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An economic assessment of agricultural brownfield revitalization – A case study of Eastern Slovakia

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Abstract
The presented article points out the possibilities of elimination of agricultural brownfield in the East Slovak region through the resumption of production by growing fast-growing woody plants, specifically Paulownia and apple trees. Based on a detailed analysis of the necessary investment costs associated with the resumption of production and the prediction of sales of produced Paulownia and apple trees, the article presents a quantification of economic payback time from the proposed three options for resumption of crop production in the agricultural brownfield. Based on clearly identified determinants of decision-making on the optimal possibility of the revitalization of agricultural brownfield in interaction with the evaluation of the so-called weighted sum (multicriteria decision-making method), the article concludes by pointing out the effective possibility of resuming crop production in the revitalized area of the agricultural brownfield. The results revealed that the growth of Paulownia for the production of biomass is the best method of agricultural brownfield remediation.

Keywords
agricultural brownfield, cash-flow, Saaty matrix, weighted sum method.

Introduction

Agricultural brownfields in the Slovak Republic arose because of social and economic changes and the transformation of the market economy after 1989, which radically changed the form of socialist agriculture, directly determining changes in agricultural practices and forms of ownership of agricultural land and currently represent unused areas with devastated buildings (Pavolová et al., 2019). Disturbance of the ecosystem balance and the permanent pollution of the environment and its impact on human development are discussed in various forums nowadays (Olah et al., 2020; Lacko et al., 2021). Brownfields are often accompanied by environmental burdens in various forms and levels of contamination (Šimková et al., 2019; Bednárová et al., 2013). However, often there is no attention paid to technological modernization and greening, which is often the most attractive for investors and preferable to the local community (Cehlár et al., 2019; Bialy et al., 2020) Decrease in purchase prices, abatement programs, gradual reduction of subsidies, secondary insolvency and other factors caused the dissolution of some agricultural holdings and a decrease in average cultivated agricultural land (Puškárová et al., 2016) as a result of which the area of weed and unused land and land with natural succession, which on the one hand contributes to biodiversity, but on the other hand can also be a negative benefit in the form of reducing phytocenotic diversity (Pavolová et al., 2012). This is one of the ways agricultural brownfields gradually began to emerge (Kyseľová, 2010). Currently, the most common agricultural brownfields include the former areas of Agricultural Cooperatives, where there are storage halls, cattle stables, garages, small office areas, external silage areas, various paved areas, etc. Pollution of organic origin and gutters from agricultural machinery and heavy machinery can be expected in these areas (Hajaš et al., 2007). Agricultural brownfields are mostly part of villages and have a very low investment potential because their revitalization, which is complicated mainly by unsettled land relations, is unprofitable without financial subsidies (Puškárová et al., 2016). Lieskovský (2002) states that the advantage of fast-growing woody plants, grasses but also oilseeds is that they can create a large amount of plant matter in a short time, that is biomass, which can be subsequently processed and used for energy by combustion. Their planting prevents possible soil erosion, and some plants can even be used for wastewater treatment. Piszczalka and Maga (2006) confirmed that one of the disadvantages is the fact that the application of fertilizers is a necessary condition for growing fast-growing trees. However, when planting energy crops, it is possible to use lower-quality soil, for example, around roads or contaminated soil.

Material and Methods

For the need to explore the possibilities of the revitalization of agricultural brownfield through the cultivation of Paulownia and apple trees, a brownfield was selected on the territory of a former Agricultural Cooperative in the East Slovak region, which got into liquidated in 2010 and which currently negatively affects the landscape – aesthetic nature of the natural environment, quality and also determines the different types of diversionary activities (Pavolová, Kyseľová, 2011). The Cooperative focused exclusively on agricultural production, an integral part of which was the processing and sale of unprocessed agricultural products for the purposes of further processing. For the need to value individual possibilities of the revitalization of agricultural brownfield, the development trend of cash-flow (CF) was identified because, as one of the basic tools of financial analysis, it points to the success of the investment plan, according to the relationship below:

