

Automatic delineation of forest ecosystems by combining GIS layers and Remote Sensing images

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Abstract— The survey of forest is made by analyzing representative samples of the different ecosystems. Even if expert knowledge is necessary it's often difficult to manually explore wide surfaces to define and localize the ecosystems. We propose in this article an automatic process to estimate and localize the ecosystems by integrating GIS information Layers, remote sensing images and expert knowledge.

One observation is that same ecosystems are localized in close environmental conditions (i.e. elevation, ground, humidity, temperature ...). All the required information are contained in GIS information layers (more than 20) that we combined in a specific way to obtain areas having same environmental conditions. We name such areas ecological units. Experts also observe that same kinds of forests are visually close so we use a texture analysis of remote sensing images to eventually discriminate ecosystems within the same ecological unit.

The research of ecological units close to the ecosystems requires to correctly select the layers and eventually to simplify them. This leads to an iterative algorithm that we detail in this article. The selection of the most important ecosystems or the localization of the more representative samples won't be discussed here.

Keywords: Remote sensing, Ecological Unit Delineation, GIS, Environmental Monitoring, Ecosystems Survey, Texture Analysis

I. INTRODUCTION

During the previous decades the information collected on the earth surface have increased considerably. Indeed GIS were filled in different ways (automatically, manually ...) and by different actors (biologist, authorities ...) depending on the thematic field (geography, forest preservation, country planning ...). It represents major data which summarizes some expert knowledge.

During the same period, the resolution of satellite images also increase and is now below 1 meter (QuickBird: 0.6m, IKONOS: 1m). This allows extracting vegetation from satellite image scenes with a fair accuracy [1, 2, 3, 4] and studying forest border with one tree precision [5, 6, 7].

Besides, the survey of the whole forest can mask the disappearance of some ecosystems. Indeed the wide surface covered by forests and the complex structure of the canopy

don't allow splitting the forest into different ecosystems only using image analysis.

To realize such a task we use other information such as GIS information layers to define and characterize each ecosystem.

In this article we propose an iterative algorithm to estimate theoretical ecosystems by integrating vector information (GIS information layers) and raster images analysis.

Section II defines the way to estimate ecosystems. Section III presents the algorithm composed of two main steps. Section III presents the main results and section IV the conclusion and perspectives.

II. DEFINITION

An ecosystem is relatively complex to define and biologists often have a coarse definition of the existing ones. One observation is that close ecosystems evolve in close environmental conditions. So we estimate the ecosystem by this way using the different information contained in GIS layers. We use more than 20 layers such as elevation, humidity, ground, vegetation, temperature, slope

We define an ecological unit as being a land surface having common values for some selected layers. An ecological unit could be composed of several samples having disjointed areas. Figure 1 summarize this definition.

III. THE ALGORITHM

A. Principle

The use of all layers to define the EU leads to a lot of small units. This is not useful for biologists because they have to control each of them. Moreover, some ecosystems are artificially split into two or more units.

So we have to carefully choose the layers to use in order to have wide and representative units.

The algorithm is an iterative process which alternates two steps. The first step combines some selected GIS information layers in order to obtain theoretical Ecological Units (EU). The second step validates or not the EU by computing a criterion. Then at the end of the algorithm we

solve local problems with a clustering process apply to each EU separately.

The EU are a trade-off between wide surface and homogeneity.

