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ATTEMPT TO APPLY METHODS OF ANALYSIS OF SATELLITE IMAGES AND ELEVATION MODELS FOR REGIONALIZATION AND VALORIZATION (CASE STUDY OF NIGERIA)

key words: regionalization, valorization, satellite images, Nigeria

INTRODUCTION

The article is an attempt to apply methods of analysis of satellite images and computer visualizations in order to work out detailed physical-geographical divisions. The authors took the region of Nigeria as the research area. The country covers a large territory and is situated within several climate/vegetation and landscape zones. Moreover, the area shows highly diversified surface features, is characterized by variable hydrological conditions and, due to the rapidly growing population, experiences dynamic transformation of the natural and cultural landscape. Furthermore, there is relatively good comparative material for the region of Nigeria, i.e. regional divisions known in the reference books (compare Udo, 1970; Kimble, 1960; Mansel Prothero, 1960; Jelonek, Plit, 1997; Kawalec, 1987; Gilarowski, 2005). Thus, the aim of the article is to compare historical regionalizations of Nigeria made using traditional methods – that is basing on field research or aerial photos, with the results that can be obtained with modern methods of satellite image interpretation. The article is an attempt of a slightly different approach to the matters of regionalization of geographical space and valorization of scenic objects made from an external point of view (in the orthogonal projection) (Olędzki, 2007). This is the opportunity given by analysis of aerial and satellite photos as well as Digital Elevation Models (DEM). A new model of regional division of Nigeria, which was based on diversification of surface features, was created during the research.

The authors made an attempt to comment on and compare the obtained results with those existing in the literature on the subject (Nichol, 1984, 1991; Ogunjumo, Salami, 1990; Salami, 2004, 2006 a,b; Salami, Balogun, 2005, 2006).

THESES

- Modern methods of analysis of satellite images, facilitated by computer technology, give an opportunity for a new outlook on existing regional divisions (macro- and mesoregions) as well as landscape zones.
- Verification of new divisions should be made by means of support with field research, in order to exclude possible mistakes which could result from methodology and imperfect data processing by computer software (error correction).

Having studied various methods of spatial analyses, the authors chose a group of methods which were relevant for the assumed aim and source material. The methods were tested for their efficiency in regionalization and valorization procedures. Out of known methods of landscape valorization (listed below), methods were chosen which allowed for multi-criterion assessment of spatial units; this, in turn, made it possible to point to the possibility of distinguishing new spatial divisions, including regional and scenic units.

The following are worth mentioning among valorization methods:

- **Cartographic methods, e.g.:** bonitation method, matrix method, model of landscape as surface features, method of determining boundaries and ranges of scenic units, their features, intensity, needs, significance, relations, etc., method of cartometric determination of outlines of objects (scenic units) as basic fields of evaluation – determination of shape and size;
- **Terrain methods used mainly in landscape architecture, e.g.:** method of scenic interiors and units by J. Bogdanowski, method of impression curve by Wejchert, method of rural landscape classification by Sóhngen, "photographic" method by Cymerman and Hopper;
- **Methods of landscape evaluation based on the infrastructure value** (landscape as an element of the cultural-architectonical value) e.g. evaluation and valorization of landscape by means of assessing the value of objects included in it, e.g. property, building structures, monuments;
- **Methods of functional evaluation** e.g. agricultural, forest, urban landscapes, etc.;
- **Methods of evaluation of the photo-tonal value** (color range);
- **Methods of landscape evaluation by means of selected statistical parameters** (e.g.) basing on provisions of the fuzzy set theory for the value of space represented by the open space index, characterized by parameters of descriptive statistics.

The following methods proved most useful for verification of the existing units of physical-geographical regionalization of Nigeria: method of model of landscape as surface features, method of determining boundaries and ranges of scenic units basing on the diversity of surface features and relative altitudes, method of carto-metric determination of outlines of objects (scenic units) as basic fields of evaluation – determination of shape and size of spatial objects. These methods will be presented below on examples of procedures concerning evaluation of open areas using satellite photos and DEM models of the region of Nigeria.

