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Environmental Disaster Risks Identification in Arda River Basin, Bulgaria

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Synopsis

The paper explores environmental disaster risk and applies the system approach in Arda river basin, Bulgaria. Target area is located in Southeast Bulgaria and much affected by environment disaster risk (floods, soil erosion) and also suffered a severe socio-economic decline in the last 15 years. The Interpretive Structuring Method (ISM) has been implemented in order to fix the relationships between elements of social, eco and geosystem, to determine the input and output and to analyze cause-effect interactions. 15 components have been determined and located on 7 levels.

Keywords: environmental disaster risk, systems approach, Interpretive Structuring Method (ISM)

1. Introduction

Studying disaster risk processes requires a profound knowledge on social, ecological and physical environment regarded as systems where these hazardous events evolve, take place and cause damages to people and economy. In that sense disaster risk is to be regarded as a significant social phenomenon impacting life and existence of people.

Considering risk from the point of view of systems engineering, it can be hierarchically ordered, since “most organizational as well as technologically-based systems are hierarchical in nature, and thus the risk management of such systems is driven by this hierarchical reality and must be responsive to it. The risks associated with each subsystem within the hierarchical structure contribute to and ultimately determine the risks of the overall system. The distribution of risks within the subsystems often plays a dominant role in the allocation of resources.” (Haimes, 1998).

In that aspect, risk is a composite, complex concept that reveals and reflects the mutual relationships between systems and their elements both in horizontal (the relationships between elements or systems of one and the same level in the hierarchy) and vertical (the relationships between elements or systems of different levels in the hierarchy).

Present paper focuses on environmental disaster risk as a complex phenomenon interweaved with social, ecological and geosystem.

The first one comprises people and all aspects of their life. Nature disaster risk events inflict damages to human society and hence they can be considered as social system phenomena. Ecosystem constitutes of all the living organisms. It’s a vulnerable entity because of the composite relationships between its elements. Geosystem involves the non-living nature features and their state – air, rocks and waters, where abrupt oscillations of processes trigger nature disaster risk events that affects the eco and social system.

Spatial and temporal aspects of nature disaster risk are of a great significance for studying the genesis and occurrence of hazardous events. Certain areas appear to be much prone and/or vulnerable to disaster risk while others not, but with the time spatial occurrence may change.

2. Basic characteristics of Arda river Basin

Basin of Arda River located in the Southeast part of Bulgaria is evidently one of the territories in the country most strongly affected and by various types of nature disaster risk. Target area comprises a surface of about 5200 km^2. It includes territories of the Central and East Rhodope mountains (Fig. 1). This surface has a well-elevated mountainous relief (the highest peaks in the west reach about 1800-2000m of elevation) except for the eastern part. Volcanic rocks predominately constitute the geologic background of the mountain. Climatic conditions are varied, depending on the elevation and slope exposition.

The water resources are irregularly distributed over the time. The river runoff marks extremely high values in winter, since summer shows to be a fairly dry period. Soils are very shallow, only 15-20cm in depth, and extremely susceptible to erosion and disturbance of structure. Vegetation is varied but impacted to a high extent by the intensive human activity.

It's evident that in the target area nature has been for long time affected by hazard and risk disasters and therefore is highly susceptible to that influence. The human activity, and especially the mining industry, has significantly contributed to deterioration of environmental conditions polluting nature with heavy metals; also making excavations and taking off the soil layer that causes development of erosion.

Apparently, disaster risk processes occur and develop in varied ways depending on the state of social, eco and geosystem components. Thus, an essential step to explore risk evidence is to construct a model considering cause-effect relationships and interactions between the latter.

Fig. 1. Map of Bulgaria and Location of Arda River Basin.

3. Basic concepts and ideas of the Interpretive Structuring Method (ISM)

Implementation of methods analyzing the structure and interactions between their various components provides valuable information for better understanding and investigating social and nature environment. One of these tools is the ISM – Interpretive Structuring Method developed in the 70's and 80's (Warfield, 1973; Steward, 1981b; Steward, 1991) to synthesize and expose on a graph components of diverse systems and their mutual relationships.

