

# Decision-Support System for Optimisation of Crop Configuration based on Artificial Intelligence

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Each year farmers are faced with the decision what crop to plant on which field. The optimal crop configuration aims to increase the profit, optimise the logistics, reduce the ecological footprint and lower the negative impact of extreme weather events.

This study was conducted in cooperation with Krivaja DOO, an agricultural company from Serbia that is actively using precision agriculture services on more than 6,000 ha. The dataset provided by the company consisted of information about raw material costs, operation costs and yields for 70 fields during the span of 3 years and crowdsourced data about the crop yields with more than 700 samples from 8 different years.

Firstly, statistics about crop rotation were derived from the dataset, to infer the influence of previously grown crops on the next season's yield. Also, next season's prices were extrapolated from a 20 year long time-series acquired through the Serbian agricultural stock market. These inputs in conjunction with historical yields and statistical analysis were used for generation of probability density functions (PDF) of next season's yields of different crops at different fields. The problem was set within the portfolio optimisation framework, where there were 7 mutually confronted objectives that needed to be optimised. They consisted of: profit, yield risk, price risk, total fertiliser, total pesticide, crop rotation and crop grouping. The profit was the multiple of yield and price, which both had risks associated to them. Yield risk was calculated as the sum of variances of PDFs of chosen crops at all fields and it indicated the sensitivity of crop configuration as a whole, to drought, hail and other extreme weather events. On the other hand, price risk indicated the uncertainty of prices that the products are expected to achieve at the market. Environmental aspects and sustainable soil nutrient balance are contained in the next three objectives (total fertiliser and pesticide used and the crop rotation). Finally, crop grouping was the objective that aims to minimise transport costs and optimise the logistics by cultivating a certain crop on fields that are close to one another.

The problem was set in the framework of multi-objective portfolio optimisation, where there were 70 decision-variables (one for each field) and 7 objectives. While having 70 decision-variables may not have posed a problem, having 7 objectives made the problem extremely computationally demanding. This study used NSGA-III, a state-of-the-art multi-objective evolutionary algorithm, which yielded a population of 100 different solutions. Among them were three characteristic solutions which maximised the profit, minimised the risk and maximised the Sharpe ratio (profit/risk ratio). The change in profit and risk was +60.5% and -9.6% for maximum-profit strategy, +33.4% and -15.2% for minimum-risk and +60% and -10.7% for Sharpe strategy, respectively, with reduced environmental footprint and more optimal spatial distribution of fields. The results prove that there is huge potential in application of multi-objective evolutionary algorithms in agriculture and that crop configuration is another task where decision-support systems based on artificial intelligence may help us produce more with less.