# Remote sensing and management of large irrigation projects

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# Remote sensing and management of large irrigation projects

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**Abstract:** Satellite data now give localized and regular information for use in agriculture. Recent results obtained by CEMAGREF, France, ORMVAG and IAV HASSAN II, Morocco, in the irrigation project of Gharb, Morocco, show that remote sensing can be applied to irrigation management.

Applications that are not specific to irrigation projects are presented first:
— land use mapping
— static and dynamic mapping of floods

This is followed by an examination of the applications related to irrigation management:
— mapping of irrigated crops
— detection of intra-plot heterogeneity, to improve irrigation management
— irrigation control in sugarcane plantations based on water balance monitoring on a regional scale

**Résumé**

*Applications de la télédétection à la gestion des grands périmètres irrigués – cas du Gharb (Maroc)*

*Les images satellitaires fournissent désormais une information localisée et répétitive utilisable en agriculture. Les résultats obtenus par le CEMAGREF (France), l'ORMVAG et l'IAV HASSAN II (Maroc) dans le périmètre irrigué du Gharb (Maroc) débouchent sur des applications de la télédétection à la gestion des grands périmètres irrigués.*

*On présente d'abord deux applications non spécifiques des périmètres irrigués :*
*— cartographie d'occupation du sol,*
*— cartographie et suivi des inondations.*

*Puis sont présentées les applications à la gestion de l'irrigation :*
*— cartographie des cultures irriguées,*
*— détection d'anomalies dans les parcelles irriguées,*
*— contrôle de l'irrigation de la canne à sucre par suivi du bilan hydrique à l'échelle régionale.*

Satellite data give now localized and regular information that can be used in agriculture. Recent results obtained by CEMAGREF, France, ORMVAG and IAV HASSAN II, Morocco in the irrigation project of Gharb, Morocco, show that remote sensing can be applied to irrigation management.

The study area is a plain extending over 250 000 ha, of which 100 000 ha are irrigated, in northwestern Morocco. Annual rainfall is between 400 and 600 mm and average temperatures are between 11°C in winter and 27°C in summer. Soils are generally clayey. Main crops are sugarcane, sugar beet, rice, orange, and dry farming cereals. Remote sensing data have been successfully used for land use mapping, flood monitoring, and to meet the specific needs of irrigation management.

# I. – Land use mapping

Authorities of the irrigated area of Gharb need a quarterly updated land use map for irrigation management and agricultural monitoring. The map is also useful for remote sensing applications. High-resolution remote sensing is an appropriate technique for obtaining such a map.

A series of ground measurements of radiometric properties of crops were carried out in 1987. Three periods were identified for a correct discrimination of crops (1 in winter, 1 in spring, 1 in summer). It was subsequently decided to program SPOT acquisition a few days before each period.

The final land use map with a global confusion rate of 18% is obtained each year in July.

# II. – Flood monitoring

The area of Gharb is generally flooded once every 3 year. The feasibility of monitoring and mapping the floods by remote sensing during the submersion period was tested; it was found that 3 SPOT and 14 NOAA cloud-free images can be obtained during this period.

NOAA data are used to monitor the flood extension on a daily basis under cloud-free conditions. The level of submersion is determined by histogram slicing on NOAA AVHRR band 3 (i.e. 3.55-3.93 µm), except when the band is disturbed by instrumental noise (then the normalized difference vegetation index, NDVI, is used). The following levels were defined: dry, wet, partially flooded crop, completely flooded crop.

With these maps, it is possible to analyze flood spread, and produce a map of submersion duration. As flood duration is related to loss of production of the inundated crop, it is possible to predict production losses in the area. Such information is useful for postharvest processing industries for the national economy as Gharb is a major cereal-growing area in Morocco.

SPOT data can also be used to accurately map the maximum extension of the flood and different levels of submersion. They can also be used to get other information on the flood, such as:

- location of river overflows
- location of flow areas where irrigation and/or road infrastructure may be damaged
- control of drainage system
- erosion in cultivated plots

# III. – Applications for irrigation management

## 1. Mapping of irrigated crops

The Gharb area is irrigated by pumping stations along rivers with upstream dams for flow regulation. Private pumping units along the rivers between the dams and the irrigated area considerably decrease available flow.

The problem is to know the exact area irrigated by these private pumping units as many of these are not authorized.

A SPOT XS or a Landsat TM image can be used to map irrigated crops by NDVI histogram slicing. The resulting map is useful for updating irrigation taxes and for estimating the flow to be released in the rivers from dams.

