European Commission

CropSyst

Modelling Solution

Reference documentation

Joint Research Centre

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Disclaimer

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Feel free to contact us, in case you need additional explanations or information.

Contents

About this document

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This document is targeted to the users of the BioMA Software Framework.

In particular, is targeted to end users who load the CropSyst modelling solution and run it in BioMa. It provides detailed information on how this modelling solution is built and how it works.

Furthermore, it provides links to the Web-based reference documentation for users who want to further understand how the modelling solution has been developed from the technical and scientific point of view.

For scientific information about the models used please refer to the documentation of the specific components.

The topics are organized as follows:

Web resources of interest

Resource	What you will find
BioMA Framework User Guide	A comprehensive Web-based help that provides a description of the BioMA framework, as well as an overview of its main components.
BioMA Framework Portal	The BioMA portal, which links to all components' available documentation.

Resource	What you will find
Composition Layer documentation	A document addressed to advanced users who want to deepen their knowledge on how the composition layer of the BioMA framework is coded.

CropSyst modelling solution description

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This section is organized into the following topics:

Other resources:

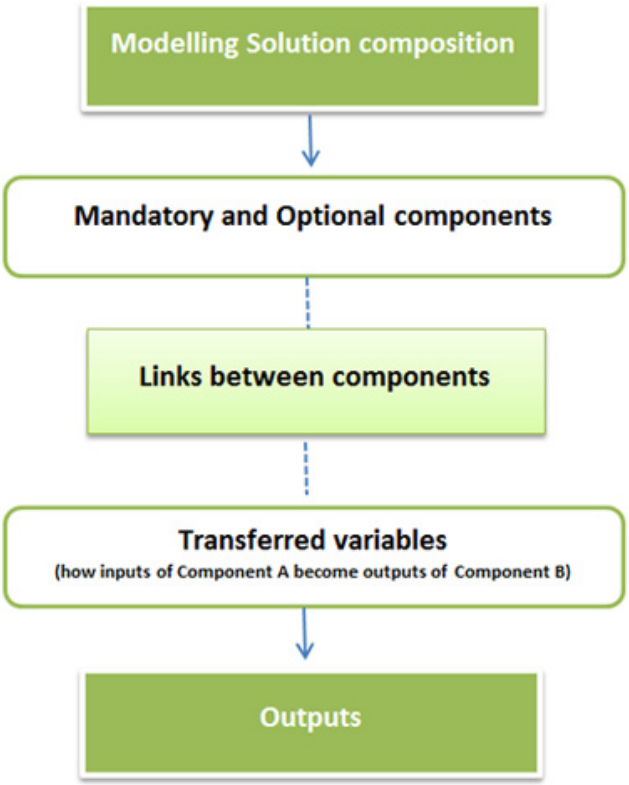
- Composition Layer documentation
- Web-based BioMA Framework User Guide
- CRA Web site: Tools for Agro-Meteorology and Biophysical Modelling

What is it and how it works

The CropSyst modelling solution is developed in the BioMA framework. It implements several approaches to model crop development and growth.

A modelling solution is the composition of many components. In this document you will find the details of the composition. However, this document does not cover the details of each component. Links to Web-based specific documentation is provided, when needed.

The following schematises how the CropSyst modelling solution works:



For further information, see:

- "Components of CropSyst" on page 7
- "How components are linked to each other" on page 12
- "CropSystModelling solution outputs" on page 22

Components of CropSyst

A component is a software library (or a set of libraries) that encapsulates a specific aspect of the simulated system.

A BioMA component must fulfill the constraint of the BioMA Composition Layer. Please refer to the Composition Layer Documentation for further details.

There are two types of components:

- “Mandatory components” on page 8
- “Optional components” on page 10

See also:

- “How components are linked to each other” on page 12
- “Required data providers” on page 19
- “CropSystModelling solution outputs” on page 22
- “Modelling solution simulation control” on page 23
- “Modelling solution switches” on page 24
- “Modelling solution agromanagement impacts” on page 26

Mandatory components

The following table lists the mandatory components that compose the CropSyst modelling solution. Click the link to go to a Web-based detailed description of the component, if any.