METHOD DESCRIPTION

Comparison of satellite images overlapping the Digital Elevation Model (DEM) was very useful in the analyses. It made it possible to adjust scenic elements to the existing variability of surface features. The analysis of photo-tonal value assessment of objects in various satellite images was particularly remarkable. NASA LandSat-5 (pixel size of 28.5 m) and LandSat-7 (pixel size of 14.25 m) imagery, with by far the best pseudo-color range in landscape analyses, was selected for the analysis. Similar results were given by images obtained from the Web portal Google Earth (it is partly the same LandSat imagery), and full spectrum SPOT imagery (pixel size of 10 m) was also very helpful in the analyses (fig. 3).

With more detailed scopes of scenic research, it would probably be much more efficient to obtain images from SPOT-5 (pixel size of 2.5 m), or IKONOS (pixel size of 1 m).

Precise determination of regional units and physical-geographical units is possible e.g. with methods of analysis of terrain diversity of a given territorial unit, building a model of relative altitudes, or DEM analysis and comparison with an overlapping satellite image. Thus distinguished units are characterized by objectivity – they are based on the constructed spatial model rather than only intuition of the re-searcher and biased analysis of a physical-geographical map.

The maps of Nigeria (fig. 1A,B) presented below prove relatively significant differences in that regard. One of them (A) presents units distinguished with traditional methods in the 1960s (after Udo, 1970), while the other (B) was generated by the authors with computer methods based mainly on the altitude model corrected by overlapping satellite imagery from LandSat-7. Particular differences can be obser-ved in the NE part of Nigeria, near Lake Chad. Borders of other units also differ from the traditional division scheme.

