to Law on amelioration through afforestation (Law no. 1041 from 15.06.2000 on Forestation of Degraded Land, Forest Code, art. 54, Ch. X) and could be transferred to the Reserve Fund for being afforested through the Government Decision.

Conclusions

Areas of very high and high suitability cover about 13% of the total surface area of Moldova and 9% of the total surface area of Moldova without taking into account areas already covered by forest.

About 49% of the "very high" and 43% of the "high" classes of suitability are already covered by forest, while for the "Moderate" "Low" and "Very Low" classes these percentages are reduced to 9%, 4% and 4% respectively, showing the correctness of the methodology used.

The most important areas for reforestation are located in the Codri Plateau, Nistru Heights and North Moldova Plateau.

Most of the territory of Moldova (51%) has a moderate suitability for afforestation or reforestation. Territories with low and very low suitability (36%) occupy floodplain areas (covered by pastures, and, also, settlements and water bodies), with low slope (less than 6^0) and with weak eroded or non-eroded soils.

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APPLICATIONS OF GEOGRAPHICAL INFORMATION SYSTEMS TO SEISMOLOGICAL PROBLEMS

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Abstract: *The concept of the Geographical Information Systems (GIS) which has found to be very useful in seismological problems, particularly, in seismic hazard and risk studies is presented. GIS can be used to integrate vast amounts of spatially distribution seismological data, provides effectively application of complex mathematical models and graphically analysis of results. The central part of Chisinau (6.3km² site), capital of the Republic of Moldova, is the case study of the study. Collection, classification and digitization in ArcView GIS format of the main characteristics of the subsoil such as mean shear wave velocity, natural period of vibration and amplification factor, compilation of database for existing structures as well as construction of digital terrain model (DTM) were performed. The final product is the GIS database and software module for purposes of seismic hazard and risk evaluation.*

Keywords: *earthquake, Vrancea, magnitude, intensity, attenuation, earthquake hazard, earthquake risk.*

Introduction

In frame of assessment of seismic hazard, measured in terms of probability of occurrence of future seismic event [8], the probability of exceedance of ground shaking parameters: peak ground acceleration, PGA, and effective peak ground acceleration, EPA, for the city of Chisinau exposed to the influence of Vrancea seismic source is discussed in context of microzonation studies. The presence of geotechnical databases, including measured shear wave velocities for the subsoil of Chisinau, allows detailed investigation of influence of soft soils on spectral and amplitude level of free-field ground motion. Values of natural period of soil vibration and amplification factors for different frequencies are calibrated by the available microtremor observations and records from blasts. GIS proved to be the adequate tool for storing, processing and mapping of the spatial information , such playing the basic role in seismic hazard and risk studies.

1. Seismic Hazard for Chisinau from Vrancea Source

Seismic hazard assessment for Vrancea zone, suggests new magnitude-frequency regression equations accounting for maximum credible magnitude, Mmax, which is estimated as M=7.7-7.8 (Gutenberg-Richter). Mmax is proposed to constrain by physical parameters of Vrancea source on the base of Wells and Coppersmith models [1], which take into account surface rupture length (SRL) and surface rupture area (SRA). Another important factor considered in the analysis is moderate positive correlation between magnitude and focal depth, as well as clear N45E directivity of the seismic source. Directivity effect of Vrancea seismic zone results in different attenuation of ground shaking parameters in NE, SE and SW directions as well as periodical predominant unidirectional energy release along NE-SW.

The analysis of the attenuation functions for PGA and EPA values taking into account different attenuation in NE, SE and SW directions for Vrancea zone was performed recently for the free-field seismic records, medium soil conditions, available through the seismic networks of Romania and Moldova [2]. The model used for the attenuation analysis is based on the wave model from the point source in the elastic medium [3]:

$$\ln(PGA) = c_1 + c_2 M_w + c_3 \ln R + c_4 H + \varepsilon \quad (1)$$

where: PGA is the peak ground acceleration at the site, M_w- the moment magnitude, R - the hypocentral distance to the site, H - the focal depth, c_1, c_2, c_3, c_4 - data dependent coefficients and ε –random variable with zero mean and standard deviation: c_1=4.150, c_2=0.913, c_3= -0.962, c_4=-0.006, ε=4.15.

