modextreme

agriculture facing extreme climatic events

DG AGRI LUNCHTIME SESSION

The BioMA platform and applications

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Outline

- Do we need a modelling framework?
- What is BioMA?
- BioMA applications
- BioMA in MODEXTREME
- Conclusions





Model development and reuse

- The demand of model tools to perform integrated evaluation of agro-ecological systems has further increased in the last decade.
- The major obstacle to develop such simulation systems has been the fragmented availability of modelling resources, partly due to technical bottlenecks.
- Extension of modelling resources by adding modules, and replacing or changing existing ones to accommodate new modules, has not been at reach except by full recoding.





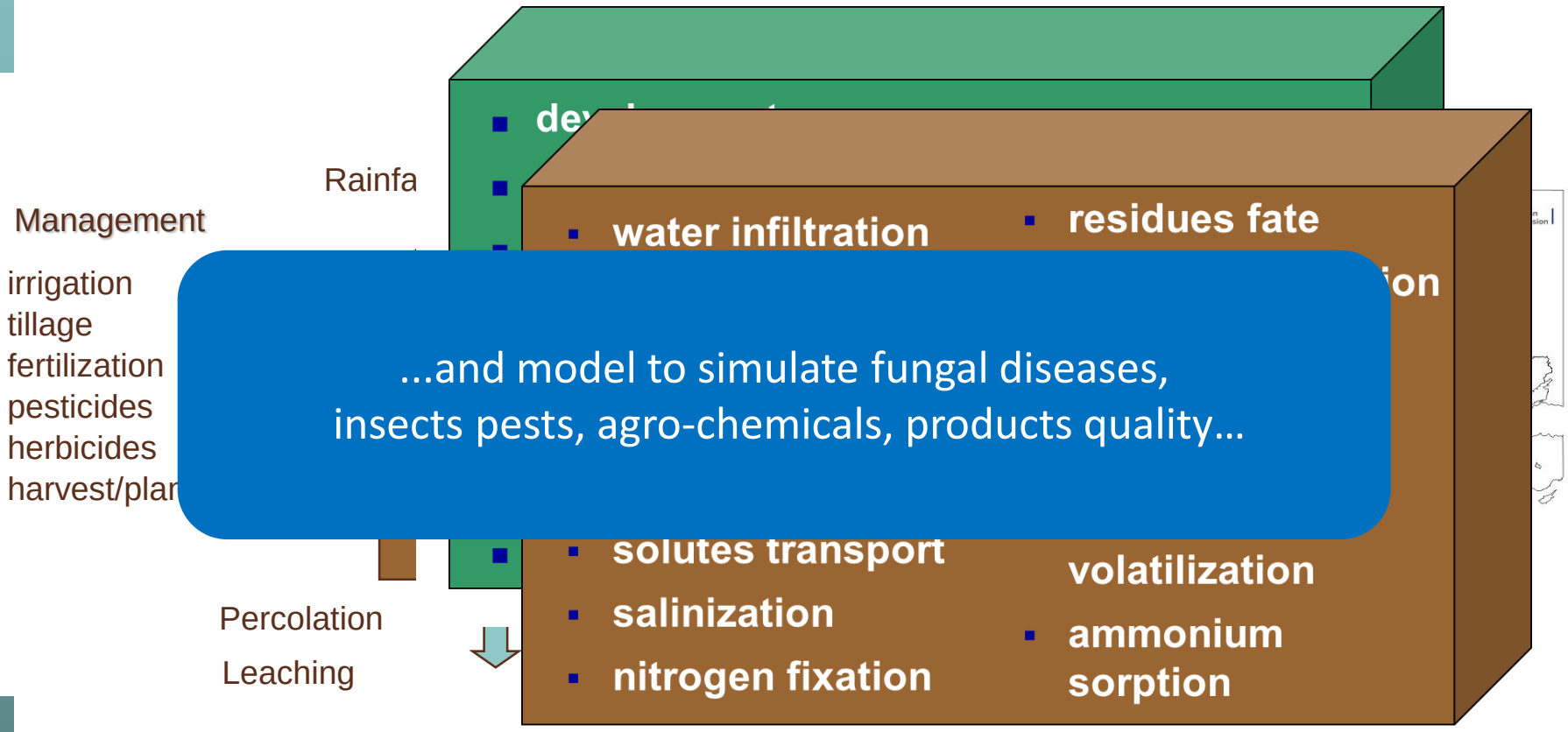
Statistical vs. process-based models in brief

- **Statistical models**: based on regression and correlation analysis
  - PROS: Robustness, relatively simple.
  - CONS: valid for conditions accounted for in the data used to develop them; show “what”, but not “why”.
- **Process-based models**: based on knowledge on physics, biology, chemistry etc.
  - PROS: Allow extrapolation to new conditions; make available insight on system dynamics.
  - CONS: Complex to build and maintain, require articulated inputs.





