Agro-ecosystems simulation models as web services for using in web applications

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Abstract. Agricultural system science includes the agricultural system models, the data needed to use them, and all the results for guiding decisions and policies. Modern cloud technologies can play an important role by providing effective interfaces for using these models. There are several websites that offer environmental data in real time. Some of these websites incorporate map-based geographical and environmental information such as weather forecasting and satellite imaginary. We implemented a simple environmental simulation model: the *Web API-SWB Basic*, as an experiment of accessing and executing agro-ecosystems models via a Web API. Our goal is to expand this model to a broader range of models that can be used for more comprehensive agro-ecosystems modeling like nutrient balances and cycling, carbon dynamics, rotations. The product would be a set of models, included in a sort of toolbox and used with Web APIs, that can be picked according to specific needs.

Keywords. Agricultural system models, cloud-hosted databases, model as a service, environmental decision support system.

1 Introduction

Agricultural system science includes the agricultural system models, the data needed to use them, and all of the information used to communicate results for guiding decisions and policies. Up to now, agro-ecosystem models have been largely developed, tested and applied in a big range of situations worldwide. One example of this extensive evolution is the Agricultural Model Intercomparison and Improvement Project (AgMIP). This created a global community of agricultural system modelers with cutting-edge information technology to produce improved models and the next generation of climate impact projections for the agricultural sector [1].

However, most of these models, although freely available, are still confined to the academic and research fields. Model packages are distributed as closely integrated desktop applications for multiple purposes with cumbersome parameterizations making them difficult to setup and manage. There is a tendency towards modularization of packages but primarily intended for program reconfiguration and not for use with third party software. These models require detailed configured and locally available input data sets. On the other hand, with cloud computing, such as Spatial Data Infrastructure (SDI) which provides 'Data as a Service', Big Data and other cloud-hosted databases, environmental data have become quite accessible over the internet [2, 3].

The crop model *SWB* (Soil Water Balance) evaluates crop production especially limited by water supply [5]. Hence, it was extensively tested in areas where water deficits are important in limiting crop potential [5, 6]. The SWB was used to assess corn production in the US Pacific Northwest as an alternative dryland crop [5], water needs in irrigated corn in the arid region of Castilla de la Mancha, Spain [7] and the evaluation of water balance in the Central-Argentine croplands [8, 9].

In this work we implemented a very simple environmental simulation model: a soil water balance, the *Web API-SWB Basic*, to test accessing and executing agro-ecosystems models as a web service. The *Web API-SWB Basic* is a lightweight version of the more comprehensive *SWB* and estimates in a very simple and direct manner the soil water balance.

Our idea is to expand this simple model to a broader range of models that can be used for either simple environment-crop relationships (e.g. water balance, crop development) or for more comprehensive agro-ecosystems modeling (e.g. nutrient balances and cycling, carbon dynamics, rotations). The product would be a set of models, included in a sort of toolbox and used with Web APIs that can be picked according to specific needs.

2 Methods

This experiment tests a method of accessing and executing agro-ecosystems models via a Web API. The API obtains results by running the model server-side based on the input data sent by the user. The data calculated by the model are ready for using in web applications, the potential users.

The *Web API-SWB Basic* is currently located at: http://www.agro-data.net/client.php and can be tested by providing the user name: "guesttoswb" and the password: "guesttoenter". Input data examples are provided in the API web page. They are ready to simulate soil water balance over a period of 90 days (December, January and February) at three Argentinian locations: General Pico, Rio Cuarto and Junín; during two contrasting years: 2010/11 and 2011/12. These examples can be used as reference on how to build input data sets.

The *Web API-SWB* is described first from the agronomics and then from the making of the API.

