Supplementary Materials

Text S1: Code documentation of the call to the RESTful API of the Arungro model.

In order to access the online simulation service and make RESTful API requests to the Arungro model, the user must first take out a subscription to the product named "Models for bioenergy" at CREA API portal (https://developer.progettoagridigit.it/). The registration allows users to set their own profile, to obtain corresponding access credentials and personal keys to include when submitting requests to the service.

Once the credentials are obtained, the service can be called via a POST request at the URL: https://apim-https://developer.progettoagridigit.it/model/v1/ModelExecution, which can be made with dedicated web API testing tools (e.g. Postman application, freely downloadable at https://www.postman.com/downloads/). A typical POST request to the Arungro model made by Postman is shown as shown in Fig S.1

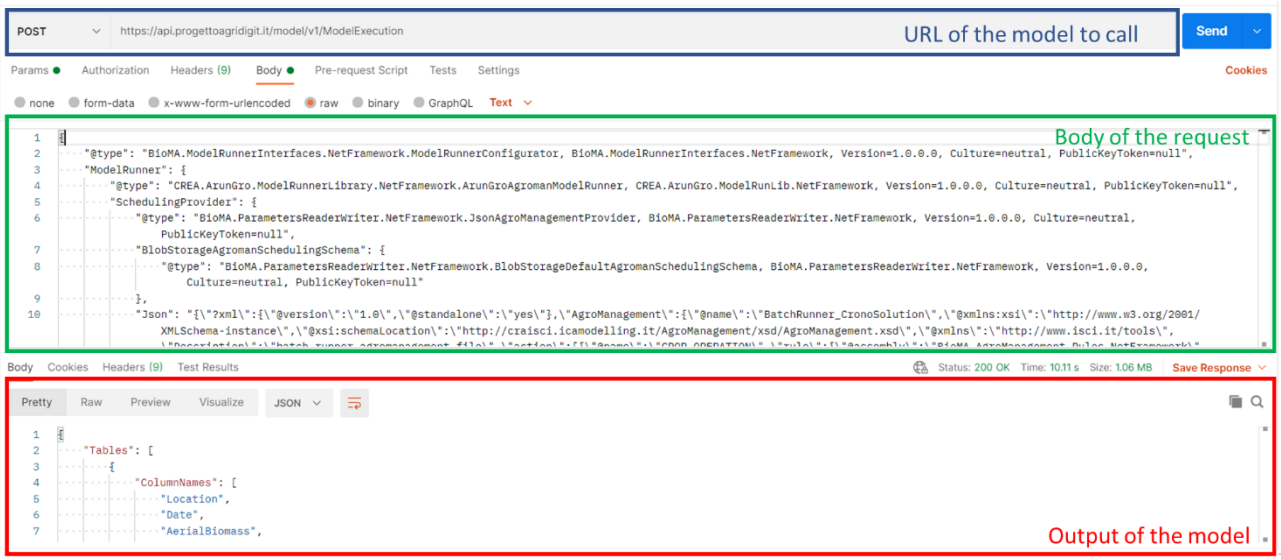

Fig.S1. POST request to the online service for Arungro model simulation.

Each request consists of two sections:

(i) the URL address of the API to be called;

(ii) the body of the request, which must contain the information needed to configure the simulation and provide weather and soil data, together with the scheduling of the management practices. The body of the request must be provided in json format.

The call returns results in a text format.