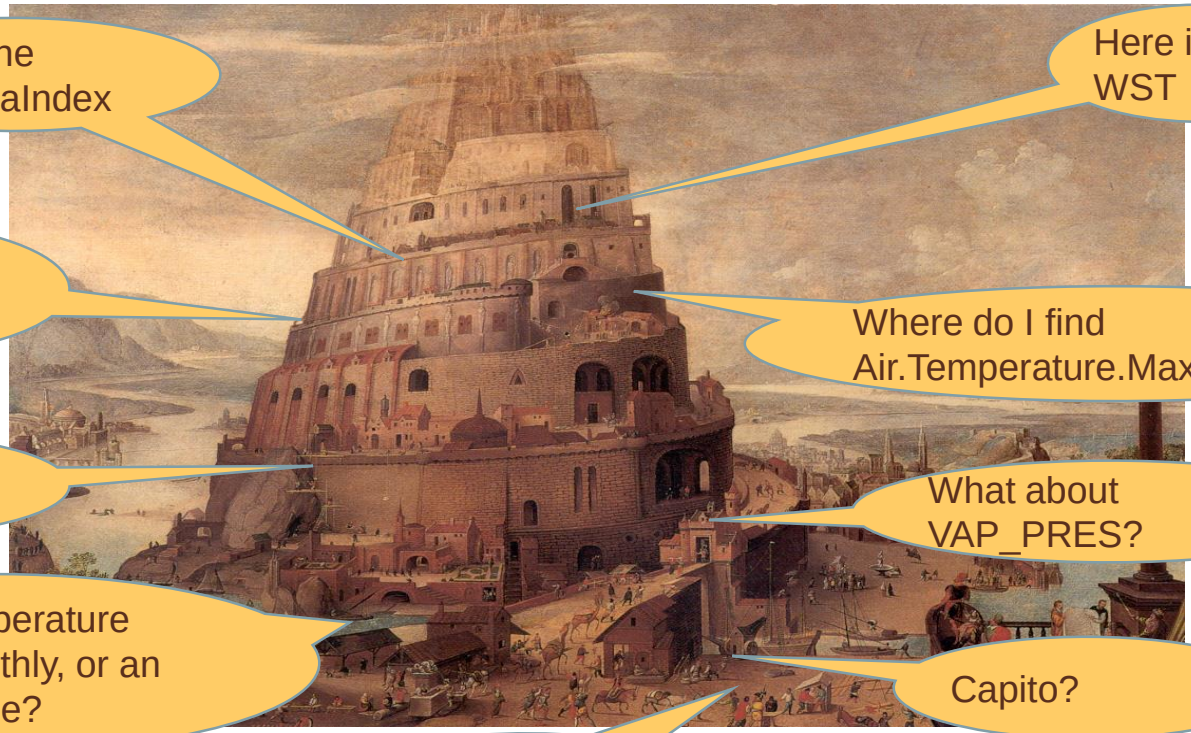
The generic modelling problem







Agronomists, Soil scientists, Geographers, Meteorologists, …



I need the LeafAreaIndex

Here it is my WST

I can produce AirTempMIN

Where do I find Air.Temperature.Max.Daily?

Εχω χάσει τον μπούσουλα

What about VAP_PRES?

MeanSoilTemperature is a daily, monthly, or an annual average?

Capito?

!@#$%#$%^?

Slide courtesy of I.Athanasiadis

Model frameworks

- Since many years model frameworks have represented a substantial step forward with respect to monolithic implementations of biophysical models.
- The separation of algorithms from data, the reusability of services such as I/O and visualization procedures, have brought a solid advantage in the development of simulation systems.
- However, the reusability of model units has proved to be negligible; a model unit for a given framework is not usable in other frameworks.





New requirements

- Also, some new high level requirements emerged for modelling frameworks:
  - To increase the **transparency** of the modelling solutions being built compared to legacy code available, for each of the modelling solutions being built;
  - To increase the **traceability of performance** of each modelling unit used in modelling solutions;
  - To **involve teams without requiring them to commit to a whole infrastructure** they would not own.
- To maximize both reusability and accessibility, we chose to develop a simulation system based software components for models and tools, limiting dependencies.





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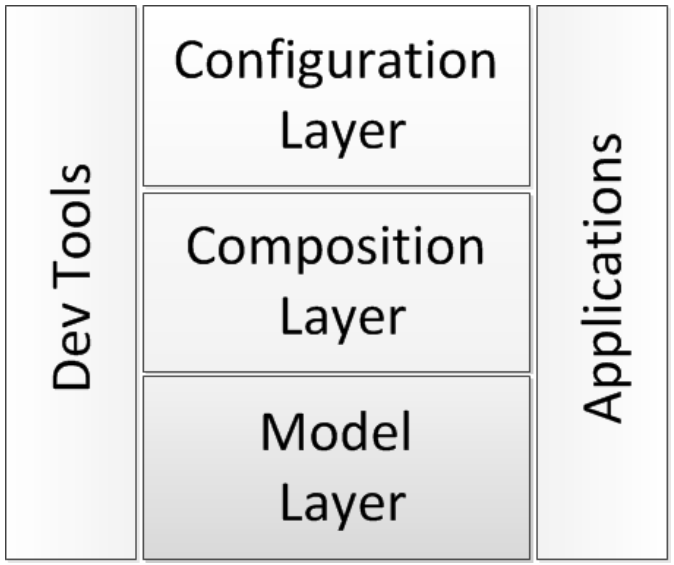
What is BioMA?

- BioMA (Biophysical Model Applications) is a open software framework designed for analyzing, parameterizing and running modelling solutions based on biophysical models.
- The framework is provided by a set of tools to perform **sensitivity analysis** based on different methods, **optimization** extensible for objective functions and solvers, and **model evaluation**, based on simple and composite metrics.
- The goal of this framework is **to rapidly bridge from prototypes to operational applications**, enabling also **running and comparing different modeling solutions**.



