VISUAL INTERPRETATION OF COLOURED COMPOSITIONS OF SATELLITE IMAGES AND MAPPING OF LANDSCAPE UNITS

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How should satellite images be read, how should this visual reading be interpreted and how can the elements necessary for mapping landscape units be identified? These are questions faced daily by users of high-resolution SPOT satellite images in the fields of agriculture, forestry and other land uses. The following we shall attempt to describe the main parameters making it possible to draw up a grid for the reading and interpretation of SPOT images in multispectral mode, with particular emphasis on the problems of recognising and describing the visual entities identified in this way.

1. WHAT CAN BE SEEN ON AN IMAGE?

1.1. FROM PIXEL TO IMAGE

Any satellite image is made up of picture elements known as *"pixels"*, which in the case of the SPOT satellite represent land areas of $400m^2$ (20m x 20m) in multispectral XS mode associating the three satellite channels, XS1, XS2 and XS3. In panchromatic P mode or in combined P + XS mode, obtained by mixing spectral bands XS1 and XS2 with band P and re-sampling band XS3 at 10m, the land area represented is 100m2 (10m x 10m).

Depending on the type of screen used, the image which appears covers an area of either 262 144 pixels (512 x 512), or an area of 1 048 576 pixels (1024 x 1024 pixels), as is the case of the equipment used by LATICAL in Noumea. In multispectral mode, the resolution on the ground being 20m, the screen represents an area 20.480 km long (1024 x 20m) and 20.480 km wide, i.e. 419.43 km^2. In multispectral P + XS mode, the dimensions of the area appearing on the screen are 10.24 km by 10.24 km, representing a total area of 104.85 km^2. The whole of a SPOT image covers an area of 3600 km^2 (60 km x 60 km), a total of nine million pixels (3000 x 3000) in multispectral XS mode and 36 million pixels in multispectral P + XS mode.

When the three channels of the multispectral mode are on the screen, each pixel is represented by a colour corresponding to the combination of the spectral signatures in channels XS1, XS2 and XS3 of the landscape occupying the geographical area identified by the pixel. A total of 255 spectral signatures combined in this way can be represented on the screen by 255 different colours, ranging from white to black.

Lecture notes

1.2 THE IMPORTANCE OF SCALE AND THE PERCEPTION OF COLOURS

In general terms, scale is an indication, expressed as a fraction, of the difference between a distance represented graphically (numerator) and the actual physical measurement of the distance (denominator). By small scale we mean a fraction where the numerator is very small compared to the denominator; for instance, on a scale of 1/100 000, each centimetre represents a value 100,000 times greater, in other words 1km. Similarly, a large scale differs from a small scale by the higher value represented by the numerator. Thus, on a scale of 1/25 000, each centimetre corresponds to an actual distance of 250m and each kilometre is represented by 4cm. In other words large scale will show the details whereas a small scale will show an overview.

On the screen, observation of an image enlarged to the point where each pixel can be visually identified shows that:

i) the pixels corresponding to different spectral categories are intimately mixed,
ii) groups of pixels belonging to a single spectral category are rare,
iii) it is difficult to visualise groups of pixels corresponding to landscape units by means of colour differences.

A gradual reduction in scale makes it possible to gain a clearer view of colour groupings.

It is impossible for the eye to distinguish 255 colours. In addition to black and white, the pupil can distinguish easily 6 shades, the three primary colours (blue, red and yellow), together with the colours produced by these colours in combination: violet (blue + red), green (blue + yellow) and orange (red + yellow). Depending on the amount of black or white they contain, each of these six shades forms the origin of a whole range of tones. Pink, for example (red + white), is a tone red. Beyond five tones of the same shade, it appears that the perception of the retina begins to weaken (Brunet, 1987). We therefore feel that the eye can easily distinguish up to 32 colours (6 shades x 5 tones + black and white) on a screen. But with 255 colours, the retina will tend to reduce the spectrum by amalgamating neighbouring colours into one single colour.

The smaller the scale, the smaller the size of the pixels on the screen and the easier it is for the eye to distinguish colour combinations. As the scale is reduced, of course, so is the amount of information, but this is often useful as it enables the interpreter of the image to gain a clearer perception and to identify the main trends, which in many cases are not apparent on a larger scale.