The general structure of the body of a request is reported in Fig. S.2. An example of input formatting for different input domains is reported from figure S3 to S6. The scheduling of agricultural practices must, at least, define the transplanting date, and cutting and irrigation dates, if any (Fig. S3). The valorization of the complete list of model parameters is reported in Fig. S4, which are fully discussed in the main text of the paper. The model needs as weather input daily records of minimum and maximum air temperature (°C), cumulative rainfall (mm d^{-1}), global solar radiation (MJ m^{-2} d^{-1}), and wind speed(m s^{-2}), and formatted as reported in Fig. S5. The set-up of soil data requires the definition of soil texture (sand and clay, % v/v) and organic carbon (dag kg^{-1}) for each soil layer and horizon (Fig. S6).

```
{
    "@type": "BioMA.ModelRunnerInterfaces.NetFramework.ModelRunnerConfigurator,
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    PublicKeyToken=null","ModelRunner":
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        CREA.ArunGro.ModelRunLib.NetFramework, Version=1.0.0.0, Culture=neutral, PublicKeyToken=null",
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            PublicKeyToken=null","BlobStorageAgromanSchedulingSchema":
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            "Json":
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        },
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            "ArunGro":
            {
                "Reader":
                {
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                    "StreamProvider":
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                        "@type": "BioMA.ParametersReaderWriter.NetFramework.BlobStorageDefaultSchemaProvider,
                        BioMA.ParametersReaderWriter.NetFramework, Version=1.0.0.0, Culture=neutral, PublicKeyToken=null"
                            },
                             "Json":
                                                    <placeholder model parameters>
                            }
                }
            },
            "StrategiesToConfigure":
            {
                "Layering":
                {
                    "ParametersReader":
                    {
                        "@type": "BioMA.ParametersReaderWriter.NetFramework.JsonParameterReader,
                        BioMA.ParametersReaderWriter.NetFramework, Version=1.0.0.0, Culture=neutral, PublicKeyToken=null",
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                             BioMA.ParametersReaderWriter.NetFramework, Version=1.0.0.0, Culture=neutral, PublicKeyToken=null"
                        },
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                        8\",\"@standalone\":\"yes\"},\"ParametersValues\":{\"Description\":{\"NameSpace\":\"UNIMI.SoilW\",\"TypeName\":\"Layeri
                        ng\",\"URL\":\"http://\",\"ParameterKey\":\"ParameterKey\",\"Description\":\"Parameter class to load from XML for the
                        Layering class - Layering strategy\"},\"VarInfoAttributes\":{\"VarInfo\":{\"@name\":\"LayerThickness\",\"Description\":\"Soil
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                        URL\":null}},\"Values\":{\"KeyValue\":{\"@name\":\"Default\",\"Description\":\"Default\",\"Parameter\":{\"@name\":\"LayerT
                        hickness\",\"Value\":[\"0.05\",\"0.05\",\"0.10\",\"0.10\",\"0.10\",\"0.10\",\"0.10\",\"0.10\",\"0.10\",\"0.10\",\"0.10\",\"
                        0.10\",\"0.10\",\"0.10\",\"0.10\",\"0.10\",\"0.10\"]}}}}}"
                    },
                    "ParametersKey": "Default"
                }
            }
        },
        "ModelOutputPersister":
        {
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            Version=1.0.0.0, Culture=neutral, PublicKeyToken=null"
              },
        "WeatherProvider":
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            Culture=neutral, PublicKeyToken=null",
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              },
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            Version=1.0.0.0, Culture=neutral, PublicKeyToken=null",
                             "Json":
                            <placeholder soil data>
              },
              "Location": "Anzola"
}
```


Fig. S2. Structure of the body of the API call. Input data required for model simulation must be placed in json format in yellow regions, whereas the boolean parameter to switch on/off the water stress is reported in the green code section.

"{\"?xml\":{\"@version\":\"1.0\",\"@standalone\":\"yes\"},\"AgroManagement\":{\"@name\":\"BatchRunner_CronoSolution\",\"@xmlns:xsi\":\"http://www.w3.org/2001/XMLSchema-instance\",\"@xsi:schemaLocation\":\"http://craisci.icamodelling.it/AgroManagement/xsd/AgroManagement.xsd\",\"@xmlns\":\"http://www.isci.it/tools\",\"Description\":\"batch runner agromanagement file\",\"action\":[{\"@name\":\"CROP_OPERATION\",\"rule\":{\"@assembly\":\"BioMA.AgroManagement.Rules.NetFramework\",\"@name\":\"RuleDate\",\"parameter\":[{\"@name\":\"RelativeDate\",\"@value\":\"74\"},{\"@name\":\"RotationYear\",\"@value\":\"1\"}]},\"impact\":{\"@assembly\":\"BioMA.AgroManagement.Impacts.NetFramework\",\"@name\":\"CropPlanting\",\"parameter\":[{\"@name\":\"CropName\",\"@value\":\"Crop_Trial\"},{\"@name\":\"CropOperation\",\"@value\":\"Planting\"},{\"@name\":\"PlantingDepth\",\"@value\":\"0.02\"}]}},{\"@name\":\"CROP_OPERATION\",\"rule\":{\"@assembly\":\"BioMA.AgroManagement.Rules.NetFramework\",\"@name\":\"RuleDate\",\"parameter\":[{\"@name\":\"RelativeDate\",\"@value\":\"295\"},{\"@name\":\"RotationYear\",\"@value\":\"1\"}]},\"impact\":{\"@assembly\":\"BioMA.AgroManagement.Impacts.NetFramework\",\"@name\":\"CropHarvest\",\"parameter\":[{\"@name\":\"CropName\",\"@value\":\"Crop_Trial\"},{\"@name\":\"CropOperation\",\"@value\":\"Harvest\"}]}},{\"@name\":\"CROP_OPERATION\",\"rule\":{\"@assembly\":\"BioMA.AgroManagement.Rules.NetFramework\",\"@name\":\"RuleDate\",\"parameter\":[{\"@name\":\"RelativeDate\",\"@value\":\"295\"},{\"@name\":\"RotationYear\",\"@value\":\"2\"}]},\"impact\":{\"@assembly\":\"BioMA.AgroManagement.Impacts.NetFramework\",\"@name\":\"CropHarvest\",\"parameter\":[{\"@name\":\"CropName\",\"@value\":\"Crop_Trial\"},{\"@name\":\"CropOperation\",\"@value\":\"Harvest\"}]}},{\"@name\":\"CROP_OPERATION\",\"rule\":{\"@assembly\":\"BioMA.AgroManagement.Rules.NetFramework\",\"@name\":\"RuleDate\",\"parameter\":[{\"@name\":\"RelativeDate\",\"@value\":\"295\"},{\"@name\":\"RotationYear\",\"@value\":\"3\"}]},\"impact\":{\"@assembly\":\"BioMA.AgroManagement.Impacts.NetFramework\",\"@name\":\"CropHarvest\",\"parameter\":[{\"@name\":\"CropName\",\"@value\":\"Crop_Trial\"},{\"@name\":\"CropOperation\",\"@value\":\"Harvest\"}]}},{\"@name\":\"CROP_OPERATION\",\"rule\":{\"@assembly\":\"BioMA.AgroManagement.Rules.NetFramework\",\"@name\":\"RuleDate\",\"parameter\":[{\"@name\":\"RelativeDate\",\"@value\":\"295\"},{\"@name\":\"RotationYear\",\"@value\":\"4\"}]},\"impact\":{\"@assembly\":\"BioMA.AgroManagement.Impacts.NetFramework\",\"@name\":\"CropHarvest\",\"parameter\":[{\"@name\":\"CropName\",\"@value\":\"Crop_Trial\"},{\"@name\":\"CropOperation\",\"@value\":\"Harvest\"}]}},{\"@name\":\"CROP_OPERATION\",\"rule\":{\"@assembly\":\"BioMA.AgroManagement.Rules.NetFramework\",\"@name\":\"RuleDate\",\"parameter\":[{\"@name\":\"RelativeDate\",\"@value\":\"295\"},{\"@name\":\"RotationYear\",\"@value\":\"5\"}]},\"impact\":{\"@assembly\":\"BioMA.AgroManagement.Impacts.NetFramework\",\"@name\":\"CropHarvest\",\"parameter\":[{\"@name\":\"CropName\",\"@value\":\"Crop_Trial\"},{\"@name\":\"CropOperation\",\"@value\":\"Harvest\"}]}}]}}"