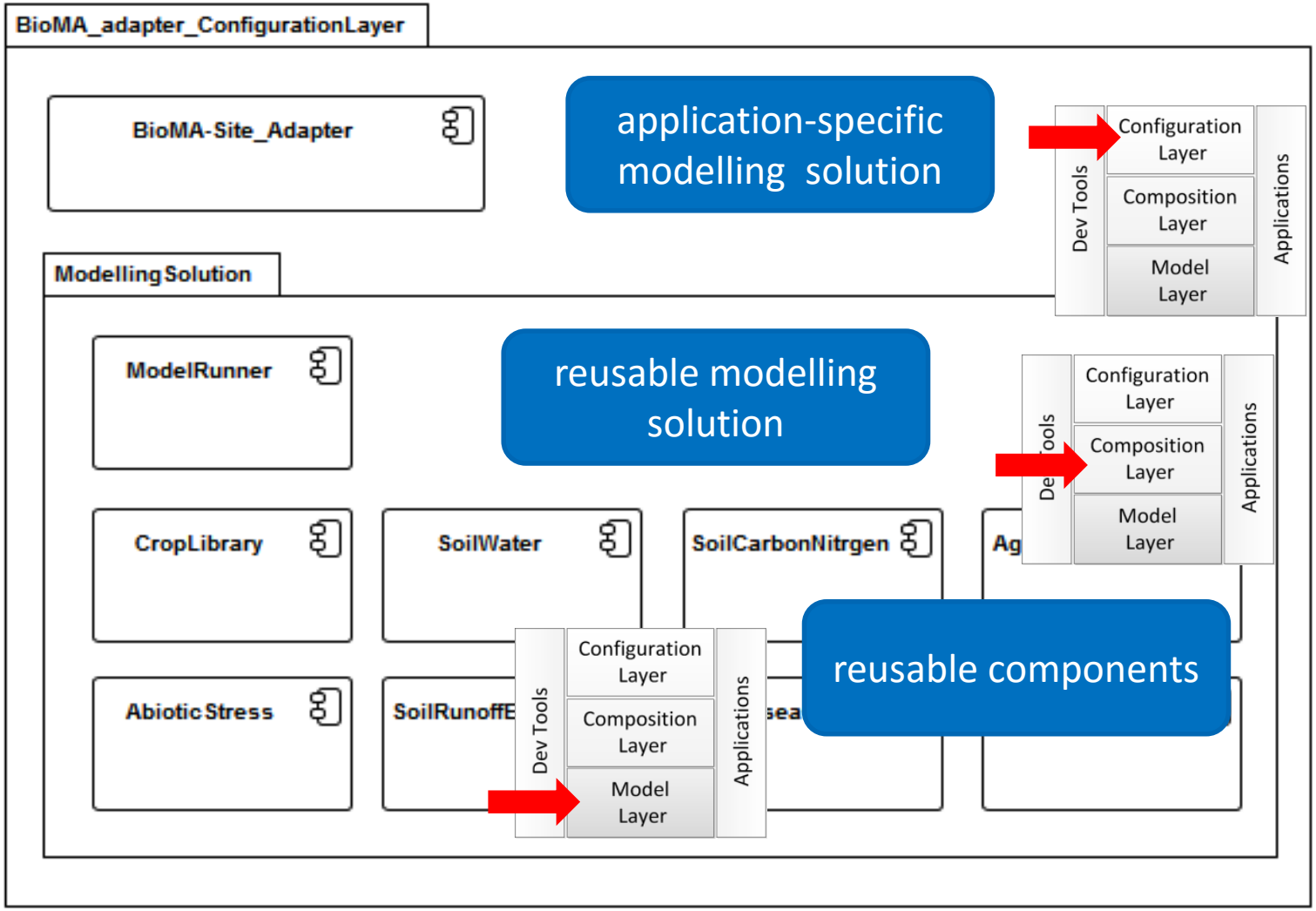


From models to viewers



- **Model Layer**: fine grained/composite **models** implemented in components
- **Composition Layer**: **modeling solutions** from model components
- **Configuration Layer**: **adapters** for advanced functionalities in controllers
- **Applications:** from console to advanced MVC implementations
- **DevTools**: code generators, UI components and applications

From models to applications





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BioMA Model Libraries

BioMA

Weather

Weather variables (*AirTemperature, Evapotranspiration, LeafWetness, Precipitation, SolarRadiation, Wind*)
Weather generators (*ClimGen*)

Abiotic stress

Heat damage, cold shocks, lodging, water stress

Biotic stress

Generic air-borne diseases simulator (*Diseases, Magarey*)
Soil-borne diseases (*SBD*)
Corn borer (*MYMICS*)

Quality

Agricultural products *(AgroProQ)*

Crop / Plant

Generic crop simulators (*Wofost, CropSyst3*; in progress *AcquaCrop*, new *CropSyst*)
Rice (*WARM*)
Wheat (in progress *SiriusQ*)
Tree species: (*Hazelnut;* in progress *Grapes, Poplar*)
Sugarcane (*Canegro*)
Giant Reed (*Arungro*)
Generic pasture (*STICS-Pasture*)

Agro-chemicals

Agro-chemicals dynamics *(AgroChemicals)*

Soil

Soil water erosion runoff (*CN, Eurosem*)
Soil water (*cascading, cascading travel time, Richards*)
Soil surface and profile temperature
Soil carbon and nitrogen
Soil Pedotransfer functions (*SoilPAR)*

Agro-management

Rule-based models (*AgroManagement*)

Impact models responding to *AgroManagement* events in crop/plant, soil, diseases, agro-chemicals models





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The IPR model

- Working with a model framework requires investing resources, and it requires a medium-term perspective;
- No institution will do it on a code base of core components which are owned by someone else and which have code not accessible;
- BioMA has adopted a **MIT license with open source access to core components on GitHub.**





