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AN ASSESSMENT OF DIFFERENT SCENARIOS FOR AGROFORESTRY ENVIRONMENT REGULATION OF DEGRADED LAND USING INTEGRATED SIMULATION AND A MULTI-CRITERIA DECISION MODEL – A CASE STUDY

OCJENA RAZLIČITIH SCENARIJA POLJOPRIVREDNO-ŠUMARSKE OKOLIŠNE REGULACIJE DEGRADIRANOG ZEMLJIŠTA PRIMJENOM INTEGRIRANIH SIMULACIJA I VIŠEKRITERIJSKOG ODLUČIVANJA – STUDIJ SLUČAJA

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Abstract

In this paper, we examine different scenarios for appropriate environment regulation of degraded areas with silvopastoral system establishment using integrated computer-based deterministic simulation and a multi-criteria decision model. We test the possibility for the wild game farming of red deer (*Cervus elaphus*) and fallow deer (*Dama dama*) in the game enclosure. The simulation model can simulate different scenarios for periods of 30 years and 50 years. Scenarios are further assessed with a multi-criteria decision model using the analytical hierarchy process (AHP) (supported by the software tool Expert Choice (EC) 2000™). With the multi-criteria assessment, EC = 0.054 scenario for a period of 50 years is considered most appropriate for environment regulation. The scenario includes organic farming of red deer in a silvopastoral system, settlement of all four areas in the first year, and hinds intended for sale. The silvopastoral system includes the tree species *Acer pseudoplatanus, Fraxinus excelsior, Prunus avium,* and *Alnus glutinosa*, with a tree density of 248 tree/ha (62 of each tree species/ha) intended for logging after 50 years. The net present value (NPV) of this scenario at an 8.0 % annual discount rate is 280.685 €, while the internal rate of return (IRR) slightly exceeds 10 %.

KEY WORDS: Simulation model, Multi-criteria decision analysis, Analytical hierarchy process (AHP), Silvopasture, Wild game, Game enclosure

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Introduction
Uvod

In a society as demanding as the one we live in today, landscape reclamation projects should not only respect biological diversity, minimize resource dilapidation, preserve water and nutrient cycles, and maintain the quality of habitats, but also reinforce landscape character. This should be done taking into consideration the spirit of the place, integrating the pre-industrial existence in the new landscape, and promoting the creation of multifunctional resilient landscapes capable of incorporating change and enhancing quality of life. Degraded landscapes occur as a byproduct of economic, functional, spatial, and social transformation of cities and regions, and all this is accompanied by a temporary devaluation and abandonment of areas. Furthermore, it is extremely important that new redevelopments in degraded landscapes help people realize that reclaiming, restoring, and giving new uses to degraded landscapes are indispensable actions for maintaining landscape sustainability (Loures 2009). No single best method exists for assessing land degradation. Studies conducted at the global level are mainly based on expert opinion. Experimentally, field measurements, field observations, land users' opinions, productivity changes, remote sensing, and modeling act as the backbone for many approaches used to assess land degradation (Kapalanga 2008). According to Gruenewald et al. (2007), the establishment of an agroforestry system can be a viable solution for degraded land. In this light, the yield potential and the sustainability of yields were studied for different clones of *Populus* spp., *Salix viminalis,* and *Robinia pseudoacacia*, considering different rotation periods (3-, 6-, and 9-year rotations). The highest yields of woody biomass were found for *R. pseudoacacia*. Special emphasis was given to the interaction between trees (*R. pseudoacacia*) and crops (*Medicago sativa*). *R. pseudoacacia* hedgerows have practically no negative influence on yields of *M. sativa*. Biomass plantations are useful tools for natural phytoextraction; namely, the ideal plant for trace element phytoextraction has to be highly productive in biomass and take up a significant part of the trace elements of concern (Vangronsveld et al. 2009). Klang-Westin and Eriksson (2003) estimated long-term Cd (Cadmium, heavy metals) removal by *Salix* using commercial *Salix* stands grown in different soil types. The net removal of Cd from the plough layer by *Salix* varied between 2.6 and 16.5 g Cd/ha/year using 8 t/ha as the highest *Salix* biomass value in the models. The authors concluded that *Salix* has a high potential for Cd removal from a long-term perspective (6–7 cutting cycles–approximately 25 years) and that it would be possible to extract theoretically a maximum of 413 g Cd/ha. With a higher yield of *Salix* biomass per ha, Cd phytoextraction would also be higher. Taškar (2009) carried out research on a fly ash landfill, where nine tree species were planted. The purpose was to determine which species would successfully adapt to the situation that prevailed in such degraded areas. From 2001 to 2008, the parameters (e.g., the growth of trees in height, development of roots, increment growth of trees) and ecological conditions were analyzed. The results showed only *Ostrya carpinifolia* and *Betula pendula* successfully adapted to the soil conditions. The arrival of animal species (e.g., birds, large game, insects, rodents) was noticed already within the first years of research. Birds also nested. Thus, it was confirmed that biodiversity increased when trees were planted in degraded areas. If managed in a sustainable way, agroforestry (silvopastoralism) can favorably affect biodiversity, landscape, and rural welfare issues that underpin agri-environment objectives through a number of attributes. These include efficient nutrient cycling, buffering against non-point source pollution, fulfilling animal welfare criteria, employment generation and income enhancement, reversal of rural abandonment and creation of viable rural communities (Mosquera-Losada et al. 2005, Rigueiro-Rodriguez et al. 2011). Interactions in silvopastoral systems generate economic, environmental, and social benefits (De Baets et al. 2007). Hislop and Claridge (2000) found that sheep spent more time in the shade and shelter of trees on hot, sunny days and cold, windy days than they did in the open. This could be considered a positive welfare benefit. Silvopastoralism requires less mechanical labor than alley cropping and is advantageous for reclaimed soils; therefore, silvopastoralism should be preferred (Eichler and Herzog 1997). A major role for agroforestry is also emerging in the domain of environmental services. Environmental services can be defined as "externalities," because they are not incurred by a party who did not agree to the action causing the cost or benefit. Throughout Europe, the aesthetics and representation of pastoral cultural heritage have been recognized as main benefits of agroforestry systems (Herzog 1998, Franco et al. 2003).

The scientific literature suggests different approaches for the assessment of agroforestry systems before major investments are decided (Alavalapati and Mercer 2004, Tojnko et al. 2011). Multi-criteria decision analysis (MCDA) is a useful methodological approach when the evaluation of several variables cannot be easily transformed into quantitative units and our goal is influenced by multiple competing criteria (Mendoza and Martins 2006). There has been significant growth in the environmental applications of MCDA over the last decade across all environmental application areas (Huang et al. 2011). The basic problem in research is developing the system in order to support decision-making in the selection of the most appropriate alternatives, with a combination of the technological-economic simulation model (cost-benefit analysis (CBA)) and analytical hierarchy process (AHP) multi-criteria decision analysis (Belton and Stewart 2002).

The merger of the technological-economic simulation model with the multi-criteria decision analysis represents a modern approach in developing systems to support decision-making on investments. A similar approach was used by Herrero et al. (1999), Pažek et al. (2006), Rozman et al. (2006), Kühmaier and Stampfer (2010), and Vindiš (2010). Despite the general consensus on the environmental and social benefits of agroforestry systems, the full scope of a comprehensive analysis of the agroforestry systems pronounced deficit (Cacho 2001). Previous research focused on modeling the financial effects of agroforestry systems (Neupane and Thapa 2001, Molua 2005). Tamabula and Sinden (2000) took a step forward and included the impacts on the environment in simulation. Palma et al. (2007) proposed the use of multi-criteria analysis for a comprehensive economic analysis of the environmental effects of agroforestry systems.

