Effects of JPEG2000 lossy compression on remote sensing image classification for mapping natural areas

ALAITZ ZABALA [(1)], XAVIER PONS [(1,2)], JOAN MASÓ [(2)], FERNANDO GARCÍA [(3)], FRANCESC AULÍ [(3)], JOAN SERRA [(3)]

[(1)] Department of Geography. Edifici B.
[(2)] Center for Ecological Research and Forestry Applications (CREAF). Edifici C.
[(3)] Department of Information and Communications Engineering (DEIC). ETSE.
Autonomous University of Barcelona
E 08193 Bellaterra, Barcelona.
SPAIN

Abstract: This study measures the effect of lossy image compression on the digital classification of forest areas. A mixed classification method comprising satellite images and topoclimatic variables for mapping vegetation land cover was used. The results contribute interesting new data about the influence of compression on the quality of the cartography produced, both from a "by pixel" perspective and also regarding the homogeneity of the polygons obtained. The area classified in classifications only carried out with radiometric variables increases as image compression increases, although the increase is smaller for JPEG2000 formats, especially in fragmented areas. On the other hand, the area classified decreases in classifications which also take into account topoclimatic variables. Overall image accuracy diminishes at high compression levels, although the point of inflection occurs in different places depending on the compression format (highest accuracy for JPEG and fragmented images occurs at lower compression levels). As a rule, the JPEG2000 format gives better results both quantitatively (accuracy and area classified) and visually (images with less "salt and pepper" effect).

Key-Words: Remote sensing , image classification, lossy compression, natural areas

1 Introduction and aims

In 1991 the JPEG format [1], developed by the Joint Photographic Experts Group, first appeared and revolutionized image compression due to the fact that it achieves very high compression levels with no appreciable loss of image quality, at least for file sizes up to approximately 20% of the original. Later there appeared compression techniques based on wavelet transformations which permit even higher compression levels with similar image quality. In recent years, SID, ECW and JPEG2000 formats [2] have been particularly popular with the Remote Sensing (RS) and Geographic Information Systems (GIS) community. It is important to bear in mind that in every case we are dealing with lossy compression algorithms, which sacrifice part of the data in order to achieve a higher compression ratio.

In spite of the spectacular nature of the compression levels achieved, there has been little quantitative analysis of the implications of these compressions. This study aims to assess the influence of image compression on digital classification applied to areas of natural vegetation and is based on the authors' own experience and on that of studies [3], [4] and [5].

Moreover, our study covers a wider area, which should provide more representative results. In line with current practice, it also aims to evaluate multitemporality and the use of topoclimatic variables to improve the classification.

2 Material and methods

The classification method used is a combination of satellite images and other topoclimatic variables over vegetation land covers, which is designed to improve the accuracy of the classifications [6].

The training areas were obtained from the *Mapa d'Hàbitats de Catalunya* (Habitat Map of Catalonia) and underwent statistical treatment to guarantee their quality.

In order to measure the effect of topoclimatic variables and compression on the results of the classification, various scenarios were considered.

In each case, both situations were analyzed: **scenario R** had only images (radiometric variables) whereas **scenario RTC** also had topoclimatic variables. **JPG** and JPEG2000 compression techniques were also analyzed for each scenario. JPEG2000 will be referred to as **J2K**.

Compression size was based on compression ratios (CR) and not on compression quality (standard for JPG) since we considered it more relevant given the clearly practical applications of our research. It should be borne in mind that the same compression ratio may produce different degrees of quality depending on the type of image:

$$CR = \frac{Size\ \ of\ \ Compressed\ \ File}{Size\ \ of\ \ Original\ \ File}$$

The compression ratios used for each scenario were: 100% (uncompressed image), 60%, 50%, 40%, 30%, 20%, 10%, 5% and 1%.

Analysis of classification accuracy (with or without compression) is based on test areas (ground-truth layer) which are different from the training areas.

2.1 Areas and scenes used

Two medium-sized areas with different levels of spatial fragmentation were chosen. These were analyzed using Landsat images recorded on 26-04-02, 13-06-02, 16-08-02, and 12-03-03 for the first area and 13-06-02, 12-03-03, 26-07-03 and 11-08-03 for the second. The first area is the Garrotxa, the dimensions of which are 1264x1264 pixels of 20x20m (50175.8 ha. of vegetation land cover). The second area centers on the Maresme-Vallès and its dimensions are 3474x2323 pixels of 20x20m (146687.3 ha. of vegetation land cover).

