Monitoring of Permanent Fallow Land Parcels Funded by the EEC-Temporary Set-Aside Arable Land Program with Remote Sensing

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ABSTRACT

Nowadays, European agriculture is characterized by overproduction. This excessive production causes many problems and is considered responsible for extra expenditure of EEC agricultural funds.

To reduce agricultural overproduction and the associated costs, the EEC introduced specific agopolitical regulations. One of them is the Temporary Set-Aside Arable Land Program. It financially supports a reduction of arable land for five years to reduce excessive agricultural production on the one hand, while guarantying the farmer’s income on the other hand.

Within this program, different possibilities exist on how to use the temporary set-aside arable land. The most attractive one to the farmers is the set-aside alternative of permanent fallow land, probably because it causes the least amount of expenditure and effort during the period of financial support.

The funding of the temporary set-aside arable land program involves the agreement of the farmers that some control of their parcels will be exercised by the administration. The administration has to control at least 5% of the funded farms per year. This 5% sample is selected randomly by a computer where all funded farmers are filed. They are thus selected by chance and not because they are under suspicion for any reason. Due to limited personnel resources in the regional administration, the sample for visual inspection on the ground would not be much greater than necessary.

The present study is designed to examine the justification of funding for the temporary set-aside arable land program by means of remote sensing. In this context, the principal advantage of satellite remote sensing is the simultaneous data acquisition of large areas. This allows simultaneous mapping of the areas of interest.

The present study addressed Kreis Bitburg-Prüm where 80% of the farmers decided to set aside former crop land as permanent fallow land. The study area was monitored only for this set-aside alternative.

This study investigates what remote sensing can do in this aspect of agriculture. It seeks to describe how permanent fallow land parcels spectrally behave with time. It also examines what type of plant cover comes into existence on the set aside parcels; and whether, or not the set-aside parcels can be classified with a multitemporal classification approach, and what prerequisites are, therefore, necessary.

It was considered that a geographic database could be established to help to manage the different spatial and descriptive data necessary for a long-term monitoring of the set-aside parcels.

INTRODUCTION

Nowadays, European agriculture is characterized by overproduction. This excessive production causes many problems and is responsible for extra expenditure of EEC agricultural funds.

To reduce agricultural overproduction and the associated costs the EEC introduced specific agopolitical regulations. One of them is the Temporary Set-Aside Arable Land Program. It financially supports a reduction of arable land for five years to reduce the excessive agricultural production on the one hand while guarantying the farmer’s income on the other hand.
Within this program different possibilities exist on how to use the temporary set-aside arable land. The most attractive one to the farmers is the set-aside alternative of permanent fallow land, probably because it causes the least amount of expenditure and effort during the period of financial support.

Since about 80% of the farmers within Kreis Bitburg-Prüm decided to set aside former crop land as permanent fallow land it was decided to monitor this set-aside alternative solely.

Generally, the program supports five different set-aside alternatives:

1) Rotational fallow land (25-30% of the set-aside land will be used as agricultural land (with crop rotation), the rest will be fallow land),

2) permanent fallow land (no use for five years),

3) afforestation,

4) use for non-agricultural purposes,

5) change into extensive pasture areas.

Financial support for converting agricultural into set-aside land requires that the respective fields were actively used to grow agricultural products which were financially supported under the common market organization, during the period, 1 July 1987 to 30 June 1988, and that the same parcels are actually put into specified types of use (set aside) after this date. Due to the limited personnel resources in the regional administration, it will be almost impracticable to adequately control the respective land units by visual inspection on the ground (the administration specifies about 5% of the parcels per year).

Remotely sensed satellite data from Landsat TM are considered to be a suitable source of information to independently control and justify the use of public funding for the purpose of the Temporary Set-Aside Arable Land Program.

