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Group drop of sustainability: Trade-off solutions between low returns and portfolio stability

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Abstract:

Portfolio design is the most difficult aspect of financial investment decisions. This paper presents a trade-off solution between low returns and portfolio stability by a fixed predetermined niveau of conservatism. A conservative model that combines both risk-free assets as agricultural land and risky assets is proposed. An experimental model with one-year historical data for four assets was built and tested to find a globally optimal solution using an evolutionary algorithm. The results showed that a positive return can be realized with a share of 13-14% in the assets of agricultural land.

***Keywords**: Evolutionary algorithms, Multi-criteria optimization problems, Portfolio design*

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1. INTRODUCTION

Portfolio diversity has long been a primary concern for private investors, financial planners, and institutional investors looking to maximize total return on a given level of risk while also lowering risk. Traditionally, investors and financial planners have assigned relatively fixed shares of their holdings to common asset categories, such as stocks or bonds, and then picked individual assets with some consideration to diversification [1]. After the end of the health crisis caused by the COVID pandemic, the expectations were for a quick recovery of the economy. In the last quarter, however, investment sentiment began to change following signals of a new crisis caused by the war in Ukraine, and prospects for a rapid economic recovery after the COVID crisis began to seem very unlikely. Investors continued to seek asylum and, in addition to the most popular gold, began to pay attention to assets such as agricultural land. These concerns, coupled with rising inflation, have prompted investors and fund managers to reconsider investment portfolio heuristics and increasingly consider a formal portfolio of balancing tactics, including real estate and, to a lesser extent, agricultural land in the set of available investment classes. This has led to increased demand for agricultural land as an asset and an increase in its price.

In response to these concerns, this paper examines the impact of including different types of assets in portfolio formation [2], in particular agricultural land and bonds, as risk-free assets in order to improve the efficiency of the mixed-assets portfolio.

Agricultural assets are one of the asset types that has piqued the interest of academics as well as practitioners. In reality, agricultural land has generated significantly greater returns than non-agricultural assets in prior decades [3], while simultaneously providing a superior inflation hedge due to the positive correlation between agricultural land returns and inflation [4]. In [5] discovered that today's agricultural land price-to-rent ratios are higher than in the past.

Furthermore, agriculture and traditional assets have a minimal association. This paper discusses a portfolio selection model based on Markowitz’s MVO model [6], including the agricultural land as a risk-free asset [7] in the portfolio under the following constraints: limited percentage of investment in agricultural land and bonds in the amount of not less than or equal to 50%, lower and upper bounds on the capital. In particular, section 2 describes the Portfolio selection model. Section 3 presents the experimental model based on one year of historical data on four assets and including agricultural land as an asset. The results of the experiment, which examine the effectiveness of the proposed model, are discussed in Section 4. Finally, Section 5 summarizes the findings of the sustainable solution for solving optimization problems with agricultural land and stocks.

2. THE PORTFOLIO DESIGN PROBLEM

Portfolio design has gotten a lot of interest from academics and practitioners alike. It has shown most multi-asset class portfolio literature [8] supports this conclusion. In [9, 10] was used non-traditional asset classes in the portfolio design process resulted in additional diversification benefits ranging from 0.40 percent to 0.93 percent. Especially for managing investment activities, sustainable management emphasizes decisions between risk minimization and a stable, acceptable return [11]. Numerous concepts for making decisions in business-related domains have been given out in [12, 13]. These realities necessitate the creation of complicated pilot models of optimal portfolios with various optimization criteria [14] by the decision-maker. [15, 16] highlight important decision-making methodologies in company management.

The real-world optimization problems in the fields of finance and economics are frequently complex and difficult to solve [17]. In many circumstances, such as portfolio optimization applications, they are multi-objective issues, in which a number of objective functions must be optimized simultaneously, some of which may be mutually contradictory in the general case [18]. The simple solution to such issues is to create an optimization problem with a single target by scalarizing the many objectives into a single function. Such issues' best solutions are non-dominated or "Pareto optimum" ones.