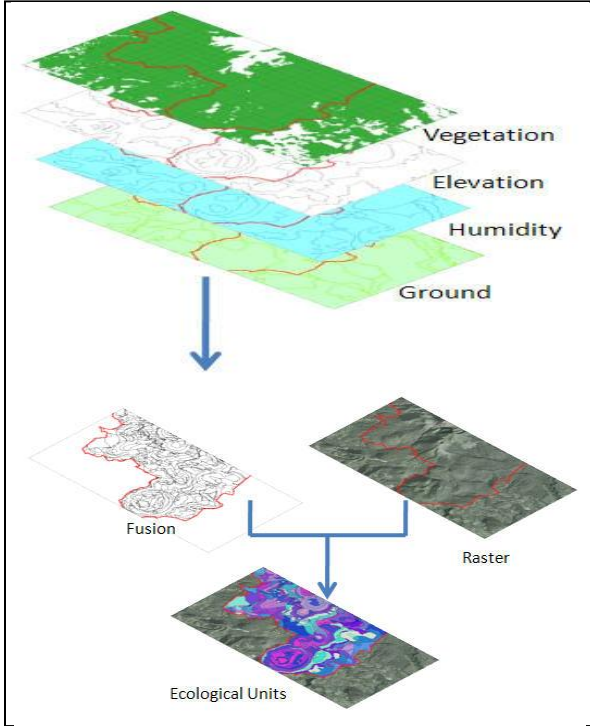


Figure 1. Ecological unit

B. Step one : layers fusion

This step consists on choosing a subset of layers and on applying fusion rules to obtain Ecological Units.

The choice is made randomly at the first iteration.

If some EU are non homogenous (see C.) we solve one or more conflicts by adding, removing or replacing a layer.

This step is a combinatorial optimization process and we explore the neighborhood of the current subset to choose the transition that reduces more conflicts than the other.

C. Homogeneity criterion: texture analysis

For each ecological unit obtained using the previous layers fusion process we compute an homogeneity criterion based on texture analysis.

We compute color [8] and texture features using co-occurrence matrix [9], Gabor filters [10], Laws filters [11], Hue moments [12] and fractal dimension [13]. This wide approach allows including geometrical, statistical, frequential and fractal approaches.

Each Ecological Unit can be composed of several separate areas. Each area should be homogenous and the

complete unit too. So we compute the distribution of the features vectors within an area and decide if it is homogenous by fixing a threshold on the variance of the distribution. Then we compute the distribution and variance of all areas in the same way.

Each EU is then set with a homogeneity coefficient. The value is set to 0 if the EU is homogenous, else it is the product of the EU surface and the distribution variance.

D. Step two: new EU production

The first step stops when the layers subset doesn't evolve anymore or when the maximum number of iterations is reached.

Most of the times, several EU are still non homogenous. The first reason is that there are several ecosystems within the same EU. Indeed, the EU don't exactly fit the ecosystems and some environmental data could lack to correctly split the forest. The second reason is that an external action has locally changed the environment (natural disaster, human activities ...). In our study the main reasons are: illegal buildings or agricultures within protected forest areas or ground slippage.

For these reasons, each non homogeneous EU will be classified using a clustering algorithm such as K-Means [14] or SVM [15].

The resulting classes are analyzed by experts to decide if they lead to new EU (as example we often have a class representing trees shadows which doesn't lead to new EU).

Figure 2 summarize the different steps.

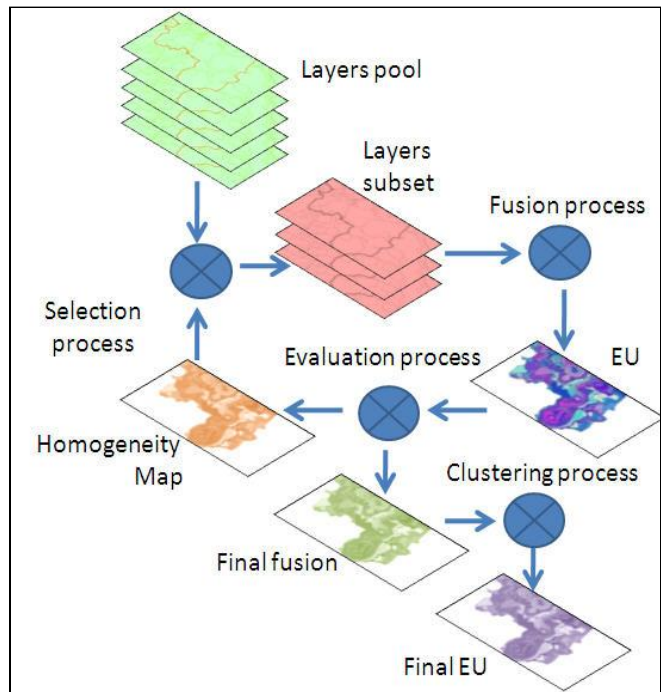


Figure 2. The algorithm

IV. RESULTS

For this study, we use very high resolution satellite images from IKONOS and QuickBird satellites and orthophoto in order to have as much details as possible.