## 2. Detection of anomalies

Heterogeneities in irrigated plots are generally due to anomalies of irrigation, drainage or farming practices.

Many anomalies can be detected, on the one hand, by ground radiometric measurement. The gradients observed in some plots in the Gharb area are significant.

The anomalies can also be detected by remote sensing, using SPOT XS data. The following anomalies have been already detected:

- localized water stress, generally due to low flow at the beginning of the plot (in gravity irrigation systems) showing a decrease of NDVI,

- water excess due to poor drainage, irrigation heterogeneities or irrigation network defects. This can be detected by histogram slicing of the near infra-red band, because vegetation is transparent and water strongly absorbs in this waveband. For example, a simple leak in the irrigation network may result in a 20 m x 20 m pool, which is the size of a SPOT pixel,

- access to certain areas diminish water excess on tracks. This excess is detected by a high vegetation index,

- excess vegetation in drainage canals can be detected by a high vegetation index.

Even if remote sensing does not automatically indicate the nature of the anomaly, it shows its location. With the help of the map the authorities in charge of the irrigated area can identify the location where a diagnostic is required.

## 3. Irrigation control by the water balance monitoring

Thermal infra-red data from NOAA-AVHRR give repetitive information on large areas, with a resolution of 1.1 km. This information can be used to monitor the water balance at a regional scale (Seguin, 1984).

NOAA data are first corrected for geometrical distortions and for atmospheric and emissivity effects (Vidal, 1989), then transformed into surface temperature maps for a defined crop (in this case sugarcane, with an assumed emissivity of 0.96). For such a crop, a simplified equation of daily evapotranspiration and surface temperature is used:

$$(ETR - Rn)^{d} = A - B\,(Ts - Ta)^{i}$$

where :

(ETR − Rn) d is the daily difference between actual evapotranspiration and net radiation,
(Ts − Ta) i is the instantaneous difference between surface and air temperature near midday.

Recent works (Vidal and Perrier 1988) show that, for an irrigated crop, A and B are almost constant and may be estimated as:

$A = 0.0$
$B = B^{o} + 0.05$

with $B_o = 0.30$ for sugarcane.

If $Rn_d$ and $Ta_i$ are known from meteorological measurements, it is then possible to compute the daily evapotranspiration for each pixel where sugarcane is dominant.

On these pixels, we control the ratio ETR/ETM, where ETR is the maximum evapotranspiration of the crop, in order to detect stressed areas, which will then be given priority for the next irrigation.

High-resolution data (see detection of anomalies) will then explain the observed stresses so that irrigation can be improved in the following year.

Thus low- and high-resolution satellite data are a reliable tool in irrigation management. Some of these applications are already operational (flood monitoring, mapping of irrigated crops). The others have to be tested in 1989 and 1990, but results obtained during the last 3 years are very encouraging.

## References

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• VIDAL (A.), PERRIER (A.), 1988, Analysis of a simplified relation used to estimate daily evapotranspiration from satellite IR data. *Int. J. Rem. Sens.*, **10** (8), 1327-1337.

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**Figure 1. Map of the flood in February 1986 obtained from NOAA of 11 February 1986 (beginning). Submerged areas appear in blue.**