2. Geotechnical Databases

The necessities of accounting for peculiarities of soil conditions are recognized by guidelines for seismic microzonation and include such parameters as natural period of soil vibration, To, and amplification ratios, A, of the surface response with respect to that of the free-field motion of the outcrop.

In frame of the pilot project, 28 boring logs with detailed geotechnical information including measured in-situ shear wave velocities, vs, were digitized and introduced into GIS for the central part of Chisinau. For each of the boring log the amplification function for horizontal ground motion was constructed on the base of 1D wave propagation model [4] such providing values of spectral amplification. Created GIS-compatible software with geotechnical data allows interpolation of selected parameters for each grid point within studied zone. Such, maps of spectral amplification for different frequencies could be constructed, Fig.1.

Along with that, maps of natural period of soil vibration, influenced strongly by the depth to the bedrock, resulted from the compiled geotechnical database. The depth to bedrock surface has been constructed (Fig. 2). It should be emphasized that for intermediate-depth Vrancea earthquakes the total thickness of soft soils down to bedrock should be taken into account while constructing spectral amplification functions. In all the cases the "soft bedrock" hypothesis was accepted and damping of 5% was assigned to the soil layers.

3. Records of Blasts and Nakamura Ratios for

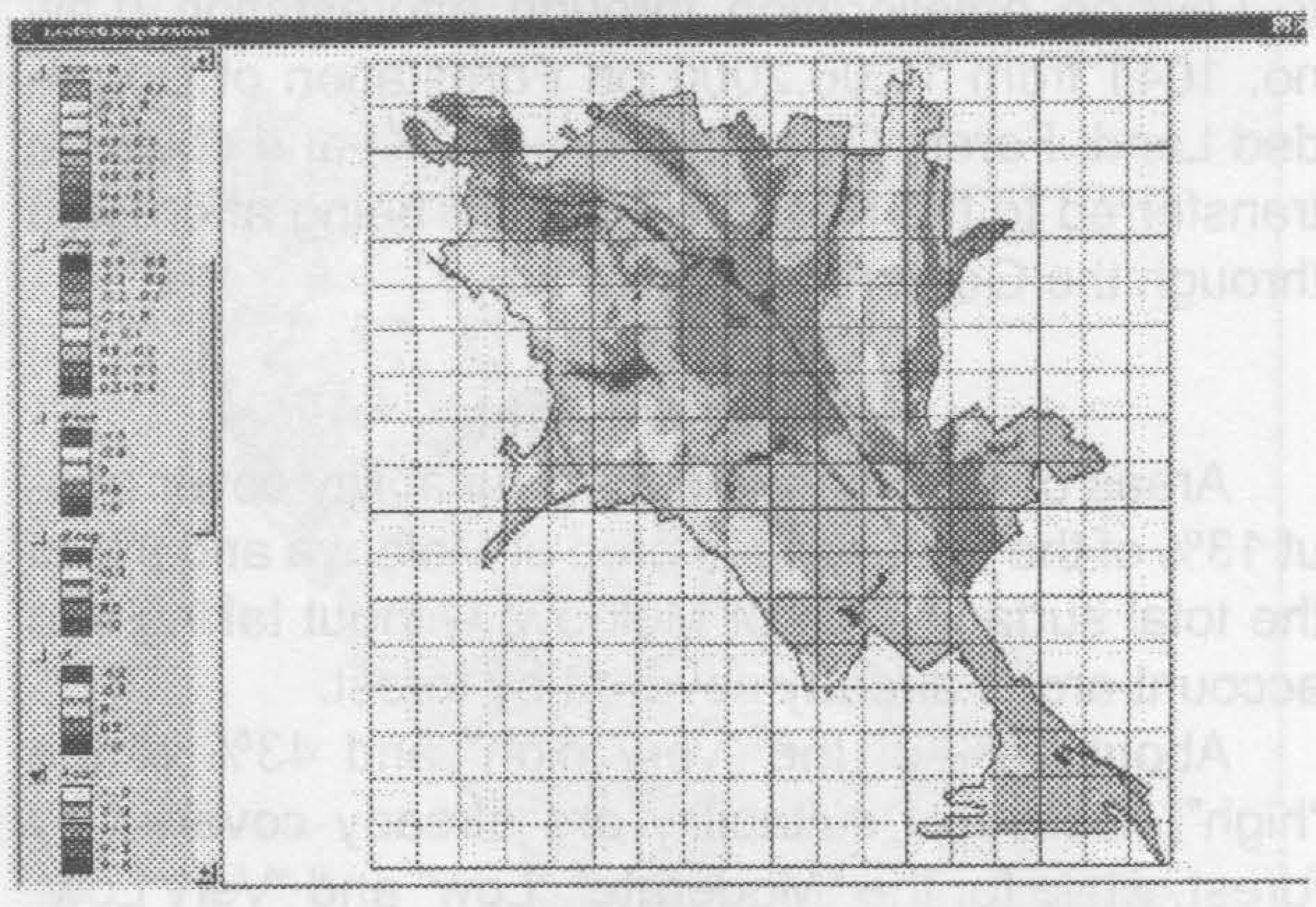

Fig.1. Amplification factor (capacity) of soils

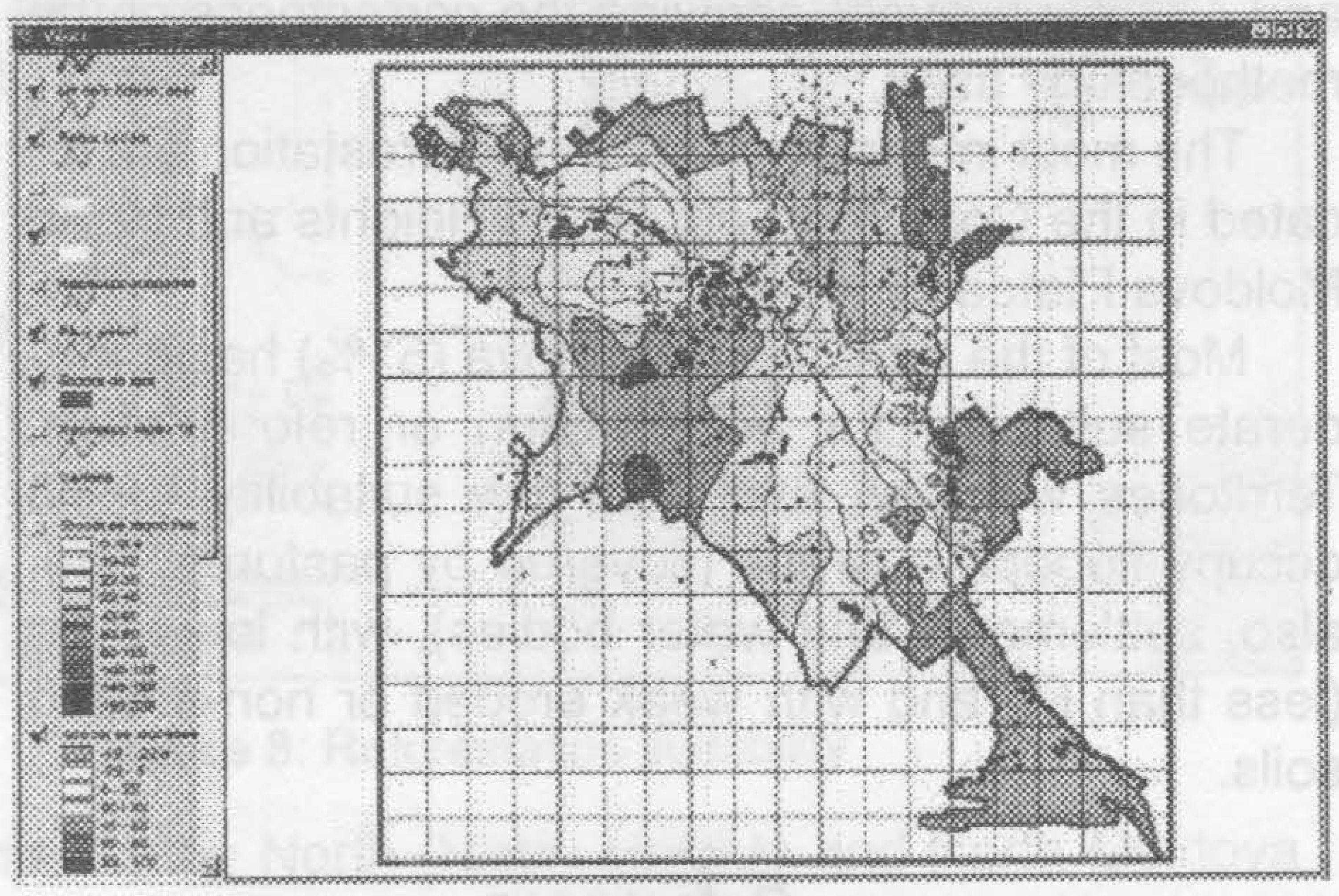

Fig. 2. Thickness of clay-sandy deposits

Validation of Soft Soil Predominant Periods

