Fuzzy Multi-criteria Model for Selecting the Best Location for a Regional Landfill

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Biomass is a renewable energy source which gains an ever increasing interest. The selection of the best location of the regional landfill represents the first and the most sensitive step in biomass waste management. This paper proposes a new fuzzy multi-criteria model, which is based on the adapted Hurwitz algorithm. The criteria values can be crisp and uncertain. The uncertain criteria values are described by linguistic expressions which are modeled by triangular fuzzy numbers. These criteria also have different relative importance. In this paper, the criteria importance is given by the pairwise comparison matrix and weight vector is calculated by applying the eigenvector approach. The proposed model determines the best location with respect to all criteria as well as their weights. The functioning of proposed model is illustrated using real world examples and data collected in a one region in Serbia.

Keywords: biomas waste management, location, uncertainty, fuzzy set, multi-criteria optimization

The expected deficit in power supply all over the world demands all types of institutions such as scientific, vocational and governmental to focus an increased attention on the problems of increasing energy efficiency, using renewable energy sources as biomass (biodegradable parts of products, waste and remains in agriculture, forestry and related industries, as well as biodegradable parts of industrial waste and urban litter, according to European Union Directive (EU) 2001/77/EC).

Although biomass is often referred to as carbon neutral fuel, it can still contribute to global warming. Energy can be obtained from biomass in different ways, for example by: (1) direct burning (wood, vegetative remains, wood waste) in order to get thermal energy, (2) digestion – processing animal waste (manure) into biogass, (3) processing biomass into alcohol (ethanol) or producing vegetable oils. It should also be noted that during its life cycle, biomass absorbs CO_2 which is released back into the atmosphere when biomass is used for obtaining energy.

The EU puts a lot of effort into stimulating the use of biomass as a fuel. 4% of the overall energy demand in the EU is satisfied by biomass production, which is equal to 69m tons of petroleum. Data found in literature (International Energy Agency (IEA), Head of Communication and Information Office, Paris, France: World Energy Outlook, 2008) suggest that using biomass as a fuel may lead to diversity in energy supply, considerable decrease in emission of gases which cause the greenhouse effect, increasing the employment rate and potential cuts in prices of petroleum as a result of declining demand.

One of subissues of using biomass as a fuel is the selection of a biomass burying location. The considered problem is important bearing in mind three different groups of aspects:

- economic and social group of aspects (this creates the possibility to improve the competitive position of regional economy, makes new production programs as growing biomass plantation, using biomass for energy, solving the problem of waste disposal and increasing the employment rate);
- socially-energetic and ecological group of aspects (preservation and/or improvement in environment protection and natural resources use, improving life quality and a contribution to the use of renewable energy sources);
- the aspect of energetics development strategy realisation (improving the reliability of energy supply in both industry and households, decreasing the use of other energy forms and giving contribution to meeting local energetic needs).

The problem of selecting location for biomass burying and processing has been discussed in a certain number of papers so far. In [12] two models have been developed: a simulation model and an optimization model, which are directed to the logistic of biomass fuel collection. The simulation model has been developed to calculate the costs and energy consumption of the biomass logistic. The optimization model which is based on a mixed-integer linear programming is used to optimize the network structure. In [10], chioce of the most suitable location for regional landfill is set as a multi-criteria problem. Solution of the considered problem is obtained by applying geographical information system (GIS). The attention is focused on searching possibilities, advantages and limits in GIS use in selection of micro-location for the regional waste landfill. In [12] the problem of choosing most suitable location for biomass burying is set as a linear programing (LP) task. The municipality goal function is defined as minimization of total net spending on waste disposal. Net spending makes tipping fee plus transportation costs. Types of solid waste are: (1) garbage-different landfills have different capacities for accepting different types of solid waste, (2) recycling-different landfills have different tipping fees for different types of solid waste; under some circumstances the tipping fees may be negative (revenue enhancing), and (3) compost-some municipalities are both demanders and suppliers of landfill capacity; so they may be net beneficiaries of greater streams of some types of solid waste.

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In the authors' opinion, the choice of possible location has to be made taking into account a number of criteria concerning many aspects that influence the evaluation of each location. Generally, the criteria weights are different.

The estimation of criteria weights and uncertain criteria values cannot be preformed with an exact numerical value. It seems as a more realistic approach to use linguistic assessments instead of numerical values. In this paper, modeling of these linguistic variables is based on the fuzzy set theory [21, 14]. The fuzzy set theory resembles human reasoning in its use of approximate information and uncertainty to generate decisions. We can come to a conclusion that the fuzzy approach in treating uncertainties in real-word applications has numerous advantages when compared to other approaches which could be expressed as follows [20]: conceptually easy to understand; flexible; capture most nonlinear functions of arbitrary complexity; tolerant of imprecise data; built on the specialists' expertise; could be blended with conventional control techniques; based on natural languages; provide better communication between experts and managers.