Web API-SWB Basic: Agronomics

The model estimates in a simple way the soil water balance. Nevertheless, it includes most of the water fluxes and storage process occurring in a soil: infiltration, runoff, drainage, evaporation, transpiration, plant water stress and water deficit. It calculates the water available for crop transpiration (AW) as the soil water content (m^3 m^{-3}) between field capacity (FC) and permanent wilting point (PWP). Those water contents are the water retained at 33 and 1500 J kg^{-1} respectively. Transpiration, the water consumption from the soil by plants, is estimated as the water uptake of a reference and permanent plant cover that explores 1 m depth of soil. This reference plant cover is assumed to have a leaf area index that gives a value of 0.85 for fraction interception of global radiation. Transpiration of this reference cover is included in order to approximate a cultivated soil water balance. By not including this reference transpiration, soil water can be overestimated.

Next, we describe input and output data. They are organized in arrays (n x m) that have no headings.

Daily outputs of *Web SWB Basic* are arranged in a d x 22 array:

1. d: simulated day (first d=1)

2. Year: (YYYY)

3. DOY: day of the year (1 = 1 First of January, 365 = 31th of December)

4. Precipitation mm

5. PET: potential evapotranspiration mm

6. PE: potential evaporation mm

7. E: actual evaporation mm

8. PT: potential transpiration mm

9. AT: actual transpiration mm

10. Run off: mm

11. AW: available water mm

12. Deficit: water to reach 100 % of AW mm

13. Water content (m^3 m^{-3}) of soil layer 1.

14. Water content (m^3 m^{-3}) of soil layer 2.

15. Water content (m^3 m^{-3}) of soil layer 3.

16. Water content (m^3 m^{-3}) of soil layer 4.

17. Water content (m^3 m^{-3}) of soil layer 5.

18. Water content (m^3 m^{-3}) of soil layer 6.

19. Water content (m^3 m^{-3}) of soil layer 7.

20. Water content (m^3 m^{-3}) of soil layer 8.

21. Water content (m^3 m^{-3}) of soil layer 9.

22. Water content (m^3 m^{-3}) of soil layer 10.

Input data consists of three arrays: *weadata*, *locdata* and *soildata*

weadata: daily weather data, size: d x 9

This array sets the length in days of the simulation, the start and end dates and has the following format:

1. Year (YYYY)

2. DOY

3. Precipitation mm

4. Maximum daily air temperature ºC

5. Minimum daily air temperature ºC

6. Daily solar global radiation MJ day^{-1}

7. Maximum air relative humidity %

8. Minimum air relative humidity %

9. Daily mean wind speed m s^{-1}

locdata: location data, size: 1 x 20. Only few positions are used:

1. Site name (string)

2. Latitude in decimal degrees (GGG.DD), negative for south hemisphere.

3. Longitude in decimal degrees (GGG.DD), negative for west.

4. Sea level altitude in m

Positions 5 to 20 are not used in this test. However, the 1 x 20 structure is kept for more flexibility when expanding the model.

soildata: soil data, size: 10 x 20. Input data are for a soil profile with a fixed number of layers of 10 and with fix values of layer thickness. Therefore, the first two columns are fixed and must be supplied as indicated in the examples.

1. Layer number 1 to 10 (fix)

2. Layer thickness m (fix)

3. Bulk density MG m^{-3}

4. FC: field capacity (m^3 m^{-3} a 33 J Kg^{-1}).

5. PWP: permanent wilting point (m^3 m^{-3} a 1500 J Kg^{-1}).

6. Water content at the start of the simulation (d=1) m^3 m^{-3}

7. Clay fraction g g^{-1}

8. Silt fraction g g^{-1}

Again, not all positions are used and the 10 x 20 structure is kept for further expansions. Daily output data were chosen among those that have some potential to be used for web applications. From the entire range of output data, the user can pick any number of variables to use in his web application. In addition, intermediate or data not supplied by this model at this time, can be provided upon user's request to the output palette.

Web API-SWB Basic: Implementation

The *Web API-SWB Basic* receives HTTP POST requests with model input data in the body of the request formatted as JavaScript Object Notation (JSON). Every request triggers an execution of the model with the input data received. Input data is checked for consistency. The service then returns simulation output data to the requesting node in the body of the HTTP response that is also formatted as JSON. The web service was implemented in PHP language due to its widespread use for server-side scripting on most commercially available web servers. JSON format was used for the model's data interfaces because of its seamless integration to the Web 2.0.