The natural period of soil vibration, obtained through geotechnical data, was controlled by the available strong motion records, implying Nakamura ratios, and special blasts generated at distance 10km from the site inducing mainly shear waves. As it could be seen through Fig.3, Nakamura ratio gives good fit with amplification function method in terms of evaluating predominant period of soil and even provides satisfactory compatibility in amplitude level, even being not conceived to provide amplification function of the soft soil. In interpretation of blasts records during evaluation of predominant period, body waves, having earlier time of arrival, were taken into considerations, as far as surface waves have less significance in amplification phenomenon.

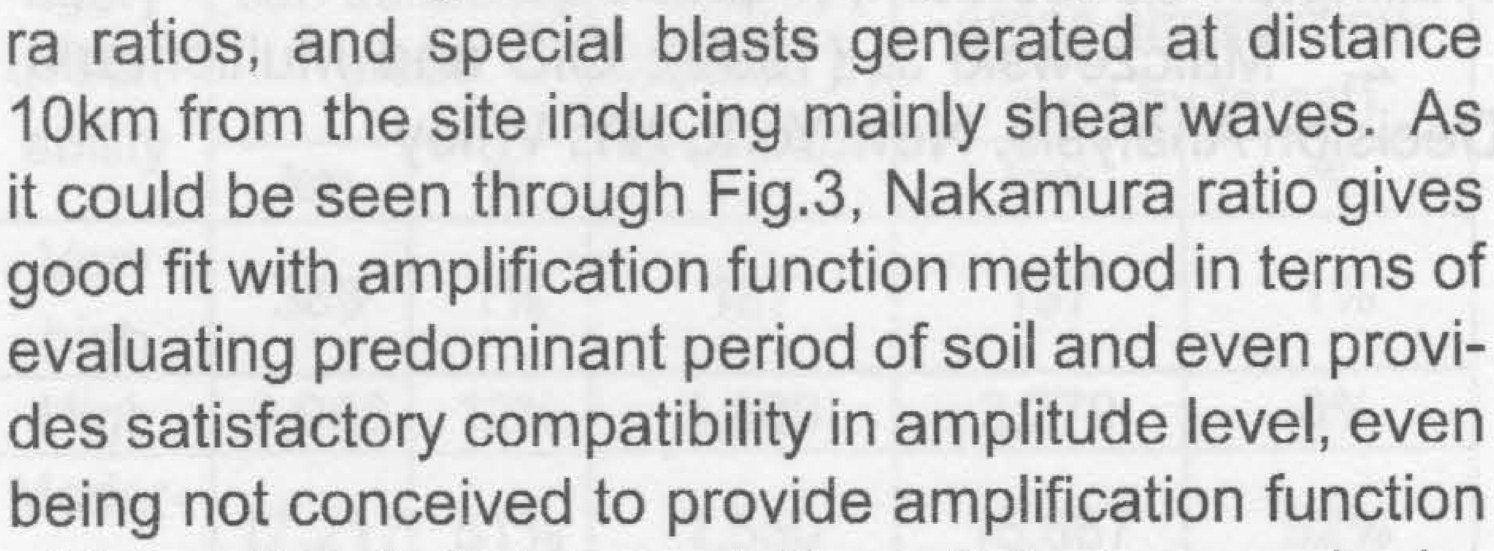

Fig. 3. ISS-2 station: Amplification function for soil conditions (left) and Nakamura spectral ratios for Mar 4, 1977 (M=7.2, Gutenberg-Richter) seismic event (right).

The dominant period of soil range 0,1 to 1,6 sec and gradually increase from center to north and south of city (Fig. 4).