A mask obtained from the *Mapa de Cobertes del Sòl de Catalunya* (Land Cover Map of Catalonia) was applied over the original images (after they had been geometrically and radiometrically orthocorrected) in order to classify only the areas of vegetation land cover.

2.2 Image compression/decompression

The compression/decompression algorithms used were the implementation of the MiraMon 5.2 classic JPEG (**JPG**) based on the JPEG public libraries and **J2K** [7] a JPEG2000 implementation for compression, while Kakadu for decompression. A conversion to byte format (8 bits/pixel) has been made in order to easy compare results with other software.

2.2.1 NODATA value

The original images display areas without data (NODATA) due to the geometric and radiometric corrections to which they were subjected and to the presence of a small number of clouds. Not all the compression/decompression programs used are currently able to recognize these NODATA values. Using them as actual values when compressing will generate gross errors in the images generated. It is therefore necessary to eliminate these values from the images before compression. Elimination is carried out using the MiraMon FagoVal module, which selectively eliminates (phagocytes) a given value in raster files, replacing it (in this case) by the arithmetical mean of the adjacent values. Finally, it is necessary to create a mask with the NODATA areas in the original images in order to reapply it over the image after compression.

2.2.2 Classic JPEG format compression

In the classic JPEG format the quality of the resulting JPEG file is usually set. In general, and even after modifying the quality, it is not possible to generate a JPEG file of a given size (in other words, one whose compression ratio with respect to the original file is a concrete value). Therefore, for each compression scenario the JPEG file whose size is nearest to the one that is necessary to obtain this compression ratio was chosen.

2.2.3 JPEG-2000 compression format

The standard JPEG2000 includes the possibility of generating a resulting image of a specific size. It is therefore a simple matter to generate compressed images with a given compression ratio.

2.2.4 Decompression and subsequent treatment

After decompressing the images, it is necessary to eliminate the 255 value (future NODATA value) assigning it to the nearest value immediately below. The mask corresponding to the original NODATA areas must be applied to each image.

2.3 Classification

The classification methodology employed demands that the variables used in the classification be standardized. The mixed classification is subsequently carried out using the MiraMon IsoMM and ClsMix modules (Fig. 1).

The same classification parameters were used in all the scenarios (those which maximize the accuracy in the classification of the uncompressed image).

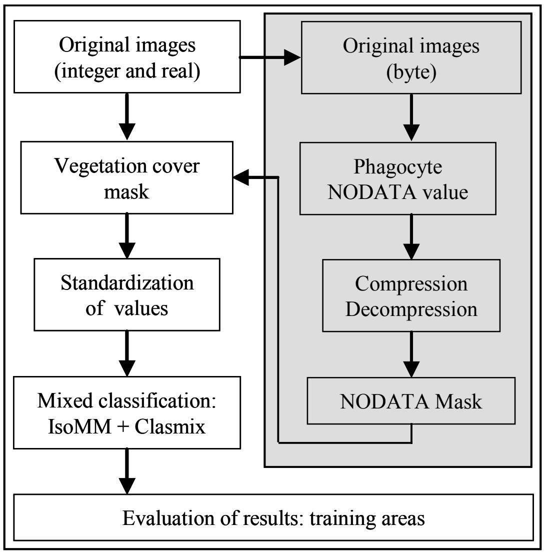

Figure 1: Diagram of methodology used

3. Results

Figures 2 and 3 show the results for the images of the areas of the Garrotxa and the Maresme-Vallès respectively. For each area, the top graph shows the global accuracy obtained by the classifications and the bottom graph indicates the percentage of area classified, both according to the compression ratio (CR).

