Modelling and Visualising Landscape and Terrain Impacts of Planned Developments

Gábor Barton, Katalin Bódis and Róbert Géczi

Abstract While it is true that modern remote sensing based terrain modelling techniques offer a fast, efficient and relatively cheap way to create terrain models, they are all limited to currently existing features. This means that they cannot provide information about future, planned changes to the terrain. In such cases we need to create surface models that can represent both the existing landforms and the planned modifications with appropriate reliability and accuracy. Such simulations can play a significant role in impact assessment studies, public consultation communication as well as offer additional insight into the consequences of a project. This paper will demonstrate some of the methods I have been developing using the example study area of a planned open-cast gold and silver mining operation in Roşia Montana, Romania. It describes the data sources used, the required conversion and harmonisation steps, the modelling of planned mining operations and the resulting visualisations and data products.

Keywords Visualisation · Terrain modelling · Hybrid surface models · Data conversion

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1 Introduction

Gold, silver, copper and other metallic ores have been mined in the Apuseni region of Romania for centuries, with archaeological finds dating back to Roman times. With regards to Roşia Montana, the most impressive of the relics is the vast network of mining shafts throughout the current settlement area, some of which is now part of the mining museum and open for visitors (Fig. 1).

Following a long history of subsurface operations, the communist era brought about the open-cast methods which included blasting away the mountains and processing the resulting rock material to extract the ore chemically. The state-owned mining activity was shut down in 2006, partly because of Romania's EU membership and the subsequent more rigorous environmental requirements, which could not have been met using the old technologies. Many of the surface waters have been heavily polluted and the landscape around the town has been altered with no (or very little) regard to environmental impacts.

Following the shutdown of the state mining company a new developer announced plans to open the largest open-cast gold and silver mine in Europe. Roşia Montana Gold Corporation (RMGC) has been lobbying at the Romanian government for support of the project since 2006. The idea met with large scale opposition in the country and its neighbours caused mainly by environmental concerns regarding the planned cyanide-based extraction process. While it is true that this method has been used previously, the new mining company planned to process the ore on site, as opposed to the previous processing location of Gura Roşiei and Baia Aries. These protests and several other activities have led to the 2014 decision of the Romanian

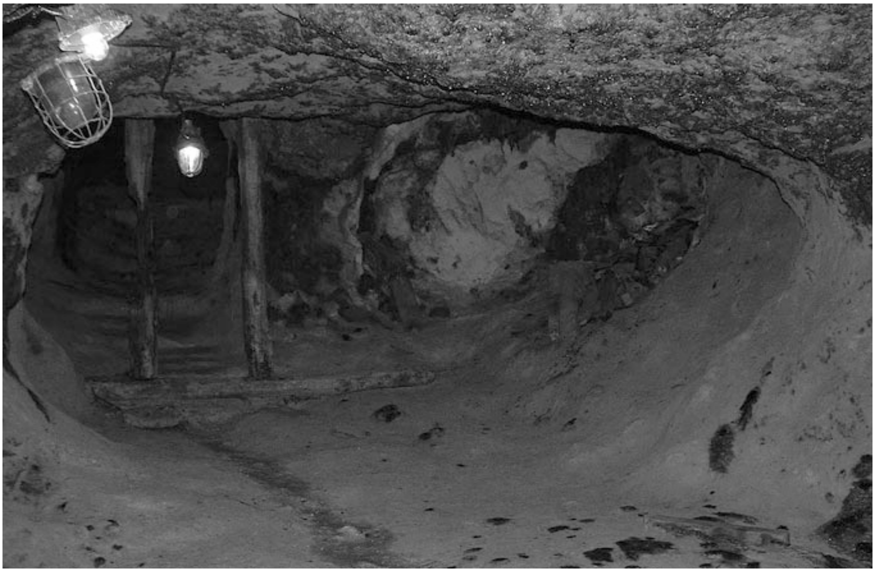

Fig. 1 Roman mining gallery in Roşia Montana (author's photo, 2005)

government to revoke its support for the project. However RMGC is still looking for a way to extract the 300 tons of gold and 1600 tons of silver that, according to their projections are present in the concession area.

