ASSESSMENT TOOL / MODEL **ROTAT+: Generation of crop rotations that make sense**

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ROTAT+ combines crops from a predefined list of potential crop candidates to systematically generate all possible crop rotations based on a number of filters controlled by the user. The tool can be used to evaluate the generated rotations using a list of indicators. The calculation is based on expert-based quantitative scorings of the characteristics of each candidate crop.

NOTE An example of this tool in use is included as a case study at the end of this learning material.

Overview

ROTAT+ was designed to make the procedure of generating all possible crop rotations more transparent and objective (Dogliotti et al., 2003). The user needs to fill in a matrix of allowed and disallowed crop sequence in time based on agronomic perspectives and farm-specific reasonings. Other filters which include planting and harvest dates, maximum frequency of crops or crop groups, and minimum years between return of a crop, eliminate in early stages those crop successions that do not make sense agronomically or are not feasible. ROTAT+ offers a list of indicators including NPK uptake and transfer, soil cover, rooting, compaction, water use, labor, and gross margin, which can be used for evaluating the crops choice in the generated rotations. It also includes Soil Organic Matter and Soil erosion simulations.

The original version of ROTAT+, called ROTAT, was developed in the early 2000's and only had the acceptable rotations as outputs. It was then further developed to contain quantitative indicators and the evaluation modules. The examples in this description are from 2003 as more recent research is still in the process of being published.

Relevance of the level of analysis

A crop rotation is important to sustain soil health, optimize nutrients in the soil, and combat pest, disease and weed pressure. As crop rotations play a central role in a (arable and mixed) farming system, it represents a logical starting point in the (re)design process of a farming system. The model can be used in all (arable farming) contexts.

Model/tool description

A well-designed crop rotation would improve the farming systems, for example in terms of crop yields, soil erosion, occurrence of soil-borne pests, diseases and weeds, and dynamics of nitrogen and labor. ROTAT+ facilitates the (re)design process by combining crops from a predefined list of potential crop candidates to systematically generate all possible crop rotations based on a number of filters controlled by the user. The tool can be used to evaluate the generated rotations using a list of indicators. The calculation is based on expert-based quantitative scorings of the characteristics of each candidate crop.

A tool such as ROTAT+ allows the users to systematically generate agronomically feasible rotations that might have been overlooked if they were to be generated manually. The generated crop rotations and their associated indicator scores can then be iteratively evaluated and discussed among stakeholders, before finally a preferred rotation is selected to be applied in a farmer's field. ROTAT+ may be used as a stand-alone tool in farming systems design processes and as an instrument in explorative land use studies (Dogliotti et al., 2003).

The output from ROTAT+ can be analyzed for example using trade-off analysis or pareto optimization analysis as in FarmDESIGN. The ROTAT+ indicators that are used in such analysis should be linked to the farm objectives and constraints. The analysis results with the associated crop rotations can be linked with farm-level assessment tools, like FarmDESIGN and LandscapeLab.