Graphs themselves are developed by elaborating matrices and processing them further on ISM program to create a visual presentation of systems and their constituents. Matrix reveals the latter in a table-shape appearance where the systems components and elements constitute the rows and columns headings, and relationships between them are depicted as information placed in each cell of the matrix. If the task is only to detect whether a relationship exists between components or not, it's a simple binary matrix to be used. In that case, the digits 0 and 1 will be assigned to each cell, showing if there is any relationship between the intersecting components (1) or not (0). Another important condition is that the matrix should be symmetric, the rows and columns in it consisting of the same compounds put in the same order (but transposed). There are 3 basic arrays in matrix cells describing the relationships between elements: parallel, sequential and interdependent. The first one comes in case where there is no relationship between components, processes and phenomena running in them separately. The second relationship is evident when one element influences the other, but there is no feedback relation. Hence, first event or element appears to be as a cause and the second is the result of it. The third interaction that is to be found in the matrix is the interdependent one and it takes place when there is a direct and feedback-loop behavior between 2 elements. Thus, matrix representation of data on relationships between systems components is a compact and way to store and process further by plotting on graphs different databases regarding systems and the multitude of interactions taking place amongst them. (The Design Structure Matrix - DSM Home Page).

For the task of researching disaster risk in terms of soil erosion, floods and heavy metal pollution in the scope of Arda river basin, Bulgaria, implementation of ISM can provide feasible results for:

[1] Recognizing the social, ecological and geosystem together with their elements;

[2] Finding out the relationships and their direction between elements of the 3 systems;

[3] Categorizing and ordering elements in accordance with cause-effect interactions and determining what the source of disaster risk event is, how does it impact the various components of the 3 systems and what the consequences are;

[4] The graph can facilitate database collection and its further analysis by knowing how systems components are classified and what the essence of interaction between them is.

4. Stages of the ISM graph elaboration

Sophisticated relationships and interactions take place between human society and nature, as a result of which disaster risk phenomena like floods, soil erosion and pollution occur and thus threaten the people and their life. These events happen independently from the humans; to a high extent they are not controllable as well, but the harms and damages they incur may inflict significant losses (in terms of money) and suffer by people. The multitude of processes and phenomena involved in disaster risk occurrence and effects can be described in a better way by analyzing the most important components of social, ecological and geosphere by ISM approach. In order to be correctly performed, the data needed have to be collected, proceed and analyzed on several stages.

4.1 Selection of components

The total number of components involved in social, ecological and geosystem is to be fixed. That can be easily done when using the conceptual scheme of the research and its explanations, f. inst. by counting the keywords and nouns related to systems. Doing so, it turns out that in aggregate there are as many as 100 and even more systems constituents. Such a large number is not intended for the objective of ISM because the matrix that is to be created will be very redundant and not understandable. The number of components therefore should be significantly reduced, whereby only basic items are to be used.

4.2 Reduction and classification of the selected components

At the second stage, reduction of systems elements is to be performed. It is fulfilled by means of combining several elements in one, which appears to have the most important properties that impact further the whole system, or cutting-off some unnecessary, repeatedly used or elements with similar or same properties. Proceeding in that way, the number of most important system components has been reduced to 15, and most of them belong to the most sensitive system – the social one. Data depicted on ISM Analysis Graph on Interactions Between Socio-, Eco, and Geosystem developed for the purpose of studying Arda River Basin, Bulgaria, have been obtained after a careful selection of the basic components of social, eco, and geosystem for the target area. Thus, the 15 systems components chosen for the purpose of ISM-modeling, can be classified as follows (Table 1).

As it's seen from the table, most of the system elements come from social system. In the latter, sophisticated interactions take place, not only between purely social phenomena, but also related to nature and ecological disaster risk events that profoundly impact economic activity and daily life of people. From the ecosystem and geosystem, only the most important components have been derived with regard to the social system. It's to be mentioned also that some processes

Table 1. Classification of the system components according to the system they belong.

Social System	Ecosystem	Geosystem
Industry (wood, textile, construction...)	Deforestation	Nature disaster risk
Soil erosion	Flora & fauna	Mineral resources
Heavy metal pollution	Environmental disaster risk	
Water utilization system		
Daily life		
Tourism		
Agriculture		
Transportation & communications		
Flood		
Mining (metallurgy)		

(deforestation) or objects (mineral resources) belong both to the social system, ecosystem or to the social system and geosystem, respectively, because their impact affects the respective 2 systems.