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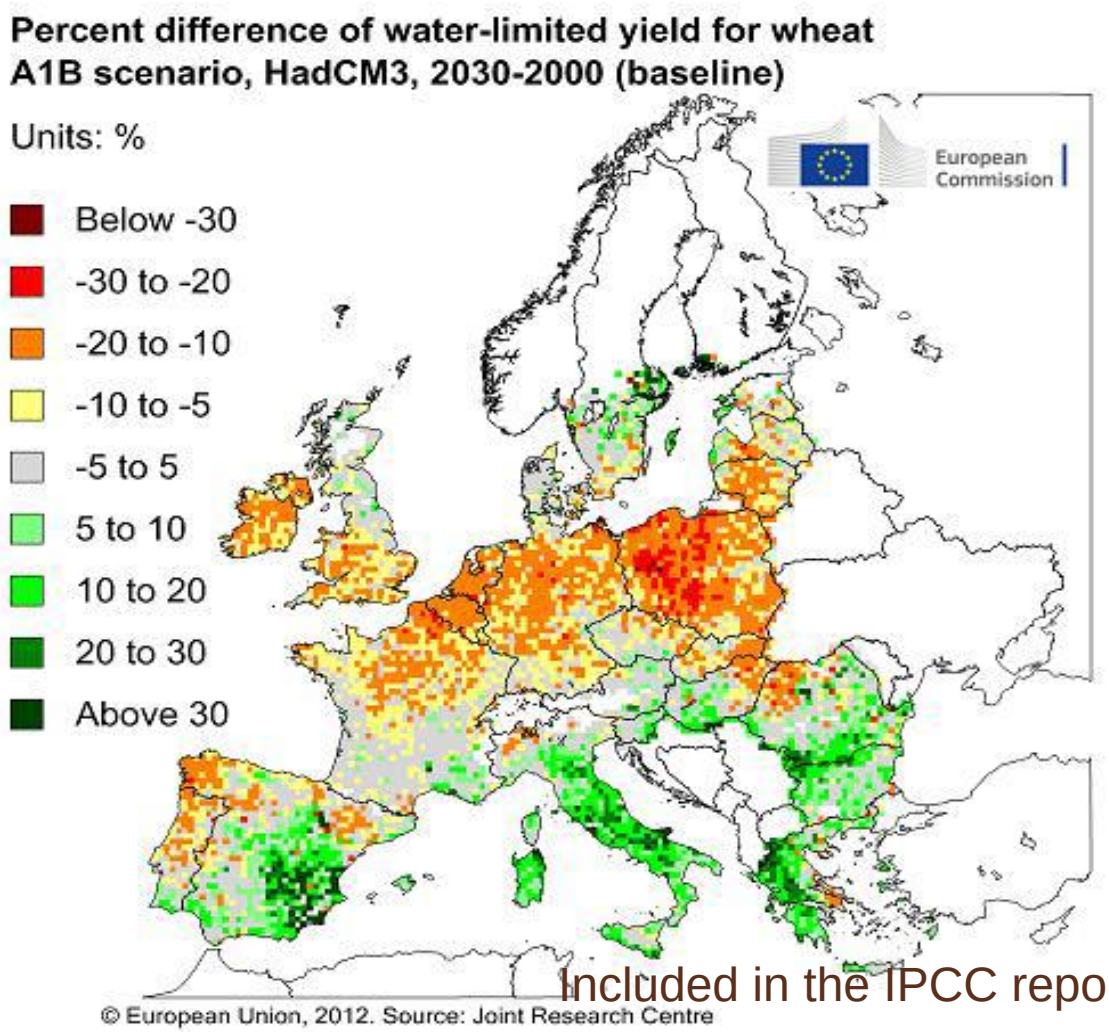
BioMA applications

- BioMA applications have been used for different research projects (https://en.wikipedia.org/wiki/BioMA):
  - weather datasets for biophysical simulation
  - estimate agro-meteorological variables
  - CC impact on crop production adaptation in Europe
  - soil pathogens under climate change
  - corn borers under climate change
  - modelling solutions comparison at sub-model level
  - impact of CC on crop production in Latin America
  - fungal infections
  - functions to estimate soil hydraulic properties
  - quality of agricultural products