2 Location of Study Area

The initial studies conducted by the researchers at the Department of Physical Geography at the University of Szeged focussed on the ecological assessment of the Roşia watershed (Géczi and Bódis 2003), but since the RMGC mining project area extends beyond the basin, the study area demonstrated in this paper has been expanded accordingly. The township of Roşia Montana is about 80 km Northwest from Alba Iulia (Fig. 2), the capital of Alba County, and it includes several smaller villages along the Roşia river, with a total population of 2656 in 2011 (INS 2011).

3 Methods and Data

In order to achieve the visualisation and modelling objectives set out in this paper several methods and tools had to be used, some of which may not seem relevant in the traditional GIS environment. The land cover component was based on Landsat

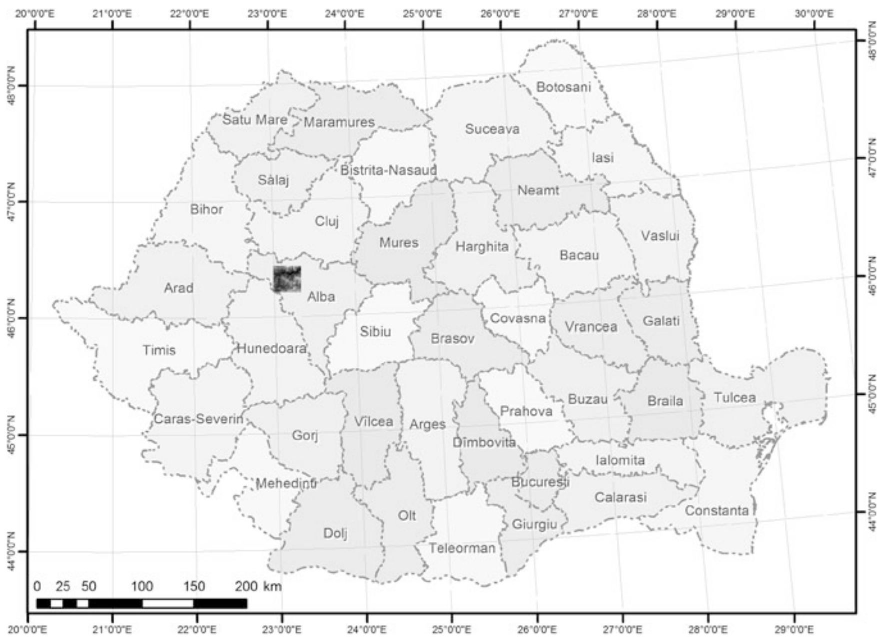

Fig. 2 Location of study area within Romania (ESRI Data and Maps, 2007)

(Chavez et al. 1991) images from 2004 at 25 m resolution. While generally we aim to use as high resolution data as possible, the limits of available computing power and financial resources did not allow the purchase of better terrain and imagery sources. However, the extent of the study area and the planned overview visualisations did not require the highest possible detail and made the processing much more efficient. The original Landsat image was modified using the Open Source GiMP software.

Terrain modelling was done using ESRI ArcGIS, specifically Spatial and 3D Analyst modules. The baseline was the freely available SRTM (Rodriguez et al. 2005) surface model at 90 m/pixel resolution, which had to be refined in order to allow the representation of artificial features. The initial SRTM surface was augmented with the models of the artificial features, whose creation and integration is the main focus of this paper. The source data of the planned surface objects was obtained from the maps found in the Environmental Impact Assessment report pages (RMGC 2014) of the RMGC website.