Most population-based multi-objective optimization applications follow the same methodology as evolutionary algorithms (EAs), where each iteration is performed on a collection of solutions (referred to as a population of individuals) and many solutions are produced [19]. The following are the primary causes of the numerous applications and rising interest in the subject of Eas.

Various trade-offs are frequently sought depending on the user's choices. A special class of optimization problems with linear constraints consists of problems in which linear constraints are also objective functions. For them, it is accepted to call tasks of linear programming or abbreviated LP tasks. Thus, for the LP problem

$$F(x) = c^T x, \qquad (1)$$

Where c is some fixed n-dimensional vector (this is not the most general form of specifying a linear function, since there is no constant term here; however, it does not affect the solution, and therefore it is usually omitted). The gradient of function (1) is c, and its Hessian matrix is identically equal to zero.

If c is a non-zero vector, function (1) is not bounded below: its value can be made arbitrarily large in absolute value by a negative number by moving along any non-zero x or which $c^T x < 0$. Therefore, in order for the problem of minimizing such a function to have a finite solution, it must have some constraints.

A portfolio is defined by a vector $x := (x_1, \ldots, x_n) \in \mathrm{R}^n$, which contains the weights $x_i \in \mathrm{R}$, of asset $i \in \{1, \ldots, n\}$ in its i-th component. All weights x_i, $i \in \{1, \ldots, n\}$ should be nonnegative. In the standard problem formulations, the weights of a portfolio are normalized:

$$\sum_{i=1}^{n} (x_i) = 1 \qquad (2)$$

Depending on the specific problem context there are additional restrictions on the weights, for example, lower bounds (a common constraint is $x_i \geq 0$), upper bounds, and/or integral constraints. The set of all unconstrained portfolios is denoted by $\mathrm{U} \subseteq \mathrm{R}^n$, and the set of feasible portfolios, satisfying the required constraints is denoted by $F \subseteq \mathrm{U}$. If the specific portfolio selection problem is unconstrained, it may be assumed that $F = \mathrm{U}$.

The model is as follows:

$$\min_x \frac{1}{2} x^T \zeta x \qquad (3)$$

Subject to the constraints:

$$\mu Tx \geq \text{Prognosis Return} \qquad (4)$$

$$\left| \sum_{i=1}^{n} x_i^2 - \textit{Land a Bond} \right| \leq 50\ \% \tag{5}$$

$$\sum_{i=1}^{n} (x_i) = 1 \tag{6}$$

To create many of the Pareto front solutions, the following steps are proposed: step one – for the assets Agricultural Land and Bonds [19] target value is assumed to be ≤ 50 %; step two - a set of six optimization tasks is chosen at various percentages of the constraint's minimal prognosis rate of return of 0,5 % (5). The prognosis of return accepts the values from 0,5 % to 3 %. As a result, six globally optimal solutions are produced, allowing the investor or decision-maker to select the best final alternative decision.

3. THE DATA SETTINGS FOR A PORTFOLIO WITH FOUR ASSETS

The above mathematical model is used to generate an optimal portfolio of four assets – stocks X_1 (S&P500), Stocks X_2 (SMI), Bonds X_3, and Agricultural land X_3. The data from May 2021 to April 2022 from Yahoo Finance were used, and agricultural land is included in the calculations with a 5% annual return. Through these historical data, the covariance matrix was calculated, which served to set the task for the optimal portfolio of stocks, stocks, bonds, and agricultural land. The portfolio optimization problem is a quadratic programming problem so that the total return of the four assets in the portfolio is not less than the prognosis return.