Component	Description	Link
Weather provider	This component provides the weather data to the other components. This component is part of the library EC.JRC.MARS.CompositionLayer.PreBuiltComponents.	
Agro management	This component reads the agro management configuration and, during the simulation, checks if some agro management rule is satisfied. When a rule is satisfied, the corresponding impact is triggered. The other components of the modeling solution can handle this impact. In the CropSyst modeling solution the components able to handle the agro management impacts are **SoilRE, CropSyst potential** and **CropSyst water limited**. This component is part of the library EC.JRC.MARS.CompositionLayer.PreBuiltComponents.	Click here
Soil data provider	This component provides the soil data to the other components. This component is part of the library EC.JRC.MARS.CompositionLayer.PreBuiltComponents	
CropSyst potential	This component performs the crop growth simulation in potential conditions. The name of the component is EC.JRC.MARS.Crop.CropML and the strategy used is **CropSyst**	Click here
CropSyst water limited	This component performs the crop growth simulation in water limited conditions. The amount of water available in the soil, and the other related variables are provided by the **Soil water content** component. The name of the component is EC.JRC.MARS.Crop.CropML_WL and the strategy used is **CropSyst_WL**	Click here

Component	Description	Link
Soil runoff erosion	This component calculates the soil runoff erosion. The component name is UNIMI.SoilRE and the strategy used in the usual implementation is **RunoffErosionCurveNumber**. The strategy used may vary according to the needs of the modeler.	Click here
Soil water content	This component calculates the soil water content and the related variables starting both from the rain/ irrigation data and the soil composition parameters. In the usual version of this modelling solution the UNIMI.SoilW component is used. In particular, the strategy used is **CropML_WOFOST_EvapCropSyst**. In this document SoilW is considered as the soil water content component and **CropML_WOFOST_EvapCropSyst** as the strategy used. But other versions of this modelling solution may use other components or other strategies to calculate the soil water content: for example the **CGMS Water Balance** component. By using different components/strategies the required inputs may vary and also the links between the components may change.	Click here

See also:

- “Optional components” on page 10
- “How components are linked to each other” on page 12
- “Required data providers” on page 19
- “CropSystModelling solution outputs” on page 22

Optional components

The optional components are not required to execute the modelling solution. However, these allow calculating additional variables, so improving the crop simulation. For example, you can simulate the impact of some plant's pathogens that might reduce the potential yield.

Currently, with the modelling solution you can simulate the soil pathogens (based on the soil temperature), some plant diseases (based on the leaf wetness), as well as the damage caused by the frost.

Please note that different versions of the modelling solution could contain different sets of optional components. Because of the modularity of the system, it is possible (and easy) to add a new optional component to the modelling solution and link it with the existing components. The list described in this document is the list of optional components used in a typical CropSyst modelling solution.

The following table lists the optional components that can be included. Click the link to go to a Web-based detailed description of the component, if any.

Component	Description	Link
Soil temperature	This component calculates the soil temperature starting both from the weather data and the soil composition parameters. The component name is UNIMI.SoilT and the strategy used in the usual implementation is **SurfacePartonSoilSWATHourlyParton**. The strategy used may vary according to the needs of the modeller.	Click here
Soil borne pathogens	This component calculates the growth of some soil pathogens from the soil temperature calculated by the **Soil temperature** component. The name of the component is CRA.Diseases.SoilBorne and the name of the strategy used is **RGRTRYanHunt**.	
Frost	This component calculates the damage caused by the frost to the plant. The name of the component is JRC.IPSC.MARS.Crop.AbioticDamage and the strategy used in the usual implementation is **FrostC**. The strategy used may vary according to the needs of the modeller.	Click here

Component	Description	Link
Leaf wetness	This component calculates the leaf wetness starting from the weather data. The name of the component is JRC.IPSC.MARS.Diseases.LeafWetness and several strategies could be used. The used strategy is set dynamically by a switch. See the switches section for further details.	Click here
Disease	This component calculates the diseases that might occur to some plants starting from the weather data and the leaf wetness. The name of the component is JRC.MARS.Diseases.Airborne.DiseaseProgress and the strategy used is **DiseaseSimulation**.	
Disease impact on plant	This component calculates the impacts on the plant as calculated by the **Disease** component. The name of the component is JRC.MARS.Diseases.Airborne.ImpactsOnPlants and the name of the strategy used is **LinearRUEBasedModelC**.	Click here

See also:

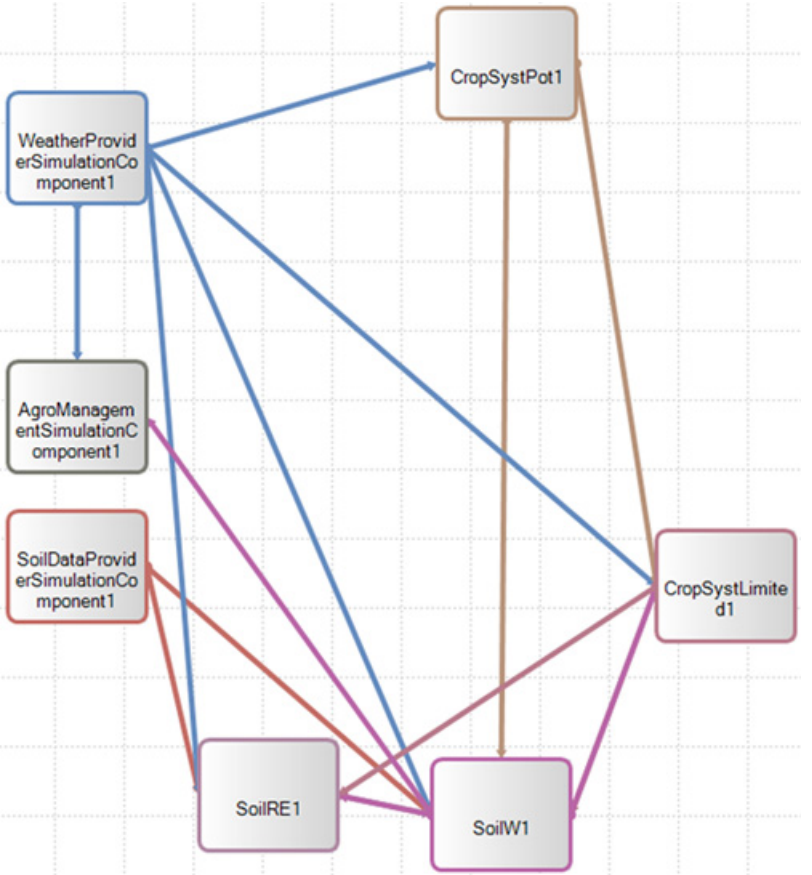
- “Mandatory components” on page 8
- “How components are linked to each other” on page 12
- “Required data providers” on page 19
- “CropSystModelling solution outputs” on page 22

How components are linked to each other

Mandatory components connections

The following flow diagram shows the connections between the mandatory components of the CropSyst modeling solution:

Figure 1 CropSyst - Connections between mandatory components



Note that a link starts from the ***source*** component and ends to the ***destination*** component. A link represents the transfer of values from the source to the destination component.

Tip:

For further details on the links between components, please refer to the BioMA Composition Layer Documentation.

The following table describes the links between the mandatory components:

Table 1 - Mandatory components links description

Source component	Destination component	Transferred value
Weather provider	Agro management	Weather data (rain, temperature).
Weather provider	CropSyst Potential	Weather data and location data (rain, temperature, radiation, vpd, humidity, evapotranspiration, CO2 concentration, day length, latitude).
Weather provider	CropSyst Water Limited	Weather data and location data (rain, temperature, radiation, vpd, humidity, evapotranspiration, CO2 concentration, day length, latitude).
Weather provider	Soil Water	Weather data (rain, temperature, radiation, evapotranspiration).
Weather provider	Soil Runoff Erosion	Weather data (rain).
Soil Data provider	Soil Runoff Erosion	Soil properties (slope, layers, length width).
Soil Data provider	Soil Water Content	Soil properties (bottom depth, clay, silt, sand, thickness, bulk density, organic carbon) for each layer.
CropSyst Potential	Soil Water Content	Set the transpiration potential of soil component as the transpiration calculated by the CropSyst potential component.
CropSyst Potential	CropSyst Water Limited	Set the transpiration potential of CropSyst water limited component as the transpiration calculated by the CropSyst potential component. Set the values of the switches of the limited component to the same values of the switches of the potential component.