In the literature, there are a numerous papers where optimal solutions to multi-criteria optimization problems are reached by applying the proposed two-stage method. At the first stage, the weights of treated criteria are determined by applying numerous methodologies (Kelemenis, Askounis, 2010; Awasthi et al 2010 and Sadi-Nezhad, Damghani, 2009; Mahdavi et al, 2008; Chen et al, 2006; Petrović, Petrović, 2001). At the second stage, some other methods are used in order to determine the best item with respect to all treated criteria, simultaneously, as well as their relative importance. The following two passages offer a short overview of the literature concerning those two stages.

It appears that the weight determination of criteria is more reliable when obtained using pairwise comparisons than when they are directly obtained, because it is easier to make comparison between two criteria than make an overall weight assignment. In [3], an assumption is introduced that the relative importance of different decision criteria in the considered problem involves a high degree of subjective judgement and individual preferences. Hence, triangular fuzzy numbers are used to decide priority of one criterion over the other. Weights vector is calculated by applying the synthetic extent analysis method which is the so-called fuzzy extended AHP[4]. In [8], specialists' judgements on criteria weights are calculated by applying Delphi method. The weights vector is gained from fuzzy AHP. In (Torfi et al., 2009), a pairwise comparison matrix of relative importance for the considered criteria is constructed. Elements of this matrix are defined with analogy to traditional AHP method [16]. The consistency of the decision maker's judgements during the evaluation phase is confirmed by consistency index [16]. Then, the real elements of constructed matrix are transformed into the triangular fuzzy numbers. The criteria weights are calculated as average of the elements of each row from a pairwise comparison matrix whose elements are triangular fuzzy numbers.

At the second stage, determining the best alternative with respect to all treated criteria, simultaneously, as well as their relative importance is given by using some of the following methods: genetic algorithm, artifical neural network, grey relational analysis, mixed integer non-linear programming, etc. In [15], a new algorithm for multicriteria selection of the best inventory replenishment policy PR* is proposed. It is based on an adaptation of a Hurwitz approach for selecting a combined optimistic-pessimistic solution. This means that if an PR* with the specific compromised characteristics has to be selected, its best criteria value has to be very high, if possible - the highest, and at the same time its weakest criteria value has to be not bad, if possible - the least bad.

An important task ahead of each and every state is the choice of the most suitable location for building a biomass processing plant. In this process, more rational decisions are made by a group of people rather than by a single person. The relative importance of criteria is given through pairwise comapison matrix. This matrix elements are triangular fuzzy numbers. Aggregated assumption of the relative importance of each pair of criteria is calculated by developed procedure. The weights vector is calculated by using fuzzy extended AHP [4]. Uncertain criteria values are described by triangular fuzzy numbers. In this paper, an effort is given to observe simultaneously both crisp and uncertain criteria in the problem of selecting the most suitable location for biomass burying and processing.

The paper is organized as follows: a multi-criteria approach to the problem of ranking and selecting the best location is given in Section 2. Modeling of uncertainties is described in Section 3. In Section 4, principles of adaptation of a Hurwitz approach are presented, whereas Section 5 gives an illustrative example offering real data.

Problem statement

Basic assumptions

Assumptions concerning the process of selecting most suitable location for biomass burying and processing in this paper are as follows:

-the I possible locations in a region are taken into account. They are formally represented by a set of location indexes I{1,...,i,...,1}.

- decision-makers team defines the group of criteria according to which each possible location is evaluated. The number and types of these criteria depend on decision-makers' estimation;

- decision-makers team (an urbanist, geologist, doctor, electrical engineer, technical engineer, and ecologist) defines the group of possible locations. Selection of locations is based on: (a) the analysis of historical data based on the experience of other countries, (b) the use of data found in official bulletins, (c) the experts' judgments, (d) professional observation, etc. In practice, different approaches are more often combined;

- to each defined criterion an organized pair (relative importance, value) is associated;

- relative importance of treated criteria does not depend on locations and is in most cases hardly changed. Generally, the relative importance of criteria is different and determined according to knowledge and experience of decision-maker team;

- values of defined criteria are determined for each locations separately. In the considered problem, these values can be crisp and/or uncertain. The uncertain values are modeled by applying the fuzzy set theory.

Modeling of uncertainties

Modeling of Criteria Weights

All the criteria for evaluating locations are usually not of the same relative importance, and do not depend on the location. Also, they can be considered as unchangeable during the considered period of time. They involve a high degree of subjective judgment and individual preferences of decision-makers. We think that the judgment of each pair of treated criteria best suits human-decision nature (by analogy with AHP method).