Potential CC impact on yield, no adaptation

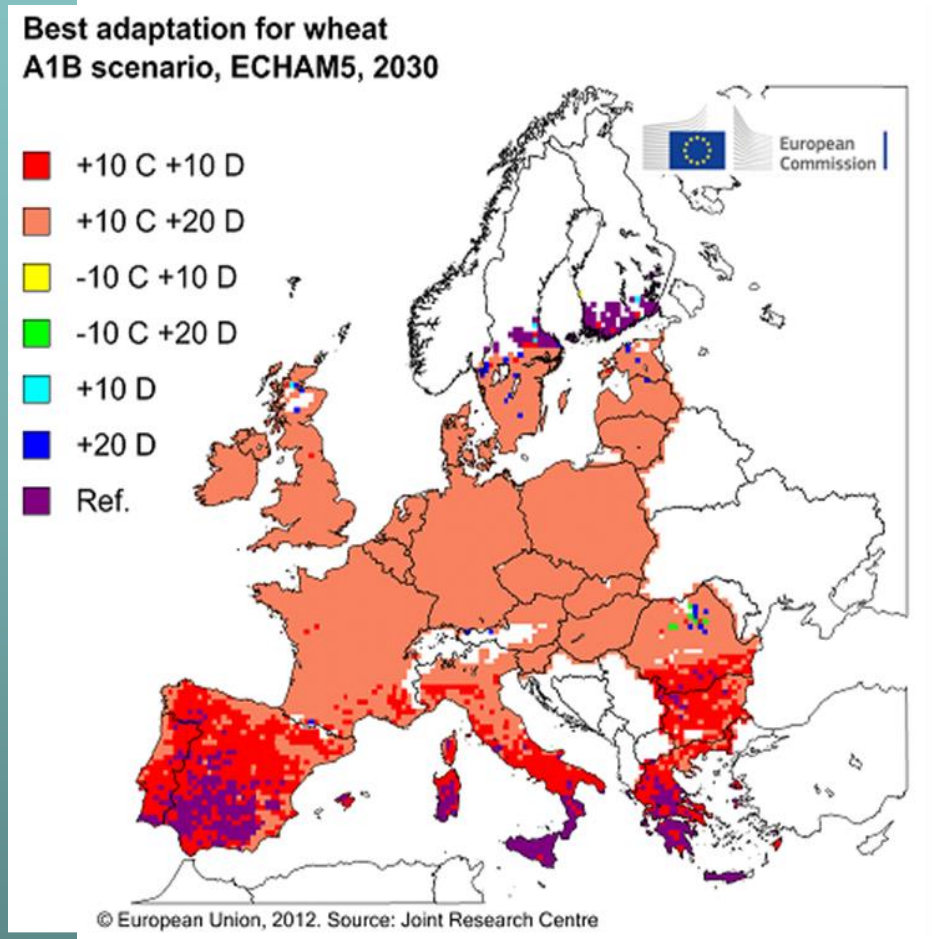


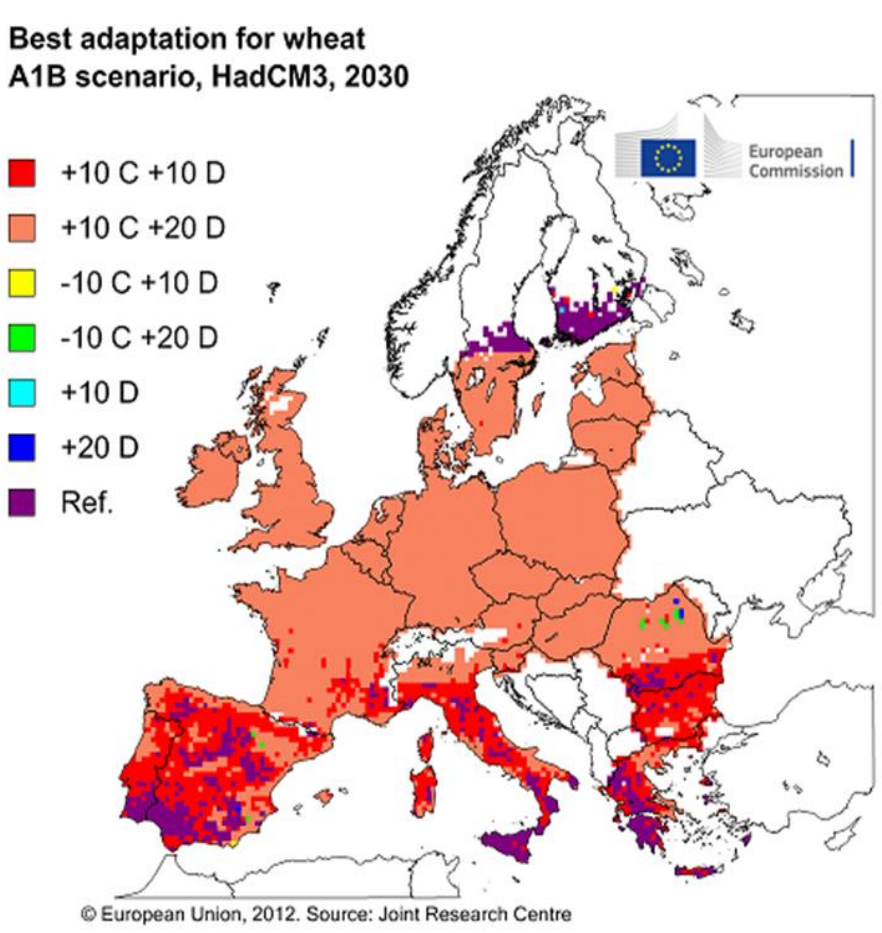
Included in the IPCC report for Europe



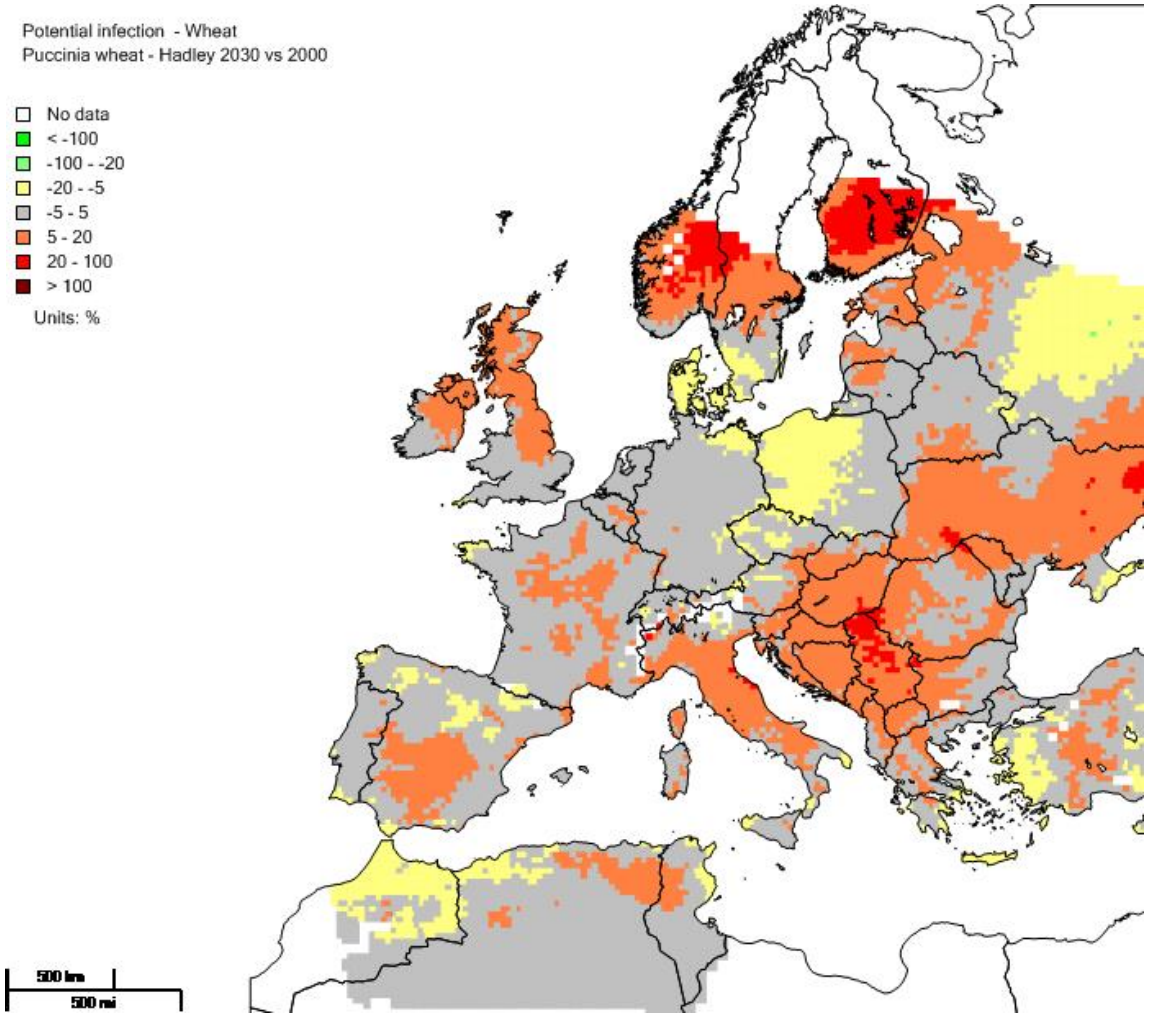


