IFEMS FOR DETECTION UNDETECTABLE FOREST FIRE

K. R. AL-RAWI, J. L. CASANOVA and A. CALLE

kamal@latuv.uva.es

Laboratory de Teledeteccion, LATUV,
Facultad de Ciencia,
Universidad de Valladolid,
47071 Valladolid

RESUMEN: El sistema integrado del seguimiento de la evolución de los incendios (IFEMS) esta compuesto por el sistema de cartografía de áreas quemadas(BAMS) y el sistema de detección de incendios (FDS). Este estudio ha sido conducido para mostrar la habilidad del IFEMS para detectar los incendios forestales que no pueden ser detectados usando métodos de clasificaciones de los canales térmicos.

Palabras clave: Teledetección,incendios forestales, IFEMS, redes neuronales, ART ANNs.

ABSTRACT: Integrated Fire Evolution Monitoring System (IFEMS) integrates Burned Area Mapping System (BAMS) and Fire Detection System (FDS). This study has been conducted to shows the ability of IFEMS for detection of forest fire that can not be detected using the classical fire detection approach using thermal channels.

INTRODUCTION

Wildfires constitute one of the major problems facing the forest ecosystem in the world. Remotely sensed data are very useful tool for monitoring of wildfires. The satellite NOAA-AVHRR images are widely used in this task.

Fire usually goes through three distinct stages, namely, the ignition phase, propagation phase, and extinction phase (Clarke *et al.*, 1994). The prediction of fire danger is a desirable goal as regards the prevention of fire occurrence. Many studies have addressed this issue (Paltridge and Barber, 1988, Lopez *et al.* 1991; Gonzalez-Alonso and Casanova, 1997), but we still have some way to go. However, fire detection in the ignition stage or early in the propagation stage will be of great help regarding fire suppression.

OBJECTIVES

This study was conducted for monitoring the spatial-temporal behaviour of multiple fire occurrences in Valencia, Spain, during the summer of 1994. The Spanish National Forestry Service (ICONA) detected this fire but did not record all the details of the fire during its evolution time from 26 May to 13 July 1994. The spatial and temporal evolution of the fire on a daily basis by means of the Integrated Fire Evolution Monitoring System (IFEMS) (Al-Rawi *et al.*, 2000b) will be addressed.

DATA

Images of AVHRR have been employed. The images represent the daily afternoon passing of the satellite, and covered the period from 1 May to 13 July 1994 - a period of 74 days. Images of all channels have been employed here except channel 5.

METHOD

Fire Detection System (FDS) is normally used for fire monitoring. However, Burned Area Mapping System (BAMS) performs better because it detects the burn scar which last for weeks, rather than the thermal radiation of the fire. IFEMS (see figure 1& figure 2) has been employed for monitoring the fire during its evolution time. IFEMS represents the integration of both the BAMS and the FDS (Al-Rawi *et al.* 2000a).

Fire evolution $E_{t,t-1} = M_t - M_{t-1}$
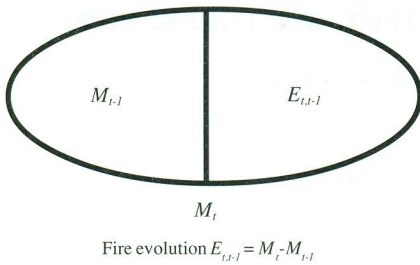
Pixels burned between two consecutive images

$$\Delta_{t,t-1} = B_t - M_{t-1}$$

Figure 1. Sketch shows fire evolution and area burned between two consecutive images. Bt is area mapped as burned at time t but not in active fire.

BAMS and FDS that developed by (Al-Rawi et al. 2000a) are applied here. BAMS requires NDVI and FDS requires channel 3 and channel 4 before and at fire monitoring time. Maximum-Value-Composite (MVC) images for a ten-day period from 1 to 21 May has been constructed. This represents the images before the fire occurred. Images for corresponding monitoring day represent images at the time of monitoring.
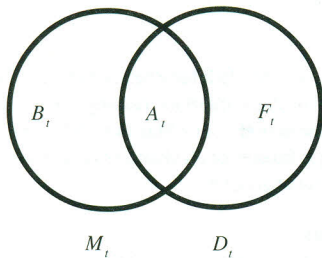
M_t Area mapped by BAMS
D_t Area detected by FDS
Active fire $A_t = M_t \cap D_t$
Burned area $B_t = M_t - A_t$
Pixels beneath flames $F_t = D_t - A_t$

Figure 2. Integration of the BAMS M_t and the FDS D_t, to differentiate between pixels in active fire A_t, burned pixels B_t, and pixels beneath the flames of the fire F_t, at time t.