In this paper, the fuzzy rating of decision-maker is described by linguistic expressions which can be represented as triangular fuzzy number $\tilde{w}_{kk'} = (x; l_{kk'}, m_{kk'}, u_{kk'})$ with the lower and upper bounds $l_{kk'}$, $u_{kk'}$ and modal value $m_{kk'}$, respectively. Values in the domain of these triangular fuzzy numbers belong to a real set within the interval 1-5.

If strong relative importance of criterion k' over criterion k holds, then pairwise comparison scale can be represented by the fuzzy number

$$\tilde{w}_{kk'} = \left(\tilde{w}_{k'k}\right)^{-1} = \left(\frac{1}{u_{k'k}}, \frac{1}{m_{k'k}}, \frac{1}{l_{k'k}}\right).$$

If k=k' (k,k'=1,...,K) then relative importance criterion k over criterion ik' s represented by single point 1 which is a triangular fuzzy number (1,1,1).

In this paper, the fuzzy rating of each decision-maker can be described by using five linguistic expressions: equally important, moderately important, strongly important, very strongly important, and most important. These linguistic expressions are modeled by triangular fuzzy numbers which are given in the following way:

equally important	$\tilde{R}_1 = (x;1,1,2)$
moderately important	$\tilde{R}_2 = (x;1,2,3)$
strongly important	$\tilde{R}_3 = (x;2,3,4)$
very strongly important	$\tilde{R}_4 = (x;3,4,5)$
most important	$\tilde{R}_5 = (x;4,5,5)$

Modeling of Uncertain Criteria

Values of most criteria cannot be stated quantitatively, because decision-makers most often base their estimates on evidence data. In such cases, their values are adequately described by linguistic expressions. In this paper the linguistic expressions are modeled by triangular fuzzy numbers $\tilde{v}_{sk} = (y; l_{sk}, m_{sk}, u_{sk})$ with the lower and upper bounds l_{sk}, u_{sk} and modal value m_{sk}, respectively. Values in the domain of these triangular fuzzy numbers belong to real set within the interval 1,9, by analogy to Saaty's measurement scale [16]. Value 1 stands for the lowest criterion value and value 9 for the highest criterion value.

The number and kinds of linguistic expressions are defined by decision-makers team depending on the number of uncertain criteria and the number of locations and estimate of decision makers. For the problem considered in this paper, it is realistic to assume the following linguistic expressions which are used to describe the values of uncertain criteria: very high value, high value, moderate value, low value and very low value.

In this paper, fuzzy rating of decision-makers team can be described by using one out of seven linguistic expressions: low value, rather low value, fairly moderate value, moderate value, highly moderate value, high value, and very high value. These linguistic expressions are modeled by triangular fuzzy numbers which are given in the following way:

low value	$(y;1,1,2)$
rather low value	$(y;1.5,2,2.5)$
fairly moderate value	$(y;2,3,4)$
moderate value	$(y;3.5,5,6.5)$
highly moderate value	$(y;6,7,8)$
high value	$(y;7.5,8,8.5)$
very high value	$(y;8,9,9)$

Fuzzified adapted Hurtwitz Algorithm

The algorithm developed for selecting the best location, i* has the following steps:

Step 1. Calculation of weights vector of the considered criteria, W, by applying the concept of extent analysis [4] which is presented in Section 3.

Step 2. Transform all the cardinal criteria values v_{ik} into r_{ik} defined on a common scale [0,1] by appying linear transformation:

- for a benefit type criterion k, k=1,..,K

$$r_{ik} = \frac{v_{ik}}{\sum_{i=1}^{I} v_{ik}}, \quad (4.1)$$

- for a cost-type criterion k, k=1,..,K

$$r_{ik} = 1 - \frac{v_{ik} - v_k^{min}}{v_k^{max}} \quad (4.2)$$

where:

$$v_k^{min} = \min_{i=1,...,I} v_{ik}, \text{ and } v_k^{max} = \max_{i=1,...,I} v_{ik}$$

Step 3. Transformation of all linguistic criteria values, v_{ik} into $\tilde{r}_k$ whose domains are defined on a common scale 1,9 by applying the linear normalization method [7]:

a)for benefit type criterion k, k=1,..,K'

$$\tilde{r}_{ik} = \left(\frac{l_{ik}}{u_j^*}, \frac{m_{ij}}{u_j^*}, \frac{u_{ij}}{u_j^*}\right) \quad (4.3)$$

where:

$$u_j^* = \max_{i=1,..,I} u_{ij}, \; k=1,..,K'$$

b) for a cost-type criterion k, k=K' + 1,…,K

$$\tilde{r}_{ik} = \left(\frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}}\right) \quad (4.4)$$

where:

$$l_j^- = \min_{i=1,..,I} l_{ij}, \; k=K'+1,…,K$$

Normalized positive triangular fuzzy numbers can also approximate positive triangular fuzzy numbers.