Fig. S3. Region for defining the scheduling of agromanagement practices, formatted as required by the API call.

"{\"?xml\":{\"@version\":\"1.0\",\"@encoding\":\"utf-8\",\"@standalone\":\"yes\"},\"ParametersValues\":{\"Description\":{\"NameSpace\":\"UNIMI.CaneML.Strategies.Composite.CropModels\",\"TypeName\":\"ArungroC\",\"URL\":\"http://bioma.jrc.ec.europa.eu/ontology/JRC_MARS_biophysical_domain.owl\",\"ParameterKey\":\"ParameterKey\",\"Description\":\"Parameter class to load from XML for the ArungroC class.\"},\"VarInfoAttributes\":{\"VarInfo\":[{\"@name\":\"TTEmergenceToPeakTillerPop\",\"Description\":\"Thermal Time Emergence To Peak Tiller Population\",\"MaxValue\":\"900\",\"MinValue\":\"300\",\"DeafaultValue\":\"600\",\"Type\":\"double\",\"Units\":\"°Cd\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaxTillerPop\",\"Description\":\"Maximum Tiller Population\",\"MaxValue\":\"50\",\"MinValue\":\"15\",\"DeafaultValue\":\"30\",\"Type\":\"double\",\"Units\":\"tiller m-2\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"FractionOfDyingTiller\",\"Description\":\"Fraction of 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emission\",\"MaxValue\":\"25\",\"MinValue\":\"5\",\"DeafaultValue\":\"10\",\"Type\":\"double\",\"Units\":\"°C\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"CutOffTemperatureForLeafEmission\",\"Description\":\"cutoff temperature for leaf emission\",\"MaxValue\":\"50\",\"MinValue\":\"25\",\"DeafaultValue\":\"30\",\"Type\":\"double\",\"Units\":\"°C\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaximumNumberOfExpandingLeaves\",\"Description\":\"Maximum number of expanding leaves on a tiller\",\"MaxValue\":\"40\",\"MinValue\":\"0\",\"DeafaultValue\":\"5\",\"Type\":\"int\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"LeafIDAboveWhichLeafAreaIsLimited\",\"Description\":\"Leaf ID Above Which Leaf Area is Limited\",\"MaxValue\":\"40\",\"MinValue\":\"0\",\"DeafaultValue\":\"15\",\"Type\":\"int\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaxLeafArea1\",\"Description\":\"Cultivar parameter for 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cin.it/tools/\"},{\"@name\":\"MaximumNumberOfGreenLeavesUnderWellWaterConditions\",\"Description\":\"Maximum Number Of Green Leaves Under Well Water Conditions\",\"MaxValue\":\"50\",\"MinValue\":\"0\",\"DeafaultValue\":\"12\",\"Type\":\"int\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"NumberOfLeavesPerShootSenescedPer100StressDays\",\"Description\":\"Number Of Leaves Per Shoot Senesced Per 100 Stress Days\",\"MaxValue\":\"50\",\"MinValue\":\"0\",\"DeafaultValue\":\"5\",\"Type\":\"int\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaximumCanopyLightExtinctionCoefficient\",\"Description\":\"Maximum Canopy Light Extinction Coefficient\",\"MaxValue\":\"1\",\"MinValue\":\"0\",\"DeafaultValue\":\"0.84\",\"Type\":\"double\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MinimumCanopyExtinctionCoefficient\",\"Description\":\"Minimum Canopy Extinction 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mass\",\"MaxValue\":\"1\",\"MinValue\":\"0\",\"DeafaultValue\":\"0.6\",\"Type\":\"double\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MinimumPartitionFractionToAerialDryMass\",\"Description\":\"Minimum Partition Fraction To Aerial Dry Mass\",\"MaxValue\":\"1\",\"MinValue\":\"0\",\"DeafaultValue\":\"0.05\",\"Type\":\"double\",\"Units\":\"t t-1\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"RootLengthPerMassOfRoot\",\"Description\":\"Root Length Per Mass Of Root\",\"MaxValue\":\"10000\",\"MinValue\":\"0\",\"DeafaultValue\":\"500\",\"Type\":\"double\",\"Units\":\"cm g-1\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"BaseTemperatureForStalkElongation\",\"Description\":\"Base temperature for stalk elongation\",\"MaxValue\":\"16\",\"MinValue\":\"0\",\"DeafaultValue\":\"10\",\"Type\":\"double\",\"Units\":\"°C\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"CutOffTemperatureForStalkElongation\",\"Description\":\"Cutoff 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(°Cd)-1\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"BaseTemperatureForRootExtension\",\"Description\":\"Base Temperature For Root Extension\",\"MaxValue\":\"30\",\"MinValue\":\"0\",\"DeafaultValue\":\"10\",\"Type\":\"double\",\"Units\":\"°C\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"CutOffTemperatureForRootExtension\",\"Description\":\"CutOff Temperature For Root Extension\",\"MaxValue\":\"40\",\"MinValue\":\"25\",\"DeafaultValue\":\"30\",\"Type\":\"double\",\"Units\":\"°C\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaxRootLengthDensity\",\"Description\":\"Maximum