Research Article

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Decision trees in environmental justice research — a case study on the floods of 2001 and 2010 in Hungary

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Abstract: Environmental justice is a normative framework for the analysis of environmental impacts on the well-being of individuals and social groups. According to the framework, the deprived social groups and ethnic minorities are often more exposed to environmental risks and hazards due to their disadvantaged situation, and due to the lack of representation and political power. To manage the impacts of injustices and to include the citizen in the decision-making processes, proper information is needed on local attitudes and decision-making processes. Therefore, this study sought to (i) identify the main factors shaping the attitudes towards environmental injustices and (ii) to analyse the attitudes and perception of the various social groups and (iii) to identify the main factors which are shaping the attitudes and actions of those who were affected by the floods of 2001 and 2010 through the use of decision tree method. The data for the predictive model was acquired from a questionnaire survey conducted in two disadvantaged and flood-hit Hungarian regions. Based on the survey data, a principal component analysis (PCA) was conducted, which resulted in three principal components; fear, social change, and change in the built environment. The study focused only on the elements of the "fear principal component", due to the decision tree tool homogenous groups identified in relation to this component. Our analysis showed that ethnicity has a determinative role in the emergence and the level of fear from floods; the Roma respondents expressed a significantly higher level of fear than others.

Keywords: decision tree, predictive modeling, environmental injustice, natural disasters

1 Introduction

In the last decades, there has been a growing interest in environmental justice. The studies are based on the theory of social justice and have usually focused on the uneven distribution of resources, risks, decision-making possibilities and the social consequences of these inequalities [1]. The evolution of environmental justice research has been linked to the civil rights movements that unfolded in the 1960s – thus the papers are often linked to political activism. The term "environmental justice" itself refers to the struggles against the inequalities in the distribution of environmental risks and possibilities [2]. The uneven impacts of climate change also highlighted the importance of environmental justice research [3–5]. Climate change has a significant effect on the probability of environmental injustices in the East-Central European region especially since the rapid increase in the frequency of extreme weather events. For example, floods and drought can occur simultaneously – but in different areas. These natural disasters processes have wide-ranging impacts on ecosystems, economic sectors, the built environment and on human health. Due to a limitation of research focusing on environmental justice in a post-socialist context, little is known on the attitudes and perceptions of the population affected by environmental injustices [6].

The fundamental idea behind the environmental injustice research is to highlight the necessity and right of a liveable and healthy environment (built and natural) for everyone, in the same, good quality, not only today but also for future generations. If these requirements are not fulfilled, it is necessary (at least) to try to ensure that the injustices experienced in the environment are fairly distributed amongst the people. This raises several criticisms, two of which are highlighted in this study. Firstly, the assessment of the injustices is very much related to the sub-

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jective judgment of the individuals, secondly, the assessment of the individuals is done in numerous ways of a different logic, such as the evaluation of the actors trying to eliminate unfair situations. This may result in discrepancies within the assessment of unjust situations which can lead to various forms of continual and further unfair, unequal situations, environmental injustices.

Different environmental justice approach analyses the above-mentioned unequal situations from several aspects, [24] approach focuses on the inequality of different social groups, founding his claims on statistical evidence. [61] doubts the legitimacy of statistically-proven inequality and highlights the importance of a dynamic and more qualitative approach. Both of them can be considered right and wrong since environmental justice is a normative framework which helps to explore the injustices caused by the uneven distribution of environmental resources, risks, harms, and procedures. Environmental injustices are often based on certain decision-making processes (locational decisions of waste sites, transport infrastructure, industrial facilities and types of economic activities) [7]. From this aspect, environmental injustices are understood as the right to a healthy environment, where the concepts and definitions require a context-based approach. Since understanding unjust situations are human-related and highly contextual, the participation and involvement of the stakeholders are essential to recognize, manage and eliminate injustice.

The present study analyses environmental justice from the side of individual decisions and the perception of unjust events. The research focuses on two Hungarian areas which were hit by major floods in 2001 and 2010. To gain a better understanding of the decisions and preferences of various groups of the affected local population, decision trees were applied in our analysis. To adapt this predictive modeling tool in environmental injustice research some minor modifications were made to the usual, widely accepted method, due to a smaller sample the parent node growth limit was set to the minimum, which is 10 and child nodes were defined in 5 cases. Our study aims to gain information on local attitudes and perceptions after in flood-hit areas and to distinguish different groups by the means of their answer given in the questionnaire survey. The paper analyses different decision trees determined by different questions, answers, and attributes. Through the use of the decision tree, this paper sought to answer two fundamental research questions: (i) is there a difference in perception of environmental injustices within different social groups according to their answers given in the questionary, are these groups relate to specific attributes, and (ii) do these groups – if there are any – find the utilitarian approach to justice just acceptable for all, or only those who were affected by the natural disasters? Answering these questions the paper can offer insights to some methodological considerations for the management of future environmental justices.