Step 4. Calculate weighted normalized IxK decision matrix $\mathbf{D}=[d_{ik}]$. The elements of this matrix are calculated as:

$$d_{ik} = w_k \cdot r_{ik} \quad (4.5)$$

for all columns k, k=1,..,K which correspond to the cardinal criteria,

$$d_{ik} = w_k \cdot \text{defuzz}\, \tilde{r}_{ik} \quad (4.6)$$

for all columns k, k=1,..,K which correspond to the linguistic criteria.

Step 5. Find the best location l* by using an adaptation of Hurwitz approach for selecting a combined optimistic-pessimistic solution [9, 15]:

$$\max_{i=1,..,I}\left\{\alpha\cdot\min_{k=1,..,K} d_{ik} + (1-\alpha)\cdot\max_{k=1,..,K} d_{ik}\right\} \qquad (4.7)$$

i* is the best-compromised location where a plant for biomass processing should be built, providing that both its best and its worst criteria values are good enough. In the two extreme cases, $\alpha=0$ and $\alpha=1$, these represent, respectively, the maximum optimism, i.e. the weight of 1 is assigned to the best criterion value and weight 0 to all others, and maximum pessimism, where the weight of 1 is assigned to the worst criterion value and weight 0 to all others. Triangular fuzzy number comparison is based on the method (Dubois, Prade, 1979, Bass, Kwakernak, 1977.).

Case study

About 27% of the overall territory in Serbia make woods and about 60% of its territory is agricultural soil, which means that Serbia has enormous energetic potential as far as biomass is concerned. The overall biomass processing from annual agricultural products in Serbia is over 12.5m tons per year. However, despite huge potential, there are still no significant results in using biomass as an energy substance. A need for creating new energy capacities in Serbia was initiated on the EU demand.

Fifteen different criteria defined according to law regulations currently in power in the Republic of Serbia are used to evaluate each potential location:

- the cost of waste collecting and transportation to a location;
- an average distance from a certain municipality territory to a landfill site;
- available waste quantities;
- humidity characteristics of biomass;
- infrastructural adaptability of the location;
- the effect on environment (the quantity of carbon dioxide and other hazardous gases emitted into the atmosphere);
- the possibility of energetic biomass utilization;
- terrain abruptness;
- the presence of running and stagnating waters on a location;
- seismic characteristics of a terrain;
- terrain penetrability;
- distance to the first populated area;
- weather characteristics of significance to a landfill location;
- local community attitude;
- the quality of the roads leading to a landfill.

The normalized weights vector *W*:

$$W=\begin{pmatrix}0.075, 0.071, 0.075, 0.076, 0.069, 0.064, 0.045, 0.069,\\ 0.069, 0.071, 0.064, 0.076, 0.071, 0.045, 0.064\end{pmatrix}$$

By applying procedure from Step 2 to Step 3 of the Algorithm, the normalized decision matix is obtained and given in table 3.

Sensitivity analysis and discussion

The parameter α is reffered to as the optimism-pessimism cofficient, and it varies in the range 0-1. In other words, the value of this parameter expresses the belief of the managemet team members that values and importances of all critetia existing in the the algorithm are precisely determined or estimated.

By applying the extension in Step 6 of the Algorithm, the best location i* is selected. The selection depends on the optimism-pessimism coefficient α.

When decision-makers team is extremely optimistic ($\alpha=1$), the best location is $i^*=i_1$ (a triangle in fig. 1).

On the other hand, when decision makers team is extremely pesimistic ($\alpha=0$), the best location is $i^* = i_2$ (a rectangle in fig. 1).

Each management team member has his/her own believes about correctness of data exisiting in the algorithm which is based on: (1) previous experience which is in a high degree determined by jobs that he/she did in the previous period of time and the results that he/she achieved; (2) how ecologically conscious is the population inhabiting and working on the potential location; (3) his/her own perception of the possibilty to realise the project