RESULTS AND DISCUSSION

The monitoring of the fire for the period from 21 May to 6 July has been presented. The fire was monitored for a total of 18 days during this period: 21, 26, 27, 28,29 May, 6, 7, 10, 14, 21, 22, 23, 27, 28, 29 June, 1, 5, and 6 July.

Figure 3 shows the performance of FDS, the BAMS and IFEMS for monitoring forest fire. Burned area (in black) is area that mapped by BAMS at both images t-1 and t. Area that burned completely between two consecutive images (in white) is area that not mapped by BAMS at t-1 but only at t. This indicates that a fire has been there during the time t-1 to t. Area in active fire (in dark grey) is area that mapped by BAMS and detected by FDS. Area beneath flame (in light grey) is area that detected by FDS but not mapped by BAMS. This area is not in fire but under flames. We should mention here that the flame is in the thermal sense not in visible sense, since FDS is based on thermal channels. In another words, flame here is hot air.

There was no fire on 21 May 1994. The fire has been detected on 26 May. We believe the fire started on this day or a day before, since it does not show area that burned completely. FDS failed to detect fire on 27 May, however, BAMS detected one pixel that burned completely between 26-27 May (white area). The fire not detected on 28 May. We believe the fire is still on but occupied very small area or it was beneath the trees, because it detected by BAMS on 29 May. The large area that burned completely as the image of 6 June shows supports this theory. This area detected by BAMS but not detected by FDS. The reason for this is that the burned area mapping approach can detect fire between the time of two images. The system detects the scar of the fire, which last for weeks, rather than the infrared radiation, which is emitting during fire life span only. Therefore a fire with a short lifetime can be detected by BAMS but cannot be detected by FDS. FDS can detect area that is in fire at the time the satellite passes over. (Robenson, 1991) stated "A fire's duration appears to be as or more important than its size in determining its probability of being observed". Fire occurrence between two images can never be detected via FDS no matter what the size, since the detecting elements (the thermal temperature of channel 3 and channel 4) are no longer there. When using FDS, a large undetected fire may occur in the area of light fuel, like dry grass or in a field of ripe wheat.

BAMS detected the fire on 7 July in two spots, while FDS did not. Fire not detected by both systems in images of 10 and 14 June. On 21 June image, BAMS detected two spots of fire, which are located approximately at the same area of the image of 6 June. This indicates that the

fire still on despite of it did not detected in the images of 10 and 14 June. As we explained before it might be very small or it was beneath trees.

Fire detected one day later (22 June). The active fire occupied five pixels. It is located just at one of the two spots that detected by BAMS a day before. If BAMS has been employed, such fire can be prevented. The fire detected by both systems on 23 June. Image of 27 June shows a quiet good area that burned completely between 23 and 27 of June. BAMS detected four spots on 28 June. One spot detected by both systems on 29 June. Two spots in active fire detected on 1 July. However, huge fire has been break out on 5 and 6 of July.

SUMMARY

IFEMS is employed for fire monitoring on a daily basis during the fire lifetime. IFEMS differentiate among area in active fire, area beneath flames, area that burned for the period between the time of the last (inferior) image and the time of the current image, and area that burned before the time of the inferior image. Such system can locate the fire front (area in active fire) at the time the satellite passes over. Determine the fire front is very important to locate fire fighter in the right location. In addition to that, the ability of the system for detection fires between two consecutive images give us the opportunity to watch such area closely, even though fire is not detected by FDS in the current image. The fire might be there but does not emits enough infra red radiation to be detected by FDS.

Hot spots that appear and then disappear before the satellite passes over can not be detected using FDS. If a hot spot is not observed by FDS does not means it has been put off. It might still in fire but not detected because it might occupy a very small area or it has been started in a light fuel area then has been moved under dense trees. BAMS might track such hot spot depending on the size of the area that has been burned, since it detects the scar of the fire rather than the infra red radiation that emitted by the fire during fire life span which is no longer there. However, IFEMS performs better for hot spot detection since it represents the integration of the two systems.

More details can be found in (Al-Rawi *et al.*, 2001).

CONCLUSION

Although BAMS performs better than FDS for fire monitoring, IFEMS is recommended in order to locate the fire front.

REFERENCES

AL-RAWI, K. R., CASANOVA, J. L., and CALLE, A., 2000a, Burned areas mapping system and fire detection system, based on neural networks and NOAA-AVHRR imagery. *International Journal of Remote Sensing (in press)*.

AL-RAWI, K. R., CASANOVA, J. L., and ROMO, A., 2000b, IFEMS: New approach for monitoring wildfire evolution with NOAA-AVHRR imagery. *International Journal of Remote Sensing (in press)*.

AL-RAWI, K. R., CASANOVA, J. L., and LOUAKFAOUI, E. M., 2001, IFEMS for monitoring spatial-temporal behaviour of multiple fire phenomena. *International Journal of Remote Sensing (submitted)*.