The aim and the goal of this paper is to investigate and offer a solution for a concrete problem of regulation of degraded land – if possible with agroforestry system (silvopastoral system). Paper presents a simulation model for different scenarios for environment regulation of degraded land, which is combined with a multi-criteria analysis. The simulated alternatives are additionally evaluated with a multi-attribute decision tool (i.e., the Expert Choice decision support system (AHP)). The paper is organized as follows: A description of the study area is provided first, followed by the methodology and model development. The results are described in the next section. Main findings and final remarks conclude this article.

Study area
Područje istraživanja

The study area is located around landfill Gajke, Ptuj, NE Slovenia (46°25’ N, 15°54’ E, 224 m a.s.l.). The dissemination of odor has greatly reduced the value of the land. Because of the exceeding of the 75 % limit values, groundwater is also degraded. The area of land (study area) around landfill Gajke is 234.5 ha and is divided into five smaller areas (Area 1 – 41.6 ha, Area 2 – 68.8 ha, Area 3 – 68.5 ha, Area 4 – 48.1 ha, Area 5 – 7.5 ha). Area 5 is intended for fodder production and not for wild game breeding (enclosure). The climatic type is sub-Panonic, with cold winters and hot summers. The annual mean temperature is 10.7 °C, and annual precipitation is 900 mm (SORS 2012).

Methodology
Metodologija

For the purpose of our case study, we developed an integrated technological-economic deterministic simulation model by which we assessed the economic viability of investments and the need for multi-criteria decision analysis gathered from the simulation model for each scenario. The structure of the decision simulation model (DSM) is shown in Figure 1.

Simulation model
Simulacijski model

The simulation model was developed in Excel and Visual Basic spreadsheets for applications, which enable the simulation of different scenarios. It consists of three main mo-

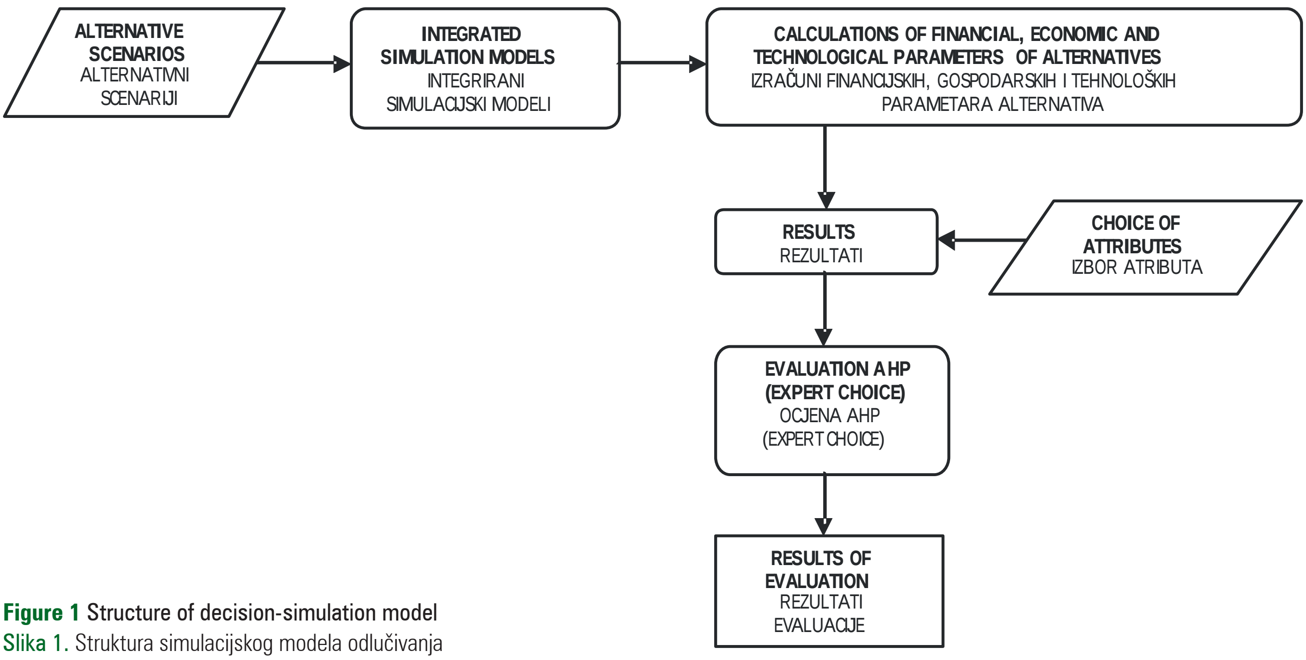

Figure 1 Structure of decision-simulation model
Slika 1. Struktura simulacijskog modela odlučivanja

dels: (i) Calculation model of fodder production, (ii) Simulation model of wild game farming (management of herd – fallow deer and red deer), and (iii) Simulation model of game enclosure. The calculation model of fodder production consists of related sub-models: fertilization (fertilizing plan), labor and machinery, and material consumption. The simulation model of wild game farming consists of related sub-models: management of the herds and feed ration. The simulation model of game enclosure consists of related sub-models: Trees-silvopastoral system and Trees-forest.

Wild game is defined in Regulation (EC) No 853/2004 Annex I as follows:

Wild ungulates and lagomorphs, as well as other land mammals that are hunted for human consumption and are considered to be wild under the applicable law in the Member State concerned, including mammals living in enclosed territory under conditions of freedom similar to those of wild game.

The structure of the simulation model is shown in Figure 2.

The simulation model can simulate different scenarios for periods of 30 years and 50 years. With this simulation model, 384 different scenarios were simulated. Each scenario consists of a combination of the following input variables: fallow deer, red deer, silvopastoral system, forest, organic farming, settlement of Area 1, settlement of Area 2, settlement of Area 3, settlement of Area 4, hind for sale.

In each of 384 scenarios, at least one of the listed wild game and at least one settlement area are included (minimal requirement). The "settlement of Area 1" variable means that in the first year, wild game is settled in Area 1, settlement in Area 2 begins in the third year, settlement in Area 3 begins in the sixth year, and settlement in Area 4 begins in the ninth year. If the "settlement of Area 1" and "settlement of Area 2" variables are selected, Areas 1 and 2 are settled in the first year. Settlement in Area 3 begins in the third year; settlement in Area 4 begins in the sixth year. If the "settlement of Area 1," "settlement of Area 2" and "settlement of Area 3" variables are selected, Areas 1, 2, and 3 are settled in the first year. Settlement in Area 4 begins in the third year. If all four "settlement of the area" variables are selected, all areas are settled in the first year.

The "hind for sale" variable means that hinds are sold and not used as breeding animals in herd (sold as yearlings). In those scenarios where hinds are used as breeding animals, the "management of the herds" sub-model is so designed that hinds are automatically moved to the next area – inbreeding is so excluded. All prickets are intended for selling.

With the "fodder production" simulation model, the cost price of pasture, hay, and grass silage in terms of organic or conventional production can be simulated. Depending on the type of production (conventional or organic), inputs like types, quantities, and prices change.