Root Length Density\",\"MaxValue\":\"50\",\"MinValue\":\"0\",\"DeafaultValue\":\"5\",\"Type\":\"double\",\"Units\":\"cm cm-3\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MinRootLengthDensity\",\"Description\":\"Minimum Root Length Density\",\"MaxValue\":\"50\",\"MinValue\":\"0\",\"DeafaultValue\":\"0.02\",\"Type\":\"double\",\"Units\":\"cm cm-3\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"FractionOfPlantElongationAttributableToStalkElongation\",\"Description\":\"Fraction Of Plant Elongation Attributable To Stalk Elongation\",\"MaxValue\":\"1\",\"MinValue\":\"0\",\"DeafaultValue\":\"0.16\",\"Type\":\"double\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"LeafAngle\",\"Description\":\"Leaf Angle\",\"MaxValue\":\"90\",\"MinValue\":\"0\",\"DeafaultValue\":\"30.2\",\"Type\":\"double\",\"Units\":\"°\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaximumNumberOfLeavesPerTiller\",\"Description\":\"Maximum number of leaves per tiller\",\"MaxValue\":\"40\",\"MinValue\":\"1\",\"DeafaultValue\":\"30\",\"Type\":\"int\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"BaseTemperatureForConversionEfficiency\",\"Description\":\"Base temperature for conversion 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parameter\",\"MaxValue\":\"50\",\"MinValue\":\"0\",\"DeafaultValue\":\"32\",\"Type\":\"double\",\"Units\":\"m-2\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"BaseRootBiomassForTillerDevelopment\",\"Description\":\"Minimum root biomass value for tiller development\",\"MaxValue\":\"5\",\"MinValue\":\"0\",\"DeafaultValue\":\"0\",\"Type\":\"double\",\"Units\":\"t ha-1\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"OptimumRootBiomassForTillerDevelopment\",\"Description\":\"Optimum root biomass for tiller development\",\"MaxValue\":\"20\",\"MinValue\":\"0\",\"DeafaultValue\":\"10\",\"Type\":\"double\",\"Units\":\"t ha-1\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaximumRootBiomassForTillerDevelopment\",\"Description\":\"Maximum root biomass for tiller development\",\"MaxValue\":\"30\",\"MinValue\":\"0\",\"DeafaultValue\":\"20\",\"Type\":\"double\",\"Units\":\"t ha-1\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"BaseTemperatureForEmergence\",\"Description\":\"Base temperature for emergence from planting or ratooning\",\"MaxValue\":\"30\",\"MinValue\":\"0\",\"DeafaultValue\":\"10\",\"Type\":\"double\",\"Units\":\"°C\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"OptimumTemperatureForEmergence\",\"Description\":\"Optimum temperature for emergence from planting or ratooning\",\"MaxValue\":\"45\",\"MinValue\":\"15\",\"DeafaultValue\":\"30\",\"Type\":\"double\",\"Units\":\"°C\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"ThermalTimeToEmergenceFromRatooning\",\"Description\":\"Thermal time to emergence for a ratoon crop\",\"MaxValue\":\"500\",\"MinValue\":\"0\",\"DeafaultValue\":\"203\",\"Type\":\"double\",\"Units\":\"°Cd\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"ThermalTimeToEmergenceFromPlanting\",\"Description\":\"Thermal time to emergence for a plant crop\",\"MaxValue\":\"900\",\"MinValue\":\"50\",\"DeafaultValue\":\"428\",\"Type\":\"double\",\"Units\":\"°Cd\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaximumLeafLength\",\"Description\":\"Absolute maximum leaf length\",\"MaxValue\":\"110\",\"MinValue\":\"60\",\"DeafaultValue\":\"100\",\"Type\":\"double\",\"Units\":\"cm\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaximumLeafWidth\",\"Description\":\"Absolute maximum leaf width\",\"MaxValue\":\"10\",\"MinValue\":\"1\",\"DeafaultValue\":\"3.5\",\"Type\":\"double\",\"Units\":\"cm\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaximumLeafArea\",\"Description\":\"Maximum leaf area assigned to all leaves above LeafIDAboveWhichLeafAreaIsLimited\",\"MaxValue\":\"650\",\"MinValue\":\"50\",\"DeafaultValue\":\"360\",\"Type\":\"double\",\"Units\":\"cm2\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"CropCoefficient\",\"Description\":\"Crop Coefficient\",\"MaxValue\":\"10\",\"MinValue\":\"0\",\"DeafaultValue\":\"1.15\",\"Type\":\"double\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"SoilWaterSupplyPotentialETCoeff1\",\"Description\":\"Soil Water Supply Potential Evapotranspiration Ratio Thershold Below Which Evaporation and Photosynthesis are Limited\",\"MaxValue\":\"10\",\"MinValue\":\"0\",\"DeafaultValue\":\"1\",\"Type\":\"double\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-