4.3 Setting components into a matrix

Next stage of work involves setting the elements into a matrix and assigning them binary values (either 0 or 1), depending on if there is any relationship between them or not. The columns of matrix represent the components as effects produced by certain developments depending on the cause-components. In order to simplify more the contents and to represent on the graph, only essential one-direction interactions between systems components, all the matrix cells from the lower section have been assigned value 0. Proceeding in that manner, it's important to arrange the studied system elements in a proper manner, so that the basic one – the sources triggering disaster risk and the disaster risk events should be set on a front place, and the elements impacted by these processes must be ordered latter. Data input into a binary matrix is performed in order to establish the possible cause – effect relationships between components. Binary matrix is symmetric, square in shape, the rows and columns of which consist of the same set of elements input in the same order. Places of intersection in the matrix indicate if there any cause-effect relationship between components exist (then it's assigned 1) or not (assigned 0). Another important condition is that elements in the rows indicate the cause, since those in the columns indicate the effect. It's often the case that all the components of the respected systems may have mutual relationships. Hence, only direct cause-effect interactions should be designated as "1". Because of the complexity of derived graph, and many junk-like arrows indicating relationships, it could be difficult to read and interpret it, so that another reduction even of the direct cause-effect relationships is needed. Some other limitations of the program do allow only one-direction arrows indicating no possible feedback linkage that may exist between systems elements. The matrix derived has the appearance (Table 2).

4.4 Derivation of ISM graph

The most important stage of analysis is implementation of ISM, as a result of which the graph of interactions between elements is created. It represents in a synthesized appearance the consecutivity of interactions between systems components and their ordering that depends on which event comes first and triggers the occurrence of other processes. On the very first, primary levels of the graph, the input elements in the system are located. This input may come either from geo or from social system and have a key importance for other components setting up. System elements from intermediate levels indicate the complex transitions and iterations of relationships between system elements after the input factors have been set and usually they react as a

Table 2. Binary matrix for the selected elements.

	industry (wood, textile, construction...)	deforestation	soil erosion	heavy metal pollution	water utilization system	flora & fauna	daily life	tourism	agriculture	transportation & communication	flood	mining (metallurgy)	mineral resources	natural disaster risk	environmental disaster risk
industry (wood, textile, construction...)	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
deforestation	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
soil erosion	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1
heavy metal pollution	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1
water utilization system	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
flora & fauna	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
daily life	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
tourism	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
agriculture	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
transportation & communication	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0
flood	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
mining (metallurgy)	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
mineral resources	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
natural disaster risk	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0
environmental disaster risk	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

response to the initial affect caused by those elements located at the system input. The components located at the latter levels in the graph indicate strong dependence on previous-level items coming as a result of all interactions in the system and therefore can be defined as output elements. They are very sensitive to any interaction in the system depicted on the graph and highly vulnerable to negative changes in the system. Usually at these levels those social system components can be found, that are related to the people and their life.

5. Analysis of systems components characteristics basing on the ISM graph

In the case of ISM Analysis Graph Developed for the Purpose of Studying Arda River Basin, Bulgaria, the 15 aforementioned components are ordered on 7 levels.

5.1 First level of the graph

The first topmost level involves as an input factor the nature disaster risk. It can be considered as a social phenomenon inflicting many hazardous processes and impacting negatively the whole social system. As nature disaster risk originates from instantaneous, rapidly occurring nature events that take place in the geosphere and its appearance cannot be avoided or controlled in any way, it's located on the uppermost level of the graph as basic input in the system.

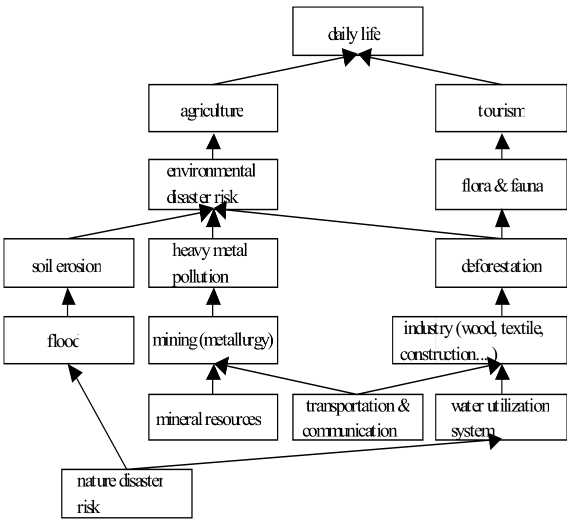

Fig. 2. ISM graph developed for recognition of systems elements and their relationships.