1. STUDY AREA

The study area (Figure 1) is located in the Eifel region close to the borders of Luxembourg and Belgium. It includes two different natural regions (Bitburger Gtland and Islek). The two natural regions are composed of different rock types. The Islek mainly consists of shale whereas the Gtland mainly consists of sedimentary rocks. The study area is part of a basin structure where the shale is at the outer border and the sedimentary rocks are in the center. According to the geology one finds fertile soils in the Gtland and poor soils on top of the shale (Werle, 1978).

The study area is less favoured because of its poor natural conditions and the border situation. This is the basis for an almost complete lack of industry, a low population density and further depopulation due to permanent migration. The region’s economy is traditionally based on forestry and agriculture.

The area has a weak economic infrastructure and it is still a sink for public funding to enhance the economic situation. According to Bundesraumordnungsbericht (1990) the Landkreis Bitburg-Prüm receives national funding and EEC-funding to develop the tertiary and quaternary sector.

For instance, the EEC funding stems from regional funds to encourage the establishment of industry, tourism, other services, environmental protection measures and measures for better infrastructure (Staatsanzeiger, 1991). This general support for non-agricultural purposes leads to a further shifting of employees from agriculture to the tertiary and quaternary sectors.

On the strength of the set-aside program, farmers have a good chance to look for other income possibilities and give up agriculture. The consequence of this could be an ensured long-term retirement of the affected agricultural land and a substantial alleviation of overproduction.

The positive effects are:
- less overproduction,
- reduced impact of nutrients, insecticides and herbicides on ground water conditions,
- conservation of good ground water
- natural conditions could be reestablished,
- more areas for natural flora and fauna.

But all these positive effects are possible only as long as farmers who started working in a non-agricultural sector do not sell or lease the land to other farmers.

2. FIELD WORK

In summer 1990 the set-aside areas of permanent fallow land were mapped to determine the established plant communities on these parcels. Eight different main types could be distinguished within 29 monitored parcels of permanent fallow land.

The following list describes the types of herbs and grasses that exist on the permanent fallow land. Only the most frequent ones are listed.
Fig. 1 - Study area.
3. USED DATASETS

For this study the following cloudfree system-corrected Landsat 5-TM quarter scenes were used:

<table>
<thead>
<tr>
<th>Date</th>
<th>Path/Row</th>
<th>Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 September 1989</td>
<td>197/25</td>
<td>4</td>
</tr>
<tr>
<td>03 May 1990</td>
<td>197/25</td>
<td>4</td>
</tr>
<tr>
<td>15 July 1990</td>
<td>196/25</td>
<td>3</td>
</tr>
</tbody>
</table>

Only the bands 1 to 5 and 7 were used, since the thermal band 6 is not relevant for this type of study.

Further, topographic maps of scale 1:25,000 of the area were used:

Map 5903 Neuerburg
5904 Waxweiler
6003 Bettendorf
6004 Oberweis

The equipment used for the digital image analysis was a PC-based system with the widely distributed ERDAS-image processing software. ERDAS is a raster-based image processing software that includes a raster GIS-module. It also allows to use vector-data, and to convert them into raster format, if necessary. Orthophotos of scale 1:10000 were used to draw-in boundaries of the set-aside land parcels. The local authorities do not offer digital cadastral maps, therefore the cadastral information had to be drawn into the orthoimages. Afterwards, these polygons were digitized to allow the superposition onto the satellite images.

4. IMAGE PROCESSING

First of all a precise geometric correction of the satellite images was necessary, to localize the funded set-aside parcels with sufficient accuracy.
4.1 Geometric Correction

A geometric correction of the September-image was performed by using 15 ground control points. These were almost equally distributed over the area.

A second-order polynomial was used for the correction. As a result the September-image achieved a mean accuracy of 1/3 pixel in x- and y-direction. This means that a residual error of 1/3 pixel was achieved. The maximum residual error was 2/3 of a pixel.

Afterwards, the May-image was registered on the geocoded September-image. There, only 10 ground control points were found again, therefore only they were used here. The spatial distribution of these points is acceptable; they are evenly distributed across the study area. Here, a mean accuracy of 1/3 pixel in x- and y-direction was achieved, hence the residual error here was also 1/3 pixel. The maximum residual error was also only 2/3 of a pixel.