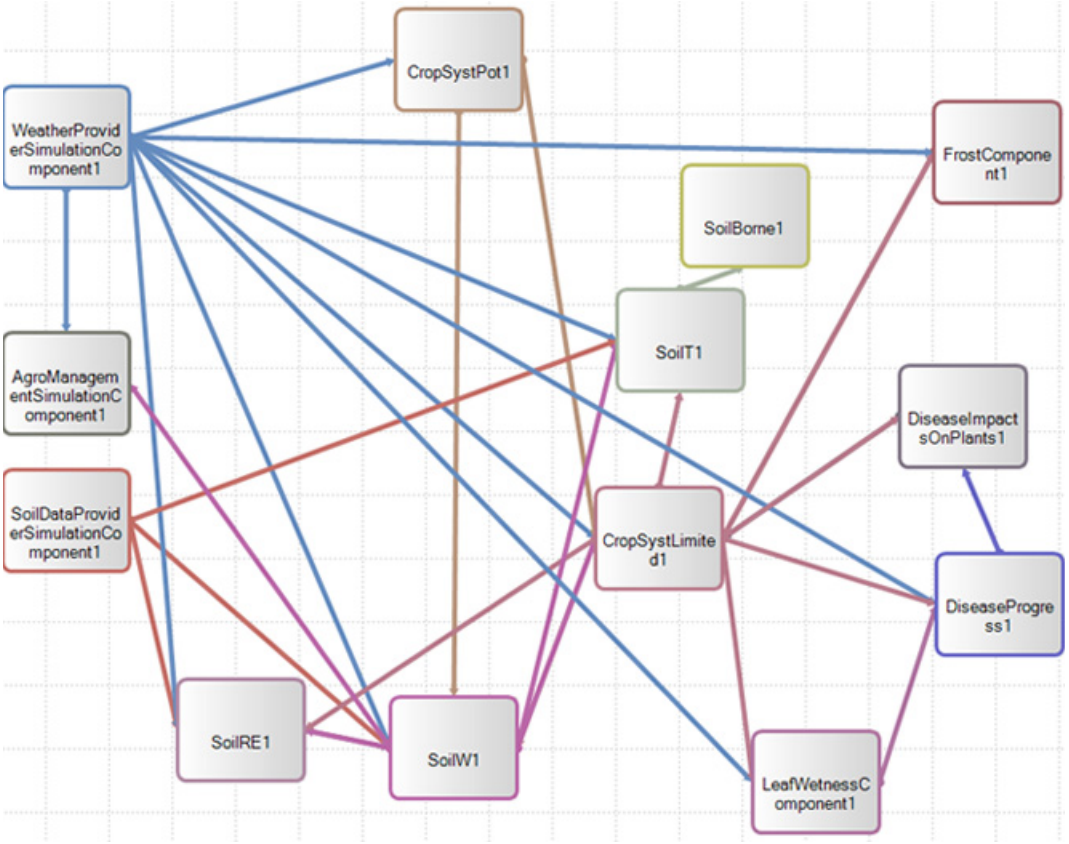
Table 1 - Mandatory components links description

Source component	Destination component	Transferred value
CropSyst Water Limited	Soil Runoff Erosion	Crop variables (crop height, leaf area index).
CropSyst Water Limited	Soil Water Content	Crop variables (crop roots depth, green leaf area, leaf area index as the soil fraction interception). Set the transpiration actual of soil component as the transpiration calculated by the CropSystwater limited component.
Soil Water Content	Agro management	Soil properties (bottom depth, clay, silt, sand, thickness, bulk density, organic carbon) for each layer.
Soil Water Content	CropSyst Water Limited	Set transpiration actual of CropSyst water limited component as the minimum of the transpiration calculated by the component itself and the root water uptake from soil.
Soil Water Content	Soil Runoff Erosion	Soil properties (bottom depth, clay, silt, sand, thickness, bulk density, organic carbon) for each layer.