The research presented several data processing and conversion challenges, namely:

- converting and georeferencing maps in PDF files
- combining TIN and raster based surface models
- modifying and re-integrating satellite imagery

3.1 Surface Model Preprocessing

As a first step a common spatial reference system had to be determined. This is very important, because the different sources of data were based on different coordinate systems and in order to achieve coherent results, we need to have all the input data in a common system. UTM 34N projection was selected, which is usable in the study area and the software offers a transformation method from all the input projections used in the source datasets.

The SRTM surface model was originally in WGS84 coordinate system. Based on the negative experiences found in earlier experiments involving the transformation of raster data from WGS84 into a metric system it was more effective to generate contour lines from the original SRTM surface and use those as the source for the terrain information. The contours had 10 m intervals, which proved sufficient for the planned spatial resolution of the output models. The contour lines were transformed into UTM34N using ArcGIS, thus eliminating the adverse effects of reprojecting raster data (which would have produced significant errors in the UTM34N raster output).

The original SRTM surface had a spatial resolution of 90 m, which does not allow for the representation of smaller artificial features. This was an additional reason to use contour lines as a basis for terrain modelling, since using contours enabled the generation of a model with any resolution as deemed necessary. It is

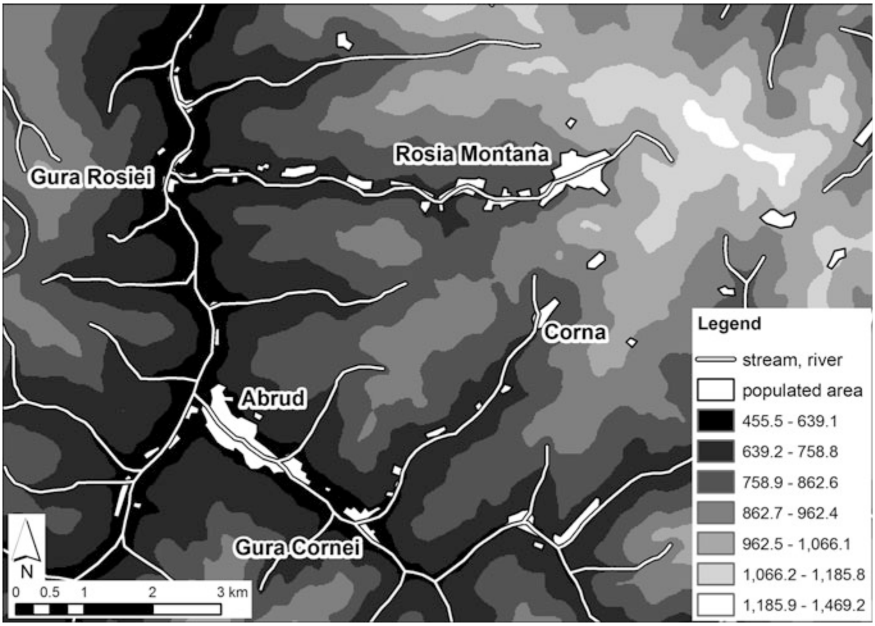

Fig. 3 Elevation, populated areas and stream network in study area

important to remember, that this "higher resolution" terrain does not mean that it offers higher detail than the original SRTM data, merely that the smaller cell size allows for better manipulation and editing that is required in the modelling process. The surface was created at 20 m resolution, which is detailed enough for the inclusion of most artificial features and still does not produce too large a dataset to handle.

One additional enhancement for the surface model was to generate a water flow network to avoid having unnatural surface elements. This stream network was manually digitised based on the morphological characteristics of the area and using the data found in the INSPIRE Hydrography view service (ANCPI 2014) of the Romanian National Agency of Cadastre and Land Registration. The river network was used in the surface interpolation as input to ArcGIS Spatial Analyst's Topo to Raster tool, including the generated 10 m interval contour lines, resulting in a 20 m resolution raster elevation model (Fig. 3).