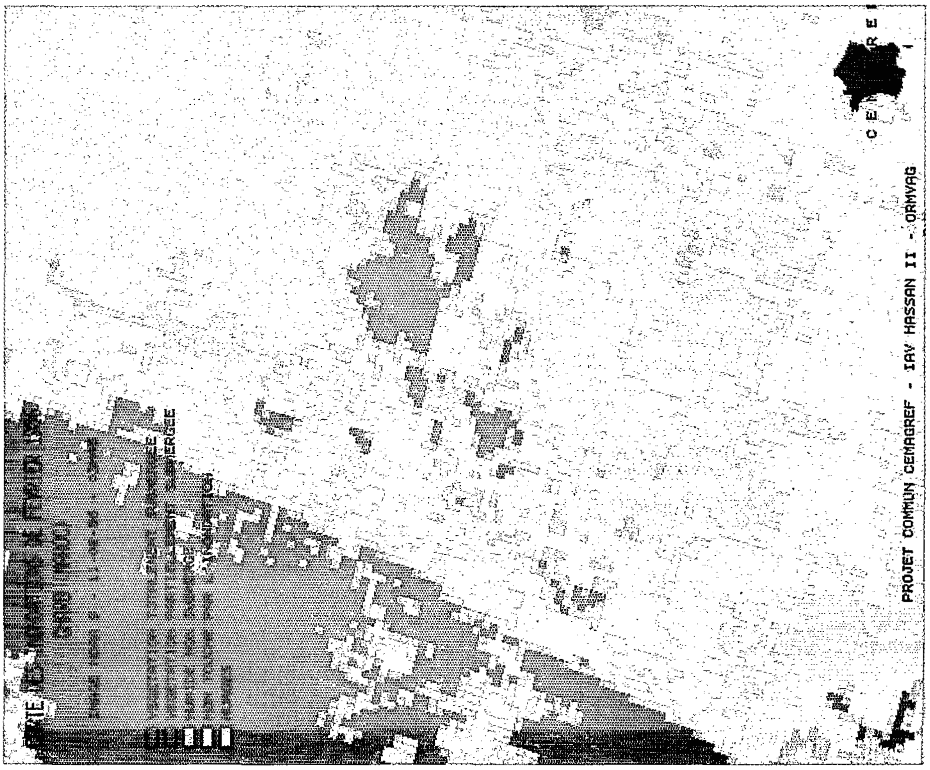


**Figure 2. Map of the flood in February 1986, 2 days later, obtained from NOAA image of February 1986 (maximum extension).**