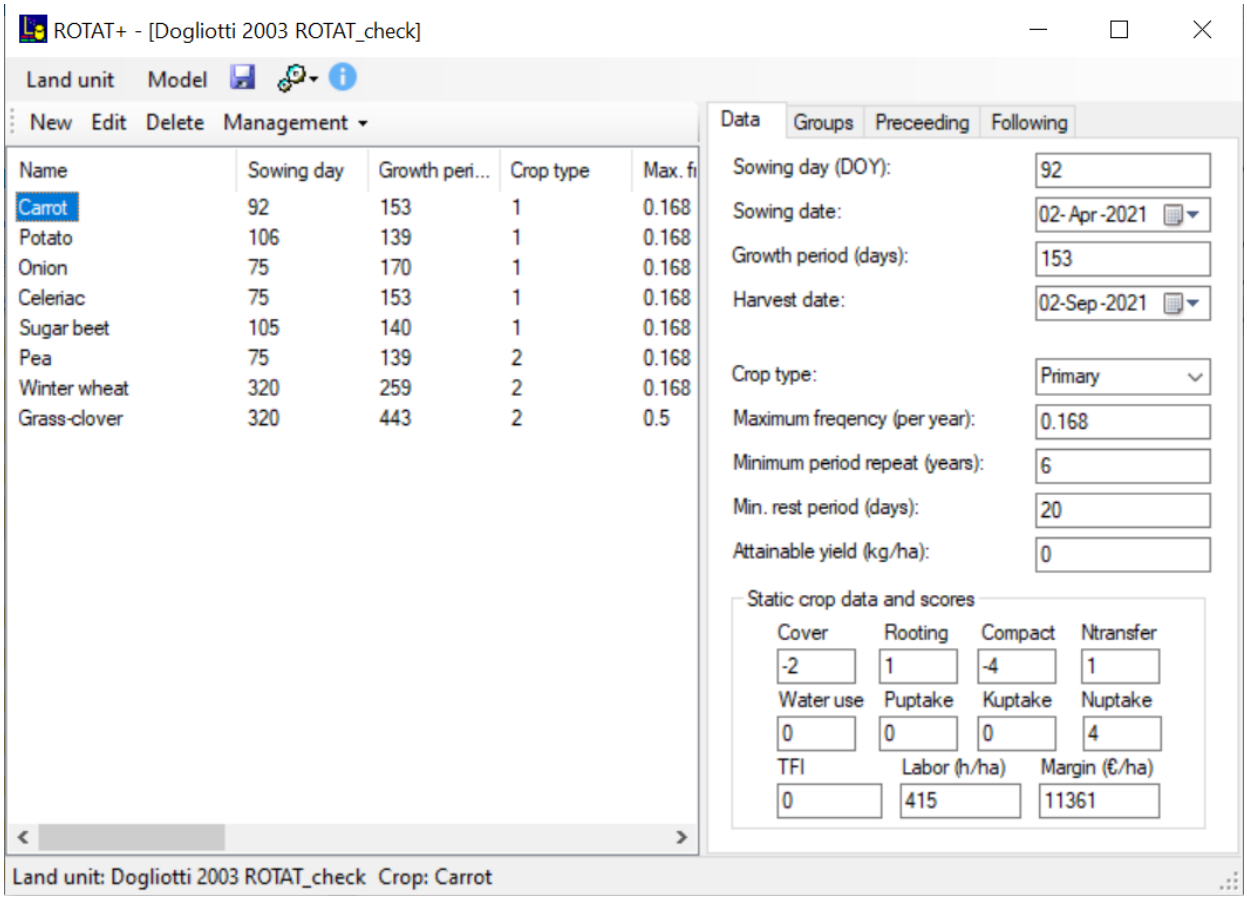

Figure 1. *Current ROTAT+ user interface showing a land unit (case study scenario) of Dogliotti et al., 2003.*

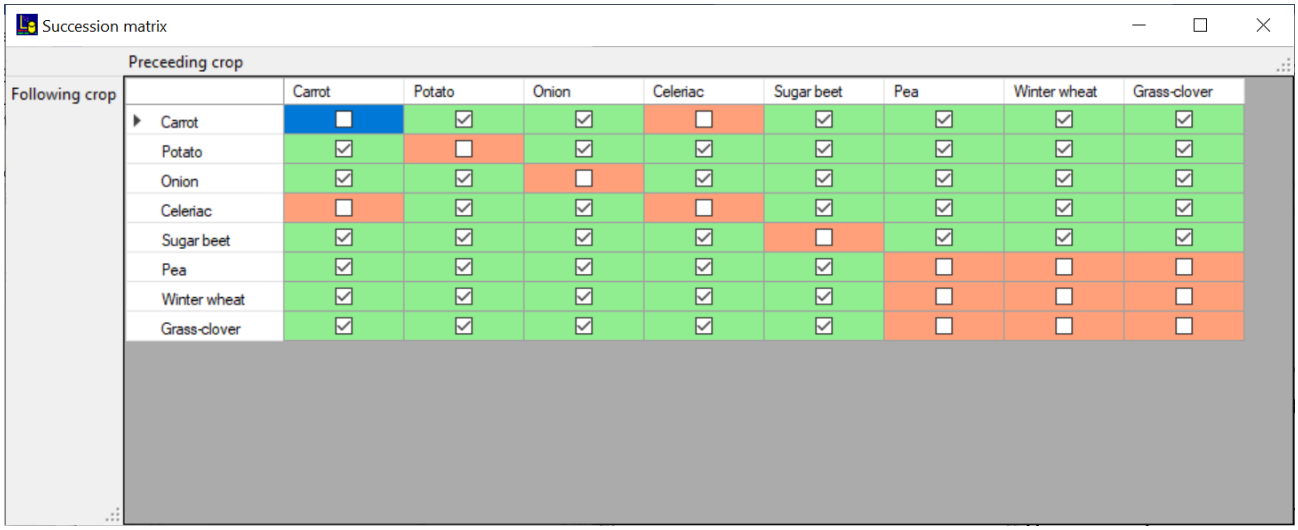

Figure 2. *Matrix of allowed and disallowed crop succession. Crops in the column headers precede the crops in the row headers. Ticked boxes (in green) represent allowed sequence specified by the users.*

Details for potential users

Proposed users - students, researchers, extension/farmers advisors

Key actors/stakeholders/beneficiaries - farmers

Model input – farmer's list of candidate crops, farmer's preference in crop rotation length, expert/farmer's input on crop sequence and frequency constraints, expert/farmer's input on crop characteristics (e.g. sowing/harvest dates, yield, price, labor requirements etc.)