$$CF = INCOME + LOAN - INVESTMENTS - PRODUCTION\ COSTS - LOAN\ REPAYMENTS - INTEREST\ REPAYMENTS - TAXES \quad (1)$$

When making the decision to make an economic investment, an annually (i) updated CF was used, the sum of which determined by the duration of the project (n) is generally referred to as the net profit value (NPV), which can be quantified as follows (Mura, Hajduová, 2021, Puzder, Koščová, 2016):

$$NPV = \Sigma[(- INVESTMENTS + CF_i)/(1+ UPDATE\ RATE)^i] \quad (2)$$

The most advantageous way of revitalizing agricultural brownfield was identified using the method of so-called weighted amount, which was dealt with as a maximization as follows (Pavolová, Tobisová, 2013):

$$U_m(x) = \Sigma \alpha_i u_i(x_i) \quad (3)$$

with α_i – the weights of the evaluation determinant,
$u_i(x_i)$ – the usefulness of the i-th evaluation determinant of revitalization for x_i, to which points from the cardinal scale < 1, 10 >were assigned,
x_i – the value of the result according to the i-th determinant,

$U_m(x)$ – the overall usefulness of the evaluated method of the revitalization of agricultural brownfield, while the method that will reach the highest value of $U_m(x)$ is the most suitable.

Based on the results of the analysis of the proposed methods of revitalization, the decision determinants, which were used to quantify the weights - α_i in terms of the principles of the Saaty matrix while accepting the generally valid condition $\Sigma\alpha_i = 1$, were defined. The dimensions of the Saaty matrix were directly determined by an interactive comparison of predefined explicitly defined determinants of identical order with the evaluation given in Tab. 1. Given the above facts, on the diagonal of a square matrix with dimensions $m\times n$, where $m = 1 \ldots i$ and $n = 1 \ldots j$, the values 1 were plotted, as the equivalence of the same compared determinants were accepted, but if the determinant in the line i was also preferred above the determinant given in column j, we assigned a reciprocal value to it.

Tab. 1. Evaluation of determinants of the weighed amount method (prepared according to Saaty 1987, White et al. 2015)

Factor value	Description of comparative factors
1	Factors *i* and *j* are equal
3	Factor *i* is slightly preferred over factor *j*
5	Factor *i* is significantly preferred over factor *j*
7	Factor *i* is very significantly preferred over factor *j*
9	Factor *i* is absolutely preferred over factor *j*

In the created Saaty matrix of determinants of the weighted sum method, partial products of the rows were created as follows (Saaty 1977; Saaty 1987; Pavolová et al., 2019):

$$S_i = \Pi S_{ij}; \quad j = 1, 2, 3, \ldots, f \tag{4}$$

with f – number of factors,
S_{ij} – single factors.

In terms of methodological procedure, the value of R_i for each assessed determinant was subsequently quantified as follows (Saaty 1977, Saaty 1987, Pavolová et al. 2019):

$$R_i = (S_i)^{1/f} \tag{5}$$

Results and Discussion

Paulownia grows up to 30 m with an annual increment of 2-3 m and a trunk diameter of about 1 m. The advantage of Paulownia is the fact that after injuring the trunk of this fast-growing tree, it is not necessary to treat it, as a new tree will grow from the remaining stump, which has several times greater growth potential. It is for this reason that the yield can be obtained each cycle of Paulownia growth without additional costs. Distances for planting Paulownia for biomass production are suitable 2×0.5 or 1×1 m, and for wood are suitable 3×3 or 3×4 m (Paulownia 2015). For the case of land on the agricultural brownfield with an area of 27.5 ha, compliance with the planting clip, procurement of an irrigation system and a small Zetor tractor, the initial investment was quantified at 191,216.67 EUR (Tab. 2).