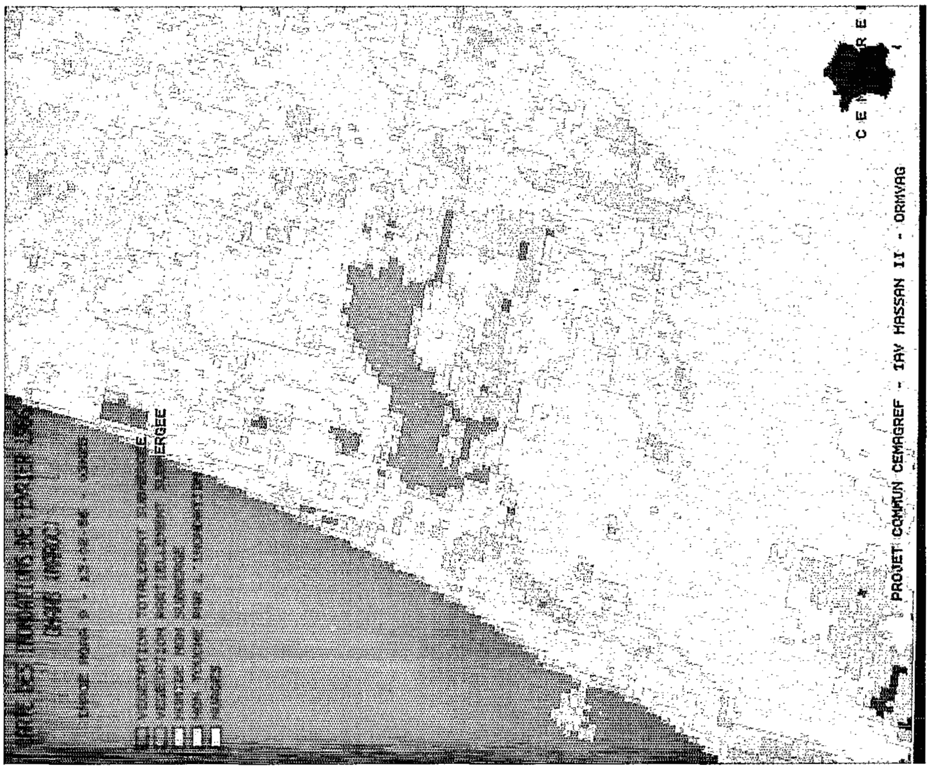

**Figure 3. Map of subversion duration, obtained from five NOAA images taken in February 1986.**

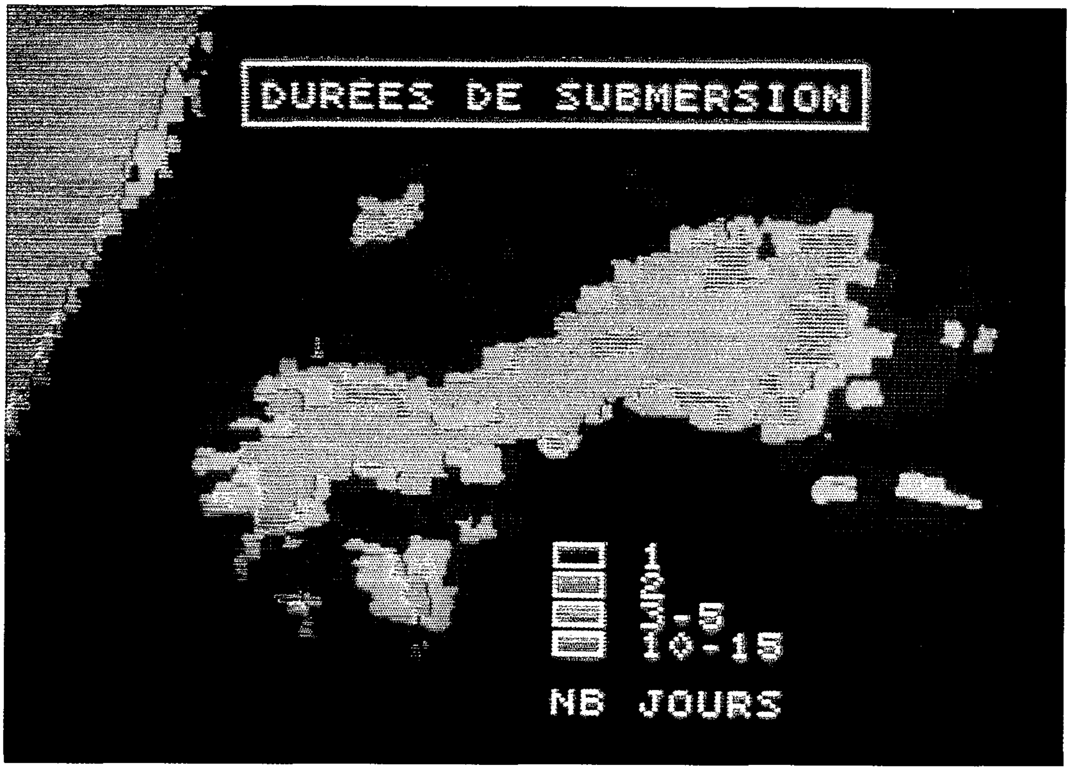


**Figure 4. SPOT XS image of March 1986 showing the flood in February. Areas with problems can de seen on the image.**

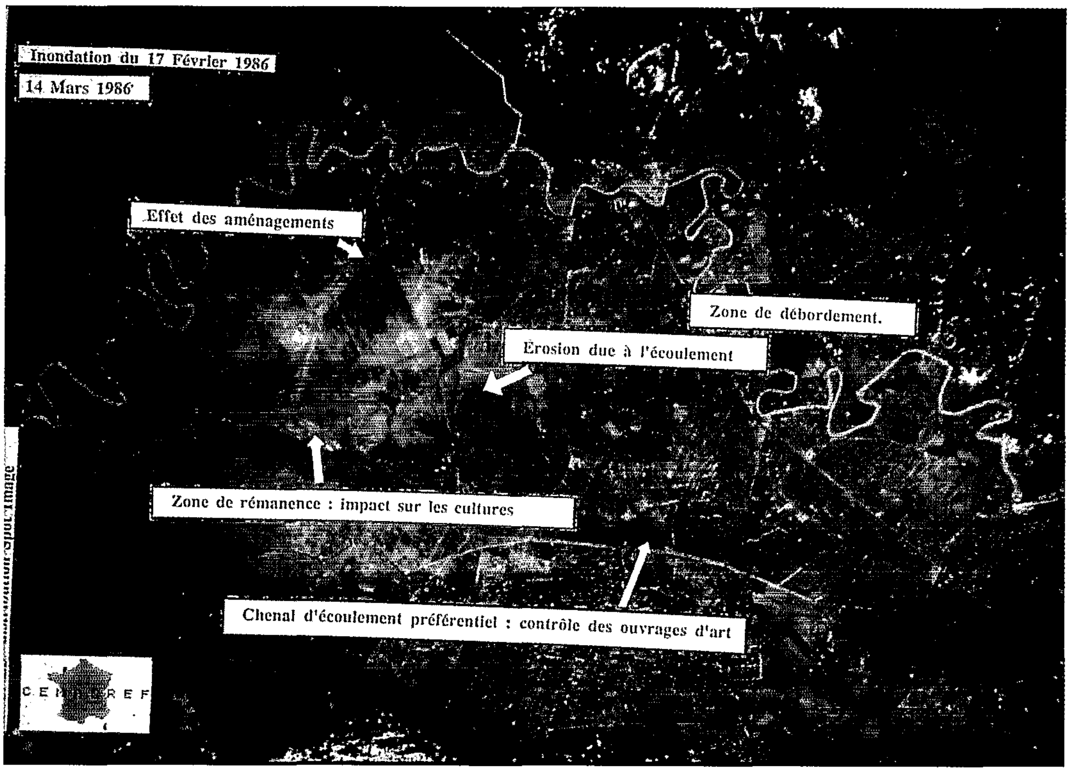

**Figure 5. Classification from the SPOT image presented in Figure 4.