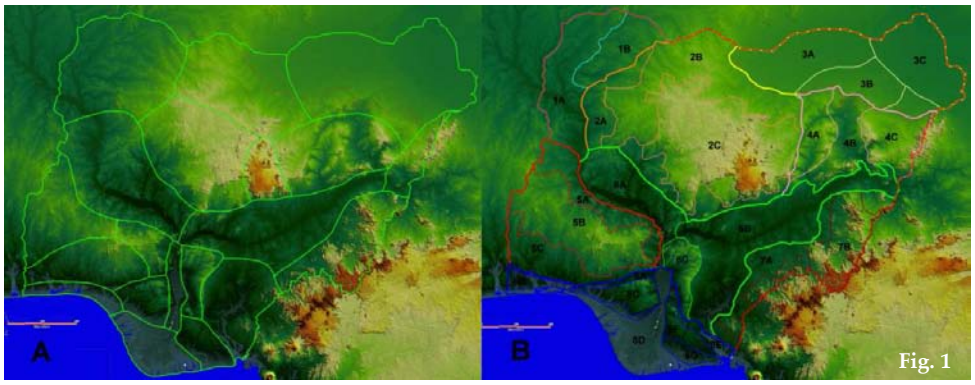

Fig. 1

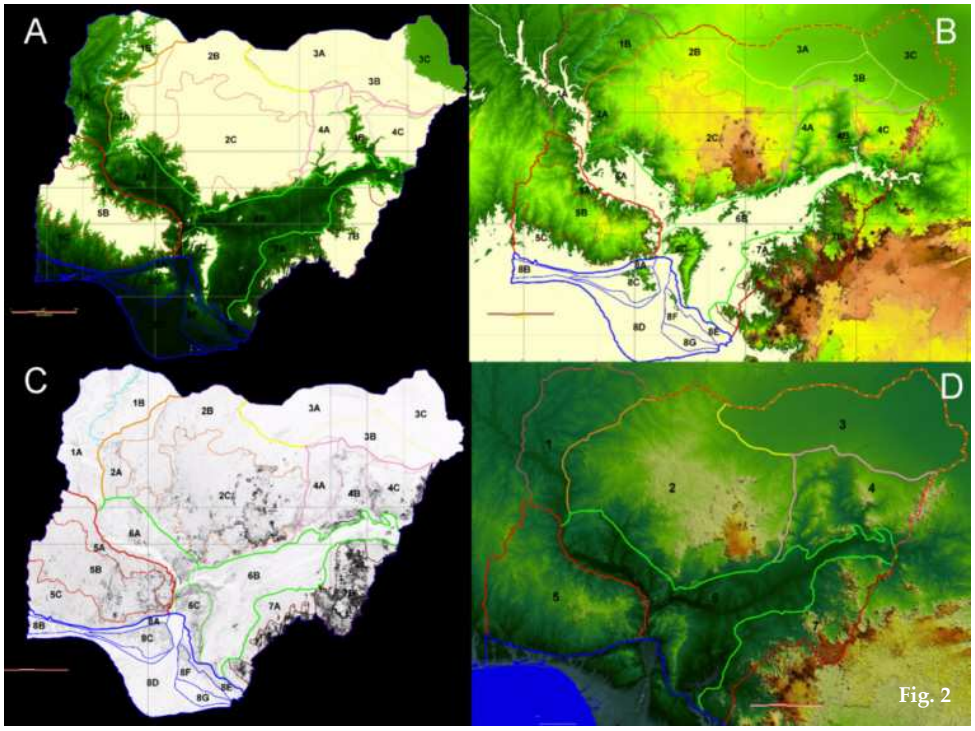

Fig. 2

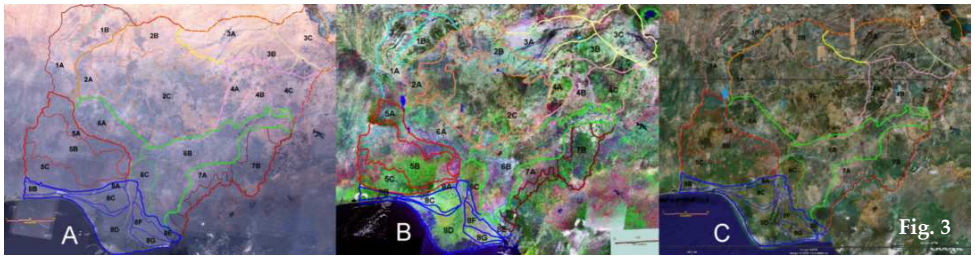

Fig. 3

Fig. 1. Hypsometric Model of Nigeria on the Basis of Digital Elevation Model and satellite pictures:
A- physiographical units delimited by traditional methods *(by R.K. Udo, 1970).*
B - physiographical units delimited by relief diversified analysis.

Fig. 2. Example of cartographical analysis of Nigeria relief on the basis of hypsometric model. Letters – province units; numbers – subprovince units:
A – shadow relief on the model up to 3000 m a.s.l.; B- shadow relief on the model
– range 250-2500 m a.s.l.; C – analysis of relative heights (the darkest colour – most different relief);
D – physiographical units on the DEM - shadow from NE direction, high of light 60^0.

Fig. 3. Mosaic of satellite pictures with overlapping physiographic units: A- Spot - 4; B- LandSat – 7;
C – Google Earth.

Basic analyses of the area of Nigeria were carried out with various modifications and processing variations of the generated DEM. Hypsometric analyses of surface features were made to confront them with the structural units marked on the geological map in the scale 1:1000000. Various models of surface features of Nigeria were generated basing on the DEM, with changes in shading directions, altitude ranges and color ranges, in order to obtain a full view of the surface features of the area. Thus created model of relative altitudes (the darker the color, the larger the level drops), allowed for assessment of variability of the surface features. Experiments showed that the best model to present the area of Nigeria would be the DEM – shaded from N-E, with the sun at an altitude of 60 degrees (fig. 2).

Detailed distinction of lower-level units was facilitated by information regarding the features of the landscapes, including predominant vegetation, river network, changeability and variety of surface features, etc. The scenic analyses allowed for more precise generation of lower level regional units (letter symbols – see fig. 1B).

Further on in the research work, the selected methods were used for identifying and determining the range of zones of uniform scenic value and transition zones. Here, the authors used available information regarding diversity of surface features and scenic values typical of a given territorial unit. Then, altitude differences and drops, along with visibility of surface features, were analyzed within these units. This method made it possible to generate maps of various scenic values for Nigeria.

The map that was chosen as an example of such values was one generated basing on bonitation assessments, stored in the database and referring to particular territorial units (fig. 4). The figure below presents how scenic values change depending on the range of observation and the selected square, as well as on presented predominant feature for the landscape. The factors that were considered included plant cover, hydrographic elements, diversity of surface features, phototonal variability,

density of infrastructure, etc[1].

The presented map is based on assessments relating to a given unit of area; the more detailed the data introduced in the database of scenic values for a given unit, the greater the preciseness of the generated map. The size of analyzed squares is extremely important, in order not to miss significant details that determine the assessment of the landscape with the applied level of generalization.