Tab. 2. Purchase prices for the cultivation of Paulownia

Item	Purchase price [EUR]
Paulownia plants	91,666.67
Irrigation system	68,750
Tractor	18,500
Revitalization	12,300

When quantifying the return on investment based on the development of the updated CF, the wage costs of five employees were also taken into account (gross wage EUR 23,400 per year, including employee and employer social security contributions of 35.2%), average annual biomass production 5,000 $kg.ha^{-1}.year^{-1}$ and average annual sales of EUR 25,437.50 per year (Table 3). It follows that the return on investment for the revitalization of agricultural brownfield by growing Paulownia for the sale of biomass will be at the end of the sixth year (Fig. 1).

Tab. 3. Prediction of revenues from biomass sales

Year	Selling price [EUR]
1	0
2	0
3	25,437.50
4	25,437.50
5 and more	25,437.50

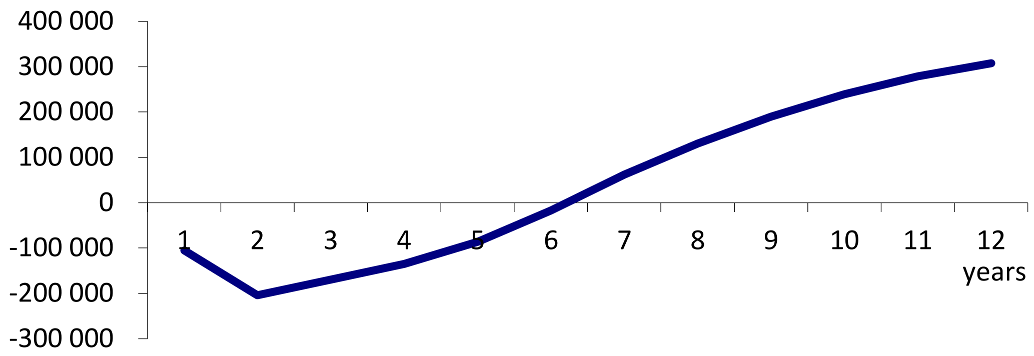

Fig. 1. The progress of an updated CF from the sale of Paulownia biomass

In the case of the possibility of the revitalization of agricultural brownfield by cultivating Paulownia for the needs of the sale of produced leaves, the same valuation of mechanical and technical equipment and labour costs were considered. When quantifying the return on investment based on the development of the updated CF, the average annual production of leaves 1000 $kg.ha^{-1}.year^{-1}$ and the average annual sales of EUR 4675 per year were considered, with the difference that with the first yield from leaf production is considered in the second year of Paulownia cultivation. It turned out that the return on investment of revitalization of agricultural brownfield by growing Paulownia for the sale of leaves will be in about 9.5 years (Fig. 2).