Mandatory and optional components connections

The following flow diagram summarizes the connections between all components of the CropSyst modelling solution, including the optional components:

Figure 2 CropSyst - Connections between all components (including optional components)



The following tables describe the links:

Table 2 - Components links description (including optional components)

Source component	Destination component	Transferred value
Frost damage simulation		
Weather provider	Frost	Weather data (rain, temperature, wind, humidity)
CropSyst Water Limited	Frost	Crop variables (leaf area index)

Table 2 - Components links description (including optional components)

Source component	Destination component	Transferred value
Soil temperature and soil borne pathogens simulation		
Weather provider	Soil Temperature	Weather data and location data (temperature, radiation, day length, latitude). Moreover annual average temperature and daily hours of sunrise/ sunset are calculated by using the CLIMA ERExtraterrestrialRadiation strategy)
Soil Water	Soil Temperature	Soil properties (bottom depth, clay, silt, sand, thickness, bulk density, organic carbon) for each layer
Soil Data Provider	Soil Temperature	Soil properties (number of layers, layers thickness)
CropSyst Water Limited	Soil Temperature	Crop variables (leaf area index, biomass)
Soil Temperature	Soil Borne	Hourly soil temperature in the first two layers of the soil

Table 2 - Components links description (including optional components)

Source component	Destination component	Transferred value
Plant disease simulation		
Weather provider	LeafWetness	Several hourly weather variables are calculated starting from the daily weather variables provided by weather provider component. The hourly variables calculated are: radiation, temperature, rain, wind speed, dew point temperature, latent heat of vaporization, humidity, vpd, slope vapor pressure. The calculations are performed by CLIMA strategies.
Weather provider	Disease	Weather data (rain, wind, temperature)
LeafWetness	Disease	Hourly weather data (wind, humidity, temperature, vpd, rainfall) and hourly leaf wetness (a boolean that indicates whether the leaves are wet or not).
CropSyst Water Limited	LeafWetness	Crop variables (green leaf area index, canopy height)
CropSyst Water Limited	Disease	Crop variables (green leaf area index, dead leaf area index, total leaf area index, development stage)
CropSyst Water Limited	Disease Impact on Plant	Crop variables (green leaf area index, dead leaf area index, yield, radiation use efficiency)
Disease	Disease Impact on Plant	Hot tissue affected daily, hot tissue diseased daily
Disease Impact on Plant	CropSyst Water Limited	Values of green leaf area index and maximum radiation use efficiency decreased by the disease. The value of the maximum RUE is a parameter in CropSyst, so it was necessary to insert a new CropML Rate property (MaximumRUE). This rate is then set as the value of the MaximumRadiationUseEfficiency parameter of strategy CropSyst before calling it in the next time step

Related topics:

- “Mandatory components” on page 8
- “Optional components” on page 10
- “Required data providers” on page 19
- “CropSystModelling solution outputs” on page 22

Required data providers

Some components may require a data provider.

A data provider is a library for providing data of any type. It must fulfill the constraints defined in the BioMA composition layer.

Tip:

For a detailed description of what data providers are, please refer to the BioMA Composition Layer Documentation.

In the CropSyst modelling solution the required data providers are the following:

- "Weather data provider" on page 19
- "Soil data provider" on page 19
- "Agro management data provider" on page 20

Weather data provider

Required by: Weather provider simulation component.

This provider connects to a data source to get a set of daily weather data from a start date to an end date.

In the BioMA framework there are many implementations of weather providers, designed to connect to many different data sources. Typically weather data are stored in databases, but they can also be stored in textual CSV files or other standards.

When a user needs to use a new set of weather data, if the format of the data is not already managed by one of the existing weather providers, the user needs to create a new weather provider implementation (C# class). For the technical details of the implementation please refer to the composition layer documentation.

A weather provider must have methods to return daily weather data, location data (latitude, longitude, altitude) and other data like day length and CO2 concentration.

Soil data provider

Required by: **Soil data provider simulation** component.

This provider connects to a data source to get a set of soil data for a specific location.

The soil is modeled in a number of layers between one and ten, according to the desired level of accuracy and the availability of soil data.

