# New Trends in Obtaining Geographical Information: Interpretation of Satellite Data

**Hana Svatoňová**

**Abstract** Visual interpretation of satellite data is a new trend of obtaining geographical information for the common populations. Research participants (11, 15 and 19 years old students) were asked to solve spatial tasks on both true and false colour images. Differences in the efficiency of task solving regarding various types of source documents were analyzed. The generated scores were evaluated according to the participants' age and gender. The research results show that young non–experts interpret satellite data in false and true colour successfully.

**Keywords** Geographical information · Interpretation of satellite data · Remote sensing · Earth observation

## 1 Introduction

Satellites orbiting the Earth can acquire an enormous amount of data over a range that would be impossible for any ground-based methods alone. Space technology is usable for lot of problems of global dimensions. For many years valuable data and equally valuable experience has been gained with satellites such as Landsat, NOAA, Meteosat, ENVISAT and many others. Satellite data are used in basic research to refine the scientific picture of the Earth, for detection landscape changes, education and disaster management (Dordain 2007). The potential of Earth observation by satellite is enormous. Satellite images are an increasingly important source of information about the geographic reality (Kovařík 2012; Talhofer et al. 2015).

The purpose of the study described in this paper is to investigate, analyze and compare the efficiency of reading images and maps, the ability of adolescent children to read images in relation to colors used, and the subjective opinions of

H. Svatoňová (✉)
Department of Geography, Faculty of Education, Masaryk University,
Porici 7, 60300 Brno, Czech Republic
e-mail: svatonova@ped.muni.cz



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research participants on the difficulty of reading various types of images and their preference for images or maps as a source for acquiring information.

## 2 Interpretation of Satellite Data

Satellite data as well as maps contain positional and thematic information. Interpretation is the specific process of study of geographic reality based on the detection, identification and spatial localization of individual objects and terrain features recorded in the satellite images. To interpret the image means to decipher its contents in terms of purpose (Svatoňová and Lauermann 2010). Information is encoded in images in different shades of colors and textures.

Acquiring geographic information from images involves the following steps:

- in the correct recognition and classification of objects,
- in determining their properties, quantitative and qualitative characteristics,
- the accurate spatial (position) localization of detected objects,
- examination and assessment of the interaction and causality between the displayed objects and phenomena,
- analysis of these links and detect patterns that characterize critical components and properties displayed area.

The elements of visual image interpretation—colour and tone, texture, shadow, pattern, association, shape, and size—are routinely used when interpreting satellite imagery (Lillesand et al. 2008).

The basic element of interpretation is the colour and tone. Both of interpretation signs represent the primary level of complexity. The size and shape as the geometrical arrangement of the colours represent secondary characters. Colorful shapes of a certain size have texture or pattern—are spatially arranged. Deductive elements are height and shadow, context and place, these constitute the highest, fourth degree of complexity.

Adults' obtaining information from images by visual interpretation was analyzed by Lloyd et al. (2002) and Van Coillie et al. (2014). Lloyd et al. (2002) investigated how people process information from aerial photographs to categorize locations. Three cognitive experiments were conducted with human subjects viewing a series of aerial images and categorizing the land-use for target locations. Van Coillie et al. (2014) analyzed the accuracy of image digitization performed by adults with various degrees of experience regarding processing images and various degrees of motivation. Digitizing accuracy varied strongly across monitored participants. Moreover, it was stated that, generally, the accuracy was very poor. Svatonova and Rybansky (2014) evaluated various types of landscape visualization with respect to reality perception. Testing of research participants proved that the most effective visualizations are simulated flights over the country and 3D visualizations using orthogonal images.

### 2.1 Colour of Image as an Important Sign of Interpretation

A colour represents another important element of an interpretation aid. Black and white images generally appear to be more difficult to interpret. In the case of colour images (both true-colour and false-colour), the method of interpretation depends on the aim of the particular task and the need to identify the features as having various physical or chemical properties. Satellite images are provided to the users in true-colour and false-colour colours. The colours in an image will depend on what kind of light the satellite instrument measured. True-colour images use visible light, red, green and blue wavelengths—so colour are similar to what a person would see from a space. False-colour (not-true-colour) images incorporate infrared light and may on expected colours (NASA 2014).