The portfolio optimization with Agricultural land is stated as follows:

$$\min f\ (\textit{WITH A LAND FOR AGRICULTURE}) = [14.04486651x_1^2 + 2.\,(-0.572138327)x_1.x_2 + 2.(4.367726293)x_1.x_3 + 2.(2.56791E\text{-}33)x_1x_4 + 19.05509916x_2^2 + 2.\,(-17.0277074x_2.x_3 + 2.\,(1.02716E\text{-}33)\,x_2\,x_4 + 2.\,(-9.24446^{E}\text{-}33)\,x_3\,x_4 + 4.81482E\text{-}35\ x_4^2], \tag{7}$$

subject to:

$$\mu^T \mathbf{x} = 2.4917842\ \mathbf{x_1} + 3.07581\ \mathbf{x_2} + 8.141973\ \mathbf{x_3} + 5.00000\ \mathbf{x_4}\ \geq \textit{prognosis return} \tag{8}$$

$$\textit{Asset Bonds} \leq 0{,}25 \tag{9}$$

$$\textit{Asset Agricultural Land} \leq 0{,}25 \tag{10}$$

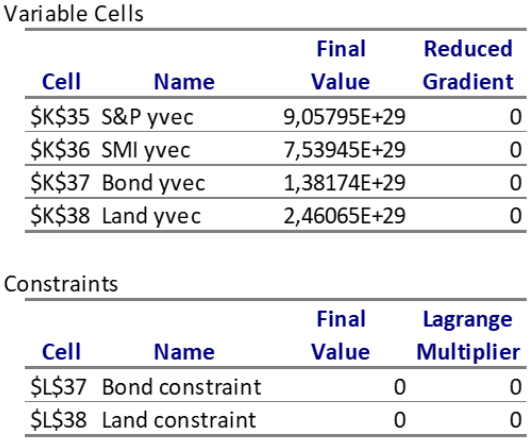
$$x_1 + x_2 + x_3 + x_4 = 1 \tag{11}$$

$$x_1 + x_2 + x_3 + x_4 \geq 0 \tag{12}$$

4. THE RESULTS SOLVING OF MODEL

Difficulties in solving the task are overcome by means of the robust optimization approach [20] and the built-in solver of the heuristic algorithm, in particular genetic, where global solutions are obtained despite the shortcomings [21]. Mixing different evolutionary techniques allows for finding an optimal trajectory more precisely, reducing the search time [22]. The consequences of portfolio optimization at a fixed annual return of the asset agricultural land 5 % and fixed reserved share of the portfolio of 50% for agricultural land and bonds for all six optimization problems for the different prognosis returns with the solver by Excel and evolutionary algorithms [23] are summed up in Table 1 and 2:

Table 1. Sensitivity of Portfolio



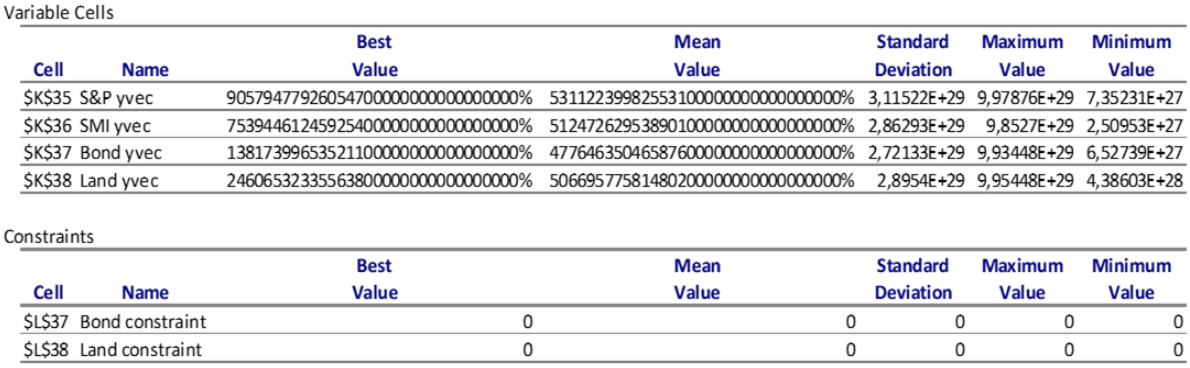
Variable Cells

Cell	Name	Final Value	Reduced Gradient
K35	S&P yvec	9,05795E+29	0
K36	SMI yvec	7,53945E+29	0
K37	Bond yvec	1,38174E+29	0
K38	Land yvec	2,46065E+29	0

Constraints

Cell	Name	Final Value	Lagrange Multiplier
L37	Bond constraint	0	0
L38	Land constraint	0	0