3.2 *Modelling of Artificial Surface Elements*

The biggest challenge of the research was to find a way to integrate the models of the planned landscape alterations into the terrain model. The source for these features was found in the PDF files available in the Environmental Impact Assessment reports page of the RMGC website. The report contains quite detailed plans and maps of the surroundings, including roads, mining pits, quarries, waste dumps, water and material reservoirs for several points in time (current conditions and years 0, 7, 14, 16 of the project). The map documents also contained the information necessary to determine the coordinate system of the shown data, which was the Romanian Stereo70 system. First the PDF files had to be converted into a format understood by ArcGIS. The easiest solution was to create TIFF files from the map, which also allowed easier georeferencing. In order to reduce the number of conversion steps the coordinate graticule on the PDF maps to determine points of known Stereo70 coordinates, reprojected them directly into UTM34N and used these as reference points to place the TIFF files into their correct geographic position.

The next step was to generate 3D elements using the information found on the map sheets. Fortunately most of the required features had elevation values as labels and the map also contained contour lines at 5–10 m intervals. The elements were grouped into the following categories based on their function and shape (Fig. 4):

- flat surfaces (water, mining terrace)
- accumulation of material (waste dumps, dams)
- extraction (mining pits, quarries)

Modelling the flat surfaces was achieved by creating simple polygon shapes and giving them the elevation value from the map. In order to ensure seamless integration of artificial shapes into the source surface, some of these polygons had to be extended beyond the actual feature they represent (e.g. adding a 50–100 m buffer to the outline of the reservoir).

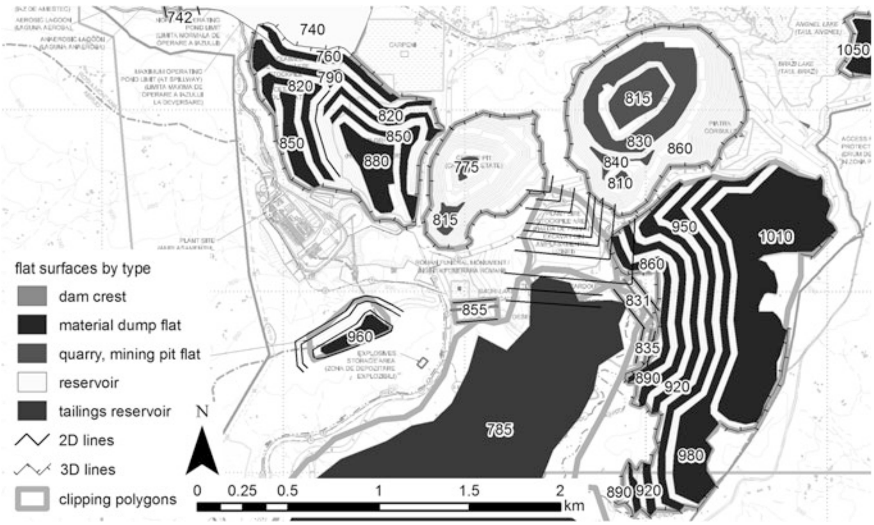

Fig. 4 Categories of artificial features and elevation values from project year 07

Fig. 5 Artificial terrain components of project year 07 in 3D (ESRI ArcScene)

Smaller dams were modelled by creating the crest as a flat polygon feature and two "contour lines" at the base on each side, setting the elevation value of the polygon to the height of the point where the dam structure meets the original surface. The large dam holding the sludge reservoir in Corna Valley was planned to be built in several stages and each stage had a different cross-section, so this dam had to be modelled for each time segment individually. The sludge reservoir presented an additional task because its surface is planned to be sloping in different directions, so additional contour lines had to be digitised as well.

Waste dumps containing the solid waste products and leftovers from quarrying are planned to be built in stages, resulting in step-like slopes and flat surfaces as the top levels. The most efficient way to represent these forms in 3D was to digitise the flat surfaces of the sides and the top with their corresponding elevation values and fill the gaps among them by simple triangulation (Fig. 5).