Soil data include many soil variables: hydraulic properties, chemical properties, texture properties. These properties must be provided for each layer in which the soil is modeled. Please note that not every variable is required by the components. The user must refer to the documentations of the soil-related components to know which variable are actually needed.

In the BioMA framework it is already available an implementation of soil data provider that reads soil data from two XML files (`Soil_SoilParameters.xml` and `Soil_SoilInitialization.xml`). The class name of this provider is "`XMLFilesSoilDataProvider`" and it is contained inside the library "`EC.JRC.MARS.SoilDataProviderBaseInterfaces`".

When a user needs to use a set of soil data, he can write his data in the two XML files, using the "`XMLFilesSoilDataProvider`" format or he can create a new soil data provider to access directly to its data. For the technical details of the implementation please refer to the composition layer documentation.

Agro management data provider

Required by: **Agro management provider simulation** component.

This provider connects to a data source to get a set of agro management data for a specific location and year. Agro management data include rules to trigger management events on the crop like sowing, irrigation, tillering, harvesting, etc.

In the BioMA framework it is already available an implementation of agro management data provider that reads data from an agro management XML file. The class name of this provider is "`XMLFileAgromanagementProviderBase`" and it is contained inside the library "`EC.JRC.MARS.AgromanagementProviderBaseInterfaces`".

When a user needs to use a set of agro management data, he can code his data in an agro management XML files (by using the AgroManagement Configuration Generator - ACG) or he can create a new data provider to access directly to its data. For the technical details of the implementation please refer to the composition layer documentation.

Please refer to the agro management documentation to understand the agro management concepts, the use of ACG and the XML data format.

Related topics:

- “Mandatory components” on page 8
- “Optional components” on page 10
- “How components are linked to each other” on page 12
- “CropSystModelling solution outputs” on page 22
- “Modelling solution simulation control” on page 23
- “Modelling solution switches” on page 24
- “Modelling solution agromanagement impacts” on page 26

CropSystModelling solution outputs

The outputs of the CropSyst modelling solution are the following:

- The plant status t in both the potential and water limited conditions. The water limited status include as well the impact of the optional components that can change the plant status, that is, damages caused by: frost, soil borne pathogens, and diseases.

  The plant status consists in the physical features of the plant for each simulated day: above ground biomass, leaf area index, height, development stage, dead leaf area index, total leaf area index, transpiration, water uptake, root depth, and other secondary variables.
- The soil's water content in the various statuses in which has been divided the soil.
- The soil's temperature in the various statuses in which has been divided the soil (if the Soil temperature component is activated).
- The soil borne pathogen daily increase rate (if the Soil borne component is activated).
- The variables that describe the disease damages: the amount of tissue affected by the disease, the decreased leaf area index, the decreased RUE, the impacts of disease on different plant aspects like leaves or CO2 assimilation (if the Disease component is activated).
- The variables that describe the frost damage (spikelet sterility induced by cold, fractional reduced of plant production, fraction of leaves damaged by the frost, root lodging, sterility rate) (if the Frost component is activated).

Related topics:

- "Components of CropSyst" on page 7
- "Modelling solution simulation control" on page 23
- "Modelling solution switches" on page 24
- "Modelling solution agromanagement impacts" on page 26

Modelling solution simulation control

The simulation control of a modelling solution is the place where the modeller defines the simulation cycle in terms of starting date, ending date and time step interval. The CropSyst modelling solution requires a daily time step because all its components perform a calculation for each day. The modeller can use any simulation control that is based on a daily step cycle.

Related topics:

- “CropSystModelling solution outputs” on page 22
- “Modelling solution switches” on page 24
- “Modelling solution agromanagement impacts” on page 26

Modelling solution switches

The switches of a modelling solution are the options that the modeller can set to enable or disable an optional component or to change the internal behaviour of a component.