2 Environmental justice – approaches and interpretations

As it was stated before the sources and forms of environmental injustices are highly diverse which is reflected in the published papers. In the last decades several aspects were highlighted such as health damage, caused by environmental degradation or various investments, waste incinerators [8–10], landfills [11], farms and agricultural activity [12–14], industrial facilities, mines [15–17], urban brownfields [58], access to and lack of access to resources [18, 19]. These studies have found that environmental injustices most often affect the poorest, most vulnerable, minority social groups and deprived people [20–24]. North American researchers highlighted, that these impacts often affect black, Hispanic or indigenous people the hardest, thus they often referred to as the manifestations of environmental racism [25, 26].

Although there are numerous/various forms of justice that have been identified in the research field of environmental justice, this paper focuses on three major justices: procedural, distributive and recognition of justice. Procedural environmental justice refers to the decision-making where potential stakeholders are involved (or have the chance to be involved) in the decision-making processes in relation to polluting or environmentally hazardous facilities. Distributive justice focuses on the effects of hazardous facilities. As mentioned above, several studies found that disadvantaged and ethnic minority communities are more likely to be exposed to the negative impacts of those facilities. Environmental justice as recognition means that the differences between stakeholders are accepted, and their identity is respected. Thus, the disadvantaged social groups' attitudes and values are respected [7].

The judgment of justice and injustice, good and bad as a 'general truth' or 'general rule' is the result of a social process, an impression of a given socio-economic state and power-relation. The truth defined by law may differ from what is considered socially fair by the local community affected by an environmental injustice [27–29]. Moreover, the above mentioned 'general rules' defined by the environmental and social policy can often be interpreted differently in the 'environmental periphery', the less devel-

oped areas, since local definitions of 'general truths' can develop.

Based on previous research [27, 28], the viewpoint that the legal environment and spatial inequalities are interlinked has become increasingly accepted. The law and legal practice are shaping our environment, certain places, and spaces with the legal environment and the process of legislation involved in the production of space [29]. Therefore, it is increasingly important to clarify what is necessarily or fairly accepted as the definition of justice, and what is the path to reach it [30]. The revealed environmental injustice is to be interpreted as the beginning of the social discourse, in which our concepts and definitions are based on mutually accepted, socially legitimate values on the given context.

The assessment of Force Majeure situations (such as flood, drought, earthquake) and the interventions made are determined by what information is considered important and what is ignored during the evaluation process [31]. Generally, such a situation will be examined by the stakeholders to determine the most favorable intervention techniques to the local population. During post-environmental catastrophe interventions, professionals usually produce cost-benefit analyses based on the traditional utilitarian approach and evaluate processes. The focal point of this approach is to increase utility and social welfare through interventions. The main axiom of the utilitarian approach is that the marginal utility of money is infinite, as any number of goods can be purchased. The evaluation should be based on real income and intervention accorded to financial benefits as an approximate measure of utility [32]. So, if after a post-catastrophe intervention the aggregate well-being of the affected group increases, the process for the local group and the society is considered desirable. In this utilitarian approach, the logical framework of the intervention corresponds to the *input-output – result* linear structure, which is essentially in line with the *found – tool – target* canonical economic development logic [33, 34].

However, such intervention logic is characterized by several deficiencies. Firstly, for example, the different personal preferences, mental states, and the interpersonal differences are not taken into consideration. This moves in line with the traditional economics view that the underlying partial factors and determinants beyond the possessions are indifferent, but many studies emphasize the opposite. For example, we can state that happiness is not linearly related to real income, as it is determined by other factors (*e.g.* mental state, relative financial situation, genetics, informal dependencies) [35]. Some study shows that people who live in poorer conditions are said to have better living circumstance than those who lived in a more developed city and had a higher income [36]. This is a phenomenon of relative deprivation when the own situation is judged to be worse than the 'real' financial situation., which highlights the importance of reference groups and context.