cin.it/tools/\"},{\"@name\":\"SoilWaterSupplyPotentialETCoeff2\",\"Description\":\"Soil Water Supply Potential Evapotranspiration Ratio Thershold Below Which Expansive growth is Limited\",\"MaxValue\":\"10\",\"MinValue\":\"0\",\"DeafaultValue\":\"2\",\"Type\":\"double\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"WaterStressProlongedImpact\",\"Description\":\"Water stress threshold for prolonged impact from severe water stress on photosynthesis\",\"MaxValue\":\"1\",\"MinValue\":\"0\",\"DeafaultValue\":\"0.2\",\"Type\":\"double\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"ThermalTimeForPhotosynthesisRecovery\",\"Description\":\"Thermal time required for photosynthesis to recover fully after a severe water stress event\",\"MaxValue\":\"1000\",\"MinValue\":\"0\",\"DeafaultValue\":\"150\",\"Type\":\"double\",\"Units\":\"°Cd\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"BaseTemperatureForPhotosynthesisRecovery\",\"Description\":\"Base temperature for photosynthesis recovery\",\"MaxValue\":\"20\",\"MinValue\":\"0\",\"DeafaultValue\":\"10\",\"Type\":\"double\",\"Units\":\"°C\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"CutOffTemperatureForPhotosynthesisRecovery\",\"Description\":\"Cutoff temperature for photosynthesis recovery\",\"MaxValue\":\"40\",\"MinValue\":\"25\",\"DeafaultValue\":\"30\",\"Type\":\"double\",\"Units\":\"°C\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"CriticalWindSpeedForLodging\",\"Description\":\"Wind speed threshold for lodging\",\"MaxValue\":\"300\",\"MinValue\":\"100\",\"DeafaultValue\":\"200\",\"Type\":\"double\",\"Units\":\"km day-1\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"SensitivityScoreToLodging\",\"Description\":\"Lodging score when crop is fully lodged\",\"MaxValue\":\"8\",\"MinValue\":\"0\",\"DeafaultValue\":\"8\",\"Type\":\"double\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MassThresholdForLodging\",\"Description\":\"Aerial mass (fresh mass of stalks, leaves, and water attached to them) at which lodging starts\",\"MaxValue\":\"250\",\"MinValue\":\"190\",\"DeafaultValue\":\"220\",\"Type\":\"double\",\"Units\":\"t ha-1\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MassRangeForLodging\",\"Description\":\"Range in aerial mass from the start to the end of lodging\",\"MaxValue\":\"50\",\"MinValue\":\"10\",\"DeafaultValue\":\"30\",\"Type\":\"double\",\"Units\":\"t ha-1\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"MaximumSensitivityScoreToLodging\",\"Description\":\"Maximum lodging score when crop is fully lodged\",\"MaxValue\":\"8\",\"MinValue\":\"0\",\"DeafaultValue\":\"8\",\"Type\":\"double\",\"Units\":\"unitless\",\"URL\":\"http://agsys.cra-cin.it/tools/\"},{\"@name\":\"RainfallRequiredToResetStressDay\",\"Description\":\"Rainfall Required To Reset Stress Day Counter\",\"MaxValue\":\"100\",\"MinValue\":\"0\",\"DeafaultValue\":\"5\",\"Type\":\"double\",\"Units\":\"mm day-1\",\"URL\":\"http://agsys.cra-cin.it/tools/\"}]},\"Values\":{\"KeyValue\":{\"@name\":\"Crop_Trial\",\"Description\":\"crop_trial\",\"Parameter\":[{\"@name\":\"TTEmergenceToPeakTillerPop\",\"Value\":\"662.431375\"},{\"@name\":\"MaxTillerPop\",\"Value\":\"226.166739\"},{\"@name\":\"MaximumLeafLength\",\"Value\":\"14.722153\"},{\"@name\":\"MaximumLeafWidth\",\"Value\":\"5.15781\"},{\"@name\":\"MaximumLeafArea\",\"Value\":\"379.930457\"},{\"@name\":\"FractionOfDyingTiller\",\"Value\":\"0.00227\"},{\"@name\":\"TillerPopulationAfter1600TT\",\"Value\":\"16.474175\"},{\"@name\":\"BaseTemperatureForTillerDevelopment\",\"Value\":\"8.92444\"},{\"@name\":\"CutOffTemperatureForTillerDevelopment\",\"Value\":\"29.827\"},{\"@name\":\"RowSpacing\",\"Value\":\"1.4\"},{\"@name\":\"UnstressedPlantExtensionRate\",\"Value\":\"0.18\"},{\"@name\":\"BaseTemperatureForPlantExtension\",\"Value\":\"3.410197\"},{\"@name\":\"BaseTemperatureForLeafEmission\",\"Value\":\"9.648902\"},{\"@name\":\"CutOffTemperatureForLeafEmission\",\"Value\":\"30.650626\"},{\"@name\":\"MaximumNumberOfExpandingLeaves\",\"Value\":\"11\"},{\"@name\":\"LeafIDAboveWhichLeafAreaIsLimited\",\"Value\":\"15\"},{\"@name\":\"MaxLeafArea1\",\"Value\":\"0\"},{\"@name\":\"MaxLeafArea2\",\"Value\":\"0\"},{\"@name\":\"MaxLeafArea3\",\"Value\":\"180\"},{\"@name\":\"MaxLeafLengthPerLeafNumber1\",\"Value\":\"0\"},{\"@name\":\"MaxLeafLengthPerLeafNumber2\",\"Value\":\"0\"},{\"@name\":\"MaxLeafLengthPerLeafNumber3\",\"Value\":\"65\"},{\"@name\":\"MaxLeafWidthPerLeafNumber1\",\"Value\":\"0\"},{\"@name\":\"MaxLeafWidthPerLeafNumber2\",\"Value\":\"0\"},{\"@name\":\"MaxLeafWidthPerLeafNumber3\",\"Value\":\"60\"},{\"@name\":\"PhyllocronIntervalBelowSwitchNumber\",\"Value\":\"40\"},{\"@name\":\"PhyllocronIntervalAboveSwitchNumber\",\"Value\":\"90\"},{\"@name\":\"LeafNumberAtPhyllocronSwitch\",\"Value\":\"18\"},{\"@name\":\"MaximumNumberOfGreenLeavesUnderWellWaterConditions\",\"Value\":\"26\"},{\"@name\":\"NumberOfLeavesPerShootSenescedPer100StressDays\",\"Value\":\"5\"},{\"@name\":\"MaximumCanopyLightExtinctionCoefficient\",\"Value\":\"0.856455\"},{\"@name\":\"MinimumCanopyExtinctionCoefficient\",\"Value\":\"0.598772\"},{\"@name\":\"LeafNumberAtWhichMaximumLightExtinctionOccurs\",\"Value\":\"20\"},{\"@name\":\"InterceptionReductionAtFullLodging\",\"Value\":\"0.1\"},{\"@name\":\"MaximumRadiationConversionEfficiency\",\"Value\":\"10.582\"},{\"@name\":\"BaseTemperatureForPhotosynthesis\",\"Value\":\"7\"},{\"@name\":\"PhotosynthesisReductionAtFullLodging\",\"Value\":\"0.28\"},{\"@name\":\"Q10ForMaintenanceRespiration\",\"Value\":\"1.68\"},{\"@name\":\"ReferenceMaintenanceRespiration\",\"Value\":\"0.004318\"},{\"@name\":\"FractionOfGrossPhotosynthesisLostForGrowthRespiration\",\"Value\":\"0.228585\"},{\"@name\":\"MaximumPartitionFractionToAerialDryMass\",\"Value\":\"0.877745\"},{\"@name\":\"PartitioningCoefficient\",\"Value\":\"0.504173\"},{\"@name\":\"MinimumPartitionFractionToAerialDryMass\",\"Value\":\"0.02714\"},{\"@name\":\"RootLengthPerMassOfRoot\",\"Value\":\"500\"},{\"@name\":\"BaseTemperatureForStalkElongation\",\"Value\":\"9.805072\"},{\"@name\":\"CutOffTemperatureForStalkElongation\",\"Value\":\"40\"},{\"@name\":\"ThermalTimeForStalkElongation\",\"Value\":\"517.939718\"},{\"@name\":\"PartitionFractionAtHighTemperature\",\"Value\":\"0.84\"},{\"@name\":\"RootDepthIncreasePerGrowingDegreeDay\",\"Value\":\"0.1\"},{\"@name\":\"BaseTemperatureForRootExtension\",\"Value\":\"10\"},{\"@name\":\"CutOffTemperatureForRootExtension\",\"Value\":\"33.629124\"},{\"@name\":\"MaxRootLengthDensity\",\"Value\":\"5.169194\"},{\"@name\":\"MinRootLengthDensity\",\"Value\":\"0.02\"},{\"@name\":\"FractionOfPlantElongationAttributableToStalkElongation\",\"Value\":\"0.45\"},{\"@name\":\"LeafAngle\",\"Value\":\"25\"},{\"@name\":\"MaximumNumberOfLeavesPerTiller\",\"Value\":\"36\"},{\"@name\":\"BaseTemperatureForConversionEfficiency\",\"Value\":\"6.82141\"},{\"@name\":\"MaximumTemperatureForConversionEfficiency\",\"Value\":\"30.277822\"},{\"@name\":\"OptimumTemperatureForConversionEfficiency\",\"Value\":\"21.226346\"},{\"@name\":\"MaximumTillerPopulation\",\"Value\":\"0\"},{\"@name\":\"BaseRootBiomassForTillerDevelopment\",\"Value\":\"0\"},{\"@name\":\"OptimumRootBiomassForTillerDevelopment\",\"Value\":\"10\"},{\"@name\":\"MaximumRootBiomassForTillerDevelopment\",\"Value\":\"20\"},{\"@name\":\"BaseTemperatureForEmergence\",\"Value\":\"3.887124\"},{\"@name\":\"OptimumTemperatureForEmergence\",\"Value\":\"25.394325\"},{\"@name\":\"ThermalTimeToEmergenceFromRatooning\",\"Value\":\"242.526501\"},{\"@name\":\"ThermalTimeToEmergenceFromPlanting\",\"Value\":\"442.40589\"},{\"@name\":\"CropCoefficient\",\"Value\":\"1.15\"},{\"@name\":\"SoilWaterSupplyPotentialETCoeff1\",\"Value\":\"1\"},{\"@name\":\"SoilWaterSupplyPotentialETCoeff2\",\"Value\":\"2\"},{\"@name\":\"WaterStressProlongedImpact\",\"Value\":\"0.2\"},{\"@name\":\"ThermalTimeForPhotosynthesisRecovery\",\"Value\":\"150\"},{\"@name\":\"BaseTemperatureForPhotosynthesisRecovery\",\"Value\":\"10\"},{\"@name\":\"CutOffTemperatureForPhotosynthesisRecovery\",\"Value\":\"30\"},{\"@name\":\"CriticalWindSpeedForLodging\",\"Value\":\"200\"},{\"@name\":\"SensitivityScoreToLodging\",\"Value\":\"8\"},{\"@name\":\"MassThresholdForLodging\",\"Value\":\"220\"},{\"@name\":\"MassRangeForLodging\",\"Value\":\"30\"},{\"@name\":\"MaximumSensitivityScoreToLodging\",\"Value\":\"8\"},{\"@name\":\"RainfallRequiredToResetStressDay\",\"Value\":\"5\"}]}}}}"