The switches of the CropSyst modelling solution are the following

- **Weather switch - Calculate evapotranspiration**: If this switch is set to `True` the Weather Provider component calculates the value of the daily evapotranspiration. The strategies used to calculate evapotranspiration are: **DRETHargreaves** and **DLHVHarrison** contained in the **CRA.Clima.dll** library. If the switch is set to `false`, the model uses the evapotranspiration read by the weather provider from the weather source. For further information, refer to the documentation here.
- **Weather switch - Calculate VPD**: If this switch is set to `True` the Weather Provider component calculates the value of the daily vapour pressure deficit. The strategies used to calculate VPD are: **DMVPDAirT** and **DVPDVPDmax** contained in the CRA.Clima.dll library. If the switch is set to `false` the model uses the VPD read by the weather provider from the weather source. For further information, refer to the documentation here.
- **Weather switch - Calculate humidity**: If this switch is set to `True` the Weather Provider component calculates the value of the daily maximum and minimum relative humidity. The strategies used to calculate humidity are: **HAirAndDewTemperature** and **HAirRelativeHumidity** contained in the CRA.Clima.dll library. If the switch is set to `false` the model uses the humidity read by the weather provider from the weather source. For further information, refer to the documentation here.
- **CropSyst Pot - Use vernalization**, **CropSyst Pot - Use PhotoPeriod**, **CropSystPot - Use temperature**, **CropSystPot - Use CO2**, **CropSystPot - Is C3**: These switches can change the internal behaviour of the CropSyst model. For further information on the effects of these switches, please refer to the documentation(CropML component) here.
- **Enable frost damage component**: If this switch is set to `True`, the frost damage optional component is included in the modelling solution, otherwise it is excluded. If this component is included, the modeller must configure its parameters before running the simulation.
- **CropSystLimited - Enable water limitation**: If this switch is set to `True` , the CropSyst limited component calculates the water limited crop

simulation by using the soil water content calculated by the soil water component. If the switch is set to `False`,the CropSyst limited component is executed without taking into account the soil water content (always set to a big number) and so the result should be equal to the CropSyst potential output. Please note that, in any case, CropSyst potential and CropSyst limited components use two different sets of parameters, meaning that they can produce different outputs.

- **Select leaf wetness strategy**: This switch is to select which strategy is used for calculated the leaf wetness. Leaf wetness is a requisite to calculate the plant disease. If this switch is set to `None`, the leaf wetness optional component is excluded from the modelling solution and leaf wetness is not calculated. By selecting one of the 6 alternative values, the corresponding strategy will be included in the model. The available strategies are: **CART**, **SWEB**, **ET**, **LWR**, **DP**, **FT**. If strategy **DP** or **SWEB** or **LWR** is included in the modelling solution, the modeller must configure its parameters before running the simulation.
- **Enable disease component**: If this switch is set to `True`, the disease damage optional component is included in the modelling solution, otherwise it is excluded. If this component is included, the modeller must configure its parameters before running the simulation.
- **Enable disease impacts on plants**: If this switch is set to `True` the **disease impact on plants** optional component is included in the modelling solution, otherwise it is excluded. If this component is included, the modeller must configure its parameters before running the simulation.

Related topics:

- “CropSystModelling solution outputs” on page 22
- “Modelling solution simulation control” on page 23
- “Modelling solution agromanagement impacts” on page 26

Modelling solution agromanagement impacts

The CropSyst modelling solution was built to manage any kind of agromanagement impacts: the modeller has to manage properly the impacts inside the code of the components involved. In the basic implementation of the modelling solution some impacts is already implemented. (For details on the impacts, see the agromanagement component documentation by clicking here).

Here is the list:

- Sowing of a crop (managed by CropSyst and CropSyst water limited components).
- Harvesting of a crop (managed by CropSyst and CropSyst water limited components).
- Irrigation (managed by SoilRE component).

Related topics:

- "CropSystModelling solution outputs" on page 22
- "Modelling solution simulation control" on page 23
- "Modelling solution switches" on page 24

Using BioMA Spatial to configure a modelling solution

BioMA Spatial is the graphical user interface of the BioMA Framework that allows you to configure and run a modelling solution.

Using BioMA Spatial, you can:

- Select the weather source data to connect to
- Edit the model parameters
- Run the model simulation
- Use the graphic visualizer to view the simulation results

Tip:

For step-by-step instructions on how to configure and run a modelling solution, please access the BioMA Spatial Help Online, then navigate to **Using BioMA Spatial to run model simulations > Choosing and configuring the modelling solution**.