Though there are many possible combinations of wavelength bands, the Earth Observatory typically selects one of four combinations based on the event or feature we want to illustrate. A false-colour image sacrifices natural colour rendition (in contrast to a true-colour image) in order to ease the detection of features that are not readily discernible otherwise (for example the use of near infrared for the detection of vegetation in satellite images, floods are best viewed in shortwave infrared, near infrared, and green light because muddy water blends with brown land in a natural colour image. Shortwave infrared light highlights the difference between clouds, ice, and snow, all of which are white in visible light). A false-colour image can be created using solely the visual spectrum (e.g. to accentuate colour differences), typically some or all data used is from electromagnetic spectrum outside the visual spectrum (e.g. infrared, ultraviolet or X-ray). The choice of spectral bands is governed by the physical properties of the object under investigation.

## 3 Research

The research was focused on a comparison of visual interpretation efficiency for true-colour satellite images and false-colour satellite images.

Research respondents solved selected spatial (and identical) tasks in pairs of documents (true-colour image and false-colour image). Tasks were focused on the identification of types of objects and land-use defined in satellite images with a scale 1:100,000. The main research questions, with subquestions, were formulated with respect to the following research objectives:

- What is the difference in the visual interpretation of true-colour satellite images and false-colour satellite images?
- Is the identification score for types of land use and the purpose of selected objects identical for true-colour satellite image and false-colour satellite image?
- Are the respondents more successful in the identification of elements in true-colour images or false-colour images?

- What types of land use are distinguished better in true-colour images and what types are easier to identify in false-colour images?
- How well can the students interpret satellite images taken at different times?

Considering the research questions, the test was focused on the evaluation regarding the efficiency of interpretation of satellite images. Used documents (see description below) were sorted in two groups and two equivalent test sets were created—version A and version B.

Three questions were aimed on the objective differences in the interpretation of images:

- Specify, which types of land and objects (water area, river, forest, field, built-up area) can be found in the not-true-colour image and the true-colour image.
- Match the map cutout into the appropriate segment in the not-true-colour image and the true-colour image.
- Analyze two satellite images taken of the same locale 20 years apart and describe how the mining area and its vicinity changed.

Testing was performed at the schools in the spring and autumn of 2013. Research questionnaires were distributed as individual tests for students. The purpose of the test and organizational instructions were presented to students at the beginning. No time limit was specified, however, students completed the test in an average time of 20 min. Eventual ambiguities were answered during the test. With respect to the test form and task specification, the score was assigned manually. Answers were evaluated by one person.

## *3.1 Test Documents: True-Colour and False-Colour Images*

Cutouts from images taken by LANDSAT satellite was used to test work with satellite images. Images taken by the LANDSAT 7 satellite were selected for testing. The participants solved identical tasks using true-colour images or false-colour images. With respect to the purpose of false colours, we were interested, if the not-trained interpreters could achieve better results identifying particular objects, even if these colours were not true.

True-colour images contain clear, needed colour combinations of channels in RGB evoking an impression of the true colours. In this image the true colours can be obtained from channels 1 (blue), 2 (green) and 3 (red). The RGB colour combination '321' is favorable for non-expert interprets, because the colours of the object match with reality. However, false colours are frequently used for practical applications. In this case, combinations of different channels and colours are used and provide better interpretability of objects or their features. The colour combination labeled '742' was selected for false-colours, which allowed for good recognition of water areas, rivers and forests. The colours of LANDSAT images combined with RGB (Red, Green, Blue) '742' option shows the water areas in blue

**Fig. 1** Cutouts from LANDSAT images, *left* true-colour satellite image, *right* false-colour image (*Source* TopGIS)

or black, water streams in blue and the forests are displayed green; fields are displayed by a pink-green mosaic, built-up areas appear in violet-pink. The image colours enabled a very good distinguishing of water areas and flows. Fields are more difficult to find a parallel with reality for non-expert interpreters; depending on the crop or surface (they appear as a pink-green mosaic).

Test documents:

- True-colour satellite images (LANDSAT 7, RGB '321'), scale 1:100000, resolution 30 m.
- False-colour satellite images (LANDSAT 7, RGB '742'), scale 1:100000, resolution 30 m.
- A pair of satellite images from the LANDSAT satellite dated 1984 and 2005 (Fig. 1).

## *3.2 Participants*

Research was performed with students aged 11, 15 and 19. In total, 378 students participated in the research: 198 boys and 180 girls. Students aged 11 and 15 were educated at elementary school. They were members of eight different classes, two different schools. One teacher conducted all the lessons in each school. The 19 years old participants were first year university students (Teaching of Geography, Masaryk University, Brno, Czech Republic). 90 % of the students studied at grammar school in the past. Two subsequent classes whose lessons were conducted by one teacher were tested.

## *3.3 Evaluation and Results*

The second part of the research was focused on a comparison of visual interpretation of true-color images and false-colour images by adolescents.