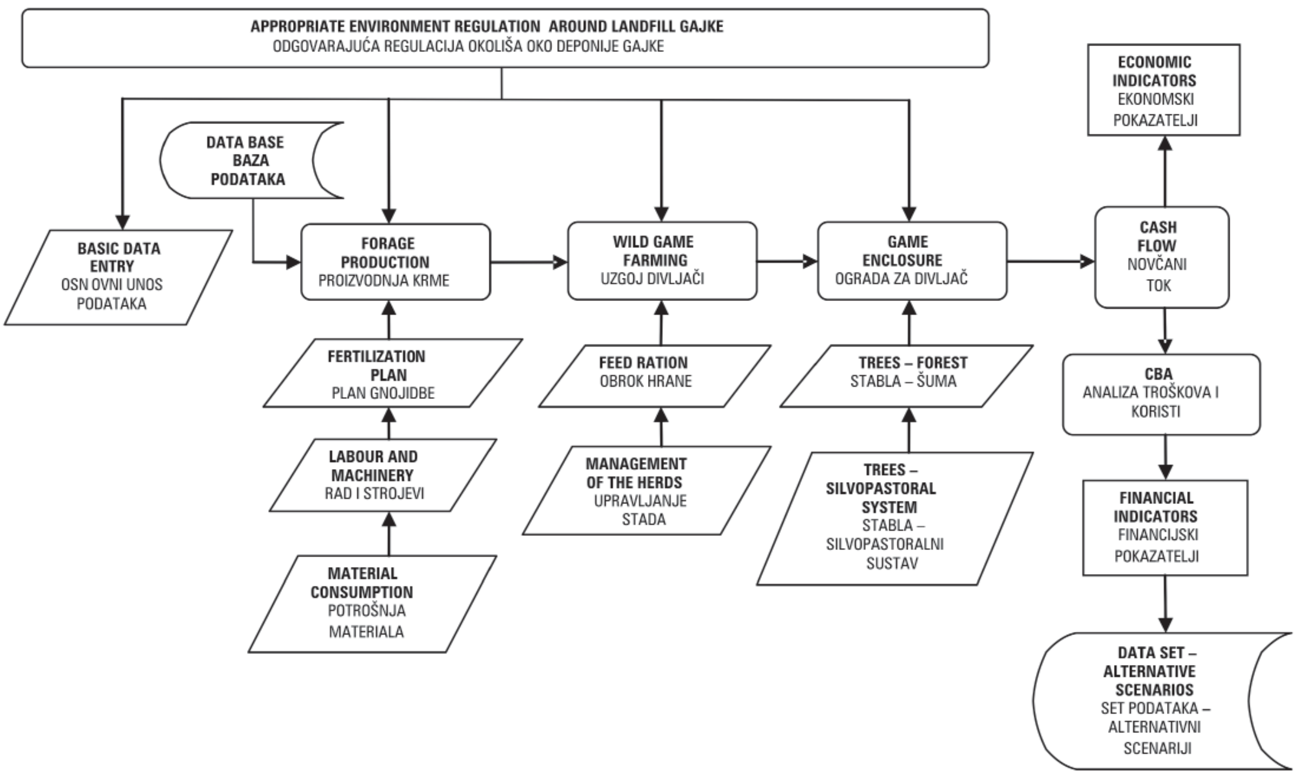

Figure 2 Structure of simulation model
Slika 2. Struktura simulacijskog modela

With the "management of the herds" sub-model, growth of the fallow deer and red deer in terms of organic or conventional farming can be simulated. In organic farming of red deer, the upper limit is 5 adult animals/ha while the upper limit for fallow deer is 10 adult animals/ha. Animals in the first year of their life, which are born in the herd, are considered in this quota. Upper limits are prescribed in the Regulation on Organic Production and Processing of Agricultural Products (Official Gazette RS, No. 71/2010). In terms of conventional farming, the maximum livestock unit for fallow deer and red deer is 1.4/ha (Kästner and Baumgärtel 2010). Performance factors (e.g., hind/yearling pregnancy (70 %), hind pregnancy (90 %), rearing of calves (85 %), annual rejuvenation of the female animals (25 %), and annual rejuvenation of the male animals (25 %)) were used in the sub-model, and they can be changed. Information on the meat growth and weight of fallow deer and red deer carcasses was taken from Kästner and Baumgärtel (2010).

The "feed ration" sub-model allows us to calculate the cost of feed, depending on the type of farming (organic or conventional). Assuming norms and needs of wildlife (Naderer and Huber 2004, Riemelmoser and Riemelmoser 2006, Golze 2007) and the nutrient content of feed (Dlg 2011), with the help of the optimization software tool "What's Best Industrial for Excel, WB", it is possible to obtain an optimal composition of feed (minimizing the cost of feed). In calculating the most favorable price of feed, data on costs per unit of output for each type of feed are used (cost price).

Table 1 Tree species and tree densities used in the forest and silvopastoral system

Tablica 1. Vrsta i gustoća drveća korištena u šumskom i silvo-pastoralnom sustavu

Tree species *Vrsta drveća*	**Forest-tree density (ha)** *Gustoća drveća – šuma (ha)*	**Silvopastoral system-tree density (ha)** *Gustoća drveća – silvo-pastoralni sustav (ha)*
Quercus robur	200	
Quercus rubra	100	
Castanea sativa	100	
Fagus sylvatica	100	
Pseudotsuga menziesii	200	
Picea abies	50	
Pinus nigra	100	
Carpinus betulus	50	
Tilia platyphyllos	10	
Acer pseudoplatanus	10	62
Fraxinus excelsior	50	62
Prunus avium	50	62
Sorbus domestica	10	
Prunus padus	10	
Acer campestre	20	
Cornus stolonifera	10	
Alnus glutinosa	/	62
Betula pendula	10	
å	1080	248

The "game enclosure" simulation model can simulate the arrangement of the game enclosure. All input data can be varied. The "trees-silvopastoral system" sub-model simulates the structure and density of trees in the game enclosure of the silvopastoral system. In order for the area to be eligible for agricultural policy measures (farm subsidies), the number of trees per hectare should not exceed 250 trees/ha. At this tree density, it is assumed that grass cover is at least 80 % and cover by tree canopy is less than 75 % (described by the Regulation on the Register of Actual Use of Agricultural and Forest Land) (Official Gazette RS, No. 122/2008). The "trees-forest" sub-model is meant for the simulation of the individual plantation "islands" of the trees in the game enclosure. In this way, the biodiversity would increase, as 17 different tree species are included in this sub-model. Surfaces in scenarios where "forest" is included are in Area 1 (4.2 ha), Area 2 (4.7 ha), Area 3 (4.4 ha), and Area 4 (4.2 ha). As can be seen in Table 1, we used the density of 1,080 trees/ha for forest plantation. In scenarios where forest is not included, the above-mentioned surfaces are under the silvopastoral system. Surface under trees, density of trees, species of trees, and prices of tree seedlings can be changed in both sub-models.

A dynamic method for investment projects has been used in assessing the investment, covering the financial part of the comparative analysis of total costs and revenues (CBA). Per-hectare periodic costs and revenues are itemized in Table 5.

The NPV is calculated as follows:

$$NPV = -1 + \sum_{i=1}^{n} \frac{Pi}{(1+r)^{i}}$$

where

I – investment in the area regulation

n – number of years

Pi – annual net income or net loss, for the year "I," where Pi is calculated with the model as described earlier – result is cash flow (Pi = R – C, where; R – revenue; C – cost), costs and revenues are provided in Table 7

r – discount rate

The internal rate of return (IRR) is defined as the discount rate that results in NPV = 0 and represents the highest discount rate acceptable for the project.

The IRR is the solution of the equation for r:

$$\sum_{i=1}^{n} \frac{Pi}{(1+r)^{i}} - 1 = 0$$

Explanation of individual variables in the equation is provided at the NPV equation.

AHP multi-criteria decision model
AHP višekriterijski model odlučivanja

The AHP is a multi-criteria decision-making technique that decomposes a complex problem into a hierarchy of less complex individual problems. The AHP is applied using the following steps (Saaty 1980):

AHP enables decision makers to incorporate both subjective and objective matters into the decision making process. This is done by describing complexity as a hierarchy and ration through a comparison of those alternatives relative to the objective (called pair-wise comparison). However, at each level of the hierarchy, the relative importance of each component attribute is assessed by comparing them in pairs. The rankings obtained by the pair-wise comparisons between the alternatives are converted into normalized rankings using the eigenvalue method. The pair-wise comparison reflects the makers' estimates made by the decision maker regarding the relative importance of each alternative in terms of a given decision criterion. A typical problem examined by the AHP consists of a set of alternatives and a set of decision objectives. In applications of the AHP to real decision-making problems, the entries in the above reciprocal matrix are taken from the finite set: {1/9, 1/8,…1, 2,…8, 9} (as suggested by Saaty (1980)). The above discrete set is usually used in practice.

