Technical sheet

Policy documents
Europe: *RDPs (Pillar I and II), CAP; Reg. 1698/05 1974/06 (rural development) Reg. 1306/2013 (cross-compliance). Dir.91/676/EEC (Nitrates Directive)*
Austria, Hungary, Italy: *CAP Greening Payment Requirements and GAEP Cross-Compliance Standards, Austrian Programme of agri-environmental measures (Austria), Act on the Protection of Cultivated Soil (Hungary), Regional RDP; dlgs 18/05/01 no. 227 (Italy)*

First draft

TOOL CROP GROWTH MODEL – *Territorial Scale: Regional*

WHY

Agriculture is one of the main production systems and it is strongly supported and regulated by the EU Common Agriculture Policy (CAP). Agriculture is not only responsible for *food, feed, fiber,* and *fuel* production but it is also the only system which is capable for preserving and safeguarding the environment, territory, and landscape when it is properly managed. The modelling analysis that is performed with the Agriculture tool can give clear results about the production and the environmental impact in a given area in what-if scenarios of field management. The tool operates thanks to the integration of the process-based crop model (Armosa) into the LANDSUPPORT geoSpatial Decision Support System (S-DSS).

FOR WHOM

This tool is targeted to farmers consortia and Public Authorities (e.g. Administrative Regions), and to whom are interested in the quantification of the crop production that can be possibly obtained and the associated environmental impact, namely the nitrate leaching and the soil carbon sequestration, in contrasting field management options. A potential user is the farmer who wants to estimate the possible change of the production of the crops that are currently grown switching from conventional (being the current situation) to conservation agriculture, as such a system is recognized to reduce the costs of the production over time and to enhance the soil fertility. For instance, the farmer could be interested in comparing two scenarios: conventional vs conservation agriculture.

HOW – if you want to *select your Region Of Interest (ROI)*[i]

The tool is actually applied to the local case study of Valle Telesina (Italy) and two regional case studies of Marchfeld (Austria) and Zala County (Hungary). It allows the free selection of any region of interest (ROI) following a very simple procedure:

Operational procedure

- Click on the "Draw (Polygon)" button on the top bar, draw the desired area (ROI) and assign it a name[ii].
- Use the "Save" button to store the ROI in the memory of the system. It is then possible to select it whenever necessary.

CROP GROWTH – FULL VERSION

HOW

Operational procedure

The crop growth tool (also named as Dynamic Armosa) can be selected from the toolbox of the Graphic User Interface: Agriculture > Full version (the button on the bottom) > Regional scale (Campania, Marchfeld, Zala County) > Toolbox > Test folder > Crop Growth (Dynamic Armosa). The interface pops up and here the user finds a long list of crop rotations. These rotations are the most common in the examined area, for both conventional and organic production systems. The information about crop rotations were derived from the database made available by Boku, Campania Region, University of Pannonia for the simulation of Valle Telesina, Marchfeld, and Zala County, respectively. For instance, in the case of Marchfeld, four rotations are the typical ones in the organic production. The conventional and the organic crop rotations are automatically associated to inorganic and organic fertilizers, respectively. Moreover, in this list the user finds two alternatives for a given rotation being the introduction of a cover crop into the rotation. Cover crops are introduced to reduce the period of time between two crops with bare soil. in these what-if scenarios the cover crop is a clover meadow. Tillage offers two options: "cvta", which means that the Crop Growth (Armosa) model simulates ploughing at 30 cm soil depth, "MT", which means that the Crop Growth model (Armosa) simulates a limited perturbation of the 15 cm topsoil layer with no soil layers mixing. The user can choose whether or not crop residues are retained in the field.
The S-DSS will return crop production of each crop being part of the rotation (for each simulated year), the mean annual nitrate leaching and the mean annual change of soil organic carbon stock in the 30 cm topsoil layer. Figure 1, 2, 3 are screenshots of the results visualization (tables and maps).

What for

The results give clear quantifications of crop production and environmental impact under alternative techniques of crop rotation (with vs. without cover crop), fertilization (mineral vs. organic), tillage (ploughing vs. minimum tillage) and crop residues management (retained vs. removed).