The presented valorization of landscape could be used for analyses of coherence (uniformity) of particular selected physical-geographical units. In this way, it would be possible to use statistical methods to try to determine the outlines of scenic units. It is therefore possible to present selections of cartometric outlines of scenic units as basic fields of landscape assessment, by showing types of landscape. Further conesquences of such approach would include basic statistics describing the structure of the landscape of physical-geographical units[2]

The authors also point to possible use of this method in determining the borders of different types of landscape use and their practical meaning, e.g. for tourism. This approach is an attempt to classify and evaluate the selected fields and an assessment of the level of their uniformity, rank and usability.

As Nigeria has large areas with poorly diversified structure and surface features, valorization analyses of landscapes require selection of a respective scale. After a number of attempts, the authors suggested the basic grid cell of valorization analysis at 25 km for the whole territory (fig. 4A). Landscape of each area has its characteristic and specific predominant elements. The analysis showed that the most important elements for Nigeria are features of plant cover and structural surface features. Fig. 4B presents an example of valorization where the predominant emphasis is on vegetation and surface features in the 25 km grid cell, although a grid with 10-km cells would also be a good field for valorization of such a big region (fig. 4D). Valorization in a thicker (5 km) grid without predominant elements (fig. 4C) may lead to lack of generalizations and may not show basic tendencies.

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[1]Due to the specifics of imaging of elements of the geographical environment, it proved appropriate to consider the assumed features depending on the season; e.g. plant cover was analyzed in photos from the wet season while diversity of surface features in those from the dry season.

[2]This could be, for example, a complete computer database with information regarding features of the physical-geographical environment, related to a particular unit, e.g. type of bedrock, type of soil, type of vegetation, etc.