The direct effect of nature disaster risk refers both to water utilization system located on the next lower stage, and floods that stay 2 levels below. Linkage on water utilization consists in severe disaster risk hazards like floods, climatic perils or escarpment processes like landslides, soil creep etc., may incur serious damages to the outfit and the proper functioning of water utilization system.

Relationship to floods is more direct since many abruptly oscillating climate hazards (intensive rainfalls, snow thawing) directly contribute to occurrence of floods. In Arda River Basin, the frequent occurrence of nature disaster risk is attributed much to geographical factors such as mountainous relief, unstable geologic bedrock, climate oscillations and amplitudes being ever more frequently apparent, and several environmental changes due to the human activity in the last half century. Certain seasonal evidence of nature disaster risk is also to be considered.

5.2 Second level of the graph

Together with the water utilization system, the second level of graph depicts yet another 2 elements that can be regarded as an input – mineral resources and transport and communications.

Water utilization system – that is the entire outfit of catchments, canals, pipelines, reservoirs and purification sets designed to catch, utilize available water resources in the economy and household and further to drain used and waste water purified back in the environment. Therefore, water utilization is highly responsible to use the water available so that the nature equilibrium is preserved and ecosystems remain unaffected. In terms of the social system, however, the most obvious impact of water utilization is over the industry (especially in the case of Arda river basin target area), since several branches such as timber and wood industry, construction material industry and textile industry implement in their technological processes large volumes of water.

In the studied area, there is a well-developed set of water utilization equipment constructed mainly to distribute equally throughout the year water resources of the main river Arda. That's the main function of the 3 large dam lakes built in the middle sector – "Kardzhali", Studen Kladenetz" and "Ivailovgrad". They provide also with water the cultivated lands downstream and the industrial enterprises in the big city of Kardzhali. Except for those 3 large reservoirs, several smaller have been constructed that have a local importance. For instance, “Borovitza” dam lake on the north supplies the city of Kardzhali with household and drinking water, since “Erma reka” reservoir on the south serves as chief water source for the mining industry and metallurgy.

Smaller towns and villages secure the necessary household, agriculture and industrial waters from local catchments or reservoirs with much lower capacity. Drainage and emitting of dirty non-purified sewage and waste waters appears to be of a high concern, as many factories do not dispose of the necessary purification and waste water storage equipment and drain the utilized waters directly into the environment. That relates also to the villages and their sewage waters, and could impose a significant risk for the local ecosystems.

Another item of the same level that highly impacts, both industry and mining together with metallurgy, is the transport and communication system. In each society, the transfer and distribution of resources, raw materials and goods determines the proper functioning of economy and thus the wealth of society. In that manner, transport and communication network could be regarded as well as a momentous input in the whole social system.

In the studied territory, the effect of transport is mainly focused upon mining and metallurgy, on the one hand, and upon the industry, on the other. Development of these 2 sectors requires especially that large quantities of raw materials and goods be transferred, sometimes over long distances. However, automobile transport that is not designed for a transmittance of large volumes of raw materials is predominately developed in the studied area.

The mountainous relief and absence of broad and suitable values for construction of railroads has always hindered the layout of convenient railroad network. Another circumstance a disadvantage to the functioning of transport and with evident negative effect on industry and mining is that mountain roads especially in the high West Rhodopes are narrow, with much curves and not well maintained. Sometimes certain nature disaster risks cause significant damages to the road pavement and it’s often the case that more isolated settlements stay for weeks cut off the other world.

The third element located at that level, the mineral resources, also appears to be an input factor that must be stressed upon. Mineral resources are the basic precondition for mining and metallurgy development. Since it’s very inefficient economically to transport these resources over long distances all the extracting and processing factories are situated near to the locations of beds. Studied area comprises the most huge and rich in metal content beds of lead and zinc ores in Bulgaria, and obviously the 2nd largest on the Balkan peninsula. Much of the resources are situated in the lowland and hilly area of East Rhodopes, and it’s easier to extract the ores and to transfer them to the flotation fabrics. Nevertheless, mountainous relief and not well-maintained road network makes the ore locations somewhat hard to be accessed.