The ARMOSA process-based crop model

The tool provides the variable estimation by running the on the fly version of the ARMOSA process-based crop model. The ARMOSA model is a versatile tool to represent the high level of complexity of agroecosystem processes which vary in response to agricultural management (i.e., crop rotation, intercropping, crop residues management, fertilization, irrigation, tillage) and pedoclimatic conditions. At field scale, the modularity of the ARMOSA software code ensures easy implementation of new modules for simulating the effects of new agriculture practices. At regional to national scale, the capability of depicting multi-crop rotation in a medium to long term perspective allows quantifying crop production and environmental aspects in response to varying market and policy needs (e.g., organic farming, greening). The model consists in three main modules: (1) crop growth and development; (2) soil water dynamics; (3) C and N cycling. Required input data: daily weather data (COSMO-LEPS and reanalysis data at 8 km spatial resolution (see https://www.landsupport.eu/dss-platform/technical-docs/), soil properties (provided layer by layer, sand, silt, clay, organic carbon content, bulk density), cropping systems information (type of crop, crop rotation, sowing and harvest date, crop residues management, fertilization, irrigation, tillage). The simulation unit is 1 hectare. The model overview is given by Perego et al. (2013)[iii] and Valkama et al. (2020)[iv].
The management input that are chosen from the interface and simulated by ARMOSA are:

1) CROPPING SYSTEM: It consists of crops sequence, and the dates of sowing and harvesting for each crop (such as winter and durum wheat, barley, grain maize, alfalfa, processing tomato, oil seed rape, sugar beet, soybean, sunflower). The crop sequence is repeated over time till the end of the weather data. Crop parameters are already available for about 25 crops in the database. The list of the crop parameters is long and encompasses different processes related to growth and development. The main parameters, which were calibrated thanks to measured data measured at local sites (Valle Telesina and Campania region: ISTAT; Marchfeld: Groenendijk et al. 2014[v], Novelli et al. 2019[vi]; Zala County: Keszthely experimental observed data), are the potential carbon absorption, water stress sensitivity, minimum and maximum cardinal temperature for growth and development, specific leaf area index, partitioning rate of dry matter between plant organs (roots, stem, leaves, storage – grain, tuber, root or fruit).
2) N-FERTILIZATION: It is possible to simulate the application of mineral (e.g. urea, ammonium nitrate) and/or organic fertilizer (e.g. dairy slurry, digestate). 10 fertilizers (urea, ammonium nitrate, ammonium sulphate, calcium nitrate, dairy slurry, swine slurry, liquid fraction of digestate, sewage slurry, dairy manure, compost) are parameterized, being the most commonly applied in the case study areas

according to the field experimental data. The fertilization is described with the amount of kg N/ha, date of application, depth of application, the type of fertilizer is to define in the simulation setting.

3) IRRIGATION: Different levels of irrigation can be simulated, responding to the aim of restoring 100% or 80% of the maximum extractable water reserve. As an alternative, the user can adopt the irrigation at fixed dates, which were derived from the field experimental data. In this case, the water amount of a single event varies between 30 and 70 mm.
4) TILLAGE: Tillage operations are simulated as function of till depth, timing, degree of soil layers mixing (e.g. 0.7 and 0.3 for ploughing and disk harrowing, respectively) and perturbation (e.g. 0.6 and 0.2 for ploughing and disk harrowing, respectively). Parameters values of many other tillage operation (spring harrow, rotary hoe, subsoiler) are available from the WEPP model manual (Laflen et al. "WEPP-predicting water erosion using a process-based model." Journal of Soil and Water Conservation 52.2 (1997): 96-102.).
5) CROP RESIDUES MANAGEMENT: Crop residues are removed or retained into the soil with an incorporation depth which is based on the tillage depth. The decomposition of the crop residues is driven by water and temperature factors and the decomposition rate of the different organs of the plant (stem, leaves, storage, roots); this rate was calibrated in previous application for many crops (such as alfalfa, maize, wheat) under a wide range of pedoclimatic conditions in European sites in France, Germany, Spain, Italy, Finland, England (Sándor et al., 2018[vii]) and in Russia and Kazakistan (Valkama et al., 2020).

Figure 1. Annual crop production (winter wheat, grain yield Mg ha^{-1}).