Fig. S4. Region for setting the value of crop parameters for model simulation in API call.

"{\r\n \"locations\": [\r\n {\r\n \"Altitude\": 0,\r\n \"Distance_to_coast\": 0.0,\r\n \"Grid_no\": \"Anzola\",\r\n \"Latitude\": 44.53,\r\n \"Longitude\": 0.0\r\n }\r\n],\r\n \"data\": [\r\n {\r\n \"IsCO2Present\": false,\r\n \"GlobalSolarRadiation\": 16.4622615,\r\n \"SurfaceOzoneConcentration\": 0.0,\r\n \"Date\": \"2007-03-15T00:00:00\",\r\n \"ReferenceEvapotranspiration\": 0.0,\r\n \"SoilEvaporation\": 0.0,\r\n \"Grid_no\": \"Anzola\",\r\n \"AirTemperatureMaximum\": 20.0,\r\n \"AirTemperatureMinimum\": 7.222222222,\r\n \"Average_temperature\": 0.0,\r\n \"Precipitation\": 0.0,\r\n \"SnowDepth\": 0.0,\r\n \"VapourPressureDeficit\": 0.0,\r\n \"Windspeed\": 2.829444442,\r\n \"AirRelativeHumidityMaximum\": 0.0,\r\n \"AirRelativeHumidityMinimum\": 0.0,\r\n \"IsHumidityPresent\": false,\r\n \"IsVpdPresent\": false,\r\n \"IsEvapotrPresent\": false,\r\n \"LeafWetnessDuration\": 0,\r\n \"WaterTemperatureMaximum\": 0.0,\r\n \"WaterTemperatureMinimum\": 0.0,\r\n \"CO2concentration\": 0.0,\r\n \"AtmosphericPressure\": 0.0\r\n }

Fig. S5. Region for setting daily weather data for model simulation in API call. For example purposes only, the code contains a single daily record.