Secondly, another difficulty in measuring and researching environmental injustices – alongside with the above mentioned relative deprivation – is that the indicators and the research methodology selected for the evaluation and analysis is influences scales which modify the data results. Shin and Angew's [37] study has found that, despite the global correlation and regression of indicators, the results of spatial autocorrelation and geographically weighted regression can produce different results. This proves that the above-mentioned traditional, tool-oriented economic theoretical model is not suitable for evaluating environmental injustices and to ground the post-catastrophe interventions. Therefore there is a need for understanding first the spatial differences, the socio-economic factors, which are also shaped by the underlying relationships between the indicators. Therefore, environmental factors are increasingly involved in the assessment of environmental injustice measurement indicators [38].

Thirdly, another criticism of the tool-oriented intervention, which proves the 'imperfection' of utilitarianism, is the Kaldor-Hickey criterion. According to this theory, the 'winners' (beneficiaries) can compensate 'losers' (disadvantaged groups or individuals) for their losses from the profits gained [39], but this is almost never realized.

In the 1970s, John Rawls, as a critique of this approach, formulated his theory of justice, stating that individuals consider different things important and they are influenced by their original position which is hardly similar. In the so-called 'libertarian' approach, the primary assets, such as the right to live must be guaranteed to all people [40]. The theory of justice was criticized for its naïve and positivist approach to decision making, disregarding the individual's capability and knowledge.

Amartya Sen's capability approach has been developed as a critique and complement to the ideas outlined above. In his opinion, development is a process of increasing freedom enjoyed by people [41, 42]. It focuses on the extent of freedom and choice, in his view, both objective well-being and subjective well-being are necessary for development. Traditional decision-making focuses on traditional development tools (such as real income, exploiting ecosystem services, market or non-market based products and services) which strengthens interpersonal and cultural differences, and reproduces conflicts within communities. Sen points out the discrepancy between real happiness and the benefits of utilitarian tool-oriented concepts.

He also sets up the five criteria of freedom and justice, which should be applied in post-environmental catastrophe interventions: (1) political freedoms, (2) economic conditions, (3) social opportunities, (4) transparency and (5) security [42–44]. According to Elekes and Bajmócy [45], the complete elimination of the uncertainty which is arising during the intervention is impossible, therefore it is necessary to formulate solutions for accepting the necessary existence of uncertainty. Therefore, the decision-maker does not differ from other stakeholders, because the knowledge is shared by the local groups, but the decision-making position will strengthen its role. Thus, the active involvement of the local population will expand the opportunities and capabilities of the local in the post-catastrophic intervention process.

Various forms of interventions can take place after the emergence of environmental injustices, in order to restore original positions or compensate those who were exposed to the unjust situation. International organizations, state, and community-based initiatives all have the ability to be the actors of change.

State intervention is one of the most common intervention types, in Hungary, following environmental injustices – this is certainly true in the case of floods since the state is perceived as the main responsible actor for the management of floods [1]. The interventions during and after catastrophic events, are carried out for socio-economic well-being and political benefits but should never result from the restriction of rights. The former standpoints and views about social compensation or certain technologies [46, 47], may change during the intervention, because of the unique and complex nature of society and economy or the post-catastrophic interventions. It is important to understand that the process of recognizing justice or injustice are subjective – may it be based on expected or real environmental hazards and risks.

Environmental catastrophes are unique environmental-socio-economic Force Majeure where the active involvement of the local community is limited, but not impossible – mainly due to the extent of the damage and lack of local resources. Similar to the present study, the transfer of information between local and national actors is a crucial element when designing and implementing interventions. In this study, we use the decision tree method that can foster the process of involvement and support information transfer between decision-making levels. Previously, this method was mainly used for traditional economic analysis and cost-benefit studies. In this research, the decision-trees are used to explore opinions, attitudes and help to understand decision-making and grouping in society.

3 Methods

During a post-catastrophe intervention management information is needed. Researchers often aim to evaluate the impacts of catastrophic events using statistical models or remote sensing data [48–51]. Our study has a similar aim; gain information on local attitudes and perceptions after in flood-hit areas.