5.3 Third level of the graph

Components located at next lower level – the third one, are no more input factors, since all of them are impacted in any way by the former levels. Anyway, they exert high impact on the other components down the graph; hence their influence as system building-up factors is high.

3 items stay also at that level, 2 of which represent significant economic sectors − the industry, and the mining and metallurgy. Both are impacted − the former by water utilization and transport, and the latter by mineral resources and transport as well. The third component constitutes a disaster risk event with high frequency of occurrence in Arda river basin – floods.

Industry comprises of many factories and plants of wood and timber processing and production, machinery production plants, constructing materials production, textile and food industry.

Before 1989, the relative percentage of industry in gross economic product for the studied area was the highest, and in the period of economic transition it decreased due to low efficiency of production and bankrupting of many enterprises. That led as a consequence an increase in unemployment, social stagnation and deterioration of people’s daily life. At the same time, new production sectors emerged like timber and furniture production and especially textile industry. Such industrial enterprises have small capacity, and one very severe circumstance for rising conflict is that employers intentionally keep up the salary rates very low (about twice lower than the minimum monthly wage permitted by law), because of the high unemployment in particular in the small villages.

Larger industry enterprises are located in the big towns and cities like Kardzhali, Smolyan, Madan, Rudozem, Momchilgrad, Dzhebel and Krumovgrad. In spite of that they work with a lower capacity, and unemployment remains still high. But the most severe aggregate effect of industry and household is related to the environment.

Deforestation is due to illegal logging, the timber being used then in wood industry or in household for winter heating as a combustible. Such human-induced hazard can be limited or avoided, if issues persisting with restitution of forest ownership and enforcement of law clauses by forestry authorities will be ultimately settled.

During the period of communist rule, mining and metallurgy was the most important branch of economy in Arda river basin securing the local people high living standard and prosperity. However, environmental problems appeared not to be so significant, the people not being informed or aware of them. Lack or complete absence of purification equipment or storage depots at many mines or factories was not considered as a problem of concern, although severe outflows and drainage of high polluted mining and metallurgy wastewaters often occurred. It caused strong contamination on arable land and pastures located at flood pan where dirtied underground and river waters come in touch with soil and plants and harmful pollutants are fixed by the vegetation. Thus, most severe consequence of the mining and metallurgy was heavy metal pollution.

In the period of economic transition after 1989, most of that industry suffered a serious decline, the high unemployment rate nowadays owing basically to significant reductions in that branch. Another issue to be taken into consideration is that after closing the mines or plants, there have been no expertise conducted or any safety measures taken to avoid future eventual drainage of polluted waters, which might be possible (usually it depends on the way of mining and the internal layout of each separate mine).

Largest beds and mines of lead and zinc ores lie near the town of Madzharovo (no more functioning), the villages Enyovche, Erma reka, the towns of Ardino, Madan and Rudozem. Those areas have been severely affected by the breakdown of mining industry, nowadays characterizing with high unemployment rates of population and migration to Turkey or other countries in West Europe.

Floods have always been imposing a severe threat in the target area. They are easily triggered by environmental hazards like heavy rainfalls, rapid snow thawing and favored by the steep slopes and fast outflow of rainwater. Although in the 50s and 60s of the past century 3 large dam lakes haven been constructed on the main river and they significantly decrease the risk of flood disaster there, the peril on Arda river tributaries remains high.

The cases reported in January 1990 when 11 soldiers perished in the rising waters of Varbitza river due to negligence of their commanders, and in December 1997 when another flood on the same river swept away bridges and incurred severe damages to infrastructure and buildings in the town of Zlatograd, are much evident of the high flood risk persisting nowadays.

The better way to control that kind of disaster consists first in developing a system for monitoring, control, prediction and emergency alarming the population threatened; and second, sanitation and restoration of all the available outfit against floods – dams, barrages, ditches, canals, pipes etc., in order to enhance their functionality.

Another specific trait of flood disaster that should be under consideration is its seasonable occurrence. Winter months characterize through high precipitation quantities and snow thawing, thus impacting the frequent accidence of flood disaster especially during that season. Usually summer precipitation rate is 3-4 times lower than that in winter, and the risk of flood significantly dwindles.