Generally speaking, a combination of pixels of identical or similar colour will produce three different kinds of geometrical figure on a satellite image:

i) points or circles of very small radius,
ii) lines or bands,
iii) areas, often similar in shape to a polygon.

When using a large scale, the forms making up the image can be identified only in accordance with the criteria of colour or structure, in other words the way the forms fit together with one another. On a small scale the criterion of *texture* is also used, the internal arrangement of the forms, regardless of their colour. In general terms, texture takes the form of dark lines which, when they accumulate, give the sector in question a granular appearance.

2. IDENTIFICATION AND DESCRIPTION OF GROUPS OF PIXELS

A total of eleven parameters can be used to describe and identify the forms making up a satellite image: *size, form, texture, colour, order, linearity, connexity, direction, continuity, homogeneity* and *contrast* (GASTELLU, 1985).

These parameters can be divided into two groups, those of strict differentiation, such as contrast, homogeneity or heterogeneity, continuity or discontinuity, and those of description and differentiation.

2.1. PARAMETERS OF DESCRIPTION AND DIFFERENTIATION

Two sub-categories can be identified: primary and secondary parameters.

2.1.1. Primary parameters of description and differentiation

There are four Primary parameters: *size, form, texture* and *colour.* These are basic parameters which make it possible to distinguish between two groups of pixels and describe them. *Size* and *form* refer to the contours of the groups of pixels, in other words to what separates them and what surrounds them. *Texture* and *colour*, on the other hand, refer to the content of the groups.

(a) Size

Five size categories will be distinguished:
i) *very small, from 1 to 10 pixels,*
ii) *small, from 11 to 100 pixels,*
iii) *medium, from 101 to 500 pixels,*
iv) *large, from 501 to 2500 pixels,*
v) *very large, more than 2500 pixels.*

(b) Form

If size can be described in terms of quantity and the number of pixels concerned, form can only be described in qualitative terms.

We shall therefore distinguish five basic forms:
i) *square;*
ii) *rectangle;*
iii) *triangle;*
iv) *circle;*
v) *star;*
vi) *and a composite form, incorporating 2-5 basic forms, which we shall call "multiform".*

In addition to these six forms, defined solely in terms of quality, we shall also include three "mixed" forms, combining qualitative and quantitative aspects, which could also be called "complementary" since each of them complements one of the six forms listed above, with the exception of the circle, which by definition can be described quantitatively only in terms of its size. These three "mixed complementary" forms are:

i) *narrow form;*
ii) *wide form;*
iii) *extended form.*

A *narrow form* is distinguished by the small distance between its sides. The description applies essentially to triangles, rectangles and stars. In the case of the triangle, the description *"narrow"* refers respectively to the base of the triangle and the ratio between the base and the height. For the rectangle it is the small breadth and small breadth/length ratio which marks it out as narrow. Finally, in the case of the star, the description applies to three cases: where one of the star's axes is substantially longer than the others, where the base or width of this axis is very small and, lastly, where the width/length or base/height ratios of the axis are very small.

The term *"wide"* is applied where the distance between the sides is great and, in the case of a star, where the length of all the axes is similar.

The description *"extended"* applies to the width/length ratio in the case of a rectangle, the base/height ratio in the case of a triangle and the ratio between the main axis and the other axes in the case of a star. Unlike the description "narrow", however, the extended form does not imply any intrinsic limitation of the width of the rectangle, the base or the triangle or the base of the principal axis of the star.

(c) **Colour**

As was seen above, colours may be described in terms of shades and tones. In view of the vast spectrum of possible shades and tones on the screen, a full description of all colours is impossible and we shall confine ourselves here to nine different shades:

i) the three primary colours: blue, red and yellow;
ii) the three secondary colours: violet, green and orange;
iii) pink, which as we have seen is actually a tone, but we will treat it as a shade because of the wide range of pinks and reds existing;
iv) brown, combination of orange and black;
v) grey, combination of black and white which we shall also treat as a shade because of its extensive range.

Each of these shades may be described in terms of four tones:

vi) *very pale*, where there is a large quantity of white in the shade;
vii) *pale*, where the quantity of white is smaller;
viii) *dark*, where there is an addition of black rather than white to the shade;
ix) *very dark*, where there is a substantial quantity of black.

A further tone description, *"quite dark"* could be used, but it can sometimes be difficult to apply and is best avoided.

In all then 38 colours (9 shades x 4 tones + black and white) are available to describe the colours of the groups of pixels on the screen. The addition of an extra tone ("quite dark") would bring this figure up to 47.

(d) Texture

Texture is a concept whose meaning often creates difficulties and is frequently confused with that of structure. It is necessary to draw a distinction between these two concepts. Of all the natural sciences, it is probably the soil sciences which offer the clearest definition. Soil scientists define the *"texture of a soil"* as its granulometric composition and measure it in terms of the soil's percentage content of coarse and fine sand, alluvium, clay, humus or limestone. They define *"soil structure"* on the other hand as the way in which the solid constituents of the soil combine (SOLTNER, 1982).

The application of these concepts to the reading and visual interpretation of satellite images leads us to define *structure* as ***"the way in which visually different groups of pixels combine, from the point of view either of their colour or their texture or a combination of these two factors"***. *Texture*, however, like colour, refers exclusively to the content of the groups of pixels. It can be described as "the internal disposition of these groups, irrespective of colour". In visual terms, this can be expressed by four characteristics:

i) the presence or absence of clearly defined dark lines;
ii) the presence or absence of dark lines which are not clearly defined and are composed of granules;
iii) the "coarseness" of these groups of granular lines, which can be assessed in terms of the size and form of the granules and corresponds to the granulometric composition of the area in question;
iv) the uniformity of the granulation, measured by the distribution of granule density over the area.

Using these four characteristics, we shall distinguish between 10 main texture categories:

1 *Uniformly smooth,* where there is a total absence of granulation, as for example with a homogeneous grassy savanna;

2 *Smooth with a few, clearly defined lines,* e.g. grassy areas crossed by a screen of trees or by roads;

3 *Smooth, with a large number of clearly-defined lines,* e.g. areas of bare land furrowed by erosion gullies;

4 *Heterogeneous granules or scattered points,* e.g. grassy savanna with thick bush cover;

5 *Heterogeneous granules or scattered points interspersed with a large number of clearly-defined lines.* This type of texture is characteristic of grassy slopes with sparse woodland, the lines corresponding to treeless crests, erosion gullies or water courses.

6 *Low to medium uniform coarseness,* as in pasture land created in forest areas and dotted with clusters of surviving trees;

7 *Large-grain, very coarse;* this texture is usual for areas of rain forest;

8 *Fine-grain, very coarse,* found in less dense rain forest;

9 *Low to medium coarseness, with superimposed lines;* this texture has two kinds of lines, those marking the edges of the granules and thicker straight lines often corresponding to a road network. It is characteristic of young tree or shrubbery plantations and fully exposed adult shrubberies;

10 *Medium to high coarseness with superimposed lines;* this texture differs from the previous one only in its greater degree of coarseness, which reflects a denser and more heterogeneous plant cover. It is frequently found in adult forest plantations or shrubbery plantations (coffee, cocoa) under forest cover.

Variations in uniformity of granulation are the distinguishing features of ***compound textures,*** of which there are two types relating mainly to forest areas:

i) *contact texture,* an example of which is where secondary forest meets primary forest, which, with its broader crowns gives coarser granulation;
ii) *sland texture,* which often corresponds to clearings in forests or islands of primary forest surrounded by degraded forest.

2.1.2. Secondary parameters of description and differentiation

These are four secondary parameters: *order, linearity, direction* and *connexity.* They are described as secondary because they are used mainly in conjunction with primary parameters whose meaning they complement.

(a) **Order**

Applied to space, the concept of *order* implies regularity and equidistance, which are generally the marks of human activity. *Order* is thus characteristic, and by the same token, indicative of a landscape bearing the imprint of human activity.

As a secondary parameter, *order* can be employed in conjunction with each of the four primary parameters mentioned above -*size, form, colour* and *texture* - to create the following four combined parameters: *ordered size, ordered form, ordered colour* and *ordered texture.*

Ordered size

This combination is closely linked with man's technological potential in the shape of the control he exerts over his natural environment. Village gardens created by clearing the bush and tended manually by the members of a single household are an excellent illustration. The size of these gardens is directly related to the means of production and the workforce employed to establish and maintain them.