In addition to the generic features described above, some smaller size shapes were also required for the modelling which would add details that could not be modelled using the generic methods. Such features include the walls or ridges dividing mining pits, which are necessary to improve the accuracy of the model and the results of area and volume calculations. These were digitised as 3D lines where each vertex would have its specific elevation value based on the contour lines it intersects on the map.

In order to ensure the seamless integration of these surface components into the original terrain a 3D boundary line was created around the modelled features, which would obtain the elevation of its vertices from the original surface model. This is required for the outward slopes around the top level flat element of the waste dumps to reach the natural terrain where they are supposed to instead of creating vertical (or near vertical) walls around them.

The resulting component surfaces were all stored as individual TIN models covering only the area affected by each feature, except where the specific case warranted the use of a larger coverage for better integration. These cases were the dams and the various reservoirs, where using a larger area avoids the occurrence any gaps between the artificial feature and the original terrain surface.

3.3 Integration of Terrain Components

Once the component surfaces were ready they were joined together and merged into the original surface. At this point a choice had to be made between creating a fully vector or raster output surface. Both solutions have their pros and cons, some of which are listed in Table 1.

Based on the final output requirements and the spatial resolution of the available input datasets, it was decided to use raster surfaces in the integration process. This allowed better control of defining the relationships between the partial surfaces and the source terrain model as well as among the individual components themselves.

The integration process involved logical raster mosaic operations based on whether the component(s) represented features above the original surface or below. The artificial forms that overlapped one another also had to be taken into account and to make sure that each of them is mosaicked correctly (Fig. 6). One example was a smaller soil stockpile just south of the large sludge reservoir, which was supposed to cover parts of the dam slope, but not cut into it.

3.4 Satellite Image Manipulation

In order to simulate the visual impact of the various artificial features they also had to be represented in the imagery data. While the draped location map shown above

Table 1 Comparison of raster versus vector surface modelling techniques

Raster surface		Vector surface	
Advantages	Disadvantages	Advantages	Disadvantages
Simple storage logic	Detail level limited by cell size	Higher detail possible	More "edgy" visual output
More "natural" visual output	Larger files sizes	Smaller file size	Difficult to modify
Easy to manipulate with raster arithmetic			Higher display processing requirements

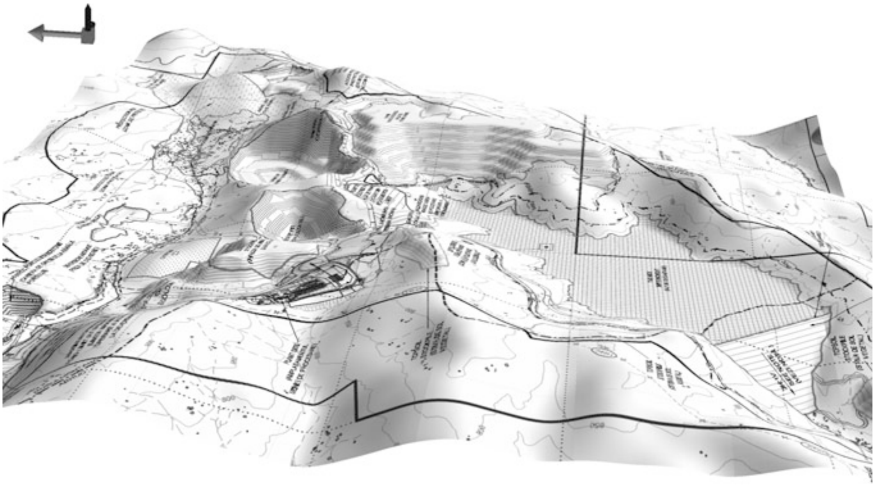

Fig. 6 RMGC map of year 07 draped over merged terrain components (ESRI ArcScene)

is quite informative for a more professional audience, the general public is more interested in the visuals rather than the technical details. The spatial resolution of the input data, the level of detail achieved in the terrain modelling process allowed the use of free Landsat images from 2001 with 25 m pixel size. Aiming to produce a visual simulation of the landscape, the standard RGB bands were used from the image and a simple minimum/maximum stretch with no modifications to the colouring to achieve a more natural result.