Table 1

CRITERIA VALUES FOR EACH POSSIBLE LOCATION

	k=1	k=2	k=3	k=4	k=5	k=6	k=7	k=8	k=9	k=10	k=11	k=12	k=13	k=14	k=15
i=1	265000	25	530	*rather low value*	*low value*	*rather low value*	*low value*	*fairly moderate value*	*fairly moderate value*	*high value*	*higly moderate value*	550	*high value*	1400	*rather low value*
i=2	669600	31	1080	*higly moderate value*	*fairly moderate value*	*high value*	*fairly moderate value*	*rather low value*	*rather low value*	*high value*	*rather low value*	2580	*moderate value*	15628	*fairly moderate value*
i=3	340300	20.5	830	*moderate value*	*low value*	*rather low value*	*moderate value*	*fairly moderate value*	*fairly moderate value*	*high value*	*moderate value*	200	*fairly moderate value*	32293	*High value*
i=4	1420200	27	2630	*moderate value*	*rather low value*	*high value*	*fairly moderate value*	*low value*	*rather low value*	*high value*	*rather low value*	350	*moderate value*	83000	*fairly moderate value*
i=5	367000	27.8	660	*moderate value*	*moderate value*	*rather low value*	*low value*	*fairly moderate value*	*fairly moderate value*	*high value*	*very high value*	800	*high value*	24614	*fairly moderate value*
i=6	445200	31.8	700	*moderate value*	*moderate value*	*high value*	*moderate value*	*fairly moderate value*	*rather low value*	*high value*	*moderate value*	1500	*moderate value*	19784	*fairly moderate value*
i=7	1028560	59.8	860	*low value*	*higly moderate value*	*rather low value*	*fairly moderate value*	*higly moderate value*	*high value*	*high value*	*rather low value*	1800	*very high value*	35445	*higly moderate value*
i=8	864600	39.3	1100	*rather low value*	*moderate value*	*high value*	*fairly moderate value*	*fairly moderate value*	*rather low value*	*fairly moderate value*	*moderate value*	1450	*moderate value*	29151	*fairly moderate value*
i=9	4049100	49.5	1170	*high value*	*low value*	*very high value*	*low value*	*Rather low value*	*rather low value*	*high value*	*moderate value*	600	*moderate value*	117722	*higly moderate value*
	min	min	max	min	max	min	max	min	min	min	min	max	min	max	max

Relative criteria importance is given through a pairwise comparison matrix of relative criteria importance (table 2).