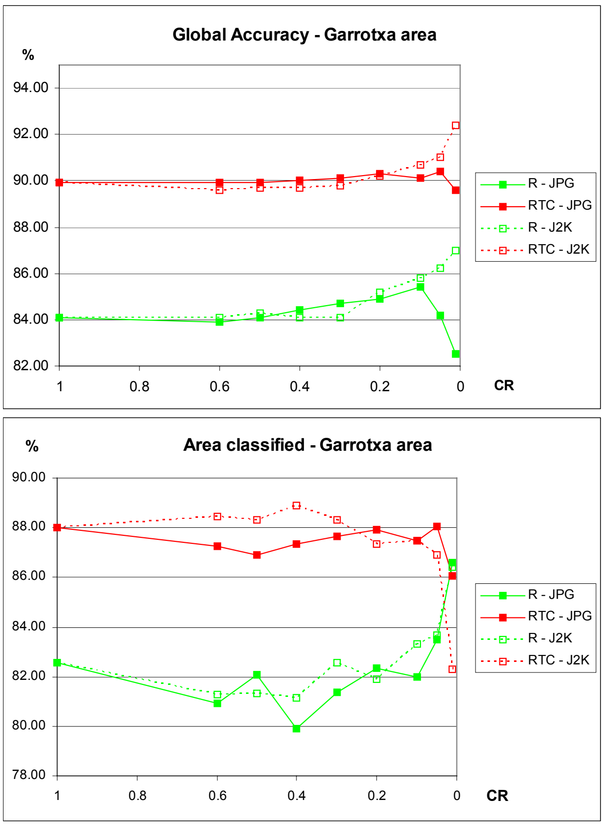

Figure 2: Results from the Garrotxa area. a) Global accuracy, b) Area classified

In all the graphs, the color green indicates classifications that only include radiometry (scenario R) and in red those that also include topoclimatic variables (scenario RTC). Continuous line: JPG compression; dotted line: J2K compression.

As the CR decreases, in scenario R the tendency is for the **classified area** to increase. This is probably due to a beneficial homogenization of the images. The increase in area is smaller for the J2K compression, especially in fragmented areas (Maresme-Vallès). On the other hand, in scenario RTC, the area classified decreases. This would seem to indicate that compression affects the topoclimatic variables more profoundly, perhaps because they are more continuous.

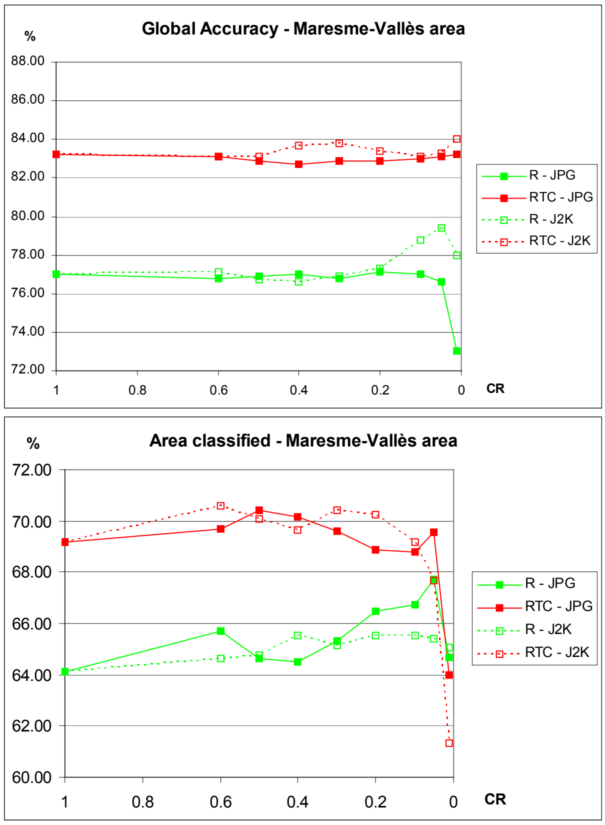

Figure 3: Results for the Maresme-Vallès area. a) Global accuracy, b) Area classified

As CR decreases, the **global accuracy** increases at first, but decreases for JPG at low CR, especially in scenario R – JPG. In scenario RTC – JPG, accuracy decreases, but to a lesser degree. On the other hand, for the J2K format global accuracy appears to increase indefinitely for the Garrotxa area, but not for the Maresme-Vallès area.

4. Conclusions

The conclusions of the study suggest the following optimal work scenarios:

- Scenario R – JPG: CR 0.2-0.1 is optimal for less fragmented images (Garrotxa) as accuracy is greater (higher than the original image) and the percentage of area classified is similar or only slightly smaller. CR between 0.5-0.1 for more fragmented images.
- Scenario R – J2K: for less fragmented images we have not reached the optimal CR limit (in any CR, accuracy and area classified increase), but in more fragmented images, optimal CR is 0.05.
- Scenario RTC – JPG: optimal CR is 0.2 for only slightly fragmented images, although the results are similar to those for the original images. In more fragmented images, CR 0.5 has the largest area classified and only slightly less accuracy.
- Scenario RTC- J2K: maximum CR 0.3- 0.2 (Garrotxa) or 0.4-0.3 (Maresme) as the area classified later decreases below the area classified in the original image.