Villages at a similar stage of technological advancement and with comparable demographic trends will have gardens of similar size, thus creating an order in the landscape.

Ordered form

This combination is mainly characteristic of urban areas or urbanised rural zones where the distribution of residential areas and communications networks produces ordered forms. In agricultural areas, this order can be found mainly in the patchwork patterns made by pasture land or, more rarely, in the concentric circles in which crops are laid out around a population settlement.

Ordered colour

This combination is frequently found in urban centres because of the uniformity of the materials used in roofing. In rural areas it is mainly found in village gardens where it reflects a seasonal similarity in the agricultural calendar. More rarely, it may indicate a similarity in the crops grown.

Ordered texture

Of the four combinations involving the parameter "order", this is the most widespread. It applies in particular to road networks or patches of forest surviving in pasture areas.

(b) Linearity

This parameter is essentially an attribute of the primary parameters of *"form"* and *"texture"*. Linear form relates to any element of the natural or man-made landscape whose contours take the form of straight line segments. With regards to *texture linearity* applies to the contents of a group of pixels. *Linearity* is particularly apparent in the following three texture categories:

i) smooth with clearly-defined lines,
ii) low to medium coarseness with superimposed lines and
iii) medium to high coarseness with superimposed lines.

Linearity can be described in three terms: *perfect linearity, medium linearity* and *low linearity.*

(c) Direction

Direction is a parameter linked closely to *linearity* and is expressed by reference to the four cardinal points.

(d) Connexity

This parameter is also associated with linearity, of which it is a complex variant. It occurs when a straight line encounters successively several small segments of straight lines. An example would be the confluence of rivers or a line of crests.

2.2. PARAMETERS OF STRICT DIFFERENTIATION

Three parameters can be identified : *contrast* and the two pairs of opposites, *heterogeneity/homogeneity* and *continuity/discontinuity* . These parameters cannot be used to describe groups of pixels. Their use is limited either to the recognition of distinct groups of pixels, as in the case of contrast, or the visualisation of the internal disposition of the image and the recognition of its structure, as in the case of heterogeneity/homogeneity and continuity/discontinuity. These parameters can therefore be called "*structural parameters*".

2.2.1. Contrast

This parameter quantifies a difference in kind or quantity between two or more contiguous landscape elements. This difference relates either to the form of these elements or to their size, colour or texture.

(a) Contrast in size

This is a purely quantitative parameter. It makes it possible to distinguish between one or more groups or pixels belonging to two or more of the five size categories mentioned above: *very small, small, medium, large, very large.* These five size categories can be graded according to their "proximity" on a scale of increasing values. We can therefore distinguish between:

i) four categories of proximity of degree 1: (very small - small), (small-medium), (medium-large), (large-very large);

ii) three categories of proximity of degree 2: (very small to small-medium), (small-large), (medium-very large);

iii) two categories of proximity of degree 3: (very small-large), (small-very large);

iv) one category of proximity of degree 4: (very small-very large).

The further apart the two categories, the easier it is to distinguish between two groups of pixels; thus it is easier to distinguish a group of 11-100 pixels (small size) from a group of 500-2500 pixels (large size), than from a group of 101-500 pixels (medium size).

(b) Contrast in form

This is a qualitative parameter. *Contrast* derives from the difference in form between two groups of pixels belonging to two or more of the form categories defined above. In general terms, two forms possessing the same number of angles are difficult to distinguish. However, forms with few or no angles, like the triangle or the circle can easily be distinguished from an angular form such as a polygon.

When they are the same size, the basic forms which are hardest to distinguish are the circle and the square, and the square and the rectangle.

(c) Contrast in colour

This parameter is both qualitative and quantitative. The contrast lies in the variations in *shade* (qualitative) and in *tone* (quantitative gradation).

(d) Contrast in texture

This contrast is both qualitative and quantitative and refers to two parameters of *texture*, granulometry and the existence of clearly-defined lines.

Contrast in granulometry

The greater the difference in granulometry between two groups of pixels, the greater the contrast and the easier it is to distinguish between them. A classification of the five types of *texture* defined above (*smooth, heterogeneous granules, low to medium coarseness, medium to high coarseness, high coarseness*) in accordance with their proximity on a scale of increasing values makes it possible to distinguish four categories of proximity of degree 1, three of degree 2, two of degree 3 and one of degree 4.