Table 2
RELATIVE IMPORTANCE OF EACH PAIR OF THE CONSIDERED CRITERIA

	k=1	k=2	k=3	k=4	k=5	k=6	k=7	k=8	k=9	k=10	k=11	k=12	k=13	k=14	k=15
k=1	(1,1,1)	$\tilde{R}_2$	(1,1,1)	$(\tilde{R}_1)^{-1}$	$\tilde{R}_2$	$\tilde{R}_3$	$\tilde{R}_5$	$\tilde{R}_2$	$\tilde{R}_2$	$\tilde{R}_2$	$\tilde{R}_4$	$(\tilde{R}_1)^{-1}$	$\tilde{R}_2$	$\tilde{R}_5$	$\tilde{R}_4$
k=2	$(\tilde{R}_2)^{-1}$	(1,1,1)	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_2)^{-1}$	$\tilde{R}_1$	$\tilde{R}_2$	$\tilde{R}_4$	$\tilde{R}_1$	$\tilde{R}_1$	(1,1,1)	$\tilde{R}_3$	$(\tilde{R}_2)^{-1}$	(1,1,1)	$\tilde{R}_4$	$\tilde{R}_3$
k=3	(1,1,1)	$\tilde{R}_2$	(1,1,1)	$(\tilde{R}_1)^{-1}$	$\tilde{R}_2$	$\tilde{R}_3$	$\tilde{R}_5$	$\tilde{R}_2$	$\tilde{R}_2$	$\tilde{R}_2$	$\tilde{R}_4$	$(\tilde{R}_1)^{-1}$	$\tilde{R}_2$	$\tilde{R}_5$	$\tilde{R}_4$
k=4	$\tilde{R}_1$	$\tilde{R}_2$	$\tilde{R}_1$	(1,1,1)	$\tilde{R}_3$	$\tilde{R}_4$	$\tilde{R}_5$	$\tilde{R}_3$	$\tilde{R}_3$	$\tilde{R}_2$	$\tilde{R}_4$	(1,1,1)	$\tilde{R}_2$	$\tilde{R}_5$	$\tilde{R}_4$
k=5	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_1)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_3)^{-1}$	(1,1,1)	$\tilde{R}_2$	$\tilde{R}_3$	(1,1,1)	(1,1,1)	$(\tilde{R}_1)^{-1}$	$\tilde{R}_2$	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_1)^{-1}$	$\tilde{R}_3$	$\tilde{R}_2$
k=6	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_2)^{-1}$	(1,1,1)	$\tilde{R}_2$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_2)^{-1}$	$\tilde{R}_1$	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_2)^{-1}$	$\tilde{R}_2$	$\tilde{R}_1$
k=7	$(\tilde{R}_5)^{-1}$	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_5)^{-1}$	$(\tilde{R}_5)^{-1}$	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_2)^{-1}$	(1,1,1)	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_5)^{-1}$	$(\tilde{R}_4)^{-1}$	(1,1,1)	$(\tilde{R}_2)^{-1}$
k=8	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_1)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_3)^{-1}$	(1,1,1)	$\tilde{R}_2$	$\tilde{R}_3$	(1,1,1)	(1,1,1)	$(\tilde{R}_1)^{-1}$	$\tilde{R}_2$	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_1)^{-1}$	$\tilde{R}_3$	$\tilde{R}_2$
k=9	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_1)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_3)^{-1}$	(1,1,1)	$\tilde{R}_2$	$\tilde{R}_3$	(1,1,1)	(1,1,1)	$(\tilde{R}_1)^{-1}$	$\tilde{R}_2$	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_1)^{-1}$	$\tilde{R}_3$	$\tilde{R}_2$
k=10	$(\tilde{R}_2)^{-1}$	(1,1,1)	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_2)^{-1}$	$\tilde{R}_1$	$\tilde{R}_2$	$\tilde{R}_4$	$\tilde{R}_1$	$\tilde{R}_1$	(1,1,1)	$\tilde{R}_3$	$(\tilde{R}_2)^{-1}$	(1,1,1)	$\tilde{R}_4$	$\tilde{R}_3$
k=11	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_1)^{-1}$	$\tilde{R}_2$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_3)^{-1}$	(1,1,1)	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_3)^{-1}$	$\tilde{R}_2$	(1,1,1)
k=12	$\tilde{R}_1$	$\tilde{R}_2$	$\tilde{R}_1$	(1,1,1)	$\tilde{R}_3$	$\tilde{R}_4$	$\tilde{R}_5$	$\tilde{R}_3$	$\tilde{R}_3$	$\tilde{R}_2$	$\tilde{R}_4$	(1,1,1)	$\tilde{R}_2$	$\tilde{R}_5$	$\tilde{R}_4$
k=13	$(\tilde{R}_2)^{-1}$	(1,1,1)	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_2)^{-1}$	$\tilde{R}_1$	$\tilde{R}_2$	$\tilde{R}_4$	$\tilde{R}_1$	$\tilde{R}_1$	$\tilde{R}_1$	$\tilde{R}_3$	$(\tilde{R}_2)^{-1}$	(1,1,1)	$\tilde{R}_4$	$\tilde{R}_3$
k=14	$(\tilde{R}_5)^{-1}$	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_5)^{-1}$	$(\tilde{R}_5)^{-1}$	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_2)^{-1}$	(1,1,1)	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_5)^{-1}$	$(\tilde{R}_4)^{-1}$	(1,1,1)	$(\tilde{R}_2)^{-1}$
k=15	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_3)^{-1}$	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_1)^{-1}$	$\tilde{R}_2$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_2)^{-1}$	$(\tilde{R}_3)^{-1}$	(1,1,1)	$(\tilde{R}_4)^{-1}$	$(\tilde{R}_3)^{-1}$	$\tilde{R}_2$	(1,1,1)

Table 3
NORMALIZED CRITERIA VALUES FOR EACH POSSIBLE LOCATION

	k=1	k=2	k=3	k=4	k=5	k=6	k=7
i=1	1	0.925	0.06	(0.33,0.5,1)	(0.11,0.11,0.125)	(0.33,0.5,1)	(0.14,0.14,0.28)
i=2	0.9	0.824	0.113	(0.11,0.14,0.2)	(0.22,0.44,0.67)	(0.11,0.125,0.14)	(0.28,0.57,0.86)
i=3	0.98	1	0.087	(0.14,0.2,0.33)	(0.11,0.11,0.125)	(0.33,0.5,1)	(0.43,0.71,1)
i=4	0.715	0.891	0.275	(0.14,0.2,0.33)	(0.11,0.22,0.33)	(0.11,0.125,0.14)	(0.5,0.57,0.86)
i=5	0.975	0.878	0.069	(0.14,0.2,0.33)	(0.33,0.56,0.78)	(0.33,0.5,1)	(0.14,0.14,0.28)
i=6	0.55	0.811	0.073	(0.14,0.2,0.33)	(0.33,0.56,0.78)	(0.11,0.125,0.14)	(0.43,0.71,1)
i=7	0.811	0.343	0.09	(0.5,1,1)	(0.56,0.78,1)	(0.33,0.5,1)	(0.28,0.57,0.86)
i=8	0.851	0.686	0.115	(0.33,0.5,1)	(0.33,0.56,0.78)	(0.11,0.125,0.14)	(0.28,0.57,0.86)
i=9	0.065	0.514	0.122	(0.11,0.125,0.14)	(0.11,0.11,0.22)	(0.11,0.125,0.14)	(0.14,0.14,0.28)

of building facilities for biomass storing and processing; (4) his/her own attitude about the present and future conditions of potential locations sites; such attutudes are formed not only on the basis of the present condition of the site, but on the forcast of the following institutions, as well: the Republic Seismological Insitute, Republic Hydro-Meteorological Institute, Soil Institute in Belgrade, Faculty of Mining and Geology, Belgrade University, appropriate ministries in the country and other renowned institutions and countries in the region.