Best technical adaptation strategy





Potential infection of brown/stripe rust on wheat under CC







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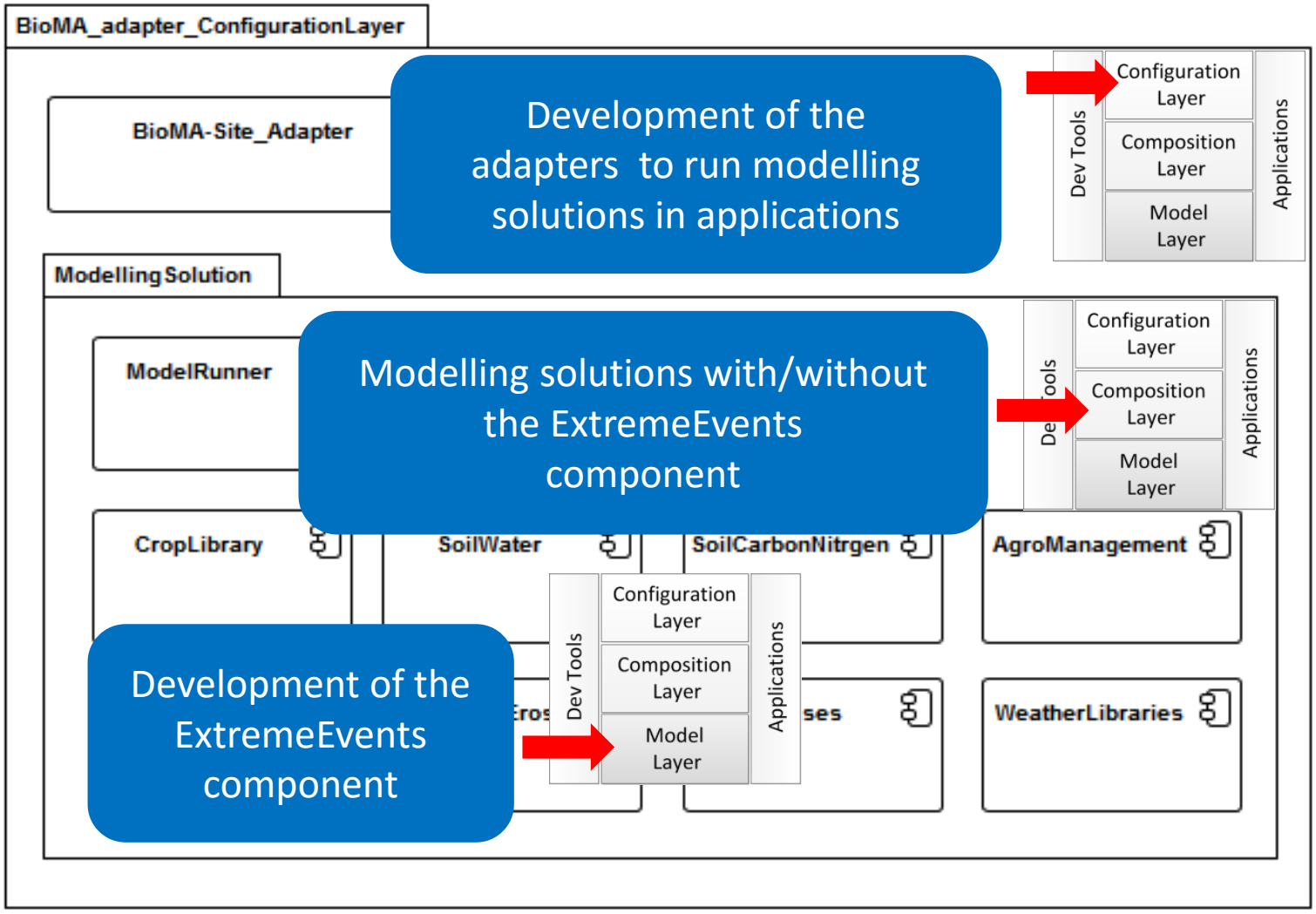
BioMA for MODEXTREME