The four categories of proximity of degree 1 are:

i) (smooth-heterogenous granules);
ii) (heterogeneous granules-low to medium coarseness);
iii) (low to medium coarseness-medium to high coarseness);
iv) (medium to high coarseness-high coarseness).

The three categories of proximity of degree 2 are:

i) (smooth-low to medium coarseness);
ii) (heterogeneous granules-medium to high coarseness);
iii) (low to high coarseness-high coarseness).

The two categories of proximity of degree 3 are:

i) (smooth-medium to high coarseness);
ii) (heterogeneous granules-high coarseness).

The category of proximity of degree 4 is:
i) (smooth-high coarseness).

Contrast in terms of clearly-defined lines

Two zones with the same or similar granulometry can be clearly identified if one contains clearly-defined lines and the other does not.

2.2.2 Structural parameters

(a) Homogeneity

The concept of *homogeneity* refers to an identity or similarity between two or more groups of pixels. This identity or similarity relates essentially to the colour and texture of the groups of pixels. More rarely, form may be taken into account.

Homogeneous colour
Two or more groups of pixels are said to be homogeneous if their colour is identical, irrespective of their texture or form.

Homogeneous texture
Two or more groups of pixels are said to have homogeneous texture when their texture is identical or similar, regardless of their colour or form.

Homogeneous form
Two or more groups of pixels are said to be homogeneous in form when they all have one of the five basic forms (square, rectangle, triangle, circle, star), whatever their colour and texture.

Homogeneity of two criteria
This relates to similarity of:

i) colour and texture, regardless of form, or
ii) colour and form, regardless of texture, or
iii) texture and form, regardless of colour.

Homogeneity of three criteria
Although possible, this is rare; it would require similarity of colour, form and texture between two or more groups of pixels.

(b) Heterogeneity

Two or more groups of pixels are said to be heterogeneous when no similarities of colour, form or texture can be identified between them.

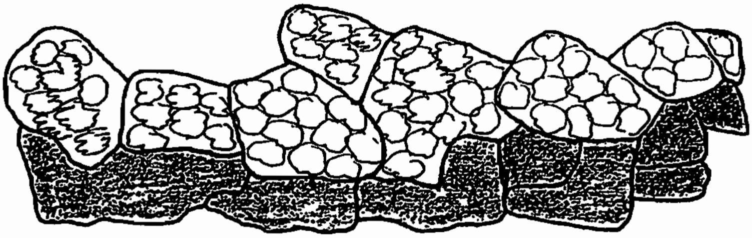
(c) Continuity

The notion of continuity refers to shared borders.

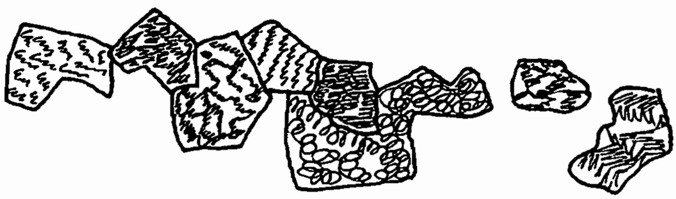
Two groups of pixels are said to be continuous if they have at least two shared edges. This notion is particularly useful for the visual interpretation of satellite images, when combined with the concept of homogeneity, in determining the continuity of several homogeneous groups of pixels (fig. 22a).

(d) Discontinuity

Two groups of pixels are said to be discontinuous when they possess no shared boundaries. Similarly, several groups of homogeneous pixels will be described as discontinuous when none of their edges touch (fig. 22b).



a) Zones which are continuous and homogeneous from the point of view of texture



b) Zones which are discontinuous and heterogenous from the point of view of texture

Figure 22. Homogeneity/heterogeneity, Continuity/discontinuity

2.3. FROM STRUCTURE TO TEXTURE - THE DIALECTICS OF INTERLOCKING SCALES

We have seen above that there are four primary parameters (size, form, texture and colour) which enable us to describe and distinguish between separate groups of pixels, which will henceforth be referred to as *"units of visualisation"*. The application to these units of the parameters of strict differentiation contrast, homogeneity/heterogeneity and continuity/discontinuity makes it possible to divide these groups of pixels into *"structural units"* made up of several *"homogeneous units of visualisation"*. This process is illustrated in the form of a diagram in figure 23.