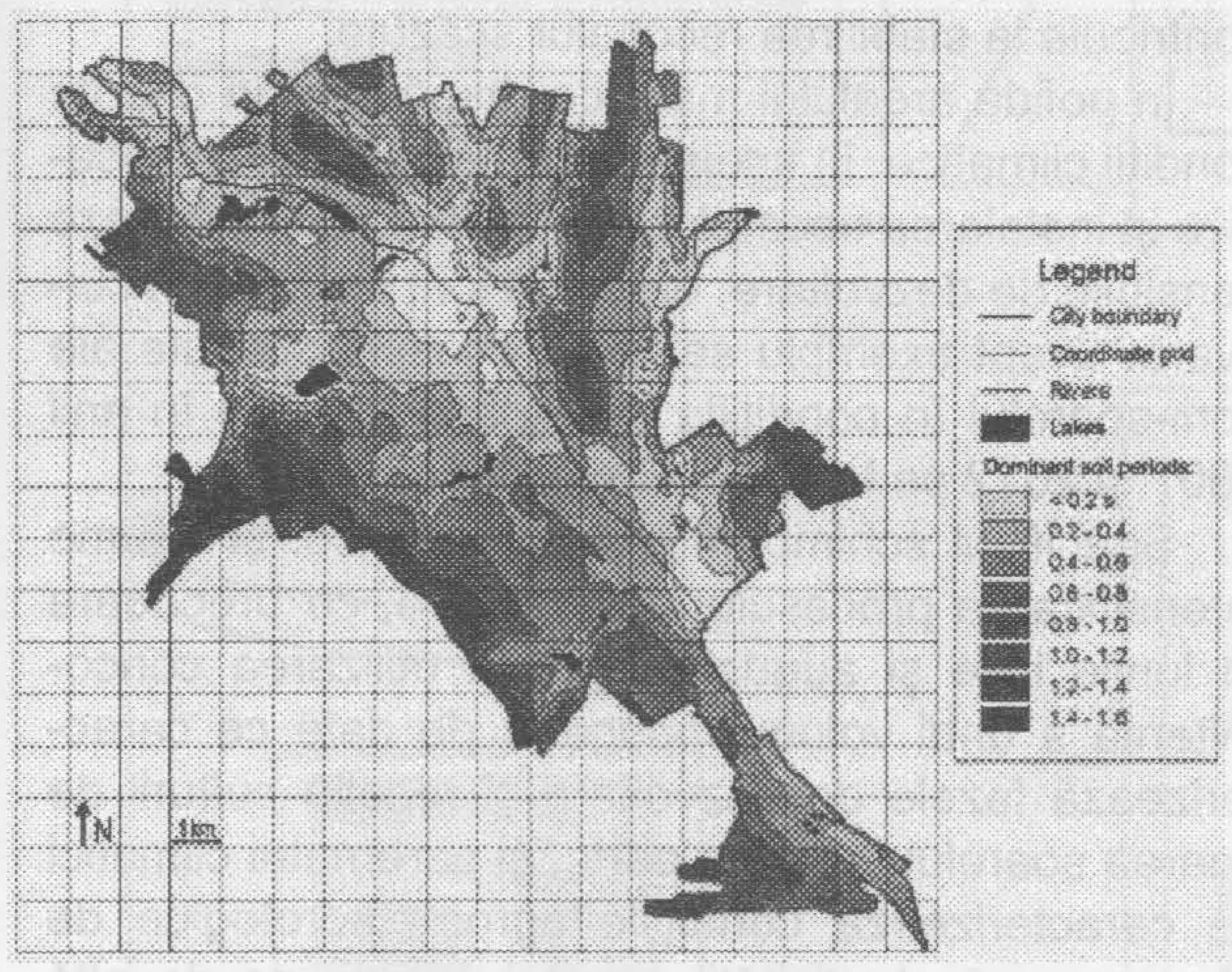

Fig. 4. Map of dominant periods of soil in the territory of Chisinau

4. Interpolation Methods, DEM and Mapping of Shaking Parameters

The application of GIS models depends strongly on the adopted interpolation methods, which should be properly chosen in connection with mapped physical parameter. The favor was done to Kriging method, being in wide use in soil science and geology. It is an advanced interpolation procedure that generates an estimated surface from a scattered set of points with z values under hypothesis of spatial homogeneity. The digital elevation model (DEM), as well as other interpolated contours and surfaces are created on the base of Kriging method.

Fig. 5 provides 3D scene generated with ArcView GIS for Chisinau city center, which includes terrain surface, network of streets, hydrographic zones and existing constructed facilities. Due to available geotechnical database and taking into account results of hazard assessment for Vrancea zone, the simulation of free-field time-histories of ground motion for scenario earthquakes is to be performed, resulting in mapping of shaking parameters and building damage degree, di, calculations, such providing vulnerability map for constructed zone.