We used 26 GIS Layers and each feature is computed on an elementary sample (5x5 pixel window). The feature vectors were normalized.

Before applying the algorithm on real data we validate the approach with synthesis data: a virtual set of ecosystems, a virtual set of information layers and a virtual image built with textures with the following constraints : an ecosystem is represented with a unique texture but different ecosystems could have the same texture.

The first set of test was realized in the following way: we built the information layers in order to have a subset of layers exactly corresponding to the ecosystems. This first set allows validating the selection, fusion and evaluation processes. For this validation time was not a limitation so we run the algorithm until the subset doesn't evolve. For 100% of the case (about 100 simulations) we reach the good subset.

The second set of test introduces errors in the layers definition. There is no layers combination leading to the ecosystems. This introduces non homogeneous EU. In this case we fix the maximal number of iterations to 50. The best subset obtained at the end of the first step is then improved with the clustering process. To evaluate the results we compute the mean homogeneity coefficient for the resulting EU. Figure 3. gives the distribution of the homogeneity coefficient for 100 simulations. We remark that most of the values are under 0.1 which indicates a good global homogeneity.

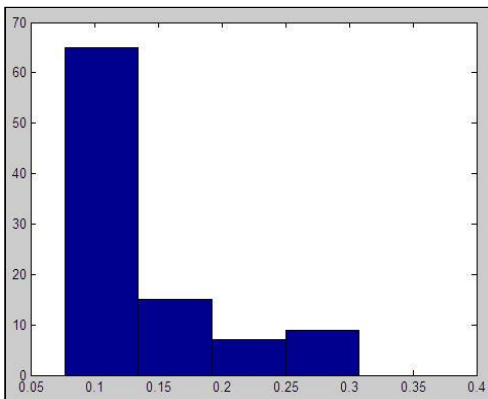


Figure 3. Homogeneity coefficient distribution

Concerning real case experimentation, the algorithm has been used over the Guadeloupean National Park in the Caribbean. The raster image is an extract of an IKONOS scene (4 spectral bands) and an orthophoto (3 spectral bands). Some ecological units have been investigated by the experts in order to validate the approach. Results are convincing but more investigation is necessary to

statistically validate the model. Meanwhile, a visual interpretation of the results shows that most of the ecological units are homogeneous.

Figure 4. gives a result for the first step of the algorithm. The resulting subset of layers is composed of 4 layers. As we can see visually close areas are split into different units using the GIS layers. The example shows 3 ecological units and the EU number 2 is not homogeneous. The homogeneity coefficients for the three units are respectively: 0.07, 0.3, 0.05.

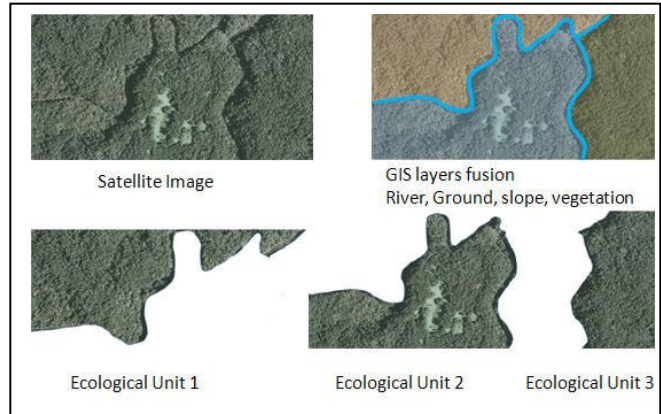


Figure 4. First step results: Ecological Units

The images in figure 4. are extracted from the resulting EU (end of first step).

