SPECIALIST AND LOCAL KNOWLEDGE AS ESSENTIAL INPUT IN CHANGE DETECTION

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ABSTRACT

For the detection of changes in land cover adequate processing and proper classification of multi-temporal images is essential. Relying only or too much on the technology in classifying images may not give the best results. Supervised automated classification of images has its restrictions and may not guarantee satisfactory results. Where this applies already to single images, it is very much more so applicable when it concerns comparison of two or more images.
A quick visual inspection of the images concerned, before and after classification, may help to avoid obvious misclassifications, especially when this can be supported by the necessary knowledge about the subject matter as well as the area concerned: the specialist and local knowledge. In this way reasonably realistic and reliable results can be obtained.

1. INTRODUCTION

The use of series of remotely sensed images for “monitoring” is widely advocated and practised. It requires adequate processing of multi-temporal data and proper classification and analysis for change detection. A number of issues come to mind that need to be addressed.
Of course one needs to know a lot about the technicalities of processing and handling of remote sensing data in the first place and the added difficulties when considering comparing sets of such data of different times. Proper geo-referencing and adjustment to differences in atmospheric conditions are required to allow a good comparison. But when such comparison is done in order to assess changes a thorough mastering of the technicalities alone may not be sufficient for a good result. Some knowledge about the subject of interest and the local conditions in which it occurs may be indispensable and can be sometimes most important.

The technological developments have gone very rapidly and resulted in new sensors with higher spatial and spectral resolutions and images being available over shorter time intervals then ever before. The image processing tools have become more sophisticated and include many possibilities for automated supervised and unsupervised classification.

The limitations may now be much more in the persons that want to use image processing for certain applications, but loose their track among the many functions at hand. Or, an even greater danger, they are so overwhelmed by the technical possibilities that they forget that they still have to abstract sufficiently reliable data from the system. And if such data can be obtained in large enough quantity and good enough quality, do they really give an answer to the question at hand? Examples of the technology running away with the user can be found time and time again (Van der Zee 2001). So reasons enough to look into the possibilities to avoid that.

2. CLASSIFICATION PREDICAMENTS

When discussing change detection it very often concerns an interest in changes in land cover and/or land use, but not always one is very specific about the distinction between the two. Still this is essential, since it is in principle the land cover that can be directly observed on remotely sensed images, whereas land use can at most be indirectly inferred (Van Gils et al. 1991).

And even if people clearly stick to land cover then still the categories that one would like to compare for a change analysis are often not the categories that can be obtained through classification of the images. That may be frustrating or, worse, it is not always recognised. Input of some basic knowledge of the phenomena and area studied, specialist and local knowledge, may help to avoid jumping to conclusions too wildly.

For example, someone applied supervised classification to a set of images of Sri Lanka with a result as shown in figure 1 and was going to proceed for change detection.

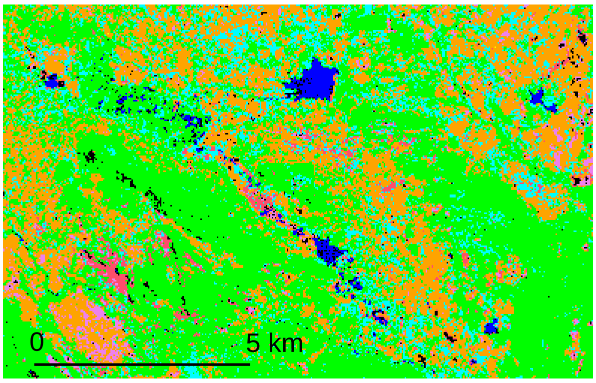

Figure 1. Classification with the “blue spots”

The person knew the area, but in the enthusiasm of getting some results was not alarmed by the many “blue spots” that appeared on places where no irrigation reservoirs were known to exist, neither by all the green, classified as “forest”, on places where since decades the forest had long gone. A quick view on a false colour composite representation of the same area (figure 2) could serve to bring back some sense of reality and lead to a revised, be it still far from perfect classification.

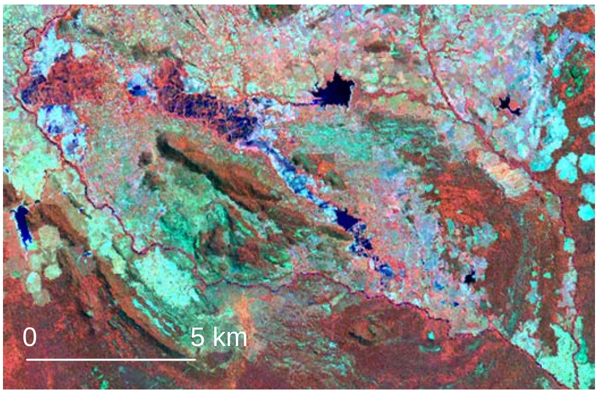

Figure 2. TM image, bands 452, of the area corresponding to that in figure 1.