"{\r\n \"Anzola\": {\r\n \"StrategyUsed\": [],\r\n \"SoilProfileName\": null,\r\n \"SoilProfileDescription\": null,\r\n \"BottomDepth\": [\r\n 0.2,\r\n 1.5\r\n],\r\n \"HorizonThickness\": [\r\n 0.2,\r\n 1.3\r\n],\r\n \"VolumetricWaterContentAtSaturation\": [\r\n 0.48,\r\n 0.52\r\n],\r\n \"VolumetricWiltingPoint\": [\r\n 0.14,\r\n 0.18\r\n],\r\n \"VolumetricFieldCapacity\": [\r\n 0.29,\r\n 0.36\r\n],\r\n \"SaturatedHydraulicConductivity\": [\r\n 6.5,\r\n 4.7\r\n],\r\n \"BulkDensityMax\": null,\r\n \"Clay\": null,\r\n \"Sand\": null,\r\n \"Silt\": null,\r\n \"Skeleton\": null,\r\n \"OrganicCarbon\": null,\r\n \"VanGenuchtenAlpha\": null,\r\n \"VanGenuchtenN\": null,\r\n \"VanGenuchtenM\": null,\r\n \"VanGenuchtenLMualem\": null,\r\n \"VanGenuchtenSWCres\": null,\r\n \"NumberOfLayers\": 0,\r\n \"LayerThickness\": null,\r\n \"ManureMineralizationConstantRate\": \"NaN\",\r\n \"LitterMineralizationConstantRate\": \"NaN\",\r\n \"FieldLenght\": \"NaN\",\r\n \"FieldSlope\": \"NaN\",\r\n \"FieldWidth\": \"NaN\",\r\n \"VolumetricWaterContent\": null,\r\n \"BulkDensity\": null,\r\n \"CarbonInHumus\": null,\r\n \"Ammonia\": null,\r\n

\"Nitrate\": null,\r\n \"Urea\": null,\r\n \"CarbonInLitter\": null,\r\n \"CNRatioOfLitter\": null,\r\n \"CarbonInManure\": null,\r\n \"CNRatioOfManure\": null,\r\n \"Date\": \"0001-01-01T00:00:00\",\r\n \"WaterTableDepth\": \"NaN\",\r\n \"NitrateConcentration\": \"NaN\",\r\n \"Salinity\": \"NaN\"\r\n }\r\n}"

Fig. S6. Region for setting soil data for model simulation in API call.

The list of model outputs together with their brief description and unit of measurement is shown in Table S1.

Table S1. Arungro model output as returned by online service.

Output variable	**Unit of measurement**	**Description**
Location		Simulation site
Date	yyyy-mm-dd	Date
AerialBiomass	t ha-1	Aerial dry biomass
TotalBiomass	t ha-1	Total dry biomass
StalkBiomass	t ha-1	Stalk dry biomass
InterceptedPAR	MJ ha-1	Intercepted photosynthetically active radiation
LAI	m2 m-2	Green leaf area index
TotalLAI	m2 m-2	Total leaf area index
TotalLeavesNumber	leaves m-2	Number of leaves per square meter
TillerPopulation	tiller m-2	Number of tillers per square meter
TotalMaxTillerPopulation	tiller m-2	Max attainable tiller population
ThermalTimeForTillerDevelopment	°C d	Thermal time for tiller development
ThermalTimeFromPlantingOrRatooning	°C d	Thermal time from planting or ratooning
PotentialTranspiration	mm d-1	Potential transpiration
ActualTranspiration	mm d-1	Actual transpiration
RootDepth	cm	Root depth
CropWaterStressForRootDepth	unitless	Water stress on root deepening (max stress=0, min stress=1)
CropWaterStressCarbonAssimilation_SWDF1	unitless	Water stress on carbon assimilation (max stress=0, min stress=1)
CropWaterStressExpansiveGrowth_SWDF2	unitless	Water stress on leaf expansion (max stress=0, min stress=1)
StressDays	counter	Number of consecutive severe water stress day
WaterStressOnTillerDevelopment	unitless	Water stress on tiller development (max stress=0, min stress=1)
SWC_3cm	mm mm-1	Soil water content of the 0-5 cm layer
SWC_20cm	mm mm-1	Soil water content of the 10-20 cm layer
SWC_40cm	mm mm-1	Soil water content of the 30-40 cm layer
SWC_60cm	mm mm-1	Soil water content of the 50-60 cm layer