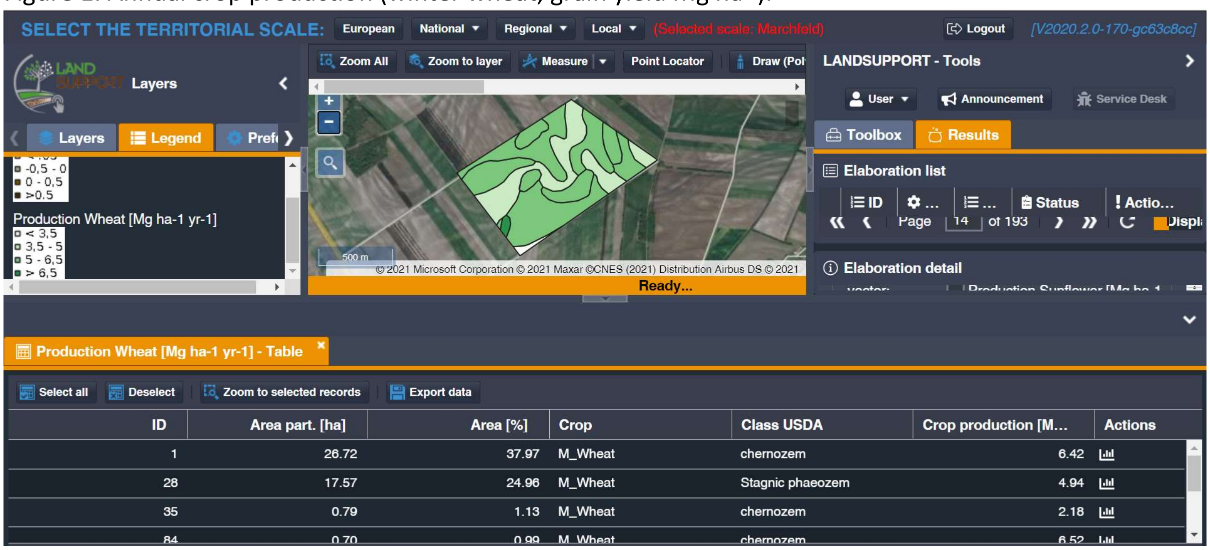


Figure 2. Mean annual nitrate leaching (NO_3-N kg ha^{-1} yr^{-1}).

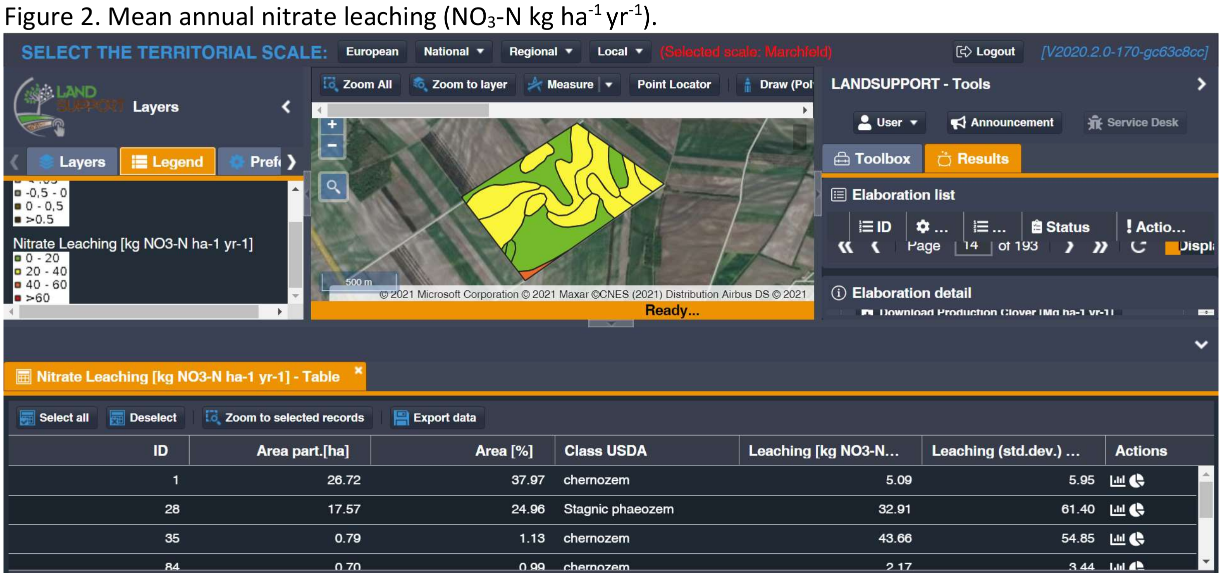
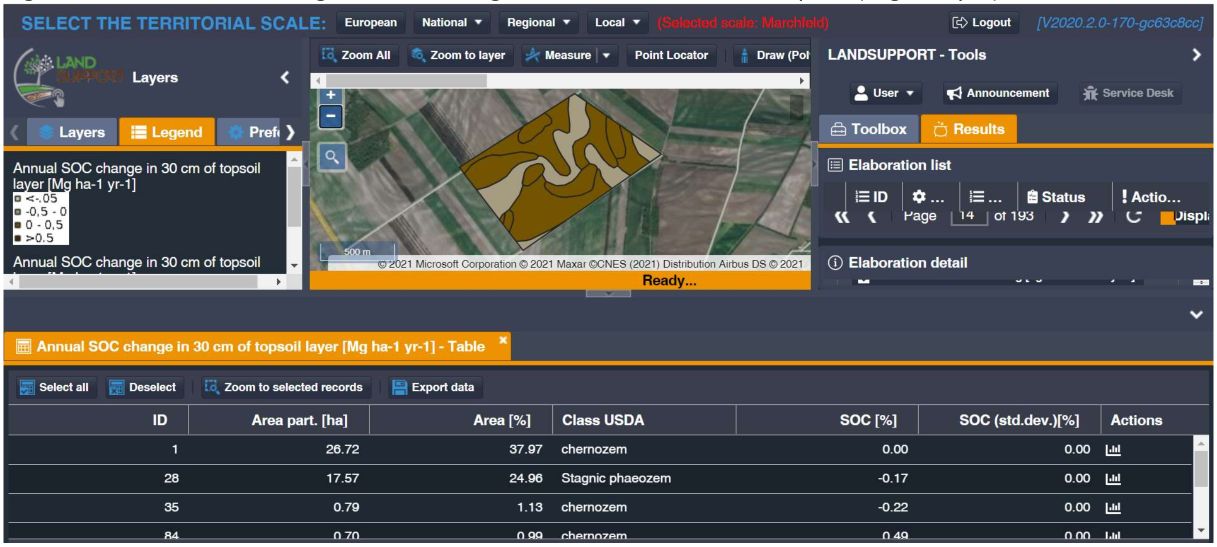