The following conclusions can be made based on an evaluation of tasks focused on the identification of particular objects in false-colour images and true-colour images:

- The participants achieved an average score from 66 to 94 %.
- The average score achieved in images with different colours is not same. Differences in score were small, differences corresponding to the age groups of participants were maximally 5 %, see Fig. 2. Slightly better scores were achieved with false-colour images.
- Image interpretation skills changed with participant age. 11 and 15 years old students achieved better results with false-colour images. That result is in contrast with their subjective evaluation of image reading difficulty as related to colours, as the participants considered the false-colour images very difficult to read.
- The evaluation of interpretation efficiency in relation to gender shows very similar values. The only exception was 11 years old girls, who had significantly better scores for true-colour images (difference 15 %). This supplements and confirms the analysis of reading of aerial images and maps. In this case, both genders showed similar results with images (there was a difference for maps).
- The efficiency of identification of selected objects and areas varies in relation to colours used in the image provided as a source for identification.
- Participants achieved very good scores in the identification of water areas and rivers shown in false colours (water areas: on average 95 %, 15 and 19 years old students achieved full 100 %; 83 % for rivers in false-colour images vs. 61 % for true-colour images). This confirms the assumption that the selected colour combination, i.e. LANDSAT 7 image with combination '742', enables a very good distinction of water areas and water flows to non-experts. The reason is that these elements appear in expected and predictable colours.

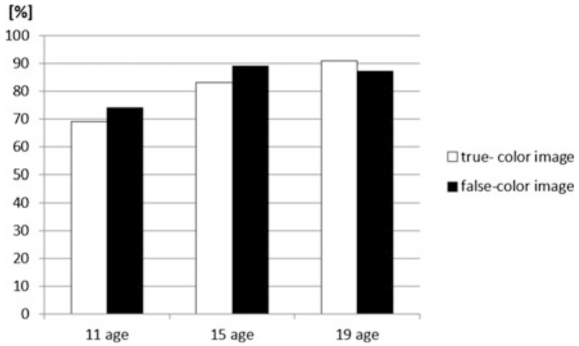


**Fig. 2** Efficiency of object identification regarding true-colour images and false-colour images

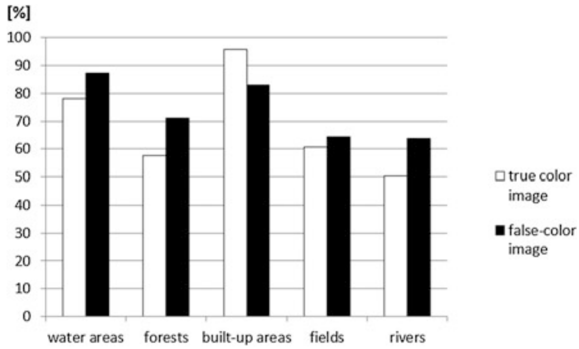


**Fig. 3** Efficiency of interpretation of types of land in satellite images in relation to image colour type

- Participants were slightly more successful in identifying built-up areas, fields and forests in true-colour images. However, the differences were within 5 %. The unusual colours used to display built-up areas in false-colour images confused only 11 years old participants, which achieved a score of 83 % (a very high score all the same) compared to 96 % achieved with true-colour images. Consistent scores exceeding 70 % were achieved for forest identification in true-colour images and the score increased with age, specifically from 58 to 93 %.
- Generally we can observe that non-experts and children without previous training are able to interpret false-colour images very well (Fig. 3).

Detailed analysis in relation to participants' age was performed for the task of identifying the type of land-use. The older participants showed a more efficient identification of land-use type.

- Significant difference was detected between 11 years old children and the other two age groups. The youngest group did achieve a significantly lower score. The other two age groups were quite equipollent. In other words, there is a big jump in score between the 11 years old students and the older participants.
- Only the score for identification of "built-up area" types in true-colour image was very similar across all age groups. 11 years old children achieved almost the same score as older students.
- The success ratio remained unchanged for various areas. 11 years old participants showed the same differences in score according to the type of the area, but the total results were ca. 20 % lower than score achieved by 19 years old participants.