It is important to point out that the J2K format is better than JPG, but in border areas between highly differentiated spectral classes, compression produces mixing effects that lead to errors in these areas. Fig. 4 indicates that the J2K classification (left), the border areas between *Pinus sylvestris* (blue) and *Fraxinus sp*. (pink) and between *P. Sylvestris* and Mediterranean mountain scrubland (green) remain unclassified (grey).

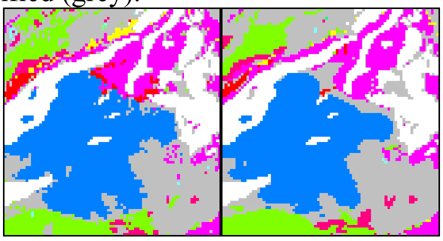

Figure 4: Border effects of the classification: original (left), J2K CR 0.01 (right).

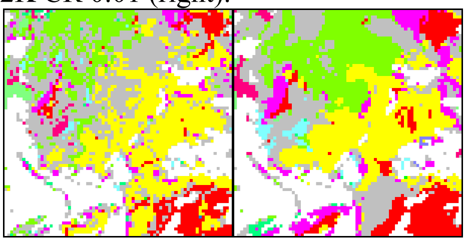

Figure 5: General detail of the classification: original (left), J2K CR 0.01 (right).

These border effects will have a marked impact on future studies of changes in land use which may produce masked results due to the erroneous classification of the border areas. This is aggravated by the virtual non-existence of test areas in these areas, which will hide the decrease in global accuracy.

It is also important to point out that for J2K the classification has a smaller "salt and pepper" effect than the others (Fig. 5) and, therefore and from a cartographic perspective, the J2K approach is much more effective.

Acknowledgements

It would not have been possible to carry out this study without the financial assistance of the Ministry of Science and Technology and the FEDER funds through the research project: "Wavelet image compression for Remote Sensing and GIS applications (WAVEGIS)" (TIC2003-08604-C04-00). We would also like to express our gratitude to the Catalan Water Agency and to the Department of the Environment and Housing of the Generalitat (Autonomous Government) of Catalonia for their investment policy and the availability of Remote Sensing data, which has made it possible to conduct this study under optimal conditions. We would also like to thank our colleagues of the Department of Geography, CREAF and the DEIC of the UAB (Autonomous University of Barcelona) who have collaborated in any way in the treatment of the images, and INTA for its efficient image subscription service.

References

[1] Wallace G.K., "The JPEG still picture compression standard". *Communications of the ACM*, Vol. 34, No. 4, 1991, pp.30-44.

[2] Taubman D.S., Marcellin M.W. *JPEG2000: Image compression fundamentals, standards and practice*. Kluwer, Academic Publishers, 2002.

[3] C. Pérez, D. Aguilera, A. Muñoz, "Estudio de viabilidad del uso de imágenes comprimidas en procesos de clasificación". *Teledetección y desarrollo regional. X Congreso Nacional de Teledetección*, 2003, pp. 309-312.

[4] F. Tintrup, F. De Natale, D. Giusto, "Compression algorithms for classification of remotely sensed images". *Acoustics, Speech and Signal Processing. ICASSP '98.* Proceedings of the 1998 IEEE International Conference, Vol. 5, 1998, pp. 2565-2568.

[5] J.D. Paola, R.A. Schowengerdt, "The effect of lossy image compression on image classification". *Geoscience and Remote Sensing Symposium, 1995. IGARSS '95.* 'Quantitative Remote Sensing for Science and Applications', International 1: 118-120.

[6] P. Serra, X.Pons, D. Saurí, "Post-classification change detection with data from different sensors. Some accuracy considerations". *International Journal of Remote Sensing*, Vol. 24, No. 16, 2003, pp.3311-3340.

[7] F. Auli-Llinas, J. Ramon-Paton, J. Bartrina-Rapesta, J.L. Monteagudo-Pereira and J. Serra-Sagrista. " J2K: introducing a novel JPEG2000 coder". In *Visual Communications and Image Processing (VCIP). (SPIE)*, Beijing, China, July 2005.