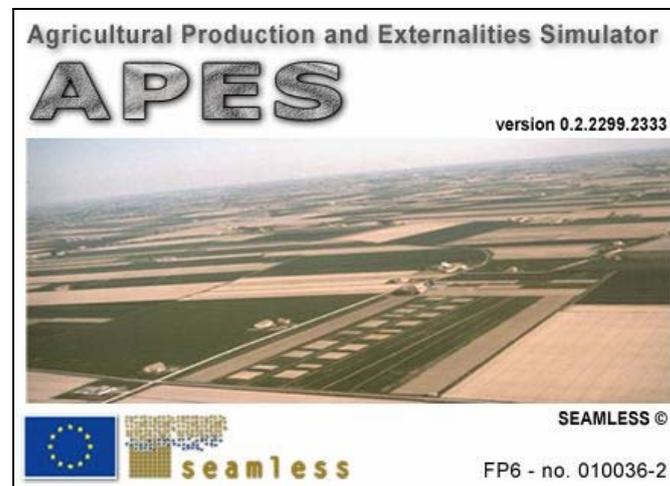
The documentation of models is quite comprehensive. Models are described in the help files which are used to document each of the components; the list below shows the correspondence between model components and relevant files. Such files are attached to this report as PDF files, and are also available as compiled HTML-style help files in APES installation (see Appendix C)

- AgroManagement CRAAgroManagement.pdf
- AgrochemicalsFate UNICATTAgrochemicalsFate.pdf
- Crops WURPPSCrop.pdf
- Soil Carbon and Nitrogen *(under development)*
- Soil RunOff and Erosion UNIMISoilErosionRunoff.pdf
- Soil Water UNIMISoilWater.pdf
- Weather
 - Air temperature CRAclimaAirT.pdf
 - Evapotranspiration CRAclimaET.pdf
 - Rainfall CRA.climaRain.pdf
 - Solar Radiation CRAclimaGsrاد.pdf
 - Wind CRAclimaWind.pdf

APPENDIX B: The APES stand alone application

All modules of this release are first prototypes linked to test hypothesis on the component based structure and to evaluate consequent modelling and technical issues; outputs should not be analyzed to evaluate model performance at this stage.

The APES stand alone application has a specific help file, attached to this report as a SEAMLESS_APES.pdf, which documents the graphical user interface and provides information for accessing information about models and tools. The APES stand alone installation also contains the tools AgroManagement Configuration Generator, the Model Component Explorer, and CLIMA.



APPENDIX C: The APES installation (v 0.3)

The APES stand alone application current release (version 0.3) is made available to project participants via internet at:

<http://www.sipeaa.it/ASP/ASP2/Apes.asp>

The application and related tools run under Windows 2000 and Windows XP. The installation of the Microsoft .NET framework 1.1 and 2.0 is required.

Model components are designed to be inherently re-usable, and are also meant to be a concrete option to share modelling knowledge and operational discrete software units with other projects and the scientific community. When made available as stand-alone software units, they include model and code documentation, and sample applications inclusive of code. The ones which are currently available for download are listed below.

Component	Owner	Download page
SolarRadiation	CRA-ISCI	http://www.sipeaa.it/ASP/ASP2/GSRad.asp
Rainfall	CRA-ISCI	http://www.sipeaa.it/ASP/ASP2/Rain.asp
Air temperature	CRA-ISCI	http://www.sipeaa.it/ASP/ASP2/AirT.asp
Wind	CRA-ISCI	http://www.sipeaa.it/ASP/ASP2/Wind.asp
Evapotranspiration	CRA-ISCI	http://www.sipeaa.it/ASP/ASP2/ET.asp
ClimReader	CRA-ISCI	http://www.sipeaa.it/ASP/ASP2/ClimReader.asp
AgroManagement	CRA-ISCI	http://www.sipeaa.it/ASP/ASP2/AgroManagement.asp
SOILWater	UNIMI	http://www.sipeaa.it/ASP/ASP2/SoilWater.asp
SOILErosionRunoff	UNIMI	http://www.sipeaa.it/ASP/ASP2/SoilErosion.asp
AgrochemicalsFate	UNICATT	http://www.sipeaa.it/ASP/ASP2/Pesticides.asp