This research is based on a questionnaire survey that took place in two sample areas, which were defined according to GIS Query [60] of natural disaster statistical data (Figure 1). One of the sample areas is in Szabolcs-Szatmár-Bereg county which is between the state border and the Tisza river. Bereg was hit by a flood in 2001, where severe damages were experienced, houses were demolished, infrastructure was damaged. The second sample area is in Borsod-Abaúj-Zemplén county and the area was affected by the floods of the rivers Hernád, Sajó and Bódva in 2010. The two sample areas are the most underdeveloped areas in the country and are highly disadvantaged based on socio-economic and infrastructural indicators. Additionally, based on the ethnic composition of both sample areas, the Roma population is higher than the national average [52, 53], which can be associated with environmental injustices affecting minorities.

The nonprobability sampling procedure was applied, the unit of the questionnaire survey was the household. At least 1% of the population for both samples and at least 10% of households were questioned. A total of 854 households were surveyed, which represented 2512 people.

The population of disaster-stricken areas, in general, afraid, or living in fear from a possible recurrence of another catastrophe. The negative externalities of these events are incorporated into their everyday lives. As first, from the questionnaire data, we have created three principal components to reveal the attitudes and perception of locals. The principal components were the following: fear, social change, and change in the built environment. In this paper, we analyze further the composition of fear principle component since it is strongly related to the security element of freedom and justice [42]. The decisive elements of the fear principal component are 5 statements.

Secondly, decision trees were generated to understand the attitudes and opinion about the perceived natural disasters, since multi-criteria decision analysis used in various research fields [59]. Usually, this statistical method is used by the financial sector for credit assessment [54], but it seems to be a relevant method for our research as it reveals the differences of opinion based on general value-based judgment. Decision trees offer a clear, tree-like struc-