Two problems come to light in this example. One is the necessity to carefully determine what is included in the categories, such as “water bodies” or “forest”, of which the change is to be monitored. The second is the difficulty to classify these categories completely and consistently.

Part of the “blue spots” in figure 1 represent inundated rice fields (paddy). At that time these are “water bodies”, but unlike the irrigation reservoirs, they are not permanent. If the interest is merely to monitor which areas at a certain moment are covered by water it is no problem to leave them in one category. But if the aim is to see whether reservoirs have been created or abandoned, then the flooded rice fields should be put in a separate category, which is not easy but appeared to be still possible.

Although “water” in general is considered to be easy to classify, in practice it may still cause problems. In figure 3, for an adjoining area in Sri Lanka reservoirs are presented on a SPOT image in three major colour ranges: dark blue (A) and light blue (B), the difference being influenced by water depth and turbidity, and pink (C), where the water surface is hidden under a layer of water hyacinth (Van der Zee & Cox 1988), see figure 4.

It may not be too difficult to imagine what problems would occur here in digital classification and especially when not taking the knowledge of the local conditions into account.

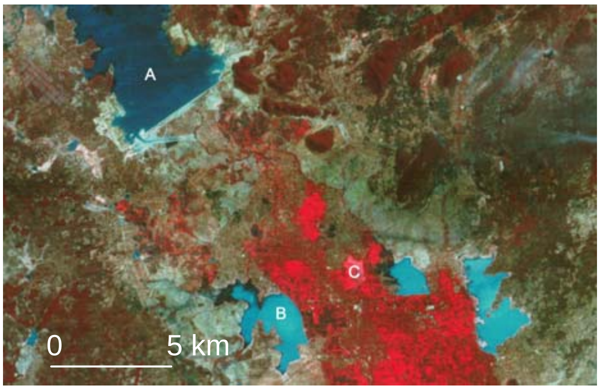

Figure 3. Water bodies with different reflectance characteristics on a SPOT image. (Van der Zee & Cox 1988)

Figure 4. Water body covered with water hyacinth *(photograph: Dick van der Zee)*

In a study of the flooding regime in a river basin in Latin America with the use of radar images, the conclusion that the flooded area moved downstream with time had to be corrected, because local observations revealed that the water still was present upstream, be it covered by a blanket of water hyacinth that obscured it from being detected by the radar. (personal communication R.H.J. Jongman, 2006).

Also the definition of the category “forest” is often thought to be easy until it has to be made operational. How many trees have to be together and in what density to call it a forest? Is the type and size of the trees also important in the definition? Some areas are classified as “forest” because they are under the management of the Forestry Department, but the amount of trees present in the area may be negligible.
And when it comes to digital classification it appears to be difficult to consistently separate forest from other vegetation cover types even when from visual inspection of the false colour composite it seems to be “a piece of cake”.

For example, on an image of the region around Bangkok, a bright red area showed up: ”coastal forest”. But when sampling in this area it did not directly clog up into a solid single class and even worse, a lot of pixels in the “interior” also responded. (Sombat & Van der Zee 1987). See figure 5. These pixels of course can not represent “coastal forest”, but how to make the distinction?

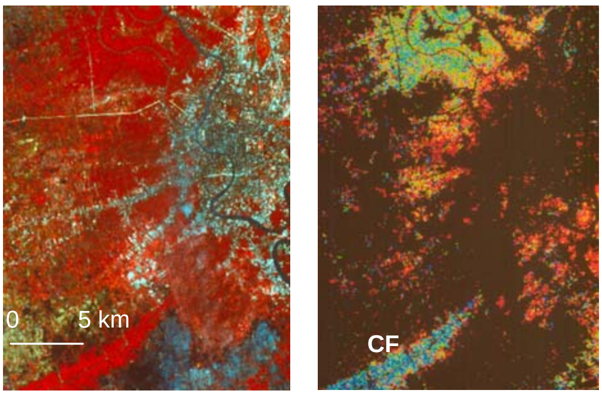

Figure 5. The “coastal forest” (CF) near Bangkok in the image (left) and what shows up after classification

The predicament of making an accurate classification of forest is already large when trying to use it for an assessment of areas that are deforested or reforested over time. It becomes even larger when not only the presence or absence of forest has to be monitored, but qualifications about the condition of the forest are wanted: degeneration, regeneration, or balance.