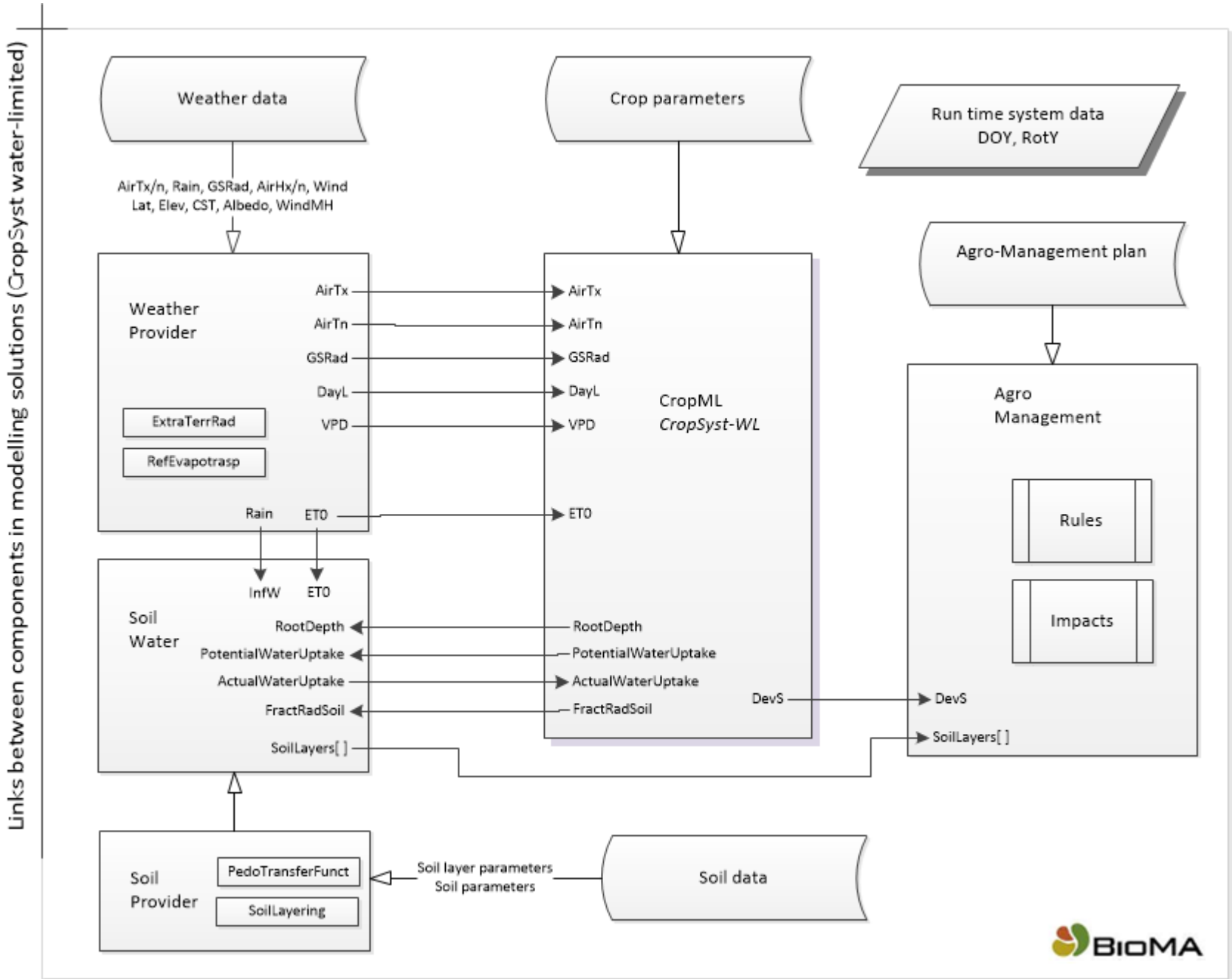
- The need of extending simulation capabilities has been key for the MODEXTREME analyses.
- Traditional modelling solutions needed to be compared to the same approaches adding the new models developed to better account for «extreme» events.
- Modelling solutions used in the analyses are:
  - CropSyst and CropSyst+ModExt.ExtremeEvents; *(crop generic)*
  - Wofost and Wofost+ModExt.ExtremeEvents*; (crop generic)*
  - WARM and WARM+ModExt.ExtremeEvents; *(rice)*
- Other modelling solutions AquaCrop *(crop generic)*, SiriusQ *(wheat)*, Grapes (*grapes*), PaSim (*pasture*) are being finalized.



