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Calculation of loss inflicted and expected caused by dangerous geological natural events (case of abrasion and landslide)

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SUMMARY

The methodology of comprehensive assessment and forecasting of socio-economic loss inflicted and expected caused by landslides and abrasion processes taking into account, climate changes has been proposed in the article. The relevance of chain effects from the simultaneous negative impacts has been emphasized. The following outcomes have been figured out: reduction of recreational opportunities aimed at health improvement and territorial unemployment rate growth due to the number of vacationers` drop. It has been proved that the assessment of the expected economic loss rate should include lower health and recreation stock loss caused by coastline beaches` loss, which fuels shorten local budget revenues and number of businesses, additional unemployed assistance, and transporters` loss. The study results` one could use when calculating the required costs to prevent and avoid natural emergencies caused by landslides and abrasion.

Introduction

The seashores suffer from dangerous natural phenomena: abrasion, landslide, destruction, erosion of accumulative forms like spits and beaches, and coastal flooding. The most dangerous among them are landslides and abrasion processes, exacerbated by sea level rise. They cause the most significant socio-economic impacts and losses. Therefore, there is a need to develop the methodology not only to assess the damage which has already been caused (traditional approach), but also to forecast it and develop possible measures to minimize it.

Method

In the analysis, general-scientific methods (analysis and synthesis, induction and deduction) and special methods of phenomena and processes analysis (abstraction, econometric and econometric-mathematical modelling) have been used.

Results

It is possible to determine total socio-economic loss from shoreline abrasion taking into account a set of components having a chain effect, i.e. they negatively reinforce each other:

1) *Losses caused by lower number of vacationers due to coastline size loss*.

These losses have some adverse effects: social (potential health deterioration due to the reduced number of health care services) and economic (caused by the falling revenues formed by recreation services supply for tourists and vacationers). It should be noted that coastal abrasion loss may get a certain maximum value (potential capacity of a beach), i.e. until the coastline reaches the buildings and health and recreation facilities, and a beach is completely destroyed. In this case, material loss could arise during destruction of buildings and facilities, which are not just losses but also a life-threatening emergency level.

As for the abrasion loss, it is not life-threatening, but has adverse socio-economic impact. Its level can be determined using the indicators like the abrasion rate on a particular coastline, real capacity of health and recreation facilities and tourism industries, and the efficiency rate (number of vacationers per season).

To determine the beach capacity of a community, it is advisable to apply data on the length and width of the coastline (beach square) and beach size standards per vacationer.

The algorithm for abrasion loss is as follows: one first determines the potential recreation area available in a community: coastline length: 0.2 m / person (beach length standard per 1 vacationer) x 0.4 beach load rate (standard value). After that, using State Geoinf data on the rate of coastal erosion, it is possible to find out potential beach`s square loss per year (sq. km and beach space per person): beach length (km) x abrasion rate (km / year). Dividing it by the standard square per vacationer (5 sq. m), one gets the number of beach occupancy loss per year.

Additional beach occupancy loss is caused by the rising sea and moderate receding of accumulative types of coasts. These processes can be taken into account as follows: beach length (km) is multiplied by the receding rate of the accumulative types of coasts (it is approximately 2 - 3 m of beach length of sea level rise by 1 cm per year). Dividing the obtained value by the standard square per vacationer (5 sq. m), one gets the number of beach occupancy loss per year caused by receding of accumulative types of coasts.

The sum of the obtained values of beach occupancy loss due to abrasion and receding of accumulative types of coasts is the total number of beach occupancy loss per person in the area.

After that, it is possible to make economic loss assessment.

Depending on time and financial resources, vacationers checked in health and recreational institutions spend different time and have unequal vacation expenses. To get an average indicator of expenses per vacationer, we use official statistics on the structure of household consumption expenditure by consumption purpose (average monthly expenses per household). Therefore, total vacation expenses of an "average" vacationer are calculated as the sum of expenditure by consumption purpose "Vacation and culture expenses" and "Restaurants and hotels" to total monthly expenses per household. We assume that an average household consists of three people, therefore, the level of monthly household expenses per person in this regard is divided into three. Also, we assume that a person goes for a vacation once a year and, thus, monthly accumulated vacation savings should be multiplied by 12 months. This will be so-called annual "vacation budget" per one person.

We suggest to take into account different vacation days and obtain mean value by introducing a special indicator – real seasonal operating rate for health and recreation (persons / occupancy), which is the ratio of the number of vacationers per season (persons) to the number of health and recreation facilities.

Thus, multiplying the obtained coefficient by the average "vacation budget" per person, we determine average vacation expenses of one vacationer per season (per one place).