In terms of spatial distribution, it's that East Rhodopes are much more prone to that disaster than the higher West Rhodopes because of climate specificities, relief features and lower forestation in the eastern part of the mountain. Most apparent impact of floods is on the soil erosion, since latter runs simultaneously with intensive rains, forming of small rivulets and glens with strong linear erosion effect. Soil erosion spreads over much larger territories than floods and its hazardous effect, especially on agriculture, is higher than that of floods.

5.4 Fourth level of the graph

The lower, 4th floor of the graph consists of other 3 elements – deforestation, soil erosion and heavy metal pollution, that impose a disaster risk. Impacted and triggered by other nature or man-made hazardous events, their effect on the links located on the lower levels remains significant. Appearing to be consequences of disaster risk occurrence, they affect in their turn more susceptible and sensitive components of the system.

Since very ancient times, deforestation has been always accompanying human development and the extension of arable land and pastures. These processes have been most evident during 18th and 19th century on the investigated territory. Coming together with people's migrations and foundation of new settlements, the need for new cultivated lands and lawns for grassing the cattle has been very urgent. During that period, deforestation has taken place chiefly in the Eastern Rhodopes. In the west part of the mountain, people didn't log that much, their economic activity was not bound with agriculture but with growing cattle, crafts etc, that didn't require to free new land for agriculture. That's the reason why vast massifs of age-old coniferous forests are to be found there even in the present days.

Deforestation process ran more rapidly in the 50s and 60s of last century with the advance of mining industry and metallurgy. Then, some sectors of mountain's western part near the towns of Rudozem and Madan have been laid barren grounds for the sake of exploitation of ore beds.

And nowadays, deforestation affects very strongly all the target area, being accompanied by illegal logging and utilizing the wood either as combustibles or for the purposes of timber industry. That process runs uncontrollable and inflicts severe negative changes in ecosystems.

In fact, deforestation has a high influence on flora and fauna located one level down the graph. Its consequences are extinction of endemic and threatened species, decrease in biodiversity and diminishing the ability of ecosystems to come in a state of equilibrium.

Soil erosion runs over barren lands or territories with scanty vegetation cover, which surface is slanted so that flowing water can wash away some soil particles.

When surface inclination is lower, usually less than 5°, a surface washout is only evident. The water coming from rainfalls or thawing doesn't form any separate streams, it only runs down the slope like a layer. The erosion power of water is not so strong and only smaller soil particles tend to be washed off. Usually more slanted surfaces are highly prone to strong erosion.

With increase of slope slant, because of the growing potential energy of water, it forms already small torrents and rivulets when running down the slope. The erosion power is much intense, and huge-sized soil particles are also swept away by the increasing water streams.

Impacted mainly by floods, soil erosion in the target area is evidently higher in the East Rhodopes. The measurements taken in the 70s and 80s to prevent and stop that hazardous process have given certain good results, nonetheless there is still much to be done in that respect.

Because of the soil erosion, the only possible agriculture crop to be grown there is the tobacco, as its roots sustain the soil washout. The percentage of barren lands there is big, and one more reason is the non-tight, crumbly and highly weathered bedrock layers.

The West Rhodopes with the dense vegetation although having higher slope steepness, are not strongly affected by soil erosion. It is a highly emphasized hazardous environmental disaster risk with severe consequences on the agriculture.

The other component of that level having direct relationship with environmental disaster risk is heavy metal pollution. It's caused by mining and metallurgy process and not strictly following the safety technologic prescriptions for storage, draining and purification of wastewaters.

Significant pollution is to be found near waste storage depots, mines and flotation fabrics in the vicinity of mining centers like Rudozem, Madan, Erma reka, and the lead-zinc extraction plant near Kardzhali. Some previous researches and studies report on contamination down the main river Arda, and the tributaries of Varbitza river. Water of the main river is reported as well to be of the 2nd or 3rd category at some sites, a fact that is a serious evidence of pollution.

One more aspect is the organic pollution, pollution caused by dirty sewage waters and agriculture. Such kind of contamination occurs near small villages and towns especially in the West Rhodopes. These settlements don't have any system of sewage water collection and purification, so they drain it directly in the rivers running nearby.