It would not be possible, based on the analysis of determining parameter α value, to give a recommandation on which the value of this parameter is chosen, i.e. if majority of management team members has a pessimistic attitude, it should be accepted that $\alpha=0$, and vice versa.

From the point of view of decision making, the most unfavourable situation is when management team members have no clearly defined attitude concerning data existing in the algorithm, or when one half of the members

	k=8	k=9	k=10	k=11	k=12
i=1	(0.33,0.5,1)	(0.17,0.25,0.5)	(0.22,0.25,0.29)	(0.11,0.14,0.2)	0.06
i=2	(0.33,0.5,1)	(0.33,0.5,1)	(0.22,0.25,0.29)	(0.33,0.5,1)	0.262
i=3	(0.17,0.25,0.5)	(0.17,0.25,0.5)	(0.22,0.25,0.29)	(0.11,0.2,0.5)	0.02
i=4	(0.5,1,1)	(0.33,0.5,1)	(0.22,0.25,0.29)	(0.33,0.5,1)	0.036
i=5	(0.17,0.25,0.5)	(0.17,0.25,0.5)	(0.22,0.25,0.29)	(0.11,0.11,0.125)	0.081
i=6	(0.17,0.25,0.5)	(0.33,0.5,1)	(0.22,0.25,0.29)	(0.11,,0.2,0.33)	0.123
i=7	(0.11,0.14,0.2)	(0.11,0.125,0.14)	(0.22,0.25,0.29)	(0.33,0.5,1)	0.183
i=8	(0.17,0.25,0.5)	(0.33,0.5,1)	(0.33,0.5,1)	(0.11,,0.2,0.33)	0.148
i=9	(0.33,0.5,1)	(0.33,0.5,1)	(0.22,0.25,0.29)	(0.11,,0.2,0.33)	0.061

Table 4
CRITERIA VALUES FOR EACH POSSIBLE LOCATION (CONTINUED)

	k=13	k=14	k=15
i=1	(0.22,0.25,0.29)	0.038	(0.11,0.22,0.33)
i=2	(0.22,0.25,0.29)	0.042	(0.22,0.44,0.67)
i=3	(0.33,0.5,1)	0.087	(0.78,0.89,1)
i=4	(0.28,0.4,0.67)	0.223	(0.22,0.44,0.67)
i=5	(0.22,0.25,0.29)	0.066	(0.22,0.44,0.67)
i=6	(0.28,0.4,0.67)	0.053	(0.22,0.44,0.67)
i=7	(0.22,0.22,0.25)	0.095	(0.56,0.78,1)
i=8	(0.28,0.4,0.67)	0.078	(0.22,0.44,0.67)
i=9	(0.28,0.4,0.67)	0.317	(0.56,0.78,1)

Table 5
CRITERIA VALUES FOR EACH POSSIBLE LOCATION (CONTINUED)

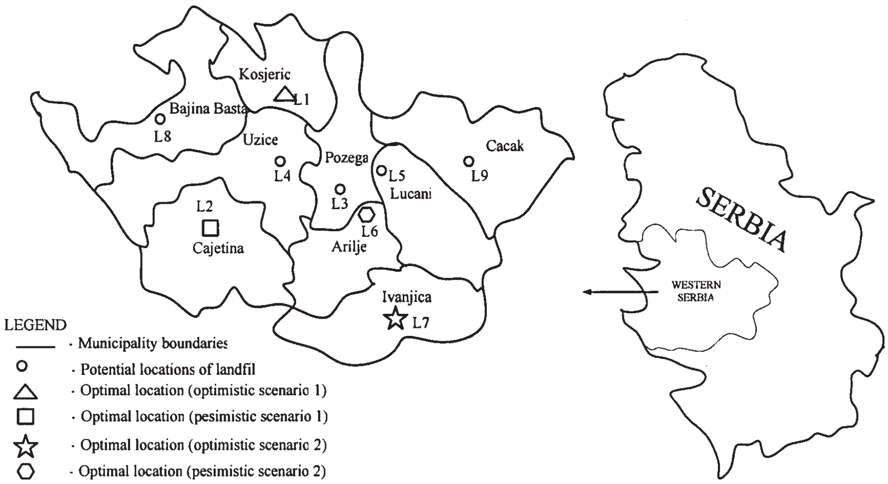

Fig.1 An overview of all possible and the most suitable landfill locations

has a pessimistic attitude, whereas the other half has an optimistic one. In such a case $\alpha=0.5$ is accepted.