Similarly, we determine the average number of vacationers` loss due to abrasion, i.e. multiplying real seasonal operating rate for health and recreation (persons / occupancy) by the number of places lost due to the abrasion per year (determined above based on the abrasion rate).

Now one can estimate the abrasion economic loss as the product of the average number of vacationers` loss and the average vacation expenses per season per one place.

The above considerations mean loss assessment caused by lower number of vacationers taking into account health and recreation facilities of an area. At the same time, there are coastlines suitable for health improvement and recreation, which are not properly equipped (not used). Thus, the abrasion reduces recreational capacity of these areas, so there is indirect loss from weak possibility of their further exploitation aimed at income generation and their dynamic development.

In case no further measures are taken to reduce the abrasion rate, the process along with the accumulative forms loss fueled by the raising sea level could cause total loss of beaches for recreation followed by the destruction of buildings, health and recreation stock.

The real operating rate of health and recreation occupancy does not always coincide with a potential one, which is determined by the spatial capability of the beach area. Consequently, the process of boosting the real operating rate of health and recreation occupancy one could describe with the equation:

$$dN = \varepsilon N\, dt$$

where ε is constant proportionality coefficient, reflecting the correlation of the increment rate of the subsystem $\frac{dN}{dt}$ quantitative characteristics to N.

From the equation:

$$\frac{dN}{dt} = \varepsilon N$$

by integrating we obtain:

$$N = N_0\, e^{\varepsilon(t - t_0)}.$$

Where $T = t - t_0$.

This is the formula of the exponential law, which states that if the time increases in the arithmetic progression, then the quantitative characteristics of the subsystem change in the geometric progression. The model is hard and, in our opinion, does not reflect with sufficient accuracy the dynamics of feasible economic processes. It is expedient to replace it with the so-called soft one:

$$\frac{dN}{dt} = \varepsilon (N)\, N.$$

Then, $\varepsilon (N) = c - d\, N;$ and:

$$\frac{dN}{dt} = c\, N - d\, N^2.$$

Formula describes the logistic model. We consider that it can be used to describe the process. The following expressions for coefficients c and d could be proposed in this model: $c = \varepsilon$, $d = \varepsilon / K$. In this case, the dynamics of process of boosting the real operating rate of health and recreation, can be described by the logistical equation:

$$\frac{dN}{dt} = \varepsilon N - \frac{\varepsilon}{K} N^2,$$

where ε – constant coefficient of proportionality, which is the ratio of health and recreational resources growth rate $\frac{dN}{dt}$ to the facilities of health and recreational resources N; К = N_{max} – maximum possible and safe level of health and recreational resources.

But there is a reverse process – the number of recreation areas dropped due to abrasion and contraction of the accumulative forms. So we build a model for assessing the permissible limit of the decrease, which does not create conditions for catastrophic threats. When adjusting the previous equation, it is possible to take into account the abrasion impact:

$$\frac{dN}{dt} = \varepsilon N - \frac{\varepsilon}{K} N^2 - \mathrm{q}, \qquad (1)$$

where q – a component, taking into account the abrasion rate impact on the dynamics of growing health and recreation stock.

Let us write (1) another way taking into consideration that

$$N = K\,B,\ \mathrm{t} = \frac{\tau}{\varepsilon_0},\ \ q = \varepsilon_0 KQ, \qquad (2)$$

we obtain:

$$\frac{dB}{d\tau} = B - B^2 - Q\ . \qquad (3)$$

If equating to zero the right part of equation (3), one receives an equation of stationary (optimal) mode:

$$B = B^2 - Q = 0. \qquad (4)$$

The roots of this equation are determined by the equality: $B_{1,2} = \frac{1}{2} \pm \sqrt{\frac{1}{4} - Q}$.

If health and recreation facilities are down (Q> 1/4), the rate of these capacities will fall dangerously low. With a slight impact (Q <1/4), there are two stationary modes B_1 and B_2. The stationary mode for the facilities B_2 is sustainable: the value of the number of vacationers at the beach going for health and recreation is somewhat lower if to compare with the absence of a lower number of beachgoers as a result of abrasion. Nevertheless, it can be quickly restored. The stationary mode for the facilities B_1 is unsustainable. As further number of beachgoers in the coastal zone goes down, a crisis situation may occur.

Thus, to provide sustainable functioning of health and recreation institutions amid abrasion, there must be taken measures to restore the zone, depending on recreation stock capacity. This condition could be described by the equation: Q = αB, where the parameter α could be varied.