5.5 Fifth level of the graph

Next, 5th level of the graph comprises 2 elements highly impacted by the others. The first one is environmental disaster risk representing the aggregate impact of hazardous events like soil erosion, heavy metal pollution and other less important perils not included in the graph. Its effect is very strong on the agriculture as they limit its capacity for producing high quality foods and other goods or even dwindling the ability of obtaining high yields.

The second component of this level is the flora and fauna. In their turn, flora and fauna are very indicative for the whole state of the ecosystems, and reflect any negative changes in it. Arda river basin characterizes nowadays with relatively preserved wildlife variety, the ecosystems being significantly disturbed only in the vicinity of the larger industry and mining centers like Kardzhali, Madan, Rudozem, Erma reka and Madzharovo.

In the high West Rhodopes the vegetation is represented by coniferous species like spruce, fir, pine and juniper. Many compact age-old forests are to be found there included in some reserved territories. The East Rhodopes have much scattered vegetation cover consisting mainly of deciduous species like cerris and conferta oak, durmast, sycamore maple and many Mediterranean bush species – thistle, hornbeam, red juniper etc.

Although the less flora variety, several rare and endemic species and many landmarks and spots of tourist interest. Ecosystems are basic precondition for development of tourism. They can be considered as tourist resources which main property – the attractiveness, is in the essence of forming and determining the tourist demand. Arda river basin possesses in that respect high diversity of flora and fauna with high potential of forming tourist demand and developing tourism.

5.6 Sixth level of the graph

The 6th, fore last stage of the graph depicts 2 very important components appearing on the forefront of the output – tourism and agriculture. Their direct impact on the daily life staying at the last level is evident in that these 2 sectors of economy nowadays appear to secure most of the livings of the local people in Arda river basin.

The studied area disposes of excellent, both nature and man-made resources for the development of tourism. Rock phenomena, comfortable climatic conditions favoring the development of ski-tourism and other types of winter recreation large dam lakes suitable for summer beach recreation activities, varied flora and fauna and beautiful scenery for trekking and other sport types of summer tourism; many historical places, monuments, architectural sightseeing from various historical periods, suitable base for sport and other events offers the studied area as a whole.

Tourist base is well developed; even in the smaller towns and villages private rooms for leisure and recreation can be found and offer fair living conditions. Number of tourist increases especially in the last years. In that respect, tourism appears to be not only one of the main sources of incomes for the local people, but also a tool for cultural exchange between them and the coming tourists from various other parts of Bulgaria or abroad.

Agriculture, like the tourism, is an immediate precondition and source of economic activity of the local people. Because the studied area is basically hilly and mountainous, arable land and pastures are dispatched and scattered, small in size and not easy to access in certain instances. Land is not suitable at all for growing industrial crops or cereals.

In the high West Rhodopes, the main crops grown are potatoes, rye, and bean on small fields near the city of Smolyan and down the stream of Malka Arda river. East Rhodopes are much stronger impacted by environmental disaster risk events, and the land there is not well intended for agricultural activity. The main crop grown there is tobacco. As soils are shallow and not well structured, only Turkish oriental sorts are grown that is the main source of incomes for all the rural population here. The separate land patches are small and sometimes remote from the settlements.

All the processing of tobacco, and the harvesting inclusively, is done manually. Because it’s a very hard deal of work, all the population, both children and adult, is involved in tobacco growing and primary processing.

In the small lowlands and river valleys near the larger cities, vegetable gardens, orchards and small vineyards are located. Their importance is local, as they only satisfy the needs for fresh fruits and vegetables of big consumption centers nearby.

It’s shown out of that characteristic that tourism and agriculture have most direct impact on everyday life of people in Arda river basin. These 2 economic activities occupy almost all the rural and about 20-30% of the urban population provided that people have small patches of land and backyards used mainly for growing vegetables, potatoes, grape and fruit trees. In the period of economic transition and after the breakdown of industry, the basic economic activity of local people in the studied area shifted towards tourism and agriculture.

5.7 Seventh level of the graph

At the last, 7th stage of graph, the daily life represents the outcome of all system interactions and relations. It’s dependent in various, but indirect aspects by all the elements of the graph located at previous levels, but the most straight and implicit is the linkage towards tourism and agriculture.

In historical aspect, daily life of the people from Arda river basin has significantly changed in the last half century. Before the mid 50s, the area was a periphery district lagging much behind in economical respect towards other regions of Bulgaria, having underdeveloped industry and extensive agriculture. Living standard has proved to be one of the lowest in Bulgaria.