Table 2. The solving results



Variable Cells

Cell	Name	Best Value	Mean Value	Standard Deviation	Maximum Value	Minimum Value
K35	S&P yvec	9057947792605470000000000000000%	5311223998255310000000000000000%	3,11522E+29	9,97876E+29	7,35231E+27
K36	SMI yvec	7539446124592540000000000000000%	5124726295389010000000000000000%	2,86293E+29	9,8527E+29	2,50953E+27
K37	Bond yvec	1381739965352110000000000000000%	4776463504658760000000000000000%	2,72133E+29	9,93448E+29	6,52739E+27
K38	Land yvec	2460653233556380000000000000000%	5066957758148020000000000000000%	2,8954E+29	9,95448E+29	4,38603E+28

Constraints

Cell	Name	Best Value	Mean Value	Standard Deviation	Maximum Value	Minimum Value
L37	Bond constraint	0	0	0	0	0
L38	Land constraint	0	0	0	0	0

The solver has stopped before finding a globally optimal solution. The best-found solution, if any will be given. All constraints and optimality conditions are satisfied. In four cases the best solution for investing in agricultural land was sold by 13%, and in two cases by 14%.

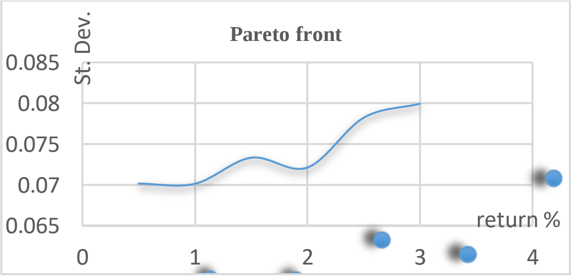


Figure 1. Pareto solutions

During the investment realization phase, the ideal amounts of each class of asset are bought. If the portfolio's efficiency is favorable, it should be kept for a new period. Once this term has passed, a fresh performance evaluation is conducted. If the efficiency of the portfolio is deemed to be insufficient, it is reassessed, which can involve changing the investment objectives and the asset mix.

5. CONCLUSION

This paper presents a robust solution to the portfolio optimization problem under a predetermined degree of conservatism. Mathematically, this conservatism was expressed through the implied constraint of investing in risk-free assets such as bond assets and agricultural land assets, as a total of less than and equal to 50%. The model was solved using Excel's built-in genetic algorithm solver. The results showed the effectiveness of genetic algorithms in finding the global optimal solution. Through the formulated practical optimization problem, the solution for the trade-off between the low return and the stability of the portfolio was shown. And by solving it through a modern method such as evolutionary algorithms in a short computing time, the combination of assets in the portfolio is found. As future research, additional constraints can be formulated, such as including agricultural fund shares in the portfolio and combining other evolutionary algorithms for sustainable management decisions.