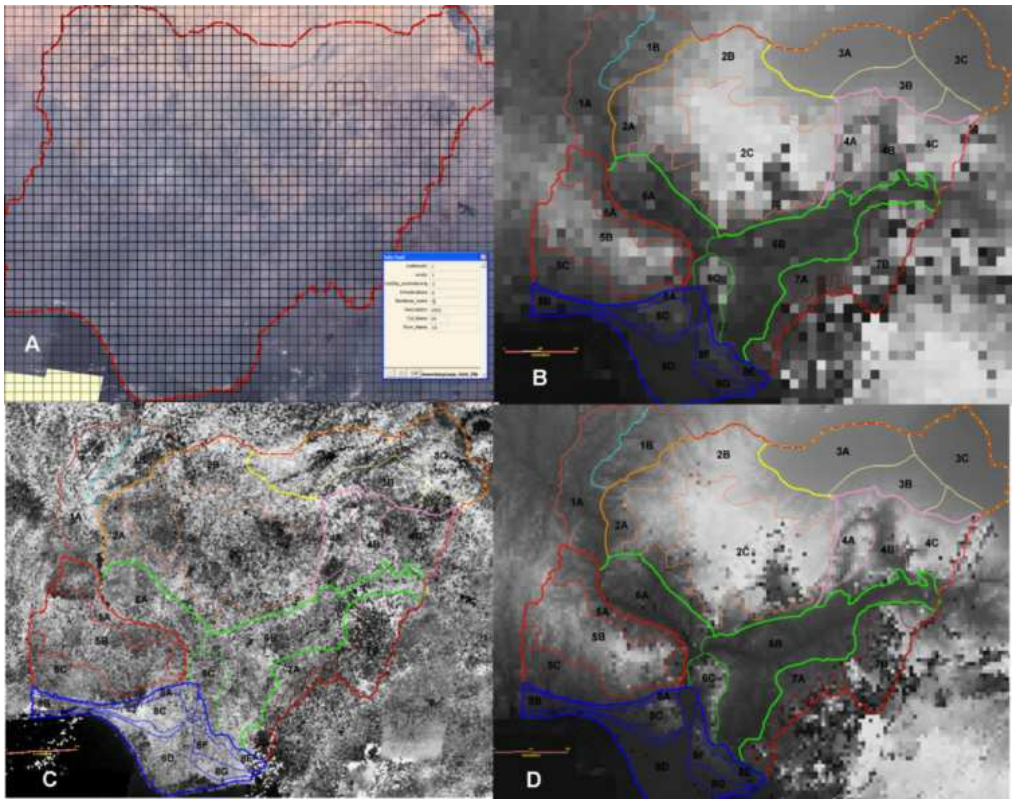

Fig. 4. Example of valorization analysis of Nigeria landscapes on the background physiographical units; A- basic grid cell 25x25 km (right-lower corner window of data base with quality class evaluation); B – example of vegetation an relief evaluation in grid cell 25 x 25 km; C- examples of valorization without dominants elements in grid cell 5x5 km; D – example o relief valorization in grid cell 10x10 km.
Source: *compiled by the authors.*

CONCLUSIONS

Landscape, regardless the way it is defined, is, and will be, subject to valorization (evaluation). The authors suggest that the group of landscape valorization methods (mentioned in the introduction) should be enhanced with other (new) methods of assessment and valorization of landscape, which are based on thorough analyses using computer technology and analyses of satellite imagery as well as statistical information included in databases.

Most researchers perceive the landscape in a complex manner as a notion both geographical and environmental – from the point of view of an observer located inside the landscape (in the spatially hierarchic, perspective projection). Enhancing

landscape studies by adding analyses of satellite imagery and DEM models is an attempt to look at the landscape from outside (in the spatially uniform, orthogonal projection). With multiple assessments of the landscape, an unbiased evaluation is necessary; this is made possible by the discussed methods and techniques. The authors see this approach as a chance for a more unbiased (reduced error of subjectiveness) analysis of scenic specifics, evaluation of features of the geographical environment, spatial regionalization or delimitation of borders. More preciseness could be introduced in landscape assessment by using statistic tools.

Regionalization and valorization procedures, described in this way, are much more precise and do not allow for too much freedom of interpretation (thus limiting the percentage of error) in comparison with methods regarded as traditional. Common use of modern computer techniques and increasing availability of satellite images may result in further specification of results of research carried out in various areas.

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SUMMARY

The aim of the presentation is an attempt of a new approach to the matters of regionalization of geographical space and valorization of scenic units made from the outside reference point (in the orthogonal grid). Such an opportunity to take a look from another perspective is given by analysis of aerial and satellite photos, and DTM.

Regardless of the adopted way of perceiving the landscape: either as a peculiar spatial structural-material unit (an approach typical of natural sciences), or a physiognomic approach (typical of humanist and technical sciences), the landscape requires appropriate categorization and evaluation.

The presentation shows methods which allow for multi-criterion evaluation of spatial units, and then basing on this, suggest possibilities of new spatial divisions.

From the point of view of analysis of Sat images and DTM, the most important methods include:

Cartographic methods, like: bonitation method, matrix method of determining landscape value, landscape model as surface features, method of determining boundaries and ranges of scenic units, their features, intensity, needs, significance, relations, etc., method of cartometric determination of outlines of objects (scenic units) as basic fields of evaluation – determination of shape and size;

Terrain methods used mainly in landscape architecture, like: method of scenic interiors and units, method of impression curve by Wejchert, method of rural landscape classification by Sóhngen, "photographic" method by Cymerman and Hopper,
Methods of landscape evaluation based on the infrastructure value (landscape as an element of the cultural-architectonical value) e.g. evaluation and valorization of landscape by means of assessing the value of object included in it, e.g. property, building structures, monuments;
Methods of functional evaluation e.g. agricultural, forest, urban, etc.;
Methods of evaluation of the photo-tonal value (colour range);
Methods of landscape evaluation by means of selected statistical parameters (e.g.) basing on provisions of the fuzzy set theory for the value of space represented by the open space index, characterized by parameters of descriptive statistics.
These methods will be presented using several examples of open space value estimation procedures in LandSat photos and DEM models from the region of Nigeria.

The presentation will continue with selected methods being used for identifycation and determination of the range of uniform scenic value zones and transitional zones. Cartometric extractions of outlines of scenic units as basic fields of evaluation will be shown, types of landscape discussed and basic statistics describing its structure presented. The authors will also refer to the issues of limits of landscape use and their practical meaning, e.g. in tourist terms.
At attempt of classification and valorization of separated fields has been presented, along with estimation of the level of their uniformity, rank and usability.