It may be very frustrating that the classification that can be obtained so seldom corresponds with the classification that would be the most useful or interesting. Important categories may not be distinguished in an image because their reflectance characteristics are too similar. But acknowledging this may help in avoiding wrong conclusions in change detection.

3. COMPARING CLASSIFIED IMAGES

When comparing two images for change detection the option to base the analysis on visual interpretation and comparison is very seldom chosen. Comparison by computer is definitely faster, and renders the illusion of high precision and quantification. Still it might be good practice to at least start and follow up with a visual comparison in order to assess whether the products of the comparison by computer make any sense.

For comparison of two images the geo-referencing and atmospheric correction are of course even more crucial than when classifying a single image. But even when this is alright, success is far from being guaranteed. There are many examples of people that try to repeat the classification of other persons for the same image, but fail to achieve an identical result simply because the formula of the classification was not recorded or documented (Castillo Gil 1999). By using different training sets of pixels a different classification may result. The differences may not be great, but disturbing enough when trying to analyse changes in a landscape. And even when it is possible to classify two different images according to the same procedure, it will be difficult to get exactly comparable results.

An important question to consider is, over what period of time the analysis of changes is needed or wanted. That is, with what temporal resolution or time intervals should data be available? With respect to water bodies or crop areas it may be interesting to monitor the fluctuations in their extent through the seasons, but is the same true for forest or settlement? For these two categories, but also for other ones, it may be more interesting to follow their decrease or increase in area through the years. To rule out the seasonal fluctuations in appearance then for optimal comparability the availability of images of the same season is essential, because a forest in autumn with bare trees looks quite different from a forest in mid-summer when the trees are full in leaves, just to give one example.

In the Sri Lankan case study from which the example in figure 1 was derived, a TM image of 25-05-1992 could be compared with an ETM of 26-05-2001. (Meera Lebbe 2005).

It seemed to be ideal until the classifications were compared and showed a lot of changes that were not logical when knowing the area and the phenomena occurring there.

A visual inspection of the processed unclassified images helped to appreciate the situation.

A first glance made clear that the same date on the calendar does not necessarily correspond to the same stage in the growing season. In some countries in one year spring may burst out at the end of February, but in other years the soil is still frozen in the middle of March and may be covered with snow. In Sri Lanka it is the onset of the rainy season which may be early or late and determines the start of the cultivation season. So in figure 6 to the left large areas of rice fields are still submerged (dark blue) and the remaining fields are bare (light blue), whereas to the right a smaller area is flooded, other areas bare and other fields under the crop of rice (red). The areas under “upland crops” on the left-hand image are predominantly pink, implying some healthy vegetation, to the right more green is shining through, bare soil or parching vegetation? In one year the rain was late, in the other year early. Which is which, can only be told after inspection of the rainfall data of both years or by asking the farmers.

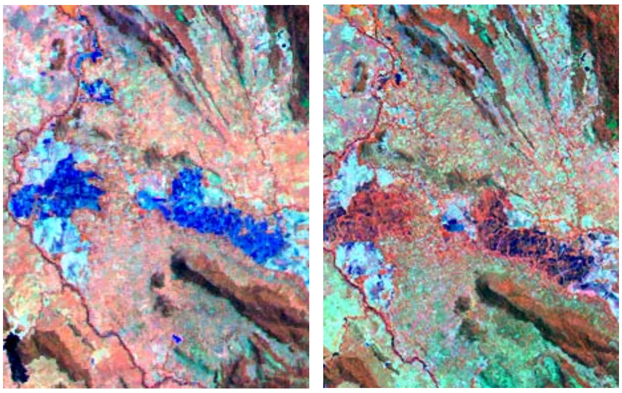

Figure 6: Segments of the image of 1992 (left) and 2001 (right) of exactly (!) the same season of an area of rice fields.

A change from bare land to agriculture, from water to agriculture and from agriculture to bare or water, as could be concluded from the comparison of the two classified images, therefore is not a real change but part of the seasonal rhythm that may differ a bit from year to year.