The AHP employs three commonly agreed decision making steps:

(1) Given i = 1, …, m objectives, determine their respective weights w_i,

The weights determination is based upon pair-wise comparison matrix. The preferences in the matrix are estimated on the 1–9 comparison scale where 1 expresses equal preference for two compared criterions and 9 the strongest preference for one criterion over the other. Weights of criteria were determined in brainstorming (from six experts) through the Means of pair-wise comparisons (Figure 3).

(2) For each objective i, compare the j = 1, …, n alternatives and determine their weights a_{ij} with respect to objective i, and

(3) Determine the final (global) alternative weights (priorities) W_j with respect to all the objectives by $W_j = a_{1j}w_1 + a_{2j}w_2 + \ldots + a_{mj}w_m$.

The alternatives are then ordered by the W_j, with the most preferred alternative having the largest W_j. For more precise description of AHP procedure, see Saaty (1980).

Judgment consistency is checked by the consistency ratio (CR) of CI. A consistency index of 0.10 or less is considered acceptable. If the value is higher, the judgments may not be reliable and have to be elicited again. The AHP has been applied too numerous real-life decisions and evaluation problems (Saaty 2008). In AHP model development, the software package "Expert Choice 2000^{TM}" (EC) was used. The final structure of attributes for the assessment of environment regulation (silvopastoral system) around landfill Gajke is shown in Figure 4.

As seen in Figure 4, the decision problem is constructed as a hierarchy. The hierarchy of the model was also established through the brainstorming of six experts involved in model development. The most common structure is a tree, where higher-level attributes depend on the direct followers. Terminal nodes on the right-hand side of the tree represent inputs to the model, and the left side represents the main output: "Appropriate environment regulation around the landfill Gajke." The decision model is constructed from three main criteria at the primary level, nine sub-criteria at the secondary level, and two sub-criteria at the lowest level. Figure 4 also shows calculated priorities.

The "technological criteria" aggregate attribute consists of four basic attributes and two sub-attributes. The "environment criteria" aggregate attribute consists of three basic attributes. The last aggregate attribute describes the econo-

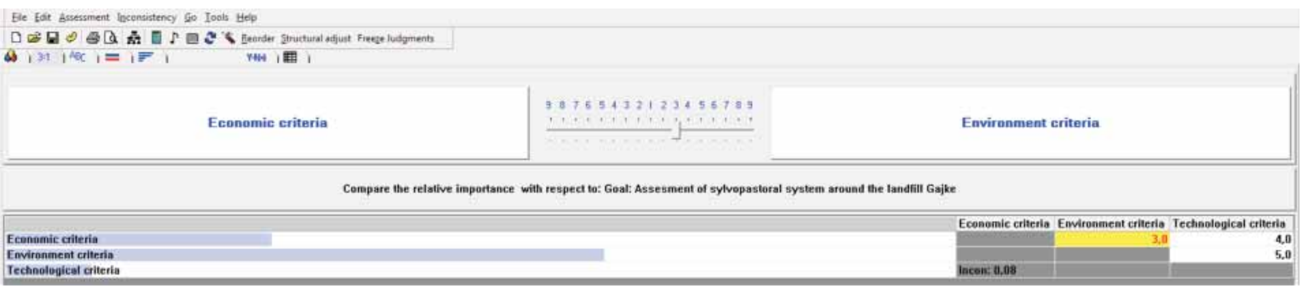

Figure 3 Pair-wise numerical comparisons (between Economic criteria and Environment criteria)
Slika 3. Parne numeričke usporedbe (između ekonomskog i okolišnog kriterija)

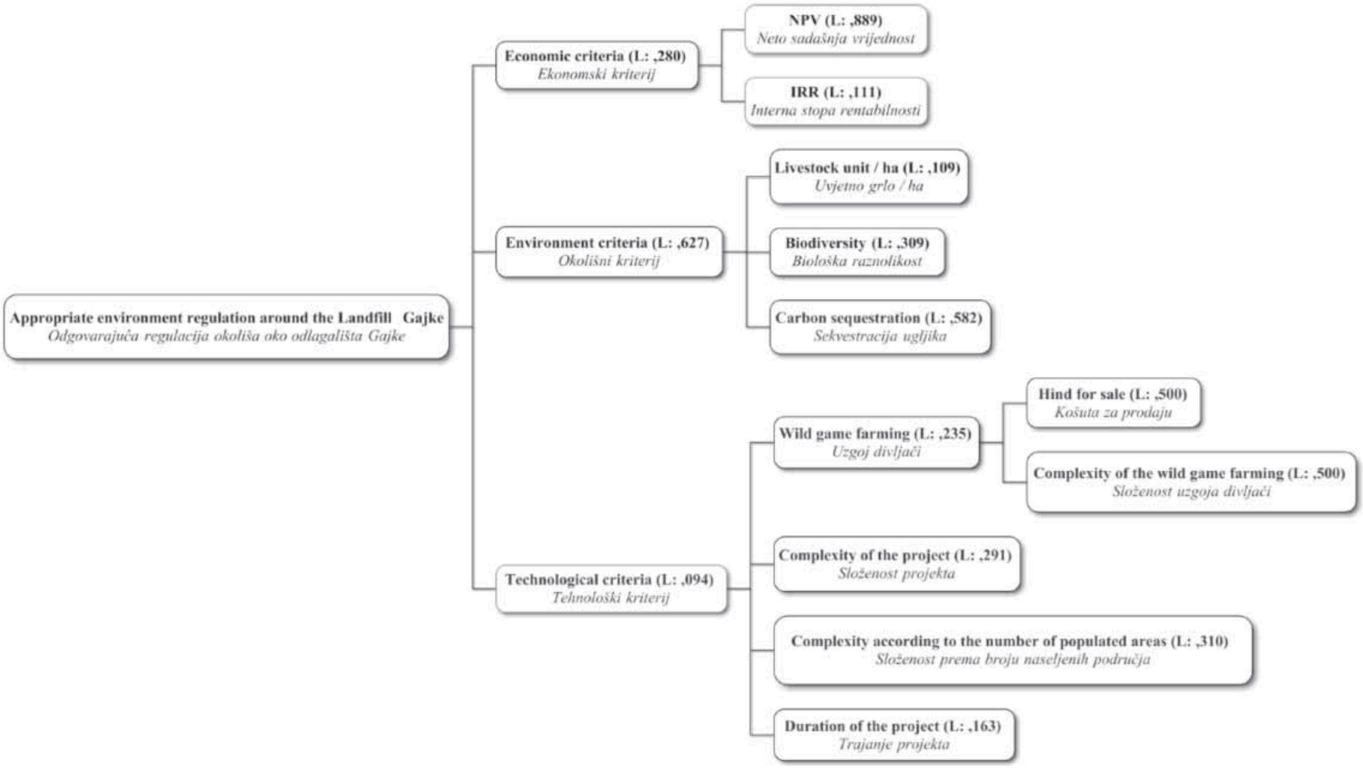

Figure 4 Structure of AHP model showing the three groups of attributes and their respective elements with calculated attribute priorities
Slika 4. Struktura AHP modela koji prikazuje tri skupine atributa i njihove elemente s izračunatima prioritetima atributa

mic assessment of scenarios and consists of two basic attributes. Detailed descriptions of attributes and their assessments are provided in Tables 2, 3, and 4. The expert opinions on individual attributes were evaluated through brainstorming of experts, two from the field of wild game farming and forestry, three experts from the field of agricultural economics and rural development and one expert from the field of projects development.