Figure 3. Mean annual change of the soil organic carbon stock in the topsoil (Mg ha^{-1} yr^{-1}).



LIMITATIONS

The tool works based on a modelling framework which integrates the ARMOSA process-based crop model. The model runs for each soil type of the selected ROI. The soils' properties are obtained from the soil map for each of the regions (or subregions). This application requires details about the current crop rotations and the suitability of alternative options. Such data are easily retrieved by European or Regional databases.

FUTURE DEVELOPMENT

By the end of the project, we seek to let the user upload his own soil data and land use in order to get customised information about the area of interest. Moreover, note that in the final release of this tool the list of the crop rotations will be split into the options of production systems ("conventional" and "organic") and the options about the use of cover crop ("with cover crops" and "without cover crops").

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[i] Special care is required when user draws/select the Region of Interest. In fact, LANDSUPPORT is a multi-scale decision support system. Each of the 15 available tools is designed for a specific application and for a specific scale. Furthermore, the databases using specific standards required for that specific scale. The users of LANDSUPPORT web platform must therefore be well aware of the limitation embedded in the different maps that they require for their specific application. The users must be expert on their specific problem and must understand if the input data offered by the platform are suitable for their problem. In light of the above, the system provides very reliable results only if used appropriately.

[ii] It is also possible to draw a ROI with numerous polygons. In this case, it is possible to assign different values (eg numbers) to each of the drawn polygons.

[iii] Perego, A., Giussani, A., Sanna M., Fumagalli, M., Carozzi, M., Alfieri, L., Brenna, S., Acutis, M., 2013. The ARMOSA simulation crop model: overall features, calibration and validation results. Italian Journal of Agrometeorology 3:23-38. ISSN: 18248705.

[iv] Valkama, E., Kunypiyaeva, G., Zhapayev, R., Karabayev, M., Zhusupbekov, E., Perego, A., Schillaci, S., Sacco, D., Moretti, B., Grignani, C., Acutis, M., 2020. Can conservation agriculture increase soil carbon sequestration? A modelling approach. Geoderma, 369, 114298. https://doi.org/10.1016/j.geoderma.2020.114298

[v] Groenendijk, P., Heinen, M., Klammler, G., Fank, J., Kupfersberger, H., Pisinaras, V., Gemitzi, A., Peña-Harod, S., García-Prats, A., Pulido-Velazquez M., Perego, A., Acutis M, Trevisan, M., 2014. Performance assessment of nitrate leaching models for highly vulnerable soils used in low-input farming based on lysimeter data. Science of the Total Environment 499:463-480.

[vi] Novelli, F., Spiegel, H., Sandén, T., Vuolo, F., 2019. Assimilation of sentinel-2 leaf area index data into a physically-based crop growth model for yield estimation. Agronomy, 9(5), 255.

[vii] Sándor, R., Acutis, M., Barcza, Z., Doro, L., Hidy, D., Köchy, M., Minet, J., Lellei-Kovács, E., Ma, S., Perego, A., Rolinksi, S., Ruget, F., Sanna, M., Seddaiu, G., Wu, L., Bellocchi, G., 2017. Multi-model simulation of soil temperature, soil water content and biomass in Euro-Mediterranean grasslands: uncertainties and ensemble performance. European Journal of Agronomy, 88:22-40 (DOI: 10.1016/j.eja.2016.06.006).