The July-image was also registered on the September image. Here, one could identify only 10 ground control points, and their spatial distribution was acceptable, too. The same accuracy, like before was achieved: 1/3 pixel as mean residual error. The maximum residual error was also 2/3 pixels.

After this geocoding step, the accuracy between different dates was checked by overlaying bands of different dates and toggling them. This check showed whether or not the image registration was successful. The result showed that no relevant displacement occurred between the different dates. The geocoding procedure was thus successful. The accuracy was within 1 pixel (with no systematic bias in any direction).

The residual errors appeared in all directions and showed no specific trend. This means that the residuals of the ground control points were randomly distributed.

From this geocoded image the central part of 401 x 511 pixels was used for the study (=180 km²).

4.2 Conversion of Digital Values into At-Satellite Radiances

A conversion of the digital data into quantitative physical values was then performed based on the principle of Hill and Aifadopoulou (1990) that the attenuated ground reflected solar irradiance, after its upward transmission through the atmosphere, is registered by the satellite sensor and transformed into an electric signal. It is then amplified, digitized, encoded, and finally transmitted to the ground receiving stations. Many research and operational applications require the conversion of digital count values (DC) to quantitative physical values of at-satellite measured radiance or reflectance which can be retrieved from these digital counts by using a set of gain and bias pairs representing the calibration of the sensor.

According to Hill and Aifadopoulou (1990) the Thematic Mapper radiances L (mW/cm²/sr/µm) for the six bands are obtained by a linear regression:

\[ L = a_0 + a_1 \text{ DC} \]

where:

\[ L = \text{Thematic Mapper at-satellite radiance (mW/cm²/sr/µm)} \]
\[ a_0 = \text{bias of sensor calibration} \]
\[ a_1 = \text{gain of sensor calibration} \]
\[ \text{DC} = \text{digital count per TM band} \]

Table 1 shows the values used for \( a_0 \) and \( a_1 \).

<table>
<thead>
<tr>
<th>Band</th>
<th>In-Flight update</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( a_0 )</td>
</tr>
<tr>
<td>TM 1</td>
<td>-0.1331</td>
</tr>
<tr>
<td>TM 2</td>
<td>-0.2346</td>
</tr>
<tr>
<td>TM 3</td>
<td>-0.1897</td>
</tr>
<tr>
<td>TM 4</td>
<td>-0.1942</td>
</tr>
<tr>
<td>TM 5</td>
<td>-0.0398</td>
</tr>
<tr>
<td>TM 6</td>
<td>-0.0203</td>
</tr>
</tbody>
</table>

The regression coefficients are based on ground measurements performed at White Sands, New Mexico (Slater et al, 1986).

In the next step the top-of-atmosphere reflectance was calculated with the formula given by Hill and Aifadopoulou (1990). Although this value still includes atmospheric influences, it provides a compensation for differences in illumination geometry. It is assumed that all objects on the surface are lambertian reflectors. With this assumption of lambertian ground reflectance the top-of-atmosphere reflectance can be computed for a given spectral band:

\[ p^* = \frac{\pi L d^2}{E_0 \cos(\Theta_0)} \]

where:

\[ p^* = \text{top-of-atmosphere reflectance (= apparent at satellite reflectance)} \]
\[ \Theta_0 = \text{solar zenith angle [°]} \]
\[ d = \text{correction coefficient for the actual sun-earth distance [AU]} \]

\[ L = \text{TM at-satellite radiance [mW/cm}^2\text{/sr/}\mu\text{m]} \]

\[ E_0 = \text{exoatmospheric solar irradiance (provided by Markham and Barker, 1987) [mW/cm}^2\text{/}\mu\text{m]} \]

Table 2 shows some spectral characteristics of the Landsat-5 TM System that are relevant for the calculations.