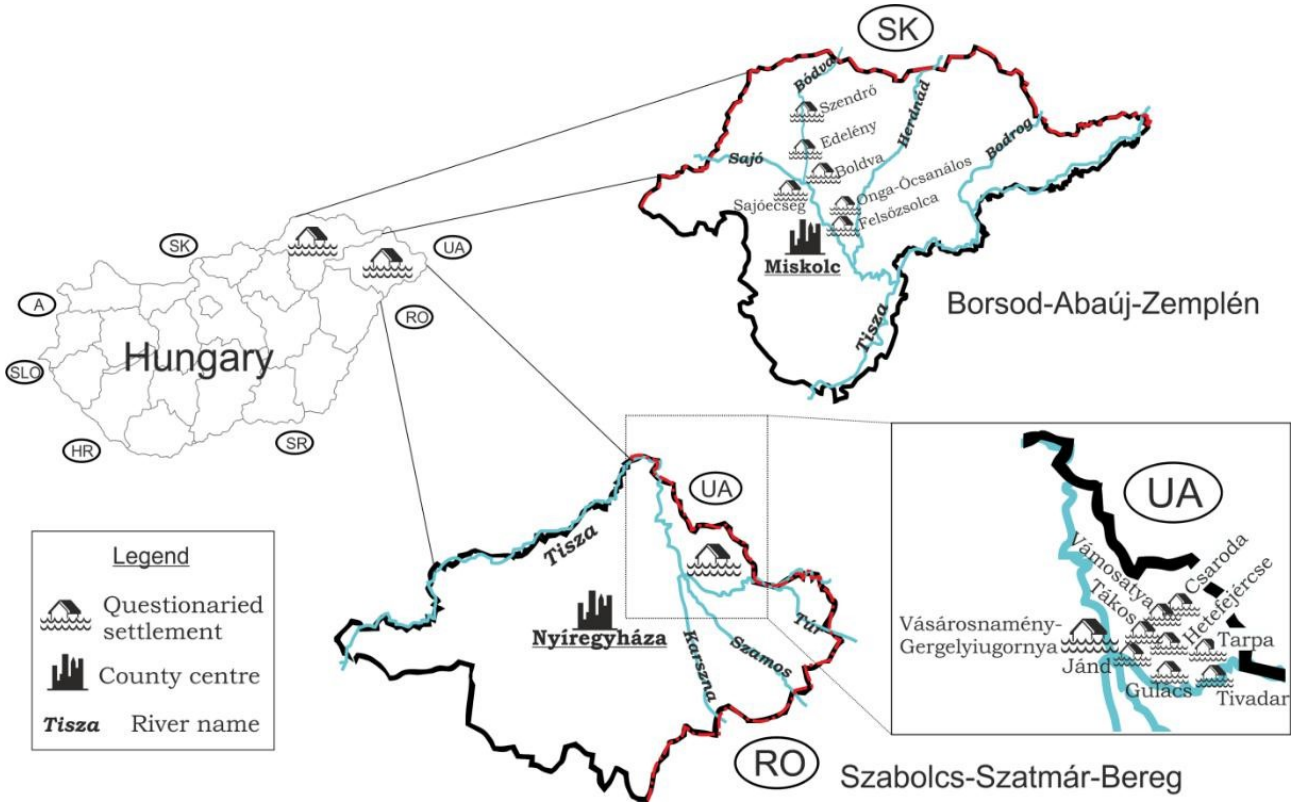

Figure 1: The sample area of the research. Source: edited by the authors

ture, with easily interpreted rules – thus facilitates the determination of rules and logic in complex situations and facilitates the identification of homogenous groups [55, 56].

In defining dependent and independent input variables, the aim was to find out the differences in opinions and their causal relationships. Therefore, from the available data, we built an unattended learning type [57], a mapping decision tree. Chi-square-based CHAID and the regression-based CRT are frequently used to differentiate the variables [54]. Through the nominal (yes-no) type input variables, which can be interpreted as dummy variables, we created a CRT-based decision tree.

Since there were deficiencies in the responses received from the questionnaire (do not know, do not respond), it was necessary to exclude them in the first round. We made relatively small depth decision trees whereby the parental and child nodes were determined for 25 and 15 people, respectively. However, because of the size of the whole sample, these element numbers provided an appropriate source to demonstrate differences between different social groups.

4 Results: decision trees in environmental justice research

For measuring the sense of fear of the population of the research area, sub-components were placed in the principal component, which was related to the sense of danger of their own and their family, the fear of the degradation of the environment and, the flood as a potential source of danger. We built up the main component from five statements, queried people responded on an ordinal scale with four options.

- ☐ People are exposed and vulnerable due to the floods
- ☐ Floods are potential threats for everyone in the region
- ☐ Flood is a huge problem in the region
- ☐ I fear the health of my family due to floods
- ☐ I fear the degradation of the environment of my neighborhood

We hypothesised that flooding is a threat to the people of the research area and as a result, it defines people's everyday lives. Therefore we expected that people will confirm the fear principle component.

Table 1: The difference in the experienced fear according to flood affection. Source: edited by the authors

Were you or your household affected by floods?			N	Mean	Difference of mean t-value
The principal component of fear	Flooded sample area	Yes	639	0.0649	3.965
		No	138	−0.3040	

Table 2: The difference of experienced fear in the subsample areas. Source: edited by the authors

	Subsample area	N	Mean	Difference of mean t-value
Principal component of fear	Bereg	332	−0.090	2.443
	Borsod	408	0.090	

Based on the statistical analysis, the hypothesis was overthrown, since major groups could be determined within the sample. Measurable differences were shown amongst the population affected and unaffected by the disaster. Confirmation and rejection of the principal component of fear are in connection with the involvement and affection by the flood (Table 1). On the basis of these, it is generally confirmed that the directly affected stakeholders significantly confirm the principal component of fear, while those indirectly affected by the disaster reject it. This may justify the assumptions that environmental injustice among those who are directly affected over the longer term may fear more the floods and fear for their lives. This resulted in long-term stamps on their mental and physical well-being.

Due to the high number of settlements that were affected by the flood, we decided to separate the settlements into different groups on a territorial basis for easier comparison. Therefore, Bereg (case study area 1 – CSA1) and Borsod (case study area 2 – CSA2) subsample areas were created (Table 2). In the case of the subsample areas, the previously measured difference of means decreased between the two CSA 1 and 2. Furthermore, there is a faultline between the respondents in the two subsample areas. In the case of the CSA1 settlements, the respondents reject the principal component of fear from the flood, while the respondents in CSA2 confirm it.

However, both confirmation and rejection rates are insignificant. This is due, on the one hand, to the extinguishing effect of the different responses of the chosen settlements. On the other hand, the time has particular importance in the case of decisions and experiences. The Bereg sample area was flooded in the early 2000s, whereas the sampling occurred in 2011 which means more than a decade had passed after the flood. This means that its memories/impacts are much lighter and less harsh in the memories of the people as compared to the Borsod subsample area as the survey was conducted a year after the flood. Therefore, the importance of the time factor described in the literature is confirmed by the perception and ex-post evaluation of disaster situations.