The EC software package allows a comparison of the quantitative and qualitative parameters. With the use of the EC feature "Data Grid," the results from the simulation model for each scenario can be directly entered. This is useful where there are a large number of alternatives that would result in a large pairwise comparison matrix. Numerical values are first adapted to the classification intervals with the help of the "Step" function. This function was

Table 2 Aggregate attribute "technological criteria," which consist of four basic attributes
Tablica 2. Agregatni atribut "tehnološki kriteriji", koji se sastoji od četiri osnovna atributa

Attributes Atributi	Determination of attributes Određivanje atributa
Duration of the project: describes the duration of the project (30 years or 50 years) Trajanje projekta: opisuje trajanje projekta (30 godina ili 50 godina)	expert opinion stručno mišljenje
Complexity according to the number of populated areas: describes number of populated areas (from 1 to 4) in first year Složenost prema broju naseljenih područja: opisuje broj naseljenih područja (od 1 do 4) u prvoj godini	expert opinion stručno mišljenje
Complexity of the project: describes complexity of project implementation Složenost projekta: opisuje složenost provedbe projekta	expert opinion stručno mišljenje
Wild game farming: this attribute consists of two sub-attributes: Uzgoj divljači: ovaj atribut sastoji od dva pod-atributa:	
Complexity of the wild game farming: describes complexity of red deer and fallow deer farming Složenost uzgoja divljači: opisuje kompleksnost uzgoja običnog jelena i jelena lopatara	expert opinion stručno mišljenje
Hind for sale: describes herd regeneration with own hinds Košuta za prodaju: opisuje obnovu stada s vlastitim košutama	

Šumarski list, 3–4, CXXXVII (2013), 147–161

Table 3 Aggregate attribute "environment criteria"
Tablica 3. Agregatni atribut "okolišni" kriteriji

Attributes Atributi	Determination of attributes Određivanje atributa
Carbon sequestration: describes carbon sequestration for given scenario Sekvestracija ugljika: opisuje sekvestraciju ugljika u određenom scenariju	expert opinion stručno mišljenje
Biodiversity: describes biodiversity for given scenario Biološka raznolikost: opisuje biološku raznolikost u određenom scenariju	expert opinion stručno mišljenje
Livestock unit/ha: describes livestock unit per hectare depending on type, category, and population density of wild game Uvjetno grlo/ha: opisuje broj uvjetnih grla/ha, ovisno o vrsti, kategoriji i gustoći naseljenosti divljači	calculated with model (scenario) izračunat modelom (scenarij)

Table 4 Description of aggregate attribute "economic criteria"
Tablica 4. Opis agregatnog atributa "ekonomski kriteriji"

Attributes Atributi	Determination of attributes Određivanje atributa
IRR: describes indicator *internal rate of return*, which is calculated for each scenario at CBA ISR: opisuje pokazatelj interne stope povrata, koja se izračunava za svaki scenarij u analizi troškova i koristi	calculated with model (scenario) izračunat modelom (scenarij)
NPV: describes indicator *net present value*, which is calculated for each scenario at CBA NSV: opisuje pokazatelj neto sadašnja vrijednost, koji se izračunava za svaki scenarij u analizi troškova i koristi	calculated with model (scenario) izračunat modelom (scenarij)

Table 5 Categorization table for numerical measured attributes
Tablica 5. Kategorizacijska tablica numeričko mjerenih atributa

Net present value (€) Neto sadašnja vrijednost (€)	Qualitative values Kvalitativne vrijednosti
< 160000	very-low / vrlo-nisko
200000	low / nisko
220000	medium-low / srednje-nisko
240000	medium-high / srednje-visoko
260000	high / visoko
280000	very-high / vrlo-visoko
300000	great / veliko
320000	super / iznimno
>340000	excellent / izvrsno
Internal rate of return (%) Interna stopa povrata (%)	
< 9	very-low / vrlo-nisko
9.5	low / nisko
10	medium-low / srednje-nisko
10.5	medium-high / srednje-visoko
11	high / visoko
Livestock unit/ha Uvjetno grlo/ha	
< 0.5	low / nisko
1	medium / srednje
> 1.6	high / visoko
Duration of the project (years) Trajanje projekta (godine)	
30	appropriate / prikladno
50	less appropriate / manje prikladno

used for the following attributes: NPV, IRR, LU/ha, and Duration of the project. Numerical measured attributes are shown in Table 5.

With the "Ratings" function, qualitative values are directly entered in the "Data Grid." This function was used for the following attributes: Complexity according to the number of populated areas, Complexity of the project, Hinds for sale, Complexity of the wild game farming, Carbon sequestration, and Biodiversity (Table 6).

The priorities for each basic attribute are calculated on the basis of pairwise comparisons where scales (ratings) are compared in a pairwise manner. The priority is then assigned according to the discrete value (rating). The final assessment of the scenario is calculated as the sum of the weights of scenarios and weights of criteria. The alternative (scenario) with the best estimate is the most appropriate (and vice versa).

Results and discussion
Rezultati i rasprava

During the first phase, we used a simulation model to calculate the NPV and IRR of each scenario. Table 7 shows costs, revenues, and activities during the implementation of the project. Table 8 presents scenarios where the NPV exceeds 160,000 €. The highest NPV and IRR have been calculated for Scenario 152 (50 years, organic farming of red deer, settlement of all four areas in the first year, hinds intended for sale). No trees are involved in this scenario, as can be gleaned from Table 8.

Table 6 Intensities for discrete attributes
Tablica 6. Intenziteti diskretnih svojstava

Intensity Intenzitet	Definition Definicija
"Technological criteria" "Tehnološki kriterij"	
Complexity according to the number of populated areas Složenost prema broju naseljenih područja	
low nisko	1 area in first year 1 područje u prvoj godini
medium srednje	2 areas in first year 2 područja u prvoj godini
medium-high srednje-visoko	3 areas in first year 3 područja u prvoj godini
high visoko	all 4 areas in first year sva 4 područja u prvoj godini
Complexity of the project Složenost projekta	
low nisko	without silvopastoral system or forest bez silvo-pastoralnog sustava ili šume
medium srednje	forest šuma
medium-high srednje-visoko	silvopastoral system silvo-pastoralni sustav
high visoko	silvopastoral system and forest silvo-pastoralni sustav i šuma
Hind for sale Košuta za prodaju	
no ne	herd regeneration with own hinds obnavljanje stada sa vlastitim košutama
yes da	herd regeneration with other hinds obnavljanje stada sa drugim košutama
Complexity of the wild game farming Složenost uzgoja divljači	
low nisko	fallow deer jelen lopatar
medium srednje	red deer obični jelen
high visoko	fallow deer and red deer jelen lopatar i obični jelen
"Environment criteria" "Okolišni kriterij"	
Carbon sequestration Sekvestracija ugljika	
high visoko	silvopastoral system and forest silvo-pastoralni sustav i šuma
medium srednje	silvopastoral system or forest silvo-pastoralni sustav ili šuma
low nisko	without silvopastoral system or forest bez silvo-pastoralnog sustava ili šume
Biodiversity Biološka raznolikost	
high visoko	silvopastoral system and forest silvo-pastoralni sustav i šuma
medium srednje	silvopastoral system or forest silvo-pastoralni sustav ili šuma
low nisko	without silvopastoral system or forest bez silvo-pastoralnog sustava ili šume

Scenarios change in the following inputs: type of wild game (fallow deer or red deer), number of animals (organic farming, conventional farming), and number of trees (depending on whether it is intended as a silvopastoral system only, silvopastoral system plus forest, only forest, or none of the above (i.e., only pasture land)). Depending on the number of animals, the size of the animal shelter changes (fallow deer 2m²/adult animal, red deer 4m²/adult animal); cost of feed also changes depending on the number, type, and category of animals and type of farming (organic or conventional). Scenarios in Table 8 (only scenarios with NPVs above 160,000 €) were further assessed in a second phase with the AHP decision model, so environmental and technological criteria were included in the decision. Table 9 shows the AHP assessment of alternatives.