In this case the equation (3) is as follows

$$\frac{dB}{d\tau} = B - B^2 - \alpha B,\ \text{де}\ \alpha > 0. \qquad (5)$$

The stationary mode $B = 1 - \alpha$ will be sustainable if $\alpha < 1$ and coastline health and recreation stock are determined by the equation: $B\,(1 - \alpha - B) = 0$, that is $B_0 = 1 - \alpha,\ 0 < \alpha < 1$.

Thus, the abrasion impact rate on coastline health and recreation stock amid stationary mode are defined as:

$$A = \alpha\, B_0 = \alpha\,(1 - \alpha). \qquad (6)$$

Let us find out the value of the parameter α at a maximum stock decrease. To do this, let us equate to zero derivative function of the abrasion impact (6), which is considered as a function of parameter α:

$$\frac{dQ}{d\alpha} = 1 - 2\alpha = 0\,. \qquad (7)$$

Obtain $\alpha = ½$. Thus, the maximum impact $Q = ¼$ is achieved when $\alpha = ½$. So, the decrease in the recreation zones` rate by 25% of their potential capacity creates catastrophic threats.

This approach allows to consider the feedback to monitor coastline health and recreation stock without losing system sustainability. If coefficient α has optimal value then slight capacity contraction of the stationary mode $B = B_0 = 1 - \alpha$ drives potential`s automatic recovery using internal system ability. A slight α deviation from the optimal $\alpha = ½$ does not lead to the system destruction, but only to lower negative impact.

2) Losses caused by the possible employees` contraction working with vacationers.

The decline of the number of vacationers fuels the need to cut the number of workers who serve them, and thus a possible surge in unemployment rate. This process will significantly affect the resorts, as hospitality and leisure industry is the key employer of the communities. In our opinion, higher unemployment rate losses could be assessed by the unemployment assistance indicators. Let us assume that the average monthly expenses per one unemployed is UAH 1,800. This is the assistance received by a person having registration as unemployed and insurance policy period more than six months. We believe that such individuals will predominate, as the recreation period adjusted for seasonality usually lasts six months (May through September). Due to the lack of detailed data on the unemployment structure in terms of recent work remuneration by regions` specifics, we consider this approach to be rational for mean values.

To determine number of unemployed persons caused by lower amount of vacationers, we propose the next indicator: operation ratio of vacationers per employee, which is the ratio of the number of vacationers during the season to the number of employees in health and recreation industry. So dividing the average number of vacationers` loss per season caused by the abrasion by this ratio, we get the number of employees who will be forced to get fired.

Moreover, it has to be taken into account that health and recreation institutions have both full-time and seasonal employees. When calculating the period of unemployment assistance, we use not the simple mean value, but the weighted arithmetic mean (for the number of full-time and seasonal employees, respectively). It is 12 months for full-time employees and 6 months for seasonal workers.

3) Losses fueled by the contraction of tourist tax revenues in local budgets.

Taking into account that the tourist tax is paid by all those who travel (tourists, as well as those who are aimed at health improvements and recreation), we use data on the total amount of tourist tax and the total number of travellers to determine potential loss. A number of losses driven by the tourist tax gap is calculated by multiplying the tourist fee per year to the average number of vacationers` loss during the season due to the abrasion.

4) T*ransporters losses*

The loss will be assessed as average cost per traveler by means of transport. A number of losses fueled by transport users` drop is calculated by multiplying transport expenses per traveler to the average number of vacationers` loss during the season due to the abrasion. To determine the share of transportation by means of transport in the region, we use the data on the structure of tour operators` expenses of the relevant region (tourists` ratio by the means of transport). Similar calculations will be made by means of transport.

5) Losses fueled by the contraction of cultural institutions`, museums` and other recreation centres` (national parks, sanctuaries, etc.) revenues

The structure of tour operators` expenses in the analyzed territory could be proposed to calculate the loss. Cultural institutions`, museums`, etc. loss refers to the determined amount of loss` share caused by the lower amount of vacationers.

6) Losses referred to the reduction of accommodation facilities` (hotels, sanatoriums, boarding houses, etc.) revenues.

As in the previous case it is possible to use the data on the structure of tour operators` expenses in the analyzed territory. Accommodation facilities` loss form the corresponding loss` share caused by the lower amount of vacationers.

Conclusions

The proposed methodology provides possibility of forecasting and assessing social and economic impact of abrasion and contraction of coastline accumulative forms, as well as development of preventive measures to minimize communities` loss. The methodology is universal one. It is based on officially published data on dangerous geological phenomena, their processes and dynamics. It is used for evaluation based on official statistics.