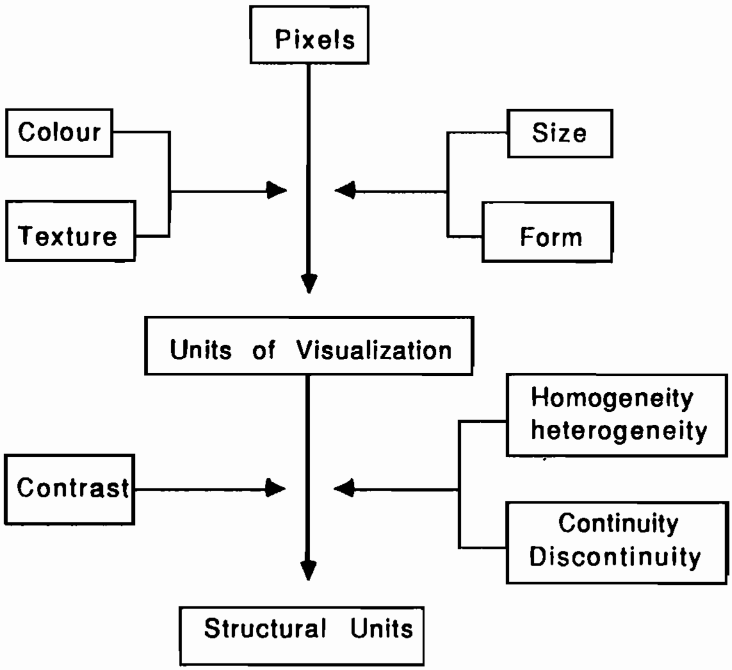


Figure 23. Process of differentiation of structural units of Spot image by visual interpretation

The structural units change in size depending on the scale used. Thus, a reduction in scale causes a regrouping of the structural units into a smaller number of units which we shall call *"first degree derived structural units"*.

On a small scale, the size of the original structural units is so small as to make it possible to obtain a clear idea of the structure of the image. However, these original structural units have become excellent units of visualisation, which we shall call *"first degree derived units of visualisation"*, the original units of visualisation having lost all relevance on this scale because of their small size. In fact, the original structural units, which on the original scale reflected the structures of the image, now reflect only its texture, in other words the internal arrangement of the new groups of pixels produced by the change of scale.

Any **decrease in scale** for a given group of pixels therefore **tends to transform structure into texture.** Symmetrically, any **increase in the scale** creates new units of visualisation, smaller than the original ones, and **texture tends to be trans-formed into structure.** Thus, according to the degree of accuracy desired in the visual interpretation of a satellite image, several *degrees of derivation of structural units* can be used (structural units derived to the degree n - 1, n, n + 1, etc. where n > 1).

This interlocking of structural units is concomitant with the interlocking of scales. Thus a structural unit derived to the "degree n" corresponds to a larger scale than a structural unit derived to the "degree n+1". Symmetrically, this same structural unit derived to the "degree n" will correspond to a smaller scale than a structural unit derived to the "degree n-1".

3. LANDSCAPE UNITS AND ORGANISATION OF SPACE

3.1. GEOFACIES, GEOSYSTEM AND REGION

3.1.1. Geofacies

According to the definition suggested by the French geographer, G. BERTRAND (1970), ***landscape*** is *"a portion of space characterised by a dynamic, and thus unstable combination of different geographical elements - physical, biological, anthropic which, by reacting dialectically with one another, make the landscape an indissoluble geographical whole which develops en bloc, as much from the influence of the interaction between the elements composing it as from that of the individual dynamics of each of the elements considered separately"*.
Like a SPOT image, which is a two-dimensional representation of the landscape, the landscape is composed of elementary units which may interlock to form larger units. These elementary units are called *"geofacies"* in the terminology used by G. BERTRAND (1968) and also adopted by J.F. RICHARD (1975). In the tropical countries, the *"geofacies"* is the unit of description of geographical space; it is the smallest homogeneous spatial unit (RICHARD, op. cit.). Its dimensions can be of the order of one hectare (10 000 m^2) or one square kilometre (1 000 000 m^2), which corresponds to a margin of 25 to 2500 pixels on a SPOT image in multispectral XS mode and 100 to 10 000 pixels in P + XS mode. It may be a coconut grove, a forest in a valley bottom, a grassy slope, etc.

Any *geofacies* can be identified by its geographical location in longitude and latitude and by the combination of elements of landscape it contains. These elements can be divided into three levels, the physical environment, the ecosystem and human activity.

A *geofacies* has a homogeneous physiognomy. This is only possible under the following conditions:

- either the combination of landscape elements making up the geofacies are homogeneous over the whole area it occupies, or

- where one or two landscape levels predominate in the geofacies - whether it is the physical environment, the animal or plant community or the human environ-ment - the elements making up the level(s) must be homogeneous.

The *"units of visualisation"* identified by the interpreter on SPOT images also have a homogeneous physiognomy. The homogeneity of colour and/or texture which characterises its visual units reflects either a homogeneous physical environment or homogeneous vegetation which may itself sometimes reflect a homogeneous human environment when the vegetation is essentially a product of agriculture or forestry. In this respect, ***units of visualisation may be equivalent to geofacies***, since they are of the same size and have the same meaning.

3.1.2. Geosystem and region

The *geosystem* is the second landscape unit widely used by French geographers. About 10 to 100 times larger than the *geofacies*, the *geosystem* occupies an area ranging from 1 to more than 10 km^2. This may be the zone covered by a village territory, a mountain valley, a mangrove, a coral reef, etc. Unlike the *geofacies*, the *geosystem* does not have a homogeneous physiognomy. The *geosystem* is a combination of *geofacies*, but the latter may differ in nature. How do these *geofacies* combine together in a *geosystem* and how are they organised? This is a vital question which merits serious consideration. First, however, we must define the third landscape unit applicable in scale to a SPOT image - the region.

The dimensions of the *region* are of the order of about 100 km^2 for the Pacific islands. The *region* is generally easy to identify on a satellite image as it corresponds to the main relief features; it can be a coastal plain or a mountain foothill.

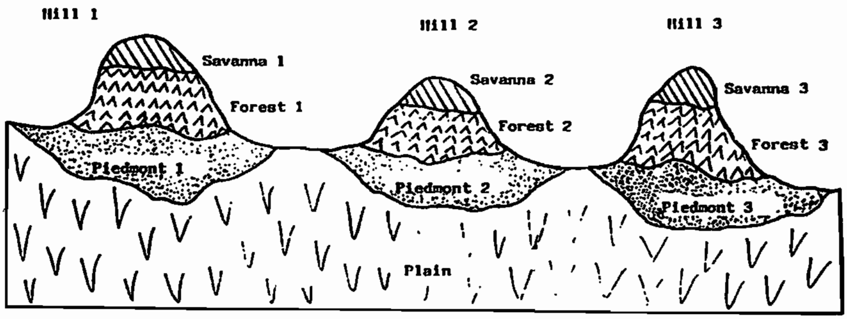
3.2. FROM GEOFACIES TO GEOSYSTEM - CHORES AND TAXONS

How do we move from geofacies to geosystem? The process is not a direct one but passes through two stages and requires reference to two key concepts in ecology and geography, *"chores"* and *"taxons"*.

Taxons can be defined as a sub-group of elementary areas with a high degree of similarity between them and can thus be distinguish from areas belonging to other categories. This resemblance relates to ecological affinities reflected in either a similar physical environment (especially vegetation) or similar flows. The concept of taxon is already a familiar one and is related to the notion of homogeneity. It was used above to explain the formation of structural units from units of visualisation. Each structural unit is equivalent to a taxon which groups together visual units of homogeneous texture and/or colour.

The concept of *chore* refers to the idea of continuity. A chore is a sub-group of contiguous elementary areas. Figure 24 illustrates these concepts.

Let us now apply the concept of chores and taxons to a problem of concern to us - how is a geosystem built up of geofacies? The first step concerns the formation of taxons from all the elementary areas or geofacies (or "*visual units*") of a region. The taxon which seems most representative is chosen. All the visual units adjacent to it are then combined with it more and more closely until all these visual units, combined with the taxon in the form of successive chores, form one or more other taxons. The limits of the geosystem are then determined.



Four taxons can be identified : savanna, forest, piedmont, plain.

Four chores can be identified : Hill 1, Hill 2, Hill 3, Plain and piedmonts.

Hill 1 consists of zones : Savanna 1 + Forest 1 + Piedmont 1.

Hill 2 consists of zones : Savanna 2 + Forest 2 + Piedmont 2.

Hill 3 consists of zones : Savanna 3 + Forest 3 + Piedmont 3.

The plain and the piedmonts consist of zones :
Plain + Piedmont 1 + Piedmont 2 + Piedmont 3.

Figure. 24. An exemple. of chores and taxons in a landscape.

4. CONCLUSION - A METHOD OF VISUAL INTERPRETATION

In conclusion, we shall outline a method to be used for the description and visual interpretation of satellite images. This outline is accompanied by a grid for the description and interpretation of the elements of landscape making up the image.

4.1. "INTERLOCKING" SCALES

Comparing different scales for the same area is the most effective method of distinguishing between and ordering the different elements (chores and taxon) composing the structure of the landscape. It is therefore important to use different scales to visualise and interpret the image. These scales will be inter-locked, as children do with tubes of different sizes, beginning with the smaller scales and then moving to the larger ones, which will be used to distinguish between the "units of visualisation", and then, if necessary, returning to the medium and small scales to visualise the "structural units" and interpret them more accurately.

The choice of scale should be based on two criteria:

a) the first is legibility. It is useless to look at a SPOT image on a scale which is either too small or too large. As the islands of the South Pacific generally cover small areas, a scale of 1/500 000, where each centimetre represents 5 km, is generally too small and details cannot be properly seen. Similarly, a scale of 1/10 000 is generally too large for groups of homogeneous pixels to be easily identifiable. The scales 1/100 000 and 1/50 000 seem the most suitable. For small areas to be studied in detail, the scales 1/25 000 or 1/30 000 can also be usefully employed.

b) the second is compatibility with existing cartographic documents, especially survey maps, relief maps and vegetation maps, which can be used as an aid to the visual interpretation of the satellite image.

4.2. SIMPLIFYING THE COMPLEX

For any given scale, identifying "*units of visualisation*" and "*structural units*" and interpreting them must be done by moving from the most simple to the most complex. In the case of "*units of visualisation*", the complexity is closely related to the small size of the areas to be examined and the meeting or overlapping of different colours and textures in a small space. It is therefore preferable to concentrate first on the larger and most homogeneous visual units and then move on to the smaller areas afterwards. It is likely that at the end of this process a "*residue*" will be left consisting of numerous small areas with textures and colours which are difficult to distinguish. This "*residue*" should be left as it is and will form a structural unit in its own right or will be visualised on a larger scale in order to break it down, if possible, into several units of visualisation.

4.3. USING THE PROPER TOOLS

In order to read and visually interpret a satellite image, it is necessary to use the parameters described above.

a) Begin by distinguishing visual units by using the primary parameters of description and differentiation: *size, form, colour* and *texture*;

b) then, if appropriate, use the secondary parameters of description and differentiation: *order, linearity, direction, connexity;*

c) then group together the visual units into structural units using the parameters of strict differentiation: *contrast, homogeneity, continuity*;

d) use the following grid to describe and interpret the units of landscape making up the image.

4.4. READING AND INTERPRETATION GRID

This grid is designed to provide a description in terms of *form, size, colour* and *texture* of all the structural units identifiable on the image and which then give an interpretation in terms of landscape units (table 6).

Table 6. Grid for the reading and visual interpretation of units of Landscape identifiable on a spot satellite image

Geosystems								
Structural units of geosystem								
Form								
Size								
Colour								
TEXTURE	Granularity							
	Linearity							
	Other Parameters							

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RAS/86/036
Field Document 10
February 1993

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22 - 27 JULY 1990 NOUMEA, NEW CALEDONIA

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FORESTRY DEVELOPMENT PROGRAMME

INSTITUT FRANCAIS DE RECHERCHE SCIENTIFIQUE
POUR LE DEVELOPMENT EN COOPERATION (ORSTOM)