The first step was to convert the satellite image from a GIS-friendly format into one that can be understood and edited by standard graphics software (in our case GiMP for Windows). This process presented the risk of losing the georeferencing information stored within the original Landsat GeoTIFF file, because the tags containing geographic data are not picked up by GiMP and are lost in the output image. To solve this issue, the GeoTIFF file was converted into a regular TIFF format with an attached world file storing the georeferencing information required for ArcGIS to locate the image properly. The world file contains the X/Y coordinates of the top left corner and the pixel size in metres, which meant that as long as the original image size and orientation were maintained, the world file would always be able to define the geographic location of the file for GIS applications.

Once the world file was created the image could be opened in GiMP for editing. The first step was to define the textures to be used for the various artificial landscape features (waste dump, sludge reservoir, mining pit, dams, lakes, different stages of reforestation). “Fortunately” the area surrounding Roşia Montana has several existing examples of such features in various sizes so many of these could be used as texture and colour sources. Once the new texture had been selected the Clone tool was used in GiMP to paint the new texture over the area affected by the given artificial surface element. In order to keep the modifications within the boundaries of artificial areas their boundaries were also imported into the image as a separate layer and turned invisible before exporting the modified satellite image.

The original satellite image had to be modified for each modelled time instant, so in the end 5 images were created, each showing a different stage of the planned project. These images could now be draped over the modified surface models depicting the corresponding time period to show a simulated 3D view of the landscape.

4 Results

The two parallel modelling exercises (terrain and imagery) resulted in 5 surface models and 5 modified satellite images for the 5 different project stages used in the process. These datasets were then used to create various 3D animations, images, and also offered an opportunity to perform displacement calculations about the volume of the material that would have been moved during the mining project. Due to the relatively low resolution of the input terrain data (20 m), the accuracy of these volume calculations only allows estimated values and they should not be considered as final, definitive results. With higher resolution input data much better estimates can be achieved, but the during the procedures described in the current paper it was not possible to obtain more accurate input datasets. Figures 7, 8 and Tables 2, 3 will show some of the results.