Model output - agronomically feasible crop rotations

Time period for different steps of model use and analysis - With sufficient context-specific agronomical knowledge and/or inputs from farmers, model results can be obtained after a few days of practice.

Key terms

- **Crop succession** - One crop following another on the same piece of land, often characterized by preceding and succeeding effects (Dury et al., 2013).
- **Crop sequence -** The order of appearance of crops on the same piece of land during a given period (Leteinturier et al., 2006).

Manuals, tutorials, or other learning materials:

- To download the model itself used here: https://www.dropbox.com/s/16dmm8yr2a2udmp/ROTATplus.Bin_Docs.v2.2.1.zip?dl=0
- (in Dutch) Bouwplan en vruchtopvolging (https://edepot.wur.nl/346555)

Key references

Dogliotti, S., Rossing, W.A.H., Van Ittersum, M.K., 2004. Systematic design and evaluation of crop rotations enhancing soil conservation, soil fertility and farm income: A case study for vegetable farms in South Uruguay. Agric. Syst. 80, 277–302. https://doi.org/10.1016/j.agsy.2003.08.001

Dogliotti, S., Rossing, W.A.H., Van Ittersum, M.K., 2003. ROTAT, a tool for systematically generating crop rotations. Eur. J. Agron. 19, 239–250. https://library.wur.nl/WebQuery/wurpubs/320354

Dury, J., Garcia, F., Reynaud, A., & Bergez, J. E. (2013). Cropping-plan decision-making on irrigated crop farms: A spatio-temporal analysis. European Journal of Agronomy, 50, 1-10.
Castellazzi, M., Wood, G., Burgess, P.J., Morris, J., Conrad, K., Perry, J., 2008. A systematic representation of crop rotations. Agricultural Systems 97, 26-33.
https://www.researchgate.net/publication/257505317_Cropping-plan_decision-making_on_irrigated_crop_farms_A_spatio-temporal_analysis

Tariq, M., Ali, H., Hussain, N., Nasim, W., Mubeen, M., Ahmad, S., Hasanuzzaman, M., 2019. Fundamentals of Crop Rotation in Agronomic Management, in: Hasanuzzaman, M. (Ed.), Agronomic Crops: Volume 1: Production Technologies. Springer Singapore, Singapore, pp. 545-559.

Case Study - Designing crop rotations in arable farm in the Netherlands (Dogliotti et al., 2003)

Time period (or an indication): modeled for 6- or 12-year rotations
Key actors/stakeholders/beneficiaries: farmer

Applying the model: Based on a predefined candidate crop list comprising eight crop species, ROTAT was used to generate all possible crop rotations for a farm case study in The Netherlands. The eight crops are: carrot, pea/bean, potato, grass clover, onion, wheat, sugar beet and celeriac. Agronomic crop rotation rules identical to those used by Vereijken (1997) were applied to create 6- or 12-year rotations. For example, the maximum frequency of each crop in the rotation was set to 0.167 (1:6 years). Also, successions of certain crops, for example carrot followed by sugar beet was not allowed, thereby forcing the model to not schedule crops with a detrimental effect on soil structure one after the other. ROTAT was able to generate a total of 840 crop rotations. In some rotations, trade-offs were observed. For example, while they performed better in soil cover, N need and gross margin, these rotations showed worse performance in soil structure and labor. However, 10% of all generated solutions showed the same or higher performance in at least two indicators compared to the original crop rotation proposed in Vereijken, 1997. This shows the potential of ROTAT to theoretically generate alternative solutions, although further evaluation on the practicality of these rotations need to be conducted and discussed with the stakeholders (i.e. farmers) prior to subsequent testing/application in the field.

Literature for further reading and details:

- Dogliotti, S., Rossing, W.A.H., Van Ittersum, M.K., 2003. ROTAT, a tool for systematically generating crop rotations. Eur. J. Agron. 19, 239–250.

- Vereijken, P. (1997). A methodical way of prototyping integrated and ecological arable farming systems (I/EAFS) in interaction with pilot farms. *European journal of agronomy, 7*(1-3), 235-250.

Questions for reflection:

1. What are criteria to take into consideration when designing a crop rotation?

2. Are there crops that are unethical to promote as part of a research and development project?

3. What are examples of 'orphan crops' (crops that are not internationally traded, mostly local food crops) that could be taken up into the crop rotation?