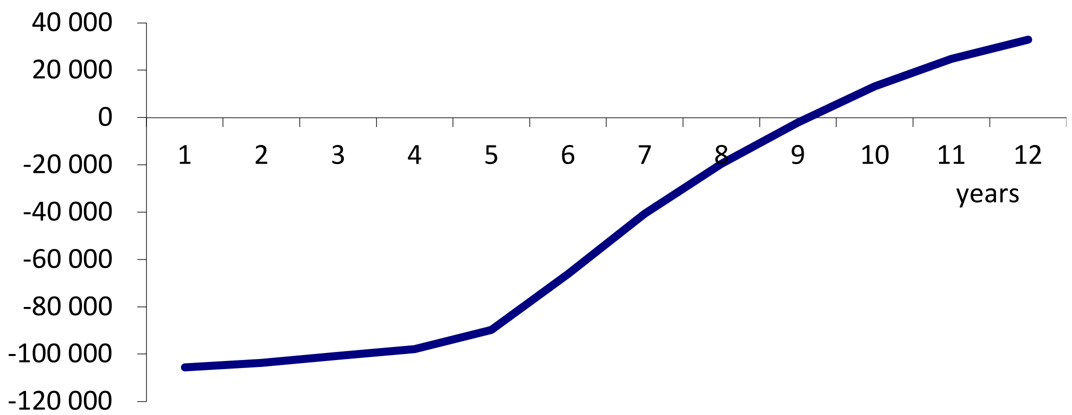

Fig. 2. Development of an updated CF from the sale of Paulownia leaves

In another possibility of the revitalization of agricultural brownfield, growing low-stemmed apple trees was considered, whose planting distances are recommended 1.5×1 m, but due to the use of the above-mentioned tractor, a planting distance of 2.5×2.5 m was selected. With the area of agricultural brownfield of 27.5 ha, compliance with the planting distance, procurement of an irrigation system and a small Zetor tractor and the necessary reconstruction of devastated buildings, the initial investment was quantified as EUR 297,550.00 (Tab. 4). When quantifying the return on investment based on the development of the updated CF, the average annual production of apples and the first yield in the fourth year of cultivation were considered with sales of EUR 57,200.00 per year, in the fifth year of EUR 114,400.00 per year, in the sixth year of EUR 200,200.00 per year and from the seventh year in the amount of EUR 286,000.00 per year (Tab. 5). It follows from the given that the return on investment of this possibility of the revitalization of agricultural brownfield was in the seventh year (Fig. 3).

Tab. 4. Purchase prices for the cultivation of Paulownia

Item	Purchase price [EUR]
Apple trees	198,000.00
Irrigation system	68,750.00
Tractor	18,500.00
Revitalization	12,300.00

Tab. 5. Prediction of revenues from biomass sales

Year	Selling price [EUR]
1	0
2	0
3	0
4	57,200.00
5	114,400.00
6	200,200.00
7	286,000.00
8 and more	286,000.00

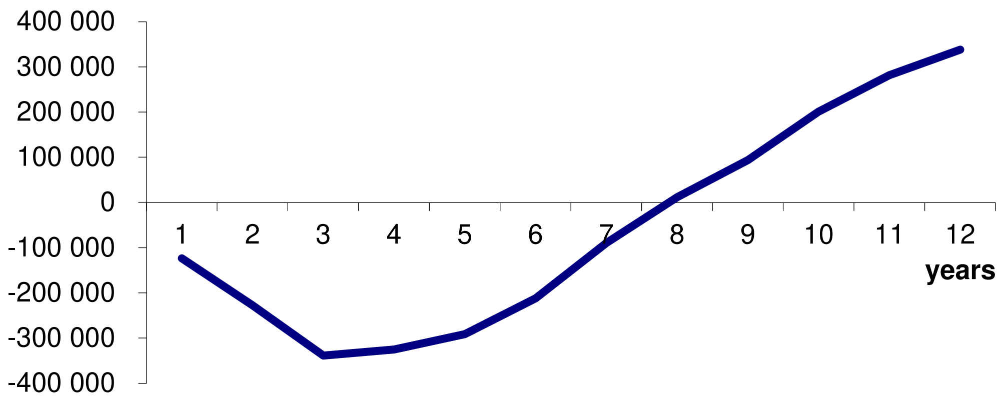

Fig. 3. The progress of an updated CF from the sale of apples

In order to assess the most suitable way of revitalizing and meaningful re-use of agricultural brownfield, the method of so-called weighted sum method was used, which belongs to the analytical tools of multicriteria strategic decision-making among several variants of solving such a problem. For the needs of the selected method, based on the results of detailed analyses of payback time and evaluation of individual proposed variants of the revitalization of agricultural brownfield, the following determinants of decision-making were defined:

- D1 – price of seedlings,
- D2 – fertility,
- D3 – payback period of brownfield revitalization,
- D4 – job creation,
- D5 – income,
- D6 – advantageous geographical location.

In terms of the weighted sum method, the weights α_i were further quantified for the above determinants using the Saaty matrix (Tab. 6).