The strongest rejection of the fear principal component was in Tivadar and Csarod, both in Bereg, which means people questioned mainly do not fear from floods. In the case of Tivadar, the affected settlements were completely renewed after the natural disaster Moreover, the high rejection value may be caused by the low number of respondents on the mentioned settlements number. The principal component of fear was confirmed in the settlements of Onga-Ócsanálos, Szendrő, Tákos, and Hetefejércse. The first two of these settlements are from CSA2 and the latter two are from CSA1. Thus, it can be seen that the rejection of confirmation of the component of fear cannot be clearly linked to the subsample areas and the time of the catastrophe. Among these settlements, Tákos was almost completely destroyed and then rebuilt, despite, it is confirming the fear component, so the people questioned still mostly fear of a flood.

In order to further analysis the above findings, we made a decision tree where we examined the ethnicity, the involvement with the flood and the sample area in order to present the relationship with the principal component of fear. The first branch of the decision tree was made by ethnicity, after which the impact by the natural disaster was a junction, finally, the subsample area was examined (Figure 2).

In the flooded areas, ethnic-based segregation and disadvantaged position were concluded in the case of the principal component of fear when preparing the decision tree. The examined sample was divided into two groups based on ethnicity: Roma and Hungarians. While the Hungarians, albeit slightly, rejected the principle component of fear, the Roma people confirmed it, those who have not been harmed, nor their house was damaged, however, reject the fear-component. The perception and damage caused by the floods caused stronger fear than amongst

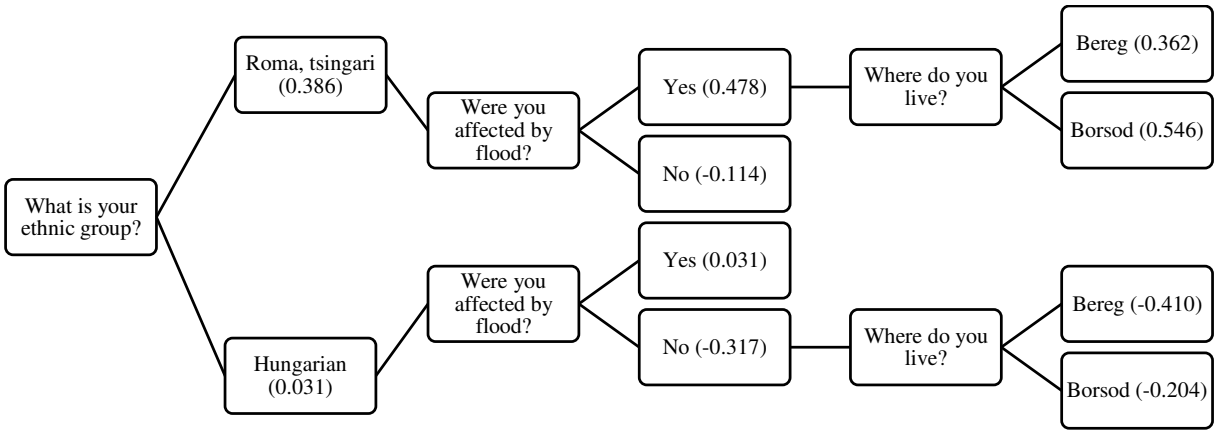

Figure 2: Three-node depth decision tree of flood affection, ethnicity, and subsample area. Source: edited by the authors

the Roma population in comparision to the Hungarian population. This can also be traced back to the unequal compensation process.

Our former hypothesis was extended, with the proviso that only the flood-affected Roma confirm the principle component of fear. The further branching of the decision tree examined territoriality and aimed to reveal whether there was any difference between the individual subsample areas. If the respondents are further divided no difference was detected along the two subsample areas between the Hungarian and the minority respondents. The Hungarians rejected irrespectively of flood affection or damage, while the Roma confirmed the principle component of fear in both case study areas.

In the case of the Roma in CSA2, where the catastrophe was closer to the time of the survey and the settlements are inhabited by the Roma in a larger proportion, therefore the fear was stronger amongst the Roma. Probably due to the longer time passed after the disaster, among the Hungarian population, those who have not been hit by the floods in the CSA1 lower level of fear towards floods was detected (Figure 3).

During the research, we also drew further decision trees, but an appreciable end result with an adequate amount of responses was only created for the aspects of ethnicity and flood risks and dangers. Thus, the first branch of the tree is ethnicity, and the second is the risk of flooding, depending on the principle component of fear. Based on ethnicity, the Roma were confirming, while the Hungarians rejecting the fear factor.

The risk was assessed by respondents on a four-grade scale, with very high, high, low and not significant values. In the case of Roma respondents, there were no respondents who did not consider the risks to be significant or low. Respondents who believed that the risk of flooding

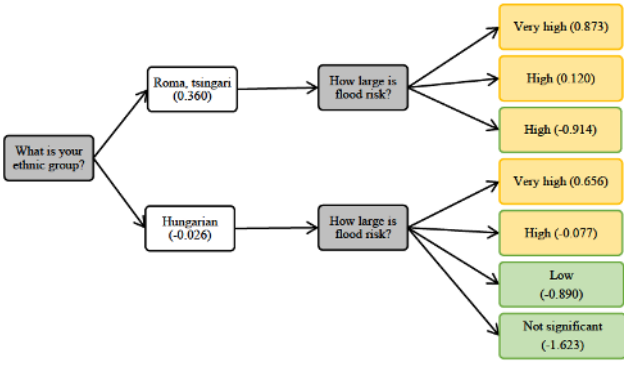

Figure 3: Two-node depth decision tree of fear perception through ethnicity and flood risk assessment. Source: edited by the authors

was very high in the region had a significant confirmation on the fear component, while those who considered the risks to be high were less confirming the component of fear. There is an interesting contradiction in the opinion of respondents who have identified the flood as a high risk, but their feeling of fear is low, the principal component is strongly rejected. This may be due to the fact that these respondents were not directly affected by the flood. Although they are aware of the dangers of flooding, they felt they are personally not in danger not threatened. Among the Hungarian population, all four possible responses to the assessment of risk were chosen, which formed separate groups of opinions with different principal component scores. The process observed in the case of the Roma can be identified in the case of the Hungarian population, those who assess the risk of floods as very high, strongly confirm the principal component. Those who chose the high, the low and the non-significant answer on risk assessment reject the principle component of fear.

5 Discussion and conclusions

As we presented in the study, the main objective and subject of environmental justice research have been transformed over the past decades. Decision-making is becoming more and more important to reveal the causes and process of the procedural injustice, which is the result of the power imbalance and of the different opinions of several interest groups, who can be identified as stakeholders of environmental injustices. The aim of the research was twofold: on one hand, to examine the possibility of the use of an economic analyzing tool and the decision tree, and on the other, to identify separate groups of opinions within the population affected by environmental injustices with this method.

The benefit of this method in social research can be that different groups are formed according to the individual responses given by the questioned population but not according to groups selected by the researchers. The disadvantage of this method is that it can only be used to make small depth decision trees, as the number of sampling elements limits the size of the parental and child branches, which was determined in 25-15 in our study. Based on these, the decision tree method has certain limitations, but it can be applied to explore the social aspects of environmental injustices.

As a result, firstly, it can be summarized that the score of the principal component is markedly different in the case of those who were affected and those who were not affected by the flood, while the former confirms it, the latter rejects the fear principle component.,Secondly, the study also examined the differences between the Roma and the Hungarian population. Considering the issue of affection by floods the decision trees show different views of the minority population. Thirdly, the research examined the differences between two study subsample areas, it can be concluded, that there are no differences along with the geographical position, but the ethnicity and the affection by flood is decisive grouping factor.

Our research highlights the importance of the context and individual positions in the perception and evaluation of environmental injustices and risk. The paper examines the differences of opinions in relation to the management of injustices. Results shows, being Roma results in a higher level of fear. This should be taken into account in the future environmental justice research in post-socialist countries. Furthermore, the results of the research on environmental racism should be incorporated into future research to reveal the similarities and differences between the East-Central European (*i.e.* post-socialist) and North American institutional, historical and cultural contexts.

As a conclusion, the results of the decision tree methods, confirm the possibility of use of this tool in environmental justice research and decision-making process afterward. In a post-catastrophic situation, the traditional intervention and a tool-based input-output-result type of evaluation disregards the different local opinions. These seem to be indifferent to the intervention and rehabilitation process, and usually only discovered after the intervention – if they were discovered at all. However, it would be favorable to involve the population affected by the disaster before and during the intervention and recovery process. So that relevant information that has a significant impact on the development process can be discovered, which can facilitate expert decision-making while emphasizing community involvement in post-catastrophic interventions.

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