Table 7 Annual costs and revenues for scenario 160 (50 years)
Tablica 7. Godišnji troškovi i prihodi za scenarij 160 (50 godina)

Year Godina	Activity Djelatnost	Cost (€/ha/year) Trošak (€/ha/godinu)	Revenue (€/ha/year) Prihod (€/ha/godinu)
0	establishment osnivanje	2,773.21	
1 to 50	feed hrana	427.75	
1; 8 to 11; 19 to 22; 30 to 33; 41 to 44	hind purchase kupnja košuta	240.34	
1; 8 to 11; 19 to 22; 30 to 33; 41 to 44	stag purchase kupnja jelena	36.38	
11, 22, 33, 43	grass overseeding presijavanje trave	95.00	
1 to 50	management upravljanje	95.94	
1 to 50	animal maintenance održavanje životinja	1.85	
1 to 50	salt lick blocks solni blokovi	0.29	
1 to 50	potable water pitka voda	1.99	
15	pruning obrezivanje	150.00	
20	pruning obrezivanje	150.00	
35	pruning obrezivanje	150.00	
50	timber harvest sečnja stabala	2,007.67	
1 to 50	wild game insurance osiguranje divljači	2.13	
3 to 50	sale of carcasses prodaja polovica		778.73
50	logs stabla		10,755.38
1 to 50	subsidies subvencije		336.25

*Land rent is not shown, as landowners are considered owners of wild game enclosure.

*Najamnina zemljišta nije prikazana, jer se zemljoposjednici smatraju vlasnicima ograde divljači.

Table 8 Contents of individual scenarios with calculated NPV and IRR at 8.0 % annual discount rate after simulation (only scenarios with NPVs above 160,000 €)

Tablica 8. Sadržaj pojedinih scenarija s NSV (neto sadašnja vrijednost) i ISR (interna stopa rentabilnosti) izračunate na 8.0 % diskontne stope nakon simulacije (samo scenariji sa NSV-i iznad 160.000 €)

Scenario Scenarij	**Fallow deer** Jelen lopatar	**Red deer** Obični jelen	**Silvopastoral system** Silvo-pastoralni sustav	**Forest** Šuma	**Organic farming** Ekološki uzgoj	**Settlement of area 1** Naseljavanje područja 1	**Settlement of area 2** Naseljavanje područja 2	**Settlement of area 3** Naseljavanje područja 3	**Settlement of area 4** Naseljavanje područja 4	**Hind for sale** Košuta za prodaju	**NPV (€)** NSV (€)	**IRR (%)** ISR (%)
50 Years / 50 Godina												
152		✓			✓	✓	✓	✓	✓	✓	342,753.17	11.1
148		✓			✓	✓	✓	✓	✓		326,630.22	11.0
151		✓			✓	✓	✓	✓		✓	324,971.69	11.0
147		✓			✓	✓	✓	✓			307,776.29	10.9
150		✓			✓	✓	✓			✓	290,095.18	10.8
160		✓	✓		✓	✓	✓	✓	✓	✓	280,684.73	10.1
146		✓			✓	✓	✓				272,266.60	10.6
156		✓	✓		✓	✓	✓	✓	✓		264,561.79	10.0
159		✓	✓		✓	✓	✓	✓		✓	262.903.25	10.0
155		✓	✓		✓	✓	✓	✓			245,707.85	9.9
149		✓			✓	✓				✓	239,240.40	10.5
158		✓	✓		✓	✓	✓			✓	228,026.74	9.8
145		✓			✓	✓					221,467.31	10.3
56	✓	✓			✓	✓	✓	✓	✓	✓	219,480.65	9.4
154		✓	✓		✓	✓	✓				210,198.16	9.6
55	✓	✓			✓	✓	✓	✓		✓	200,135.53	9.3
52	✓	✓			✓	✓	✓	✓	✓		182,045.46	9.2
157		✓	✓		✓	✓				✓	177,171.96	9.5
54	✓	✓			✓	✓	✓			✓	168,026.03	9.1
51	✓	✓			✓	✓	✓	✓			160,784.33	9.0
30 Years / 30 Godina												
152		✓			✓	✓	✓	✓	✓	✓	293,173.34	11.1
151		✓			✓	✓	✓	✓		✓	269,896.95	10.9
148		✓			✓	✓	✓	✓	✓		253,820.08	10.7
160		✓	✓		✓	✓	✓	✓	✓	✓	238,230.29	10.1
147		✓			✓	✓	✓	✓			235,095.25	10.5
150		✓			✓	✓	✓			✓	233,979.90	10.6
159		✓	✓		✓	✓	✓	✓		✓	214,953.90	9.9
146		✓			✓	✓	✓				200,945.17	10.3
156		✓	✓		✓	✓	✓	✓	✓		198,877.03	9.8
155		✓	✓		✓	✓	✓	✓			180,152.20	9.6
158		✓	✓		✓	✓	✓			✓	179,036.85	9.7
149		✓			✓	✓				✓	173,530.04	10.2

✓ variable is included in the scenario
✓ varijabla je uključena u scenarij

CI was 0.08 (which is considered acceptable). The highest alternative priority with respect to the goal (0.054) was calculated for Scenario 160 (50 years, organic farming of red deer in a silvopastoral system, settlement of all four areas in the first year, hinds intended for sale). The annual costs and revenues involved in this scenario are reported in Table 7. The last step of the decision process is the sensitivity analysis. Weights of technologic, economic and environment

Table 9 Expert choice AHP alternatives assessment for the sample of the five best scenarios
Tablica 9. Expert Choice AHP procjena alternativa na uzorku od pet najboljih scenarija

	Economic criteria Ekonomski kriterij	Technological criteria Tehnološki kriterij	Environment criteria Okolišni kriterij		Ranking Rangiranje
Weight (W^a) Težina (W^a)	0.280	0.094	0.627		
		a^b		å Wa^c	
Scenario 160 (50 years) Scenarij 160 (50 godina)	0.048	0.012	0.063	0.054	1
Scenario 156 (50 years) Scenarij 156 (50 godina)	0.034	0.019	0.063	0.051	2
Scenario 159 (50 years) Scenarij 159 (50 godina)	0.034	0.015	0.063	0.050	3
Scenario 152 (50 years) Scenarij 152 (50 godina)	0.139	0.022	0.013	0.049	4
Scenario 155 (50 years) Scenarij 155 (50 godina)	0.023	0.021	0.063	0.048	5
		Consistency index (CI) = 0.08 Indeks konzistentnosti (CI) = 0.08			

W^a – weight; a^b – alternative priority with respect to current node; å Wa^c – alternative priority with respect to goal
W^a – težina; a^b – alternativna prioriteta s obzirom na trenutan čvor; å Wa^c – alternativna prioriteta s obzirom na cilj

criteria were changed in order to observe the impact on the results – scenario 160 – 50 was assessed as best (Table 10).

Scenario 160 (50 years) is the most appropriate alternative for the environment regulation around landfill Gajke, because it satisfy to the given objectives of economic, technologic and mostly environmental criteria.