Tab. 6. Quantification of weights of defined determinants

Determinant	D1	D2	D3	D4	D5	D6	S_i	R_i	α_i
D1	1	5	3	3	1/3	5	75.00	2.05	**0.26**
D2	1/5	1	1/3	3	1/3	5	1.00	1.00	**0.13**
D3	1/3	3	1	5	3	7	35.00	1.81	**0.23**
D4	1/3	1/3	1/5	1	1/3	5	0.11	0.69	**0.09**
D5	3	3	1/3	3	1	5	45.00	1.89	**0.24**

D6	1/5	1/5	1/7	1/5	1/5	1	0.00	0.32	**0.04**
SUM								7.76	1.00

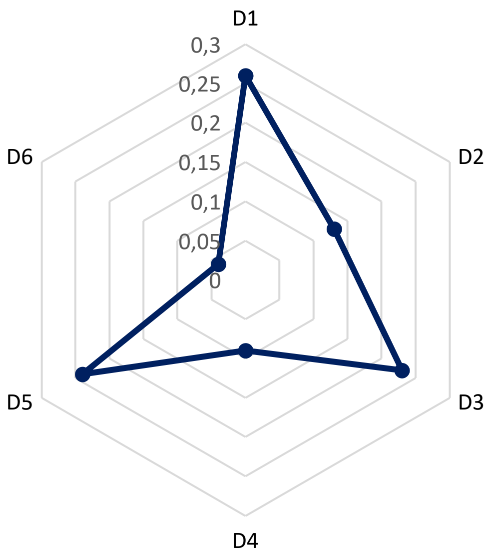

Fig. 4. Prioritization of the decision determinants

From the graphical representation of individual determinants of decision-making, a descending order of their prioritization was constructed (Fig. 4):

- D1 – price of seedlings,
- D5 – income,
- D3 – payback period of brownfield revitalization,
- D2 – fertility,
- D4 – job creation,
- D6 – advantageous geographical location.

Based on the results of the mentioned multicriteria decision-making method, which was solved as maximizing, it can be stated that the revitalization of the analyzed brownfield by cultivating Paulownia to sell produced biomass showed the highest value because its efficiency index – $U_m(x)$, showed a level of 6.24 (Tab. 7).

Tab. 7. Assessment of the value of individual methods of the revitalization of agricultural brownfield

Determinant	α_i	Biomass production		Leaf production		*Apple production*	
D1	0.26	6	1.59	6	1.59	4	0.42
D2	0.13	7	0.90	4	0.52	8	0.12
D3	0.23	8	1.86	7	1.63	6	0.43
D4	0.09	3	0.27	3	0.27	3	0.02
D5	0.24	6	1.46	5	1.21	7	0.35
D6	0.04	4	0.17	4	0.17	4	0.01
SUM	1.00	6.24		5.38		1.35	

Conclusion

Revitalization of agricultural brownfields represents a multilateral issue of intersectoral and thus also interdepartmental character, which cannot be solved in isolation and whose financing requires a combination of several types of financial resources. The amount of such brown investments depends on several specific factors directly resulting from a particular agricultural brownfield, for example, the location, the degree of contamination of the components of the environment, the extent of the devastation of production and non-production objects, its future or planned use, etc. The analysis was based on six decision-making factors that were evaluated by the method of weighted sum. The results of the Saaty matrix revealed that the growing of Paulownia for the production of biomass is the best method of agricultural brownfield remediation. However, the study has some limitations. The decision-making was based on 6 factors that were identified and evaluated. The future study may reconsider the selected factors and/or the use of other methods.

References

Bednárová, L., Pacana, A. and Chovancová, J. (2013). *Environmental information as a key to solve a problem with polluted territories*, International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM 2013, pp. 135-140. http://dx.doi.org/10.5593/SGEM2013/BE5.V2/S21.018

Bialy, W., Grebski, W., Galecki, G. and Kaniak, W. (2020). Environmental impact of the mechanical coal processing plant. *Acta Montanistica Slovaca*, 25(2), pp. 139-149. http://dx.doi.org/10.46544/AMS.v25i2.1

Cehlár, M., Janočko, J., Šimková, Z., Pavlik, T., Tyulenev, M., Zhironkin, S. and Gasanov, M. (2019). Mine sited after mine activity: The brownfields methodology and Kuzbass coal mining case. *Resources*, 8(1), 21. http://dx.doi.org/10.3390/resources8010021

Hajaš, P., Mihoková, L. and Kyseľová, K. (2007). Environmentálne záťaže hnedých priemyselných parkov, Medzinárodná vedecká konferencia Enviromentálne inžinierstvo a manažérstvo, pp. 100-106.