<table>
<thead>
<tr>
<th>Spectral Band</th>
<th>Center Wavelength ((\mu\text{m}))</th>
<th>Band width ((\mu\text{m}))</th>
<th>Spectral solar Irradiance (mW/cm(^2)/(\mu\text{m}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM 1</td>
<td>0.486</td>
<td>0.066</td>
<td>195.70</td>
</tr>
<tr>
<td>TM 2</td>
<td>0.570</td>
<td>0.081</td>
<td>182.90</td>
</tr>
<tr>
<td>TM 3</td>
<td>0.660</td>
<td>0.067</td>
<td>155.70</td>
</tr>
<tr>
<td>TM 4</td>
<td>0.840</td>
<td>0.128</td>
<td>104.70</td>
</tr>
<tr>
<td>TM 5</td>
<td>1.676</td>
<td>0.216</td>
<td>21.93</td>
</tr>
<tr>
<td>TM 7</td>
<td>2.223</td>
<td>0.252</td>
<td>7.45</td>
</tr>
</tbody>
</table>

After this calculation of top-of-atmosphere reflectance values were multiplied by 200 for adequate representation on the screen.

Now one has reflectance values that are almost comparable for images of different dates since differences in solar illumination, solar distance and different distances through the atmosphere have been considered in the calculations.

Up to this point, however, the reflectance values calculated for the three different data acquisition dates are not yet directly comparable, since the atmospheric properties of each date have not yet been considered.

### 4.3 Scene-to-Scene Radiometric Normalization

To use the data in direct comparisons, they have to be set in relation to a clear reference scene.

As reference, the May 1990 image was chosen since it provides the clearest atmosphere. The July 1990 and the September 1989 images had to be related to this image.

To set up the relations between the reference image and the other two images, pseudoinvariant features were used, based on the procedure of Schott, Salvaggio and Volchok (1988) who developed a scene-to-scene radiometric normalization technique which corrects for atmospheric degradations, illumination effects and sensor response differences in multitemporal multispectral imagery. Their technique is based on the statistical invariance of the reflectance of man-made in-scene elements (concrete, asphalt etc.). They assume that differences in grey level distributions of these invariant objects are a linear function, and this function is used to perform the normalization.

This form of radiometric scene normalization is important to interpret changes in the scene between two acquisition dates since after this process the changes are no longer masked by non-scene dependent influences. The normalization is easy to handle since "no ground truth or elaborate atmospheric measurements are required" (Schott, et al., 1988).

Man-made structures normally do not show seasonal variations of reflectivity like crops or vegetation. On the basis that objects with the same reflectivity on two different dates, the digital counts on each day are simple linear functions of the same variables and therefore are linear functions of each other (Schott, et al., 1988). Therefore, the linear relationship between the man-made structures of the two scenes can be estimated with a simple linear regression analysis. The calculated gain and bias coefficients can be used to transform the entire scene to the reference scene. Then first order illumination, atmospheric and sensor effects could be normalized.

To eliminate the man-made, spectrally pseudo-invariant features, the following technique was used: At first, the Normalized Difference Vegetation Index (NDVI) of the three different dates was calculated. All pixels with an NDVI < 0.1 were kept, all other pixels with NDVI > 0.1 were discarded. All three NDVI-masks were used to create a mask which included only the pixels that had an NDVI < 0.1 on all three acquisition dates. This allowed to eliminate the bare soil which eventually occurred on fields only for single dates.

Another mask was created for every date by using TM-band 4 to screen out the water pixels. All water pixels were discarded from the pixels with NDVI < 0.1 for all dates. The remaining pixels thus represented the spectrally invariant features that did not represent water.

The reflectance values of these pixels were used to calculate the linear regressions between May '90 and September '89 as well as between July '90 and May '90.

This normalization of scenes was then applied to the entire set of scenes of September '89 and July '90. After this transformation, the reflectance values in all three scenes were quantitatively comparable, enabling the user to find out quantitative changes of reflectivity between the three acquisition dates for the same pixel or area.