PHP script implements server side JSONRPC 2.0 protocol node for remote execution of the *Web API-SWB Basic*. The JSONRPC 2.0 protocol uses JSON for coding input and output data [10]. This format was chosen because it is fast and lightweight. As mentioned in the agronomics, the *Web API-SWB Basic* engine requires inputs arranged as one (*locdata*) and two (*weadata* and *soildata*) dimension arrays. In this application we use JSON to build multidimensional arrays by nesting arrays.

The API uses a client-server protocol that transports data through TCP or HTTP protocols. For this application we have chosen HTTP. HTTP Requests sent to the script of the Web API are of the type POST. The body of the HTTP request includes the Object Request and it receives the Response Object.

The Object Request to run the *Web SWB Basic* via the Web API (input data) has the following format [11]:

{"jsonrpc".............3,1.4,0.3,0.1,0.3,0.1,0.2,0.01,0.0001,0.00001,7,0,0,0,0,0.07,0.9,0.03,0.03]] }, "id": 1}

Output data are returned inside the Request Object that has the following format [12]:
{"jsonrpc":"2.0",result":[1,2011,350,0,7.0844594431752,1.0626689164763,1.06266
89164763,6.0217905266989,6.0113360292567,0,232.92599505427,7.074004945733
,0.27874662167047,0.29017277240435,0.29121822214856,0.293309121637,0.2958
1820102313,0.29832728040925,0.3,0.3,0.3,0.3], ………..d":1}

The Web API uses the server side JSONRPC protocol implementation for PHP coded by subutux available on GitHubhttps://github.com/subutux/json-rpc2php. This implementation allows the authentication of the requests by the addition of the "xrpcauthusername" and "xrpcauthpassword" fields at the header of the HTTP request.

3   Discussion

Agro-ecosystems simulation models are usually based on already known and proven methods for the estimation of processes relating to crops, soils and weather. They vary in their mathematical complexity and are more or less comprehensive regarding the process they address. The capacity of a model to accomplish its objective depends largely on a) the correct choice of the level of complexity to obtain the right answer without unnecessary complication and b) the correct choice of the methods or set of calculations to address the problem it intends to solve.

In Addition, experience in other fields of science suggests that its successful application is based on enhanced adoption. Moreover, the discovery, use, and contribution of data and software become critical tasks given the complexities involved in agricultural systems. Modern Web 2.0 and cloud-based technologies can play an important role in reducing such inconveniences by providing intuitive interfaces and eliminating the need for users to install and maintain software [2].

Web services, through Application Programming Interfaces (APIs), provide a very powerful form of integrating cropping simulation models with web-based environmental and geographical databases. APIs provide a peer-to-peer inter-process communication by handling events triggered by the exchange of URIs (resource identifiers). Hence, any computational algorithm, crop or environmental model can be remotely launched or executed by an application or website that also provides map-based data on geographical environmental information on the client side, e.g. Google Maps API.

Our goal is to develop online and simulation-based tools to assist on the decision-making process in agricultural systems. There are several websites that offer online weather and environmental information in real time. They might also incorporate map-based geographical and environmental information such as weather forecasting and satellite imagery. All of these informational resources have great potential in helping and supplying decision makers, growers or any player operating on agricultural systems with key information to improve the decision-making process. Though, proven estimation methods and somewhat mechanistic simulation models of agro-ecosystems, integrated with geographical information, might drastically improve the knowledge and understanding of the natural system. Thus, the prediction of its behavior will be based more on its functioning and, more likely, will allow better options for its management.

4 Conclusions

Although the *Web API-SWB Basic* is an example of one of the simplest agricultural simulators, our experiment suggests that not only more complex but also greater number of agro-ecosystems processes can be simulated and implemented using APIs for the accessing and executing the models as web services. Furthermore, the models simulating these processes, can constitute a sort of building blocks for more composite systems that will allow the assessment of either a single or multiple and combined functions of agro-ecosystems. Additionally, integrated into web services that already provide information from web-based geographical information systems, including satellite and environmental data, this adaptable architecture can enhance the assessment of agro-ecosystems by giving a more comprehensible approach.

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