Conclusions
Zaključci

In the first phase, an integrated computer-based deterministic simulation model was developed. With the help of the simulation model, the economic viability of scenarios for the regulation of the environment could be assessed. The simulation model consisted of several sub-models, which were integrally connected with each other. Each integrally connected sub-model represented a single unit. Relations between the variables of each model were expressed through a formal mathematical language in the form of a number of complex equations and expressed relationships. The result of the computer-based simulation model was a CBA, with the basic indicators being NPV and IRR. The highest NPV (342,753.17 €) and IRR (11.1 % at an 8.0 % annual discount rate) were estimated for Scenario 152 (50 years, organic farming of red deer, settlement of all four areas in the first year, hinds intended for sale). Trees were not involved in this scenario. After the first phase, the results included only economic aspects and did not include the assessment of environmental and technological aspects, so further model development was necessary. In the second phase, multi-criteria analysis (AHP) was used. Taking into account environmental and technological aspects, Scenario 160 (50 years, organic farming of red deer in a silvopastoral system, settlement of all four areas in the first year, hinds intended for sale) with multi-criteria evaluation EC = 0.054 was best estimated. The silvopastoral system included tree species *Acer pseudoplatanus, Fraxinus excelsior, Prunus avium,* and *Alnus glutinosa*, with a tree density of 248 trees/ha (62 of each tree species/ha). The NPV of this scenario at an 8.0 % annual discount rate was 280,684.73 €, and the IRR was 10.1 %. With a tree density of 248/ha and a 5 % predicted loss, a revenue of 10,755.38 €/ha can be reached. Given the current trends of self-sufficiency of energy resources in the region, we assume that in the future, there will be no problems with the sale of saw logs.

The ultimate decision to invest in any agroforestry system lies with the investors. However, the best economic results do not necessarily reflect the best decisions. The benefits of silvopastoral systems are mainly in environmental services "externalities" such as biodiversity, carbon sequestration, and animal welfare. We concluded that the presented model can be regarded as a useful tool for the assessment of environment regulation and offers investors the opportunity for planning and decision-making in a virtual environment before intervening in real environments. The final result of each model depends on the quality of the input information, since the system operates on the principle "garbage-in, garbage-out." Experienced experts should therefore be involved in model development. With appropriate modification, the model developed here could also be applied in the process of agroforestry systems planning, where individual environment regulation problems exist.

Table 10 Ranking of scenarios after sensitivity analysis
Tablica 10. Rangiranje scenarija nakon analize osjetljivosti

	Economic criteria Ekonomski kriterij	Technological criteria Tehnološki kriterij	Environment criteria Okolišni kriterij		Ranking Rangiranje
Weight (W^a) Težina (W^a)	0.257	0.208	0.535		
		a^b		å Wa^c	
Scenario 160 (50 years) Scenarij 160 (50 godina)	0.048	0.012	0.063	0.049	1
Scenario 152 (50 years) Scenarij 152 (50 godina)	0.139	0.022	0.013	0.047	2
Scenario 156 (50 years) Scenarij 156 (50 godina)	0.034	0.019	0.063	0.046	3
Scenario 159 (50 years) Scenarij 159 (50 godina)	0.034	0.015	0.063	0.045	4
Scenario 155 (50 years) Scenarij 155 (50 godina)	0.023	0.021	0.063	0.044	5

W^a – weight; a^b – alternative priority with respect to current node; å Wa^c – alternative priority with respect to goal
W^a – težina; a^b – alternativna prioriteta s obzirom na trenutan čvor; å Wa^c – alternativna prioriteta s obzirom na cilj

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Sažetak:

Degradirani krajolici nastaju kao nusprodukt ekonomske, funkcionalne, prostorne i društvene transformacije gradova i regija, a sve to popraćeno obezvređivanju i napuštanju područja (Loures 2009). Prema Gruenewald et al. (2007), uspostavljanje poljoprivredno-šumarskih (agroforestry) sustava može biti održivo rješenje za degradirana zemljišta. Ukoliko je upravljan na održiv način, silvo-pastoralni sustav može povoljno utjecati na bioraznolikost, krajobraz i ruralnu problematiku okolišnih ciljeva kroz niz atributa. To uključuje učinkovito kruženje nutrijenata, ispunjavanje kriterije dobrobiti životinja, zapošljavanje i dohodak, preokret ruralne napuštenosti i stvaranje održivih seoskih zajednica (Mosquera-Losada et al. 2005, Rigueiro-Rodriguez et al. 2011). Interakcije u silvo-pastoralnom sustavu generiraju ekonomske, ekološke i socijalne koristi (De Baets et al. 2007).

Znanstvena literatura predlaže različite pristupe za ocjenu poljoprivredno-šumarskih sustava prije odlučivanja u velike investicije (Alavalapati i Mercer 2004, Tojnko et al. 2011). Višekriterijska analiza odlučivanja (MCDA) koristan je metodološki pristup kada se ocjena više varijabli ne može lako pretvoriti u kvantitativne jedinice i na naš konačni cilj utječe više međusobno konkurentskih kriterija (Mendoza i Martins 2006). Osnovni problem u istraživanju je u razvoju sustava koji bi podržao donošenje odluka u odabiru najprikladnijih alternativa, s kombinacijom tehnološko-ekonomskog simulacijskog modela (analiza troškova i koristi (CBA)) i analitički hijerarhijski proces (AHP) višekriterijske analize odlučivanja (Belton i Stewart 2002).

U ovom radu razmotrili smo različite scenarije za agroforestry regulaciju degradiranog područja sa silvo-pastoralnim sustavom, koristeći integrirano deterministički i višekriterijski model odlučivanja. Ispitali smo mogućnost za uzgoj divljači, običnog jelena (*Cervus elaphus*) i jelena lopatara (*Dama dama*) u ogradi.

Područje istraživanja smješteno je oko deponije Gajke, Ptuj, severno-istočna Slovenija (46°25' N, 15°54' E, 224 m n.v.). Širenje mirisa znatno je smanjilo vrijednost zemljišta. Zbog prekoračenja 75 % graničnih vrijednosti, podzemna voda je također degradirana. Površina zemljišta (područja istraživanja) oko deponije Gajke je 234.5 ha i podijeljena je na pet manjih područja (Područje 1 – 41.6 ha, Područje 2 – 68.8 ha, Područje 3 – 68.5 ha, Područje 4 – 48.1 ha, Područje 5 – 7.5 ha. Površina 5 namijenjena je proizvodnji stočne hrane, a ne za uzgoj divljači (ograda).

Za potrebe naše studije slučaja, razvili smo integrirani tehnološko-ekonomski deterministički simulacijski model, s kojim ocjenjujemo ekonomsko opravdanost ulaganja. Struktura determinističkog simulacijskog modela (DSM) prikazana je na slici 1. Simulacijski model razvijen je u programu Excel i Visual Basic za aplikacije, što omogućuje simulaciju različitih scenarija. Sastoji se od tri osnovna modela: (i) Kalkulacijski model proizvodnja stočne hrane, (ii) Simulacijski model uzgoj divljači (upravljanje stada – jelen lopatar i obični jelen), i (iii) Simulacijski model ograda. Kalkulacijski model proizvodnja stočne hrane sastoji se od povezanih pod-modela: gnojidba (plan gnojidbe), rad i strojevi, i materijal. Simulacijski model uzgoj divljači sastoji se od povezanih pod-modela: upravljanje stada i obrok stočne hrane. Simulacijski model ograda sastoji se od povezanih pod-modela: stabla – silvo-pastoralni sustav i stabla – šuma. Struktura simulacijskog modela prikazana je na slici 2.

Simulacijski model može simulirati različite scenarije za razdoblje 30 godina i 50 godina. S ovim simulacijskim modelom simulirali smo 384 različitih scenarija. Svaki scenarij sastoji od kombinacije od sljedećih ulaznih atributa: jelen lopatar, obični jelen, silvo-pastoralni sustav, šuma, ekološki uzgoj, naseljavanje područja 1, naseljavanje područja 2, naseljavanje područja 3, naseljavanje područja 4 i košuta za prodaju (tablica 8).