**
**Completely and partially submerged areas appear in blue, wet areas in yellow, dry areas in red.**

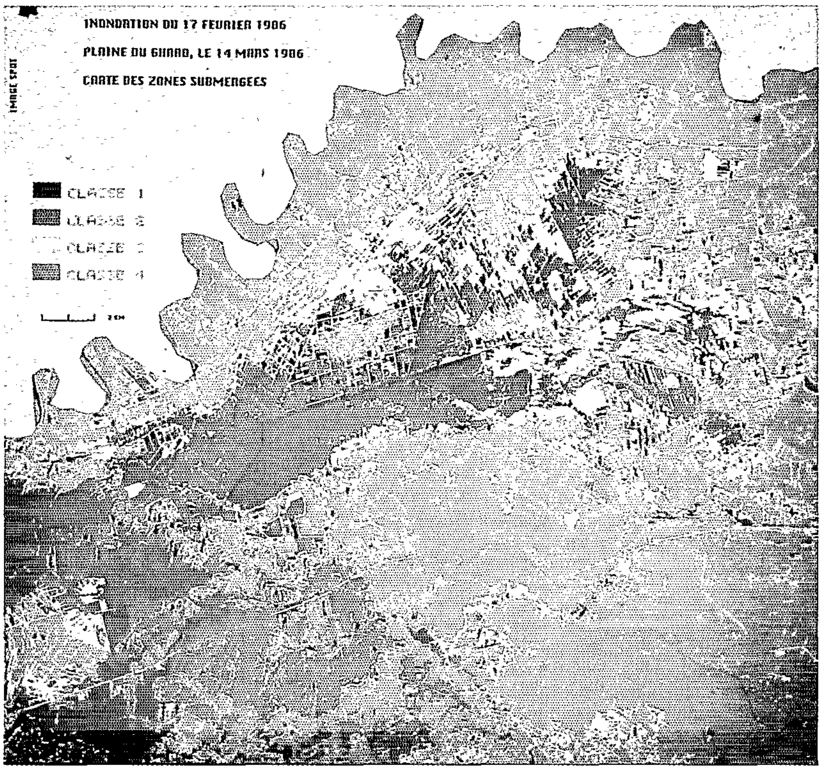


**Figure 6. Landsat TM image of 10 July 1987 showing areas irrigated by private pumping units (in green along the river)**

Figure 7 : Classification from the Landsat TM image presented in Figure 6

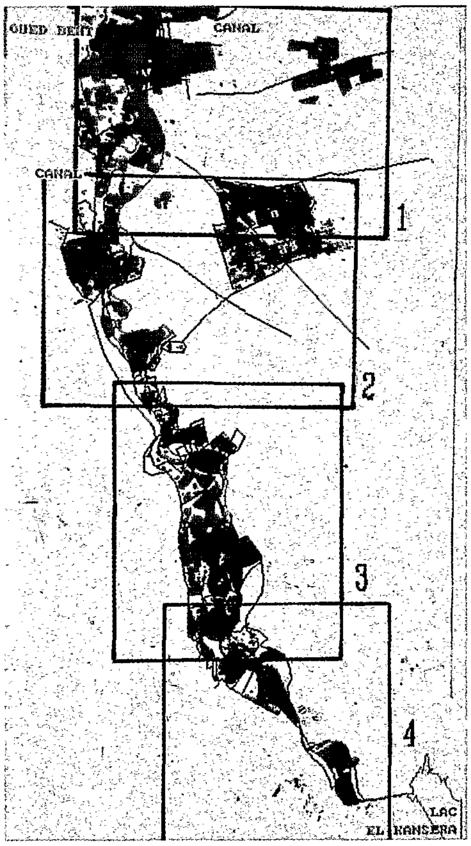


Figure 8. Map of anomalies on an area of 1520 ha obtained from Landsat TM image of 10 July 1987.