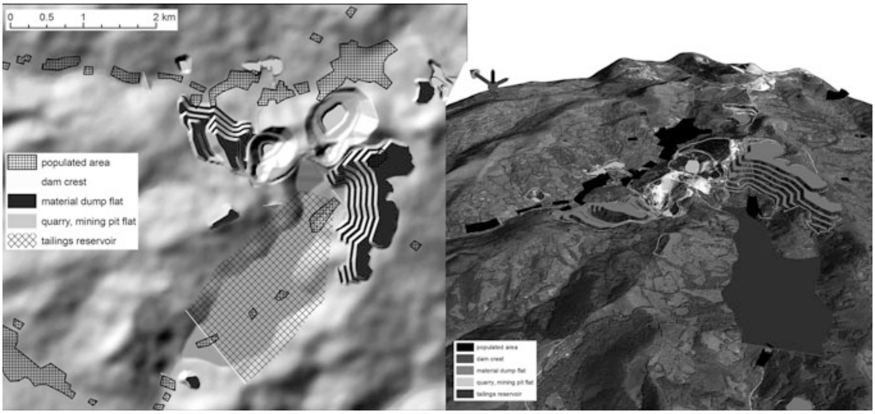

Fig. 7 Modelled features and simulated SPOT image from project year 07

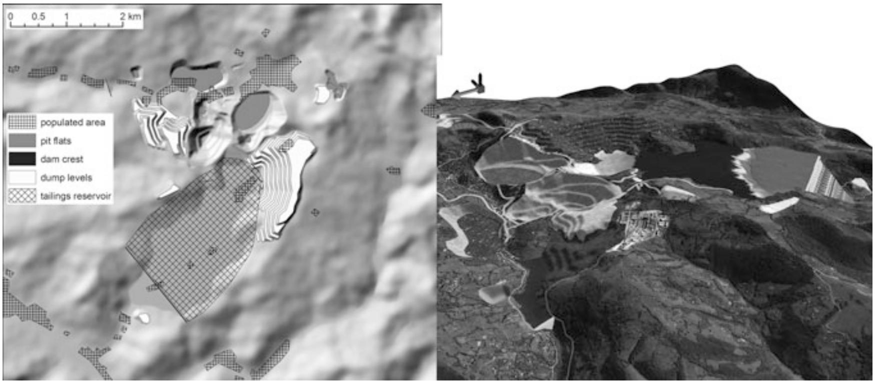

Fig. 8 Modelled features and simulated SPOT image from project year 14

Table 2 Modelled volume and area figures in project year 07 (ESRI 3D Analyst)

Landform	Volume change (×1000 m^3)	Affected area (ha)
Tailings reservoir	+15,150 (since project start)	55

Table 3 Modelled volume and area figures in project year 14 (ESRI 3D Analyst)

Landform	Volume change (×1000 m^3)		Affected area (ha)	
	From year 07	Current volume	From year 07	Current area
Tailings reservoir	+71,448	+139,136	+92	245
Cetate waste dump	0	+26,902	0	62
Cirnic waste dump	+25,885	+65,874	+18	143
Cetate pit	−41,428	−68,826	+21	71
Cirnic pit (lake)	+24,871 (water)	−51,548	0	68
Orlea pit	−24,051	−24,051	+36	36
Jig pit	−6164	−6164	+21	21

5 Conclusion

The present paper demonstrated the use of non-traditional methods and techniques which are required for the modelling and visualisation of landscape and terrain changes caused by future impacts. The main objective was to emphasise the significance and effectiveness of the combination of different data sources and modelling principles when dealing with changes that cannot be captured with remote sensing DTM techniques. The mixed application of vector and raster models offers adequate detail while maintaining the overall seamless visual integration of the resulting surfaces. It also shows the application for the time-series of surfaces in quantifying the volumes and areas of moved materials.

Another result is the procedure for modifying imagery data in order to simulate the landscape change. Converting the GIS images into graphics software compatible format while retaining the geographic information using world files allows the performance of any kind of image editing in the graphics application and easy re-integration into the GIS project for further visualisation stages. Collecting and applying the appropriate textures on modified areas can be achieved with standard graphics tools included in Open Source graphics applications as well.

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References

ANCPI (2014) http://geoportal.ancpi.ro/arcgis/rest/services/HY/HY_View/MapServer. Accessed 29 Dec 2014

Chavez P, Sides SC, Anderson JA (1991) Comparison of three different methods to merge multiresolution and multispectral data—Landsat TM and SPOT panchromatic. Photogram Eng Remote Sens 57(3):295–303

Géczi R, Bódis K (2003) Környezeti monitoring Verespatak környékén (Environmental monitoring in the region of Roşia Montana). Kriterion, Cluj Napoca, p 72. ISBN 973-26-0734-3, 973-82-3124-8

INS (2011) http://www.recensamantromania.ro/wp-content/uploads/2013/07/sR_Tab_8.xls. Accessed 2 Dec 2014

RMGC (2014) http://en.rmgc.ro/rosia-montana-project/environment/environmental-impact-assessment.html. Accessed 7 Dec 2014

Rodriguez E, Morris CS, Belz JE, Chapin EC, Martin JM, Daffer W, Hensley S (2005) An assessment of the SRTM topographic products. Technical report JPL D-31639, Jet Propulsion Laboratory, Pasadena, California, 143 pp