CLARKE, K. C., BRASS, J. A., RIGGAN, P. J., 1994, A cellular automation Model of wildfire propagation and extinction, *Photogrammetic Engineering and Remote Sensing*, 60, 1355-1367.

GONZALEZ-ALONSO, F., CASANOVA, J. L., 1997, Application of NOAA-AVHRR images for the validation and risk assessment of natural disasters in Spain, *Remote Sensing 96*, Spiteri (Ed.), 1997, Balkema, Rotterdam, 327-333.

LOPEZ, S., GONZALEZ, F., LLOP, R., and CUEVAS, M., 1991, An evaluation of the utility of NOAA AVHRR images for monitoring forest fire risk in Spain, *International Journal of Remote Sensing*, 12, 1841-1851.

PALTRIDGE, G. W., and BARBER, J., 1988, Monitoring grassland dryness and fire potential in Australia with NOAA-AVHRR data, *Remote Sensing Environment*, 25, 381-394.
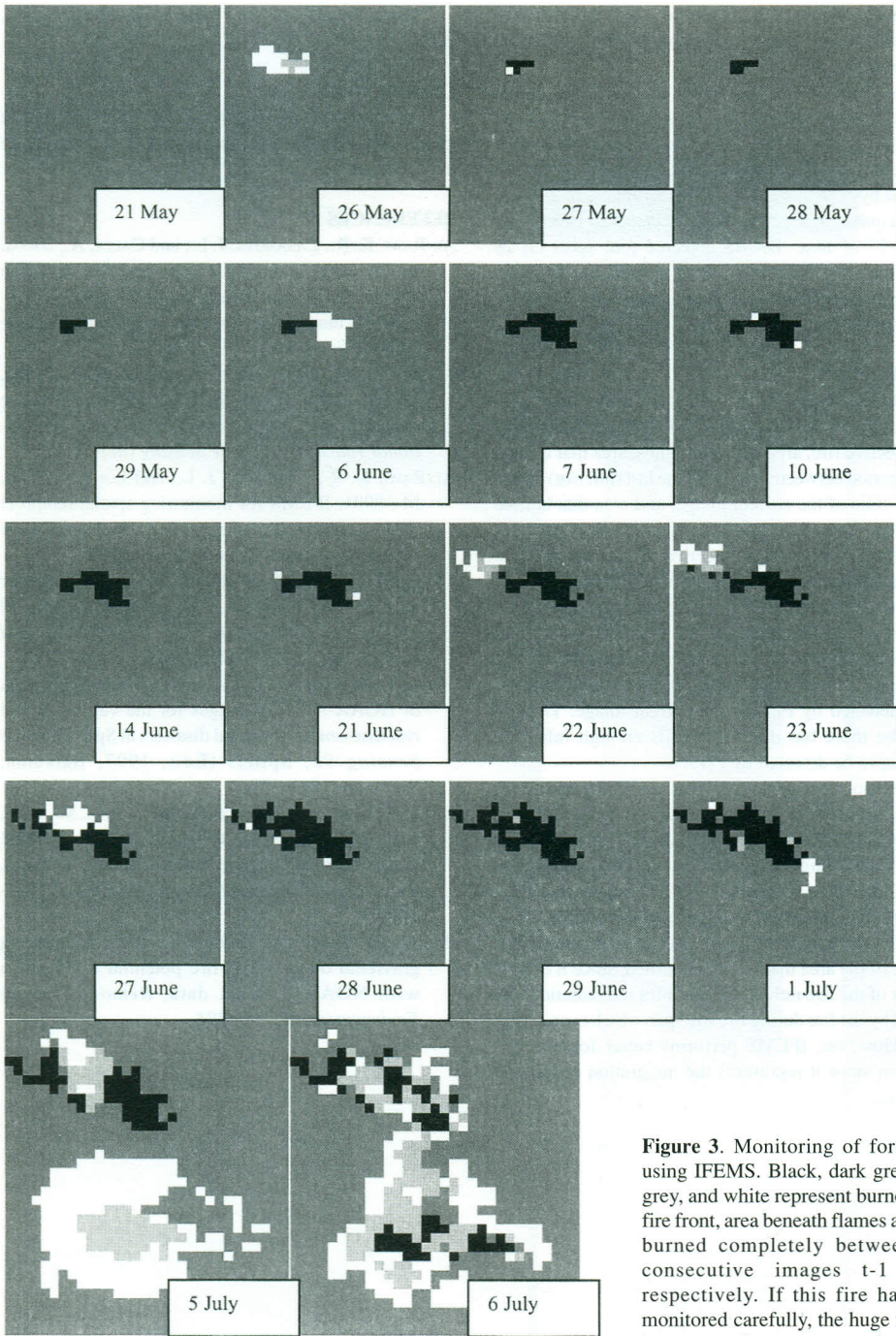
Figure 3. