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ASSESSMENT OF VULNERABILITY TO CLIMATE HAZARDS IN MUNICIPALITY OF LOM, BULGARIA

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Abstract: An important part of the natural hazard's risk management is the vulnerability assessment. There are many publications proposing different systems of indicators and tools for vulnerability assessment, but very few of them are dealing with the problem on community level. The study for municipality of Lom is carried out on the base of a framework for vulnerability assessment which includes the following important elements: hazard probability, exposure, sensitivity and coping capacity. In this paper we use the spatial dimensions of the areas prone to a particular climate hazard as an indicator for the level of exposure to this hazard. We introduce a measure for the system sensitivity as a function of hazard and exposure classes assigned to these areas. On the base of a system of indicators and scores for the hazard, exposure, sensitivity and capacity, is estimated a Vulnerability Index for municipality of Lom. The results from this case study show that implementation of the proposed Vulnerability Assessment Method provide reliable information for the level of vulnerability to ten climate hazards. It may be of use for different risk management purposes.

Key words: Climate hazards, Vulnerability Index, Vulnerability Maps

Introduction

There is relatively few studies aimed vulnerability assessment to natural hazards at municipality level. This is due to many objective difficulties arising from the need to integrate data from different fields of knowledge and to achieve consistency between them. These data have to be representative for the studied categories and quantified to be able to compare and map the level of exposure and sensitivity of each area with specific land use. Furthermore, research on vulnerability to natural hazards requires equally good competence of researchers in the natural, social and economic sciences, which necessitates an interdisciplinary approach to them. In search of solutions to these challenges are proposed a variety of methods and approaches that are most often applied to larger territorial units, mostly at the national level (IPCC, 2012). This task for

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smaller territorial units, such as municipalities become more difficult because the available statistical data on them are not always sufficient to satisfy a more precise list of indicators such as the one proposed for the assessment of Community Based Disaster Risk with 43 indicators, GTZ (2004). United Nations and the International Strategy for Disaster Reduction distinguish four groups of vulnerability factors (physical, economic, social and environmental) and 26 indicators for assessment of the vulnerability, UNISDR (2005). The more indicators we use and the more detailed information we have the more precise should be the assessment of vulnerability. However, it is a challenge to find a way to do reliable vulnerability assessment using a minimum set of indicators which would provide information about which business activities are threaded of dangerous phenomena, which of them are endangered mostly, and where to focus activities on preparedness, prevention and mitigation. Assessment of vulnerability of different groups of hazards (climatic, geological, hydrological, anthropogenic, etc.) can provide an objective view to the vulnerability of each territorial unit to them and to support the risk management process at the local level.

Study area

For the purpose of this study we estimate the vulnerability to climate hazards in municipality of Lom which covers an area of 324 km2 in North Bulgaria, in Montana administrative district. There are 10 settlements in frames of the municipality with population of 27 294 people in 2011. Town of Lom is it's administrative center and important Danube port with well developed transport infrastructure. Port Lom has 13 berths for loading and unloading activity and 40% of cargo turnover of Bulgarian river ports. The town is center of food industry which is developed on the base of the agrarian specialization of the area. The share of agricultural land in municipality of Lom is 79% and 90% of it is arable land (Kopralev, 2003). Municipality of Lom is situated in Orsoia lowland area with the valley of Lom River and plane relief to the west and east of it. The altitude varies between 20 and 194 m a.s.l. Climate is moderate continental, with average annual temperature of 12,1 ºC and annual rainfall of 500 mm. There is significant soil diversity dominated by Calcic Chernozems – Leptosols, Halpic Chernozems with Gleyc Chernozems and Fluvisols. The forest vegetation is represented by poplar, acacia, oak, ash and lime. There are protected areas at Orsoia wetlands, and some NATURA 2000 sites in Orsoia lowland (Municipality of Lom, 2007).

Method

Terms

There is broad range of terms definitions used in the vulnerability assessment. That is why it is important to clarify first the terms used in the proposed method for vulnerability assessment.

We adhere to the definition, according to which, hazard is "likelihood of an event lead to disaster or loss of life, injury, property damage, social impacts, economic losses and environmental degradation" (United Nations, 2002). It is characterized by a specific geographical location, intensity and probability. Whether the hazard will cause any damage depends on whether the object is exposed to the impact, and whether it is vulnerable to this impact (Nikolova, 1997). Vulnerability is a function of a set of factors (natural, social, economic, legal and management), which determine the sustainability of the system in terms of the impact of a hazardous event. There are many discussions about the definition of vulnerability and they are mostly related to its place in the overall structure of the components of risk. Some authors distinguish "biophysical", "social", "green" and other types of vulnerability (Brooks, 2003) and others defend the view that there is one concept “vulnerability” and from a methodological point of view is wrong to bring in the terminology above varieties, (Kobler et al., 2004, Nikolova and Nedkov, 2012). Vulnerability really depends on many different factors, but always is assessed to any specific threat and must be estimated precisely in terms of the impact from it. According to UNISDR (2007), vulnerability is “The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.” Measure of vulnerability is potential impact. It depends on the type of hazard, system’s sensitivity, it’s resilience and adaptive capacity. Sensitivity is defined as “degree to which a system will respond to a change in climatic conditions” (Guide to integration, 2002). The introduction of the term "adaptive capacity" is related to studies on risk of climate change and is interpreted in the context of vulnerability. Brooks (2003) defines adaptive capacity as a "potential of the system to adapt to changes”. In respect to this the coping capacity is critical for the reduction of disaster risks. It is defined as “The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters”,UNISDR, 2007.

Method

The implemented method for assessment of vulnerability to climate hazards on municipality level follows the framework from the method for assessment of vulnerability of agriculture to climate change at community level VAST-Agro Garcia et al. (2012). In this framework, exposure (E) and sensitivity (S) scoring provide information about the potential impact (PI). The level of vulnerability (V) depends on the difference between adaptive capacity and potential impact and is represented by a vulnerability index (1). For the purpose of this study we work with Coping Capacity Index (CCI) instead with Adaptive Capacity Index.

Vulnerability Index (VI) = Coping Capacity Index (CCI) – Potential Impact Index (PII)

Were:

$$CCI = \frac{\text{Total Coping Capacity Score (TCCS)}}{\text{Total Max Coping Capacity Score (TMCCS)}} \quad (2)$$

And

$$PPI = \frac{\text{Total Exposure Score (TES) + Total Sensitivity Score (TSS)}}{\text{Total Max Exposure Score (TMES) + Total Max Sensitivity Score (TSS)}} \quad (3)$$

Implementation of this approach includes the following steps: 1) Identification of climate hazards observed on the municipality territory; 2) Identification of the systems which are exposed and sensitive to each hazard type; 3) Assessment of exposure; 4) Assessment of sensitivity; 5) Assessment of coping capacity; 6) Assessment of CCI; 7) Assessment of PPI; Assessment of VI; 8) Mapping E, S and CC.

Scoring refers to 3 levels scale for all variables. There are ten types of climate hazards included in this research. The hazard scores refer to the highest frequency of events in the scale. If it is in level 3 of the scale, the hazard score for this climate hazard is 3.

The systems exposed to each of these hazards are characterized by the total area of the Land Cover classes in the nomenclature of CORINE level 3 for municipality of Lom. Scoring of exposure depends on the share of the system area of the total municipality area.

The scoring of coping capacity is done on the base of set of 17 coping capacity indicators presented in Table 1.

Table 1. Municipality coping capacity indicators for vulnerability assessment

Factor	Indicator	Mesiure
Demographic		
	Population density	Persons/km2
	Demographic pressure	Growth rate (%)
	Vulnerable population <9and>75	Share of mun. population (%)
	Dencity of the settlements	Number/km2
Social		
	Water suply and sanitation	Share of housing with (%)
	Health care	Population per a medical doctor
	Education	Average number of schools per a settlment
	Social institutions	Average number of social institutions per a settlment
	Community participation	Participation in last voting (%)
Economc		
	Local resourse basis	Share of industrial sectors (%)
	Diversification	Number of industrial sectors
	Accessability	Transport network km/km2
	Human Development Indices	Grade
Environmental		
	Protected areas	Share of municipality area %
	Areas under forest	Share of municipality area %
	Degradeted land	Share of municipality area %
	Irrigated land	Share of arable land %

Source: UNISDR (2005) with significant changes.

The assessment of Vulnerability Index, Coping Capacity Index and Potential Impact Index is estimated according the formulas (1), (2) and (3) and Vulnerability Index is evaluated according the scale in Table 2.

Table 2. Vulnerability Index evaluation scale

Index value	Evaluation
0.80 - 1.00	Extremely resiliant
0.50 - 0.79	Highly resilient
0.20 - 0.49	Moderately resilient
- 0.19 - 0.19	Vulnerable
- 0.49 - - 0.20	Moderately vulnerable
- 0.79 - - 0.50	Highly vulnerable
-1.00 - - 0.80	Extremely viulnerable

Source: Garcia et al. (2012)

Maps

Using the results form implementation of this method we suggest two maps: “Level of exposure to climate hazards in municipality of Lom” and “Level of sensitivity to climate hazards in municipality of Lom”.

The level of exposure of each territorial system is calculated as a value which represents the product of multiplication of hazard and exposure scores for each one hazard and each one system. The sum of these values is multiplied on the number of hazards relevant to each one system (Table 6). The visualization of the results shows the relative level of exposure of each system in frames of the municipality to the observed group of hazards or to one particular type of hazard (Fig. 2A).

The level of sensitivity of each socio-economic system is calculated as a value which represents the product of multiplication of exposure scores for each one system and sensitive scores for each one hazard in each one system. The sum of these values is divided on the number of hazards relevant to each one system (Table 6). The visualization of the results shows the relative level of sensitivity of each system in the municipality to the observed group of hazards or to one particular type of hazard (Fig. 2B).

Results

For assessment of vulnerability of Lom municipality we created a Vulnerability Assessment Tool in an Excel table. After input of the scores for the hazard, exposure and coping capacity, the results for sensitivity were calculated. This tool helps the vulnerability assessment to be carried fast, provide option for updates and for mapping of the hazard, exposure and sensitivity.

Hazard

Identification of climate hazards and of the systems which are exposed and sensitive to each hazard type was done on the base of information for the observed climate hazards in Lom during the period 2003-2012. On the base of distribution of maximum frequency of occurrence was made scoring for each hazard according three categories scales: 1 – Low, 2 – Medium and 3 – High, Table 3.

Source of meteorological information about the studied climate hazards in last 10 years (2003-2012) was the data base from the Bulgarian site for weather discussion and information (http://www.stringmeteo.com). The scoring of draught hazards was done on the base of the map “Difference between precipitation and evaporation (1976-2005)” in Bulgaria Geographic Atlas (2010).

Most common hazards in the study area in last 10 years are thunderstorms (431), fogs (392) and extreme temperature in the warm semester of the year (122), Table 3.

The average number of days with thunderstorms in Lom is 43,1 with a maximum in May (8,7). They cause negative effect on the city’s infrastructure, on the crops and forests, and in some cases thunderstorms may cause direct threat for human lives.

The average number with fog days is 39,2 but there is significant difference between theirs seasonal distribution with 53,6 % in winter months, 40,3 % in autumn and only 6,1 % in spring. The higher frequency of days with fog is prerequisite for higher level of air pollution which indirectly worsened the living environment. In addition to this the more days with fog cause inconvenient for the transport systems and for the related to them business activities.

The group of hazards which cause strong effect on the living environment, agriculture, transport and business are the temperature and precipitation extremes. While there is only one day with temperature below -20°C in Lom registered on 01.02.2012 (-22,6°C), the average number of days with temperature above 35°C during the same period of observation is 12,2 with maximum of 5,5 days in July. The observed maximum number of consecutive days with temperature above 35°C in Lom is 18 registered in July 2007 and in July 2012. Situations like this are treated as very dangerous for human health and also for ecosystems and most outside human activities. In 2007 there are registered also extremes of 40°C (26.06.2007) and 40,3°C (24.07.2007).

The average number of days with heavy precipitations above 25 mm/24h is 2,7 with maximum in August. Precipitations above this amount cause problems to the city’s sewage and drainage systems, roads and agricultural lands. They may have also triggered effect for activation of landslides, soil erosion and river rising. There are 2 precipitation extremes registered in last 10 years in Lom. The first one is in September, 2003 (133,9 mm/24h) and the second one is in February, 2005 (102,1 mm/24h).

During the winter (December-March) the number of days with snow cover depth more than 20 cm are observed rather often in the study area. Average number of days in a year is 11,5 with maximum in February – 6,1, followed by January –

3,7, December - 0,8, and March – 0,9. There are 2 extreme cases in the period registered in February (72 cm) and March (89cm), 2003. Events like these caused problems mainly to the transport systems and as a consequence to the related business activities.

The group of agro-climatic hazards (late spring frost, early fall frost, drought and hail) is very important for the observed predominately agrarian territory. Because of the influence of Danube River, the threat from late spring and early fall frost hazard in the area is relatively low. There are 116 days with frost registered in last 10 years and there is no significant difference in theirs numbers in the spring, from March to May, (57) and fall, from September to November (59). In 40% of the years the frequency of spring frost and in 50% of the years the frequency of the fall frost events is less than 3 cases in a year, (Category 1 – Low hazard). The distribution of the years with 4-6 events per a year, Category 2 (Medium hazard), is 20% for spring and 10% for fall frost hazard. The distribution of the years with more than 6 events per a year, Category 3 (High hazard), is per 40% for both spring and fall frost hazard. In this case we assume that there is higher spring frost hazard because the share of cases in Category 1 is less (40%) and those in Category 2 (20%) are higher than the fall frost hazard. As a result the spring frost hazard is scored with 3 hazard scores, and the fall frost hazard with 1 score, Table 3. The number of days with late spring frost (May) and early fall frost (September) is 0.

The hail falls are typical for the period from May to August. The average number of days with hail for the period 2003-2012 in Lom is 10,1 with maximum in June (4,2), followed by July (2,8), August (1,7) and may (1,4). In 40% of the years are registered per 7-9 events in a year (Category 1), in 40% - per 10 to 12 events in a year (Category 2) and in 20% per more than 12 events (Category 3). As general this is a hail prone area and there is a polygon for hail suppression in the frames of Montana district.

The drought is scored as high hazard with 3 scores on the base of observed difference between precipitation and evaporation which in this area is between -200 and -300 mm and indicate an arid area, (Bulgaria. Geographical Atlas., 2010). Municipality of Lom is classified also as an area with high drought hazard according to the Coefficien of humidity for the period of active vegetation (T°C > 10°C) (Alexandrov, 2011). The assessment of drought hazard according to the Palfai Aridity Index also indicates the area of Lom- Valchdram as very dry (Grigorescu et al., 2013).

As general half of the investigated climate hazards poses relatively low hazard (1 hazard score), two hazard types poses medium hazard (2 hazard scores) and three hazard types are estimated as high hazard (3 hazard scores) Table 3.

Table 3. Distribution of climate hazards frequency of occurrence and hazard scores in Lom (2003-2012).

Hazards	Meashure	Observed period	Number of days in 10 years	Frequency in category 1 – Low (%)	Frequency in category 2 – Medium (%)	Frequency in category 3 – High (%)	Hazard scores
Thunderstorm	Number of days	2003-2012	431	10	80	10	2
Snow depth > 20 cm	Number of days	2003-2012	115	50	20	30	1
Temperature Extremes > - 20 °C	Number of days	2003-2012	1	100	0	0	1
Temperature Extremes > 35° C	Number of days	2003-2012	122	70	0	30	1
Heavy precipitations > 25 mm/24h	Number of days	2003-2012	27	50	30	20	1
Spring frost	Number of days	2003-2012	57	40	20	40	3
Fall frost	Number of days	2003-2012	59	50	10	40	1
Drought*	Coefficien of humidity	1976-2005					3
Hail	Number of days	2003-2012	101	40	40	20	2
Fog	Number of days	2003-2012	392	20	40	40	3

Source: *Bulgaria. Geographical Atlas (2010)

Exposure

Identification of the territorial systems which are exposed and sensitive to each hazard type is a matter of an expert decision. The level of exposure depends on the share of area of all Land Cover classes which characterized the system Table 4, Figure 1A. When it is more than 50% of the municipality area of 32805,8 ha, it’s exposure to respective hazard is High – 3 scores. If the area is between 11 and 50% it’s exposure is Medium – 2 scores, and if it is less than 10% the exsposure is Low – 1 score. The column “Systems” in Table 4 indicate to which and Cover class to which system is referred (Living environment (LA), Agriculture and Natural systems (A), Transport (T) and Bussines (B)), Figure 1B.

Table 4.Total areas of Land Cover classes, CORINE level 3, 2006, in municipality of Lom, Bulgaria

Code	Land Cover classes	Area	Share	System	System Exposure
		(ha)	(%)		Score
112	1.1.2. Discontinuous urban fabric	1863	5,679012	LE	1
121	1.2.1. Industrial or commercial units	691	2,106386	B	1
142	1.4.2. Sport and leisure facilities	28,6	0,087182	LE	1
211	2.1.1. Non-irrigated arable land	19332,7	58,93217	A	3
221	2.2.1. Vineyards	292,8	0,892547	A	1
222	2.2.2. Fruit trees and berry plantations	191,4	0,583448	A	1
231	2.3.1. Pastures	1239,6	3,778692	A	1
242	2.4.2. Complex cultivation patterns	2157,9	6,577961	A	1
234	2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation	2359,7	7,193111	A	1
311	3.1.1. Broad-leavedforest	1479,6	4,510288	A	1
321	3.2.1. Natural grasslands	45,1	0,137479	A	1
324	3.2.4. Transitional woodland -shrub	538,7	1,642128	A	1
411	4.1.1. Inland marshes	509,2	1,552202	A	1
511	5.1.1. Water cources	1967	5,996037	T	1
512	5.1.2. Water bodies	109,5	0,333791	A	1

Source:http://sia.eionet.europa.eu/EAGLE/Information_provided_EAGLE_MS/16_CLC_to_LCCS_conversion_notes_v1.0.pdf

The highlighted sells in Table 5 indicate to which hazard type is exposed and sensitive each one evaluated system (Living environment (LA), Agriculture and Natural systems (A), Transport (T) and Bussines (B)).

The exposure weight in Table 5 for each hazard and system is result of the multiplied hazard scores and the sum of all exposure scores relevant to each one hazard. Than the exposure scores from 1 to 3 are given to the exposure weight (EW) values as follow: EW from 0 to 4 - Low exposure - 1 score, for EW from 5 to 7 - Medium exposure - 2 scores and for EW from 8 to 12 – High exposure – 3 scores.

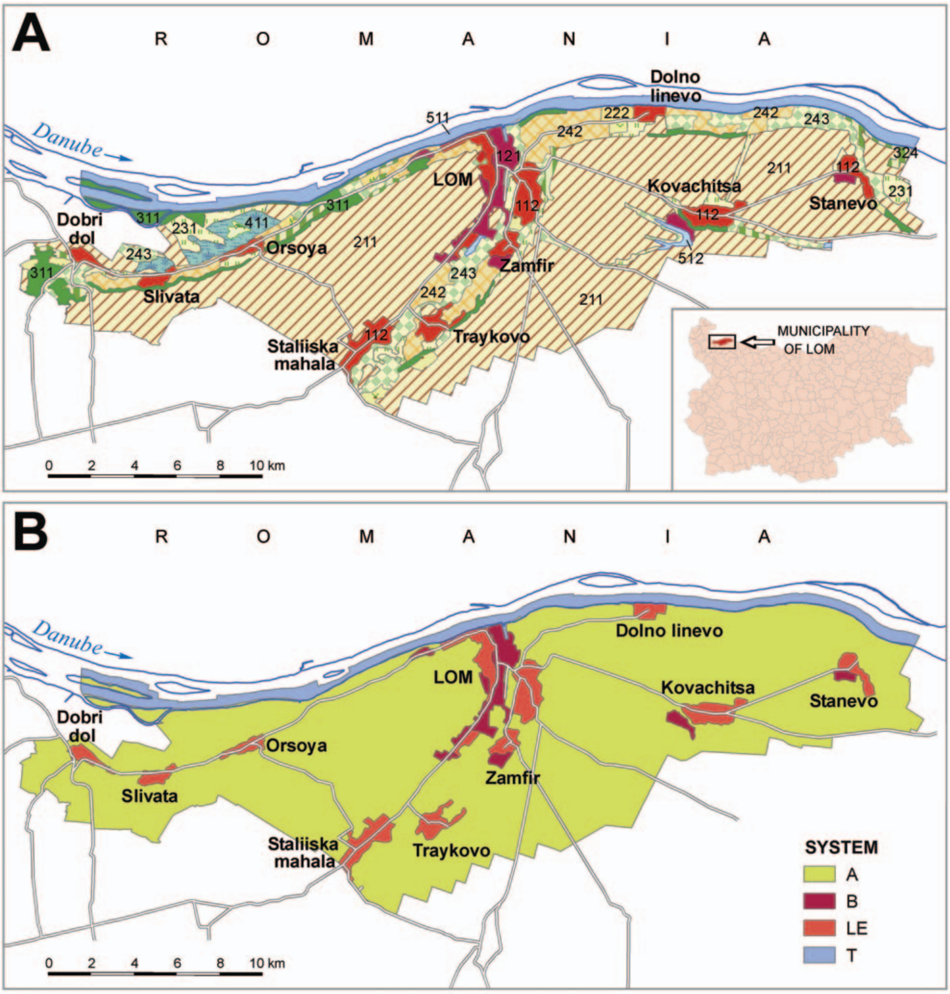

Figure 1. Land Cover classes in municipality of Lom (A) and the systems to which they refers (B).

The highest level of exposure, (EW > 10), is estimated to the impact from thunderstorm and drought hazard. Agriculture is exposed to 8 types of climate hazards, living environment – to 7 and both transport and business systems to 5 different climate hazards, Table 5.

The level of exposure of the territorial systems in municipality of Lom to the observed climate hazards is presented in Table 6 and on the map (Figure 2 A).

Sensitivity

Total sensitivity is result of the exposure weight divided on the number of systems exposed. For values of total sensitivity (TS) from 0 to 1 – Low sensitivity - 1 score, from 2 to 3 - Medium sensitivity – 2 scores, and from 4 to 5 – High sensitivity - 3 scores, Table 5.

The systems in municipality of Lom are most sensitive to the impact of thunderstorm (TS 3), hail (TS 3), and drought (TS 3) hazard. Table 5 integrates hazard, exposure and sensitivity results.

The level of sensitivity of the territorial systems in municipality of Lom to the observed climate hazards is presented in Table 6 and on the map (Figure 2 B).

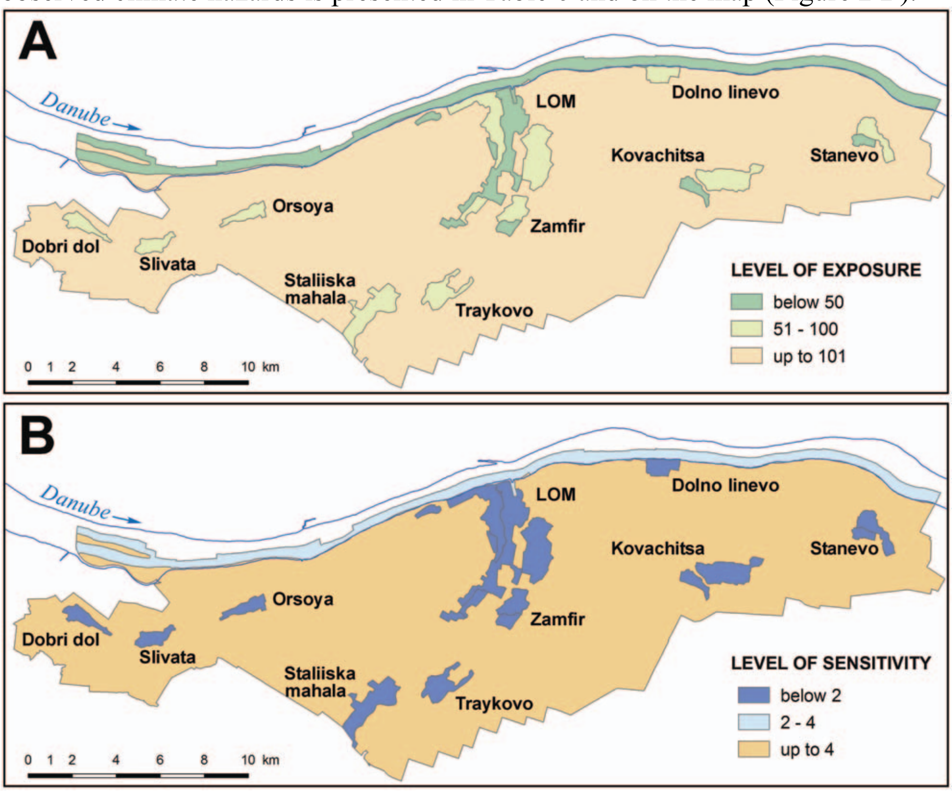

Figure 2. Level of exposure (A) and level of sensitivity (B) of the territorial systems in municipality of Lom

Coping capacity

Table 7. Coping capacity indicators for vulnerability assessment in municipality of Lom

System	Indicator	Mesiure	Lom	CC Score
Demographic				
	1. Population density*	Persons/km2	84	3
	2. Demographic pressure*	Growth rate (%)	-22	2
	3. Vulnerable population groups*	Peopole < 9 and > 75 (%)	16	1
	4. Dencity of the settlements	Number/km2	0,03	2
	5. Human Development Indices	Grade	53	2
Social				
	6. Water suply and sanitation**	Share of housing with (%)	100	3
	7. Health care**	Population per a medical doctor	611	3
	8. Education**	Average no.of schools/settlment	1,4	3
	9. Social institutions**	Average no.of soc.inst./settlment	0,4	2
	10. Community participation**	Participation in last voting (%)	65	3
Economc				
	11. Local resourse basis**	Share of industrial sectors (%)	20	3
	12. Diversification**	Number of industrial sectors	5	2
	13. Accessability**	Transport network km/ km2	0,4	3
Environmental				
	14. Protected areas**	Share of municipality area (%)	0,5	1
	15. Areas under forest**	Share of municipality area (%)	10	1
	16. Degradeted land**	Share of municipality area (%)	9	2
	17. Irrigated land***	Share of the arabel land (%)	25	2
Total				38
Total max				21

Source:* NSI Yearbook (2013) , **Municipality of Lom Deveopment Program (2007-2013), *** Kopralev (2003)