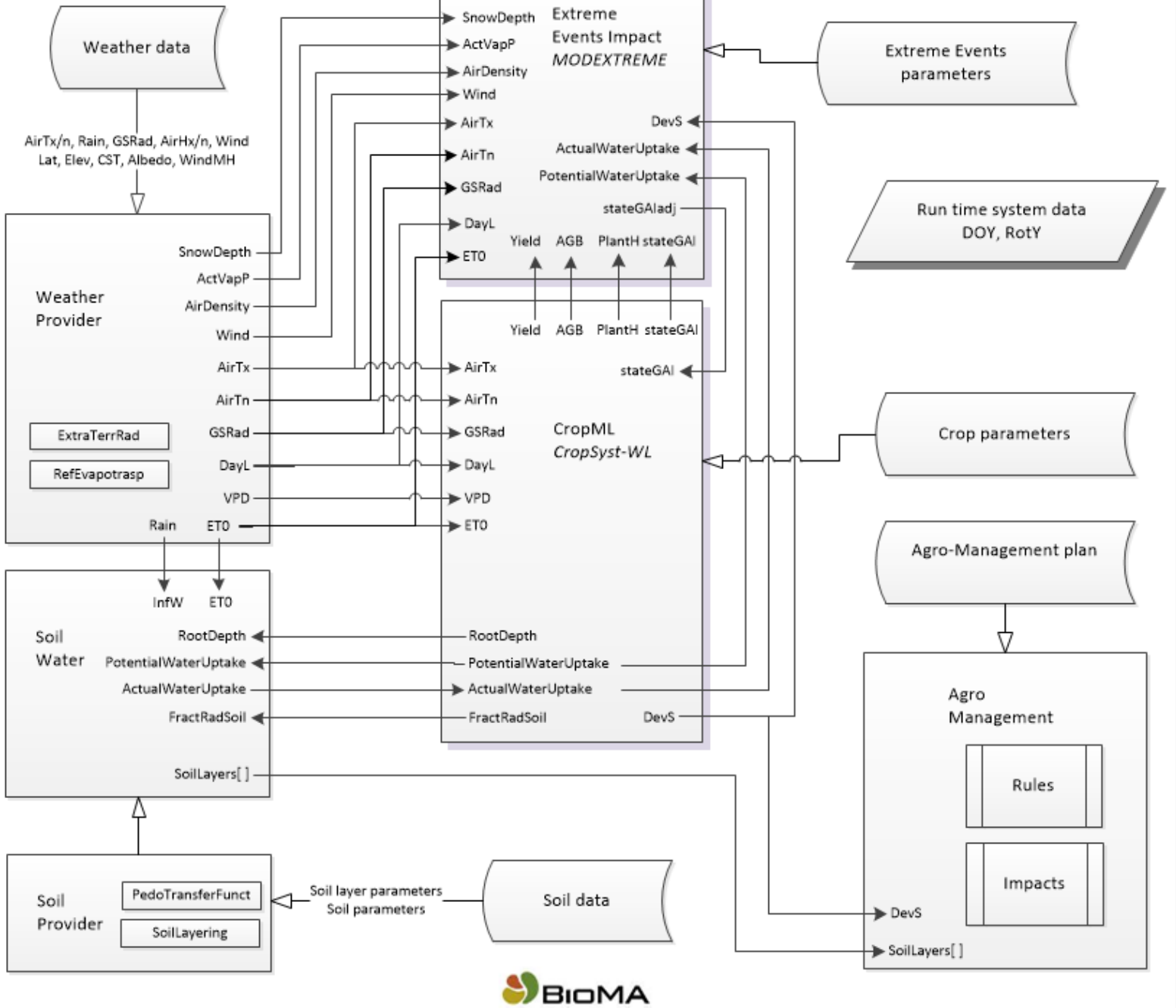


Models in MODEXTREME




Links between components in modelling solutions (CropSyst water-limited)
Weather data
AirTx/n, Rain, GSRad, AirHx/n, Wind
Lat, Elev, CST, Albedo, WindMH
Weather Provider
ExtraTerrRad
RefEvapotrasp
AirTx
AirTn
GSRad
DayL
VPD
Rain
ET0
Crop parameters
Run time system data
DOY, RotY
Agro-Management plan
CropML
CropSyst-WL
AirTx
AirTn
GSRad
DayL
VPD
ET0
Agro Management
Rules
Impacts
DevS
SoilLayers[ ]
InfW
ET0
Soil Water
RootDepth
PotentialWaterUptake
ActualWaterUptake
FractRadSoil
SoilLayers[ ]
RootDepth
PotentialWaterUptake
ActualWaterUptake
FractRadSoil
Soil Provider
PedoTransferFunct
SoilLayering
Soil layer parameters
Soil parameters
Soil data

Links between components in modelling solutions (CropSyst water-limited + Extreme events)



Conclusions, BioMA-Site

- BioMA-Site is a multi-modelling solutions runner, open to load any modelling solution respecting the interface required by the software framework.
- The modelling solutions running in BioMA-Site can also run in the application BioMA-Spatial, that is, iteratively against explicit spatial units as done operationally at DG JRC.
- Modelling solutions other than the examples provided can be loaded, becoming simulation options; if they are alternate solutions to a specific modelling problem, BioMA-Site can also be used to compare their performance.





Conclusions

- The BioMA software framework is an open system which has been enriched of simulation capabilities for extreme weather events impact on crops.
- The MODEXTREME project has allowed its further development to match project objectives.
- BioMA has allowed to test different modelling solutions to more accurately simulate crops under increased climate variability worldwide.
- The modelling system is open for further development based on a set of open source components, and with free access to a variety of tools both for model development and use.





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