A decision maker, which is a local community as far as the problem discussed in this paper is concerned, should make a decision about the location where a landfil would be built, based on the data arrived at by applying the developed algorithm.

By using the proposed algorithm, the best locations are arrived at in an exact way. Every solution that is arrived at in an exact way is less burdened by subjective attitudes of the management team, which is to say, more precise. By applying this algorithm, a decision maker is in a better situation to take into consideration a less number of potentially best locations, which gives the opportunity to look into the problem more realistically and make a proper decision in the shortest possible period of time.

The situations when the local community attitude is more important than all other criteria are not so uncommon. In such a case, it can be supposed that this criterion importance when compared to all other criteria is the biggest. According to this supposition, the normalized vector of the criteria weight is:

$$W=(0.1236,0,0,0.1873,0,0,0,0,0,0,0.1873,0,0.5017,0)$$

When decision-makers team is extremely optimistic ($\alpha=1$), the best location is $i^*=i_7$ (an asterisk in fig. 1).

On the other hand, when decision makers team is extremely pesimistic ($\alpha=1$, the best location is $i^*=i_6$ (a hexagon in fig. 1).

Conclusion

Nowdays, using biomass as an alternative energy source is one of the most important issues in both developed and developing countries. This means that Serbia, having huge potential in biomass production, should react promply and undertake all neccessary actions that would enable the biomass processing development processes, which would increase energy capacity. Unfortunately, however, there is not a defined network of locations for biomass burying and processing in Serbia, which would be an input data for defining biomass waste management strategies which, among other, increase the national economy sustainability.

Determining the network of locations for biomass burying and processing is based on selecting the most suitable locations in every region. The best location selection depends on many different criteria, such as: economic group, social group, and environmental group crietria, etc., which are very often in conflict. The considered criteria have a different relative importance whereas criteria values can be crisp or uncertain. The proposed model based on adapted Hurwitz model enables the choice of the best location for biomass burying and processing under different uncertainties and vagueness, with respect to all criteria, simultaneously, taking account of their relative importance. By using the proposed Algorithm, potentially best locations are arrived at in an exact way. Every solution that is arrived at in an exact way is less burdened by subjective attitudes of the management team, which is to say, more precise. A decision maker, according to the nature of the problem discussed in this paper is the local community, which should choose the best possible solution. In other words, the developed Algoritm gives the opportunity to a decision maker to make a proper decision in the shortest possible period of time. In this way, the proposed Algorithm is the support to the local community which is to make the final decision. The proposed model was tested on a selected group of possible locations in one region in Serbia.

The developed fuzzy models are flexible: (1) they include and operate with both precise and imprecise specific data, and (2) different changes can be easily incorporated into the model, such as those in the number of criteria or thier relative importance, or number of possible locations and membership function shape of fuzzy numbers. The proposed Algorithm characteristics enable definition of various scenaria. For each defined scenario, by applying the proposed Algorithm, potentially best locatons are arrived at. Different scenaria could be defined by management team depending on their belief that input data should be changed. The fuzzy Algorithm could be modified for solving different waste management problems.

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Ñotation

I - number of possible locations,

i - index of location, i=1,..,I

K - number of evaluation criteria,

k - index of criterion, k=1,..,K

$\tilde{R}$ - set of linguistic expressions describing the importance of a criteria,

V-set of linguistic expressions describing the uncertain criteria values,

$\tilde{w}_{kk'}$- a triangular fuzzy number (x; $l_{kk'}$, $m_{kk'}$, $u_{kk'}$) describing the relative importance of criterion k according to criterion k',k, k' - 1,...,K; k ≠ k'

w_k- the normalized weight of criterion k, k=1,..,K,

v_{ik} - crisp value of criterion k, k=1,..,K,

v_{ik} - a triangular fuzzy number (y; L_{ik}, M_{ik}, U_{ik}) describing the value of criterion k for location i, i=1,..,I; k=1,..,K,

r_{ik}- normalized value of v_{ik} i=1,..,I; k=1,..,K

$\tilde{r}_{ik}$ - normalized value of i=1,..,I; k=1,..,K,

D-the weighted normalized decision matrix,

d_{ik} - weighted normalized value of criterion k for location i, i=1,..,I; k=1,..,K,

i* - the best location.

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