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REFERENCES

[1] Herfindal, O. C. *Concentration in the steel industry*, PhD dissertation, Columbia University, 1950.
[2] Bessler, W., & Wolff, D. Do commodities add value in multi-asset portfolios? An out-of-sample analysis for different investment strategies, *Journal of Banking &Finance*, 2015; 60; 1-20 DOI: 10.1016/j.jbankfin.2015.06.021,
[3] Bjornson, B., & Innes, R. Another look at returns to agricultural and nonagricultural assets, *American Journal of Agricultural Economics*, 1992; 74(1); 109-119.
[4] Franch, X. Research challenges in information science RCIS 2022. *Lecture Notes in Business Information Processing*, 2022; pp. 1-37, Springer, Cham. DOI: 10.1007/978-3-031-05760.
[5] Baker, M. Risk neglect in equity markets. *Journal of Portfolio Management*, 2016; 42(3); 12-25.
[6] Miettinen, K., *Nonlinear Multi-Objective Optimization.* 1999; Kluwer Academic Publishers, Boston, London, Dordrecht.
[7] Madhogarhia, P. K., & Lam, M. Dynamic asset allocation, *Journal of Asset Management*. 2015; 16(5,) 293-302.
[8] Petrov, P., Kostadinov, G., Zhivkov, P., Velichkova, V. & Balabanov, T. Approximated sequences reconstruction with genetic algorithms, *In Proceedings of 28th Symposium with International Participation-Control of Energy, Industrial and Ecological Systems*, 2020; 63-66.
[9] Bekkers, N., Doeswijk, R. Q., & Lam, T.W. Strategic asset allocation: Determining the optimal portfolio with ten asset classes", Working Paper, October, 2009 https://doi.org/10.1016/j.jbankfin.2015.06.021
[10] H.M. Markowitz, *Journal of finance (Portfolio selection)*, 1952; 7; 77-91. DOI: 10.1111/j.1540-6261.1952.tb01525.x.
[11] Stoyanova K., & Balabanov, T. A combination of Broyden-Fletcher-Goldfarb-Shanno (BFGS) and bisection method for solving portfolio optimization problems, *International Conference on Engineering and Emerging Technologies (ICEET), Kuala Lumpur, Malaysia*, 2022; 1-3, DOI: 10.1109/ICEET56468.2022.10007369
[12] Li, Y., Zhou, B. & Tan, Y., Portfolio optimization model with uncertain returns based on prospect theory. *Complex Intell. Syst. 2022*, DOI: 10.1007/s40747-021-00493-9.
[13] Golmakani H.R., & Fazel, M. Constrained portfolio selection using particle swarm optimization. *Expert Systems with Applications*, 2011; 38(7); 8327-8335. DOI: 10.22436/jmcs.010.02.01.
[14] Feng X., & Hayes, D. Vine-Copula based models for farmland portfolio management. *Selected Paper Presented at the 2016 Agricultural and Applied Economics Association Annual Meeting, July 31-August 2, 2016*, Boston, Massachusetts.
[15] Borissova D. & Dimitrova, Z. An integrated group decision-making approach considering uncertainty conditions, *Business Information Systems*, 2021; 1; 307–316. DOI: 10.52825/bis.v1i.52,
[16] Borissova, D., Dimitrova, Z., Naidenov, N., & Yoshinov, R. (2022). Integrated Approach to Assessing the Progress of Digital Transformation by Using Multiple Objective and Subjective Indicators. In: Guizzardi, R., Ralyté, J.,

Franch, X. (eds) Research Challenges in Information Science. RCIS 2022. Lecture Notes in Business Information Processing, vol 446. Springer, Cham. https://doi.org/10.1007/978-3-031-05760-1_37

[17] Chen, C., & Kwon, R. H. Robust portfolio selection for index tracking, *Computers & operations research*, 2012; 39; 829-837.

[18] Miettinen, K., Neittaanmäki, P., Mäkelä, M.M., & Périaux, J. *Evolutionary Algorithms in Engineering and Computer Science*, John Wiley & Sons, Ltd., Chichester, Weinheim, New York, Brisbane, Singapore, Toronto, 1999.

[19] Juszczuk, P., Kaliszewski, I., Miroforidis, J., & Podkopaev, D., Expected mean return-standard deviation efficient frontier approximation with low-cardinality portfolios in the presence of the risk-free asset, *International Transactions in Operational Research*. 2022; https://doi.org/10.1111/itor.13121.

[20] Stoyanova K., & Balabanov, T., Optimal selection of pharma stock portfolios using DEPSO, *24th International Carpathian Control Conference, Hungary,* 2023; 419-422, DOI: 10.1109/ICCC57093.2023.10178900

[21] Bertsimas D. & Melvyn, S. The price of robustness. *Operations Research*, 2004; 52; 35–53. JSTOR, http://www.jstor.org/stable/30036559,

[22] Benotsmane, R., Dudás, L., & Kovács, G. Newly elaborated hybrid algorithm for optimization of robot arm's trajectory in order to increase efficiency and provide sustainability in production, *Sustainability*, 2021; 13(15), 8193. DOI: 10.3390/su13158193.

[23] Balabanov, T. *Fruit machine simulator with Excel input-output interface*, Velbazhd Software LLC, https://github.com/VelbazhdSoftwareLLC/Fruit, 2021.