The industrialization of 50s and 60s coming along with the discovery of lead and zinc ores has lead to profound changes in the economic face of the investigated territory. The many new factories and mines built and the employment of many local people in these industries lead to profound shifting in the way of life.

In the 70s and 80s the mining and heavy industry was in the peak of its development, and people had one of the highest living standards throughout the country. Prosperity of mining and metallurgy and the people's wealth was due to the large export rates of the country because of the relatively high prices on international markets. Japan was also one of the main importers of lead and zinc raw materials. That sector of economy actually constituted for Bulgaria the major source of incomes from foreign trade.

In the mid 80s the communist regime started persecuting and exiling the compact population of Turkish minority inhabiting the East Rhodopes. As a result of that improper policy, as many as 200 000 Turks have been forcefully expatriated to Turkey for the period 1984-1989. That had much negative reflection over the human potential and labor resources of the area.

The following years, from 1990 to the present days, characterize with a complete decline in all spheres of economy and life, a breakdown of mining and metallurgy. The unsettled relationships between stakeholders in agriculture, forestry, tourism, trade and services, the emergence of illegal, the so-called "black" or "pirate" economy are tough issues and conflicts of contemporary life.

The obviously harsh decadence in living standard has turned again the Arda river basin to a periphery region with less economic potential, high unemployment rate (about 20-25%, and up to 60-70% for some villages) and low incomes (about 1.2-1.5 times lower than the average for Bulgaria).

The vision for future development of that area is referred to improvement and construction of new transport communications with the neighboring Greece on South, advances in trade and economic exchange between the boundary regions of Bulgaria and Greece. Expectations are rendered that the mutual relationships and trans-boundary cooperation with Greece will give a tug to a new economic ascendance of the Arda river basin area.

6. Relationships between components on the graph

Three chains of mutually dependent elements are formed: the 1st starts from industry and shows its negative impact that finally affects the tourism; the 2nd starts from nature disaster risk and reveals its consequences which appear to be primarily over the agriculture; and the 3rd chain depicts the effect of mining and metallurgy also concentrated over agriculture.

Many elements have only single cause-effect relationship. Transport and nature disaster risk have 2 outgoing arrows that emphasizes their significant effect as input factors. Industry, mining and metallurgy and daily life have 2 incoming, environmental disaster risk even 3 incoming arrows which shows that they are depending on many factors.

7. Major conclusions of the present research

The application of ISM analysis reveals the internal structure of social, eco and geosystem and how their components are ordered in dependence of their interactions. It provides also useful insights where the further collecting of data and analyzing should be focused. Implementation of this graph as a final product of ISM analysis not only visualizes and elucidates the interactions of components and their behavior, but also provides valuable insight of how to approach and what method to apply when investigating the system, its constituents or the relationships between them.

8. Devising future research and works

ISM graph provides the basic scheme for further implementation of multi-factor analysis on the studied components. Structurizing components make easier application of system approach when interpreting the obtained results on the systems elements under investigation. Basing on the ISM graph and the binary matrix belonging to it, an algorithm for programming the impacts on the output, the daily life, can be elaborated and thus eventual prediction of future negative effects and developments may be possible.

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ブルガリア，アルダ川流域における環境災害リスクの構造化

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要旨

本論文では，システムズアプローチを用いてアルダ川流域（ブルガリア）の環境災害リスク分析を行う。対象地域はブルガリアの東南に位置し，環境災害リスクとしては洪水，土壌侵食による影響を受けていると考えられる。また，この地域は1990年以降，社会経済背景の著しい悪化にも悩まされてきた。この地域の環境災害リスクをISM法を用いて整理し，その構造を明らかにすることが本論文の目的である．ISM法は複雑に絡み合っている要素の関係を単純化し，構造化するための手法である。本論文では，ブレーンストーミングによって挙げられた多数の要素を縮約し，さらにそれらの帰属をエコ，ジオ，ソシオシステムに分類し，各システムの代表要素とした。ISM法を用いて要素の関係を整理した結果，エコ，ジオ，ソシオシステムの15の構成要素を7つのレベルを持つ階層システムとして構造化した.

キーワード: 環境災害リスク，システムズアプローチ，ISM法