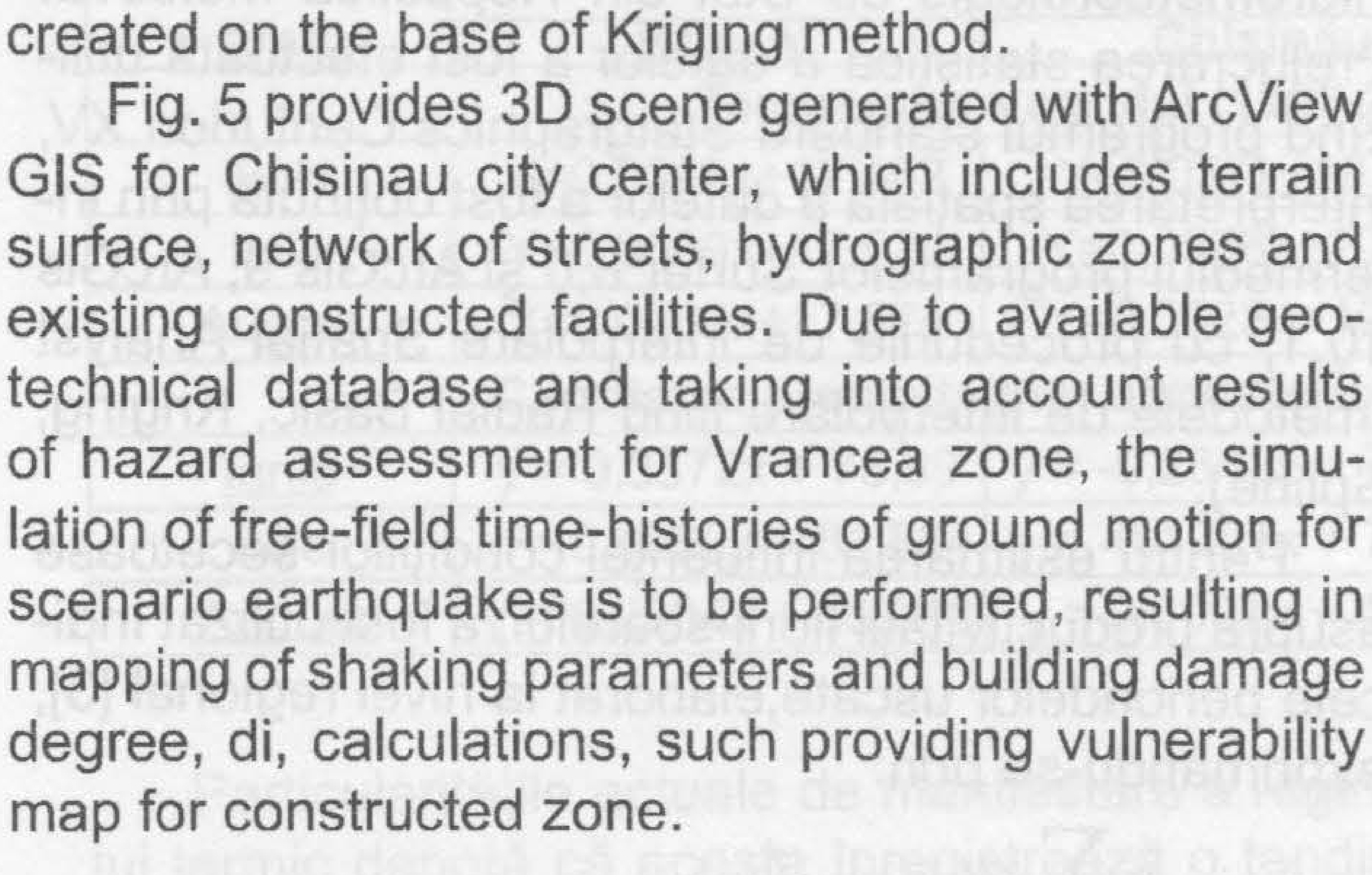

Fig. 5. Chisinau center: 3D scene using ArcView (view from North). Simulation of ground motion

5. Conclusions

The usefulness of GIS for seismic studies is emphasized due to capacity to store, process and visualize spatial information. The following databases are already have been compiled for the test site: geotechnical, building stock, records of blasts, microseisms and strong motion.

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