The participants were also asked to assign a map cutout to the appropriate location in satellite image (in both true-colour images and false-colour images). The two cutouts contained objects with noticeable colours or shapes (e.g., lake and airport runway), the other two cutouts contained less noticeable objects (suburban settlement and highway crossing). The evaluation brought a number of results:

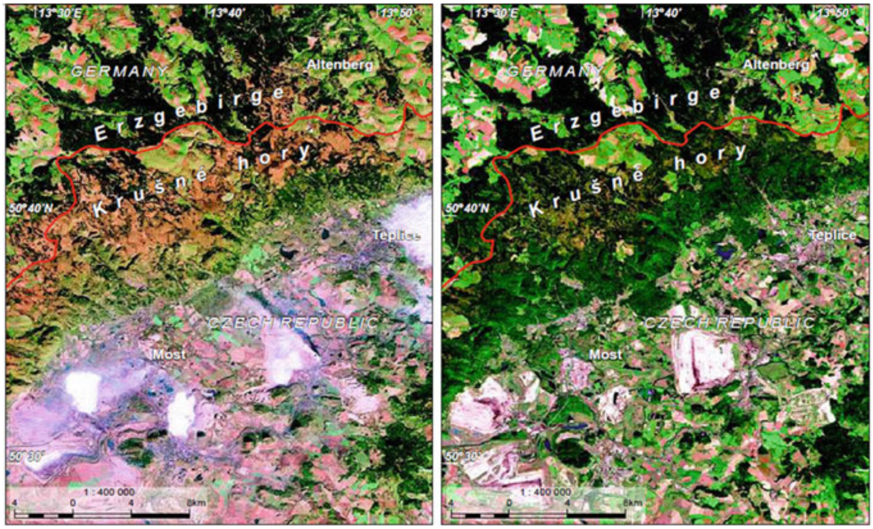


**Fig. 4** Landscape changes in time, Ore mountains in the Czech Republic and greats lignite mines Landsat satellite images, *left* 1984, *right* 2005 (*Source* ESA School Atlas, p. 200)

- Cutouts with noticeable objects (e.g., lake—shape and color, airport—shape) were assigned correctly with score up to 100 % in several groups of participants, including the youngest participants.
- For the cutouts containing less noticeable objects, the score was significantly lower: working with suburban settlements: ca. 50 % of participants correctly assigned a round settlement with a forested area; ca. 44 % of participants correctly assigned a highway crossing (both were presented in true-colour images).

The identification of landscape changes over time was quite difficult for students. The real situation in LANDSAT 5 and LANDSAT 7 satellite images displayed a landscape dramatically damaged by surface coal extraction, surrounded by damaged forest in 1984 (see Fig. 4). After 20 years this area is significantly reclaimed, but the extraction still continues into a limited extent (image dated 2005). However, all the answers containing a formulation mentioning a positive change, such as "forest ratio is increased", "forests are greener", "there are more meadows, fields and ponds", "the damaged areas are smaller", "the landscape looks more healthy, greener", etc. were considered to be correct.

The results show that:

- Participant age played significant role in the ability to specify the changes in the area. 19 years old students achieved significantly higher scores, probably also thanks to a deeper knowledge of environmental issues, as they are confronted with these issues during their entire education process.
- Further analysis of results according gender shows that the girls achieved higher average scores than boys. A reason in the 15 years old students' group could be

the faster development to maturity and better formulation and synthetic thinking in girls.

Moreover, subjective classification of the difficulty of object identification in true-color images and false-colour images was evaluated as well. We wanted to know if the subjective evaluation corresponds with the objective results, and eventually how the subjective evaluations change with participants' age.

## 4 Discussion and Conclusion

Satellite images are an important source of information about the geographic reality. Their potential for obtaining geographical information is enormous. Visual interpretation is a new trend how to take geographical information for the common populations. Childrens' ability to interpret aerial images very well was confirmed also in study realized by Liben and Yekel (1996) and Muir and Blaut (1969). The purpose of the research was to compare differences in the efficiency of visual interpretation satellite images in various color presentations. It was found that:

- The participants achieved an average score from 66 to 94 %.
- Image interpretation skills changed with participant age.
- The average score achieved in images with different colours is not same.
- The older participants showed a more efficient identification of land-use type.
- Participants were slightly more successful in identifying built-up areas, fields and forests in true-colour images.
- Participants achieved very good scores in the identification of water areas and rivers shown in false colours.
- Participant age played significant role in the ability to specify the changes in the area. 19 years old students achieved significantly higher scores.

Differences in map skills related to gender were confirmed also by Chang and Antes (1987). The development of visual and cartographic skills by tracking landscape changes in satellite images taken from different points in time seems to be very promising. It is difficult for younger students, but they achieve very good results with a teacher's support (see also studies performed by Blaut et al. (1970)). Landscape changes and their environmental evaluation represent an important part of an education in landscape and environment protection. The monitoring of landscape changes is also necessary in case of emergency situation when such changes could indicate number of natural or human-induced catastrophes (Hošková-Mayerová et al. 2013; Hofmann et al. 2013, 2015). According to the trends, satellite and aerial images are very useful tools for obtaining the geographical information.

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