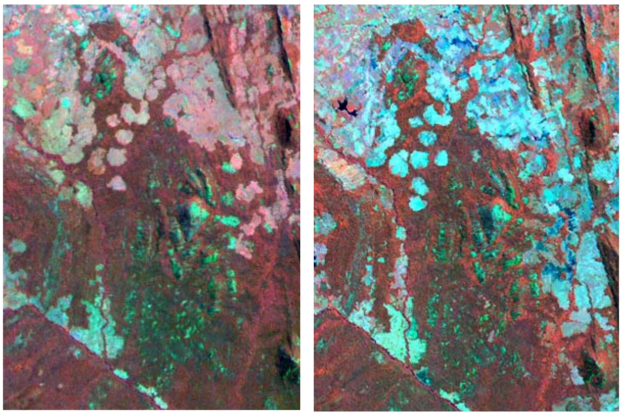

Figure 7: Segments of the image of 1992 (left) and 2001 (right) of the same season of an area with forest and dry land cultivation.

In figure 7 an area of forest (dark red) is presented with adjoining areas of dry land cultivation, which in one year are still (or already) bare (light blue) and in the other have some vegetation, be it not abundant (pink). But also in the intensity of the colour of the forest a difference can be observed.

In the digital classification this difference resulted in a lot of pixels being not identified as forest in one of the two cases, resulting in the conclusion of deforestation even for areas in the heart of the forest reserve where no human activities of major proportions can be expected.

The difference in reflection characteristics may well be attributed to the reaction of trees to fold their leaves, or partly drop them, under drought stress. This effect was already observed in the study of the first SPOT images of this region (Van der Zee & Cox 1988). In the dry season the forest not only shows in less bright red, but also shows a gradient to more greyish tones towards the coast. In the image taken just after the wet season the forest shows in bright reds all over with no gradient noticeable. See figure 8.

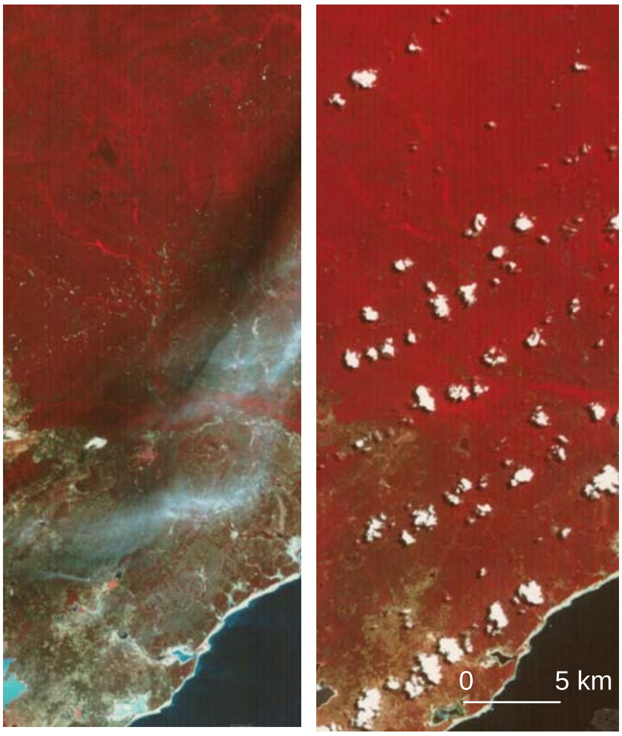

Figure 8. Sections of SPOT images of the middle of the dry season (July 1986 - left) and just after the wet season (April 1987 – right) of south-eastern Sri Lanka, showing the effect of drought on the image characteristics of forest

In the field it was observed that the forest had the same species composition and the same density and tree height all along the "gradient" (see figure 9), so that the effect of drought stress remained the only possible conclusion for the difference in image characteristics. Local foresters could confirm that.

From figures 7, 8 and 9 it can also be observed that the area that would be delineated in a visual interpretation as "forest" is not homogeneous in appearance. Especially natural forest shows some natural variety in species composition and density.

The conclusion is that when comparing two classified images it first is established what the differences between them are and that thereafter it has to be established whether and to what extent these differences are real changes.

4. TYPES OF CHANGES AND DIFFERENT DATA SOURCES

Not all differences are changes. Not all changes that can be determined by comparing sequences of images are of interest and not all changes that are of interest can be always and consistently determined by means of remote sensing.

Therefore it is important to know for what purpose the results of the change detection and analysis will be used.