Kyseľová, K. (2010). *Projekty pre brownfieldy a ich mapovanie*. 4-construction. Available at: http://www.4-construction.com/sk/vzdelavanie-kniznica/clanok/projekty-pre-brownfieldy/ (Accessed: 25 September 2020).

Lacko, R., Hajduová, Z. and Zawada, M. (2021). The efficiency of circular economies: A comparison of visegrád group countries. *Energies*, 14(6), 1680. http://dx.doi.org/10.3390/en14061680

Lieskovský, M. (2002). *Rozvoj energetického využívania biomasy*. Zborník zo IV. medzinárodnej vedeckej konferencie mladých. Nitra: SPU.

Mura, L. and Hajduová, Z. (2021). Measuring efficiency by using selected determinants in regional SMEs. *Entrepreneurship and Sustainability Issues*, 8(3): 487-503. http://dx.doi.org/10.9770/jesi.2021.8.3(31)

Oláh, J., Hajduová, Z., Lacko, R. and Andrejovský, P. (2020). Quality of life regional differences: Case of self-governing regions of slovakia. *Sustainability (Switzerland)*, 12(7). http://dx.doi.org/10.3390/su12072924

Paulownia (2015). Available at: https://paulowniask.webnode.sk/ (Accessed: 18 Jun 2019).

Pavolová, H., Bakalár, T., Emhemed, E.M.A., Hajduová, Z. and Pafčo, M. (2019). Model of sustainable regional development with im-plementation of brownfield areas. *Entrepreneurship and Sustainability Issues*, 6(3), pp. 1088-1100.

Pavolová, H., Csikosová, A. and Bakalár, T. (2012). Brownfields as a tool for support of regional development of slovakia. *Applied Mechanics and Materials*, 209-211, pp. 1679-1683. http://dx.doi.org/10.4028/www.scientific.net/AMM.209-211.1679

Pavolová, H. and Kyseľová, K. 2011. *Resolving the issue of brownfields in conditions of the EU*. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM 2011, pp. 1297-1303.

Pavolová, H. and Tobisová, A. (2013). The model of supplier quality management in a transport company. [Model menadžmenta kakvoće opskrbe u transportnoj kompaniji]. *Nase More*, 60(5-6), pp. 123-126.

Piszczalka, J. and Maga, J. (2006). *Mechanizácia výroby a využitia biomasy*. Nitra: Vydavateľstvo SPU.

Puškárová, P., Varga, P., Lechan, P. and Tutko, R. (2016). Konferencia mladých vedcov, Košice : TU, pp. 120-125.

Puzder, M. and Koščová, M. 2016. *Assessment of quarry of reopened mine Čáry based on the mining right of the Slovak Republic and Europen Union*. International Coal Preparation Congress. Switzerland: Springer, pp. 457-462.

Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, 15(3), pp. 234-281. http://dx.doi.org/10.1016/0022-2496(77)90033-5

Saaty, R. W. (1987). The analytic hierarchy process-what it is and how it is used. *Mathematical Modelling*, 9(3-5), pp. 161-176. http://dx.doi.org/10.1016/0270-0255(87)90473-8

Šimková, Z., Seňová, A., Divoková, A., Očenášová, M. and Varga, P. (2019). Possibilities of using brownfields after mining and processing of mineral resources in slovakia. *E3S Web of Conferences*, 105, 148962 http://dx.doi.org/10.1051/e3sconf/201910502023

White, T. H., de Melo Barros, Y., Develey, P. F., Llerandi-Román, I. C., Monsegur-Rivera, O. A. and Trujillo-Pinto, A. M. (2015). Improving reintroduction planning and implementation through quantitative SWOT analysis. *Journal for Nature Conservation*, 28, 149-159. http://dx.doi.org/10.1016/j.jnc.2015.10.002