U svakom scenariju uključena je barem jedna od navedene divljači i najmanje jedno područje naseljavanja. Varijabla "naseljavanje područja 1" znači da u prvoj godini, divljač naseljavamo u područje 1. Naseljavanje u području 2 počinje u trećoj godini, naseljavanje u području 3 počnije u šestoj godini, a naseljavanje područja 4 počinje tek u devetoj godini. Ako su odabrane varijable "naseljavanje područja 1" i "naseljavanje područja 2", područje 1 i 2 naseljeni su divljačinom u prvoj godini. Naseljavanje područja 3 počinje u trećoj godini. a naseljavanje područja 4 započinje u šestoj godini. Ako su odabrane varijable "naseljavanje područja 1", "naseljavanje područja 2" i "naseljavanje područja 3", područja 1, 2 i 3 naseljena su u prvoj godini, a naseljavanje područja 4 počinje u trećoj godini. Ukoliko su odabrane sve četiri varijable "naseljavanje područja", sva područja naseljena su u prvoj godini.

Varijabla "Košuta za prodaju" znači da košute prodamo (prodana kao junad) i ne upotrijebimo za rasplod u stadu. U scenarijima gdje se košute koriste za rasplod, pod-model "Upravljanje stada" dizajniran je tako da košute automatski premjesti u sljedeće područje – parenje u srodstvu (inbreeding) tako je isključeno. Svi jeleni dvogodišnjaci su prodani.

Uz kalkulacijski model "Proizvodnja stočne hrane" može se simulirati cijena paše, sijena i travnate silaže u smislu ekološke i konvencionalne proizvodnje. Ovisno o vrsti proizvodnje (konvencionalna ili ekološka), promjenjuje se vrsta, količina i cijena inputa.

Pod-model "Upravljanje stada" može simulirati ekološki i konvencionalni uzgoj običnog jelena i jelena lopatara. U ekološkom uzgoju običnog jelena gornja granica je 5 odraslih životinja/ha, dok je gornja granica za jelena lopatara 10 odraslih životinja/ha. Životinje u prvoj godini svog života, rođena u stadu, također se smatraju u toj kvoti. Gornje granice propisane su u Pravilniku o ekološkoj proizvodnji i preradi poljoprivrednih proizvoda (Službeni glasnik RS, broj 71/2010). U smislu konvencionalnog uzgoja gornja granica za uvjetno grlo/ha običnog jelena i jelena lopatara je 1,4/ha (Kästner i Baumgärtel 2010). Performanse čimbenici (kao trudnoća košuta/jednogodišnjak (70 %), trudnoća košuta (90 %), uspješnost uzgoja teladi (85 %), godišnje pomlađivanje ženskih životinja (25 %) a godišnje pomlađivanje muških životinja (25 %)) upotrijebljeni su u pod-modelu, a oni se također mogu mijenjati. Informacije o prirastu i težini polovica običnog jelena i jelena lopatara preuzete su iz Kästner i Baumgärtel (2010).

Pod-model "Obrok stočne hrane" omogućuje nam izračunavanje troškova stočne hrane, ovisno o vrsti uzgoja (ekološki ili konvencionalni). Pretpostavljajući norme i potrebe divljači (Naderer i Huber 2004, Riemelmoser i Riemelmoser 2006, Golze 2007) i hranjivih tvari hrane (Dlg 2011), uz pomoć optimizacijskog softvera "What's Best Industrial for Excel, WB", moguće je dobiti optimalan sastav hrane (minimiziranje troškova hrane za životinje).

Simulacijski model "Ograda" može simulirati razmještaj ograde. Svi ulazni podaci mogu se mijenjati. Podmodel "Stabla – silvo-pastoralni sustav" simulira strukturu i gustoću stabala u ogradi kada je u scenariju izabran silvo-pastoralni sustav. Kako bi područje bilo prihvatljivo za subvencije, broj stabala po hektaru ne smije prelaziti 250 stabala/ha. Kod ovog broja stabala pretpostavlja se, da je pokrov trave najmanje 80 %, a pokrov krošnji manji od 75 % (opisano u pravilniku o evidentaciji stvarnog korištenja poljoprivrednog i šumskog zemljišta) (Službeni glasnik RS, broj 122/2008). Pod-model "Stabla – šuma" namijenjen je za simulaciju pojedinih "otoka" stabala u ogradi. Na taj način povećala bi se biološka raznolikost, jer 17 različitih vrsta drveća uključeno je u ovaj pod-model. Površine u scenarijima gdje je "šuma" uključena su u Području 1 (4.2 ha), Području 2 (4.7 ha), Području 3 (4.4 ha) i Području 4 (4.2 ha). Kao što se može vidjeti u tablici 1, koristili smo gustoću 1.080 stabala/ha za šumske plantaže. U scenarijima gdje šuma nije uključena, spomenute površine su pod silvo-pastoralnim sustavom. Površina pod drvećem, gustoća stabala, vrsta drveća te cijena sadnica mogu se mijenjati u oba pod-modela.

Scenariji se dodatno ocjenjuju s višekriterijskim modelom odlučivanja, pomoću analitičkog hijerarhijskog procesa (AHP) (podržano od strane stručnog softverskog alata Expert Choice (EC) 2000™) (slika 4) Višekriterijski model odlučivanja izgrađen je od tri glavna kriterija (tehnološki, okolišni i ekonomski) (tablice 2, 3 i 4). Softverski alat EC omogućuje usporedbu kvantitativnih i kvalitativnih parametara. Kvantitativne vrijednosti prvo su prilagođene klasifikacijskim intervalima (tablica 5) a kvalitativne vrijednosti izravno se unose u EC (tablica 6). Ponder svakog kriterija temelji na parnoj usporedbi matrice. Preference u matrici procjenjuju se na skali od 1 do 9, gdje 1 iskazuje jednaku sklonost između dvoje kriterija a 9 najjaču sklonost za jedan kriterij iznad drugog. Ponderi kriterija bili su određeni tijekom brainstorminga između 6 stručnjaka putem parnih usporedba. Slika 3 prikazuje parno usporedbu između pojedinih kriterija. S višekriterijskom ocjenom, EC = 0,054 scenarij 160 za razdoblje od 50 godina smatra se najprikladnijim za regulaciju degradiranog zemljišta (tablice 7 i 9). Scenarij uključuje ekološki uzgoj običnog jelena u silvo-pastoralnom sustavu, naseljavanje svih četiri područja u prvoj godini i košute namijenjene za prodaju. Silvo-pastoralni sustav uključuje vrste drveća *Acer pseudoplatanus, Fraxinus excelsior, Prunus avium* i *Alnus glutinosa*, sa gustoćom 248 stabala/ha (62 svake vrste drveća/ha) namijenjene sječom nakon 50 godina (tablica 1). Neto sadašnja vrijednost (NSV) ovog scenarija na 8.0 % godišnje diskontne stope je 280.685 €, dok je interna stopa rentabilnosti (ISR) nešto više od 10 %. Posljednji korak u procesu odlučivanja je analiza osjetljivosti. Ponderi tehnološkog, ekonomskog i okolišnog kriterija bile su blago modificirane, kako bi mogli promatrati utjecaj na krajnji rezultat – scenarij 160-50 bio je rangiran najviše (tablica 10).

Krajnja odluka investirati u bilo koji poljoprivredno-šumarski sustav leži na investitorima. No, najbolji ekonomski rezultat ne mora nužno predstavljati najbolje odluke. Prednosti silvo-pastoralnog sustava su uglavnom u uslugama zaštite okoliša (eksternalije) kao što su biološka raznolikost, sekvestracija ugljika i dobrobit životinja. Zaključili smo, da se predstavljen model može smatrati kao koristan alat za ocjenu regulacije okoliša i pruža investitorima priliku za planiranje i donošenje odluka u virtualnom okruženju prije intervencije u stvarnim uvjetima.

KLJUČNE RIJEČI: simulacijski model, višekriterijska analiza odlučivanja, analitički hijerarhijski proces (AHP), silvo-pastoralni sustav, divljač, ograda