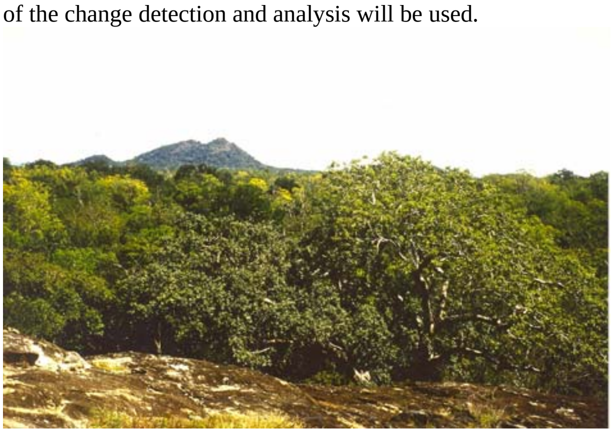

Figure 9. The type of forest present in the area depicted in figure 8.

Is it seasonal change or long term change that is the focus of interest? Is the interest in a comprehensive land cover change analysis, or is it focused on a few well defined categories?
Is it the change as such, or is it necessary to know more details of all changes, that is, what has changed into what and on which location? Is it important to know the exact location and size of the changes or is a general impression of the trend sufficient?

Comprehensive land cover change detection and analysis requires a comprehensive comparable classification of sets of images. Even with input of a lot of specialist and local knowledge this is bound to be difficult when there may be no single season for optimal distinction of all categories, and if there would be, the chances that an image of that particular season would be available for consecutive years are minimal.

When the interest is in the detection of changes in only a few specific categories, which can be consistently identified for the season in which images are almost guaranteed to be available, the chance on success may be considerably larger.
Still also then it will never work to blindly trust the computer and the software programmes. A critical review of the results at the hand of specialist and local knowledge is essential to maintain a link with reality.

A complicating factor occurs when of the satellite images to be compared parts are covered by clouds or cloud shadows, and that these parts seldom have the same location in two successive images. In some studies these parts are then "patched up" with sections of images that are nearest in season and have no clouds in such locations. But then there may be a difference in the appearance of certain phenomena at the earth's surface, resulting in a different response in the classification process. The complication will only become greater when satellite images of different type are used for the "patch-up" work.

It may go without saying that when in the change detection process images of different types are comprised, with different spatial and spectral resolution, the number of difficulties will only increase. Different spatial resolution and differences in spectral resolution necessitate a different classification process for each, possibly with the result that comparison of their categories can not be expected to yield high accuracies. See for example figure 10.

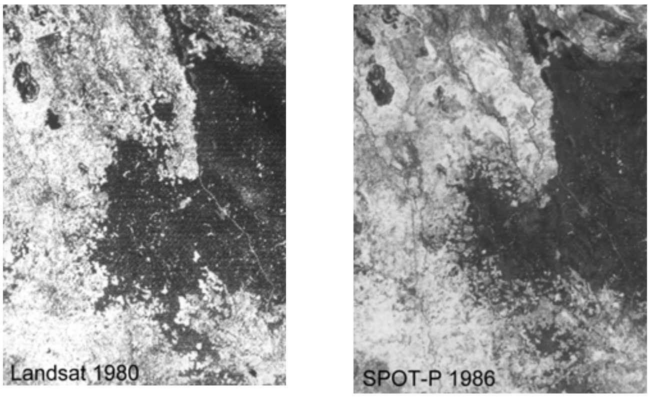

Figure 10. Sections of Landsat (left) and SPOT-Pan (right) of the same area with six years interval.
(Van der Zee & Cox 1988)

Whether the results of change detection and analysis are reasonable or disastrous to a large extent depends on whether the persons doing the analysis are aware of the possible differences in classification that they may have to work, do not get carried away by the technology and keep an eye on reality.

5. CONCLUSIONS

This paper may have given the impression that change detection and analysis with the use of remote sensing is an impossible mission. Well, difficult it is, but not impossible.

What may have become clear, however, is which obstacles are lying on the way of land cover change analysis and that in addition to mastering the technicalities of image processing and classification the input of specialist and local knowledge, and common sense in general. When one is aware of that, it may be possible to avoid mistakes that otherwise might be easily made. And if it is not possible to remove all obstacles or elegantly go around them, then one can clearly indicate the limitations to the land cover change analysis. Especially when not the exact locations of a comprehensive change are important, but rather the general trends and orders of magnitude of change in well defined categories, the limitations may not at all be prohibitive.

Still, it is important not to be carried away by the possibilities that modern technique offers, but remain realistic and conscious of the purpose for which it can be applied in a meaningful way.

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