Coping capacity (CC) evaluation is made on the base of 17 indicators divided in 4 groups: demographic, social, economic and environmental. The demographic indicators measures are evaluated in respect to the indicators values for the administrative district Montana to which the municipality of Lom belongs. If the municipality indicator value is lower that the district value it is scored with 1 – Low capacity. If the municipality indicator value is equal or around the district value it is scored with 2 – Medium capacity and if it is higher is scored with 3 – High capacity. The same evaluation scheme is used for the indicators from the rest three groups where the measure is percent but the assessment is in respect to the municipality and not to district level. For the rest indicators evaluation is done in respect to the average values for the country, national standards or the expert view by the same scheme. For example indicator 13 is scored with 3 in spite of the low roads density because the expert took under consideration the fact that Lom is transport center with a port and railway network and there is diverse transport options, which is an advantage in case of emergency situations, Table 7. A valuable indicator is the Municipality Human Development Index (MHDI). According to the last National Report on Human Development UNDP (2004), municipality of Lom is on place 53 with MHDI index 0.784. Municipal Human Development Index is a composite indicator in terms of three factors - health, education, economy. For the evaluation of these factors are used statistical variables: life expectancy, literacy rate and enrollment, municipal GDP per capita. Human Development Index is an alternative measure of development addition to economic indicators (National Report , 2004).

Indices

The Vulnerability Index (VI), Coping Capacity Index (CCI) and Potential Impact Index (PII) are calculated according the formulas (1), (2) and (3). The Vulnerability Index is evaluated according to the scale in Table 2.The index values are calculated on the base of data for TCCS (38) and TMCCS (21) in Table 7 and for TES (22), TMES (15), TSS (18) and TMSS (6) in Table 5. The values of the calculated indexes are as follow: Coping Capacity Index is (1,8), Potential Impact Index is (1,9), and Vulnerability Index is (-0,1). According to the evaluation scale in Table 2, Vulnerability Index of (- 0,1) indicate that the system is vulnerable to investigated climate hazards.

Discussion

The result shows that the study area is vulnerable to climate hazards. This result is very relevant to municipality of Lom because we assess vulnerability to climate hazards, which includes most of the observed agro climatic hazards, for a territory of which 79% is agriculture land. It is well known that the level of vulnerability depends on land use practices in a given territory, but it is important also to pay attention on the interrelationship between the type of hazard and the share of the municipality territory exposed and sensitive to the impact of a particular hazard, heaving in mind it’s intensity and frequency.

Visualization of spatial dimensions of vulnerability represented by the level of exposure and the level of sensitivity maps is a useful tool for decision makers. It provide information about the territorial systems which are more sensitive to the impact of particular type of hazard or of group of hazards and is a good option to compare the level of exposure and sensitivity to each hazard in a spatial context.

Use of Land Cover classes (LCC), level 3, also provides space for more detailed vulnerability assessment for each one LCC.

One of the serious obstacles for implementation of the national programs for adaptation to climate change and associated climate hazards is the luck of information about dimensions of threat, it's spatial distribution and resilience/vulnerability of the systems exposed to it. Both, coping capacity and adaptive capacity are closely related but not equivalent because we need to use different indicators to assess adaptive capacity to climate change.

The proposed method for vulnerability assessment provides reliable answers to a set of questions like:

What are the dangerous phenomena that occur? How dangerous they are? Which systems are most exposed to one or a grout of hazards and to what extend? How sensitive are the systems to this impact? What is capacity of the municipality to deal with the threats or to prevent them?

Local governments are faced to the need to implement successful risk management and it is very much a matter of the management of the municipality territory. The digital maps of hazard, exposure and sensitivity provide not only useful information for different management purposes but also make possible implementation of GIS modeling and testing of the expected results from one or another decision. In addition to this, the method may be applied to different hazards or hazard groups and provide base for comparison of the vulnerability between them.

There are some difficulties regarding the availability of meteorological and socio-economic information for one and the same periods of observation. In addition to this we use only indicators for which it was relatively easy to get public information and they are quite general. One more precise selection of the coping capacity indicators in respect to the particular type of threat and land use features of territory would improve significantly the vulnerability assessment.

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