Figure 2 shows the processed July-image with yellow polygons, indicating the location of the set-aside fallow land parcels.
Fig. 2 - July-image of the study area with yellow polygons indicating the location of the set-aside fallow land parcels. Red = TM band 4 - Green = TM band 5 - Blue = TM band 3.
4.4 Spectral Characteristics of Set-Aside Parcels

For quantitative comparisons the image statistics of the set-aside areas were calculated. The standard deviations showed great variations within the set-aside parcels. Anyhow, the arithmetic mean values were plotted. The resulting mean spectral curves showed the mean spectral characteristics in the six TM bands of three different images. It became obvious, that even within one mapped type of set-aside land, the variations of the mean curves were great. Between different types, no significant differences could be observed. This led to the conclusion that a classification, with the set-aside areas as training samples, was impossible due to the great spectral variations that occurred, since the spectral variations between different types were smaller than within any one type. Thus, it seems impossible to differentiate the different types mapped in the field by a classification approach. In addition it seems also impossible to classify the land cover type of juvenile fallow land in general, since confusion with other land cover types occurs.

4.5 Creation of a Geographic Data Base

Prior to this study neither a geographic data base nor a simple map indicating set-aside parcels, existed for the local authorities. All information was stored in single files. It seemed necessary, therefore, to compile a database consisting of geological, pedological, elevation, slope and aspect data, with integrated digital cadastral information. In the near future, this map-related information could be completed by descriptive information (e. g. from application forms) for every parcel. This type of geographic data base could ideally be extended with up-to-date satellite images to monitor the areas of interest. The stored information of soils, geology, slope and aspect as well as the last crop grown before the parcel was set aside, did not give any explanation to the spectral appearance. Therefore, it is assumed that all influencing factors accumulate without the possibility to extract any one major influencing factor.

RESULTS AND CONCLUSION

This study does not want to assess the effectiveness of the set aside program itself in relation to goals like environmental protection or reduction of overproduction.

In this study some selected set aside parcels have been used to study the potential usefulness of remote sensing in monitoring the set aside program. In the study area about half of the land that could be set aside according to the regulations became set aside land. From this portion about 3/4 is used as permanent fallow land. This was the reason for only monitoring this type of set-aside land.

It is the first kind of a map-related study. Presently, the administration uses only single files of the farmers, but does not draw the information into maps. This could help to control the areas more effectively in terms of time needed for the control.

Field mapping showed that the type of set-aside land being studied can be further differentiated according to the plant associations found there. The methodology adopted in this study was successfully used to quantitatively compare the spectral reflectivity of the set-aside permanent fallow land parcels.

It was found that great spectral variations occurred also in the satellite images and made it impossible to classify the image. Even within a single set-aside parcel of permanent fallow land the vegetation was often not at all homogenous. The spectral inhomogeneity of the set-aside parcels in the 1990 images might result from the juvenile age of the parcels. Since no classification was possible, however, remote sensing was used to control the areas by visual interpretation.

Only with digitized parcels it is possible to control the set-aside fields. Even with their spectral variability it is possible to find out whether or not these areas are permanent fallow land. This is due to the texture that is characteristic for these parcels. They do not look as homogenous as crop parcels.

Areas where the interpreter doubts the use can then be checked in the field. This technique enables the administration to check especially fields which became suspicious, instead of taking a random sample out of the files. This could lead to a more effective control instrument, based on visual satellite image interpretation.

Since the visual interpretation is not very effective in terms of cost and comparability, it seems reasonable to search for a strategy to find a computer-based control methodo-
logy. This is expected to be more effective. Therefore further investigations are planned in the near future.

This is especially important since the EEC favours a one-year-set-aside-program in the future. This means that only juvenile fallow land, like in this study, has to be investigated and monitored by remote sensing. Therefore, a computer-based methodology is mandatory.

ACKNOWLEDGEMENT

This study was funded mainly by the Environmental Mapping and Modelling Group (EMAP) of JRC Ispra. This support was greatly appreciated.

REFERENCES