For each of these EU we apply the second step in order to compare clustering results as if with the algorithm we only have to apply it on the second unit.

Figure 5. shows the clustering results using a K-means algorithm. The first and third units are homogenous so the number of clusters for these units is set to 2 (one for the main ecosystem and one for the shadow). The result is convincing and the clusters are representative of both classes (forest and shadow). For the second unit the number of clusters is set to 3. Results are also convincing because the second ecosystem (responsible of the non homogenous unit) is localized.

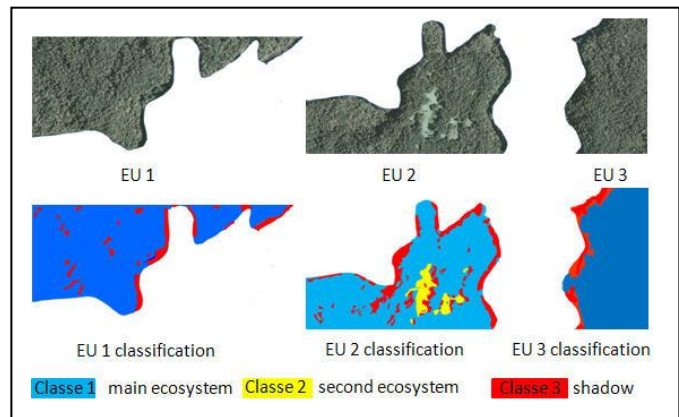


Figure 5. Clustering results

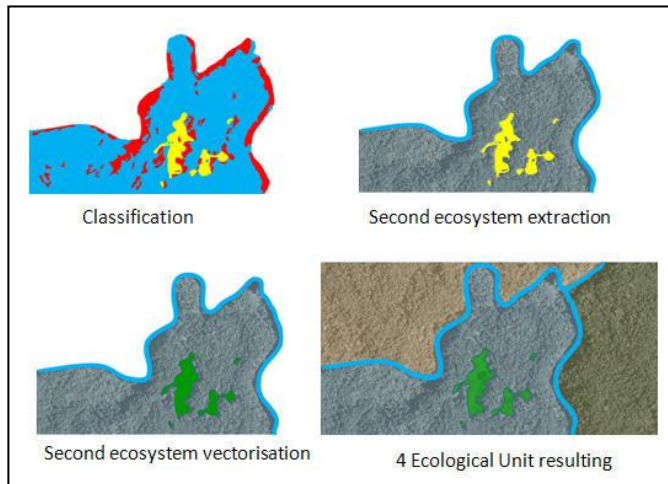


Figure 6. New Ecological Unit

After having classify the non homogenous unit, the experts validate the clusters representing an ecosystem. In the illustration the new ecosystem is linked to a ground slippage.

Figure 6. shows the extraction of one cluster which leads after a vectorisation to a new Ecological Unit.

V. CONCLUSION

On conclusion, the GIS framework offers to remote sensing technologies a way to reach more applications and users. There is more and more data which are collected by different ways and different institutions and accessible in a GIS environment. Remote sensing images are often used as background images to bring out some information layers but rarely used as a real information layer. By computing local features (color or texture features in the scope of this study) we also produce a new vectorial information layer.

In this study we present the interest of using images to handle problematic not reachable with vectorial data. As an illustration we use both vectorial and raster information to define and localize ecosystems.

The algorithm proposed in the article is composed of two steps, the first one manages GIS layers to approach ecosystems and uses satellite images so validate each unit, the second one uses the image to eventually produce new units.

In this article the selection of ecosystems and the localization of interesting unit samples used by biologists to survey the forest is not discussed. The experts define some criterion to guide the choice of units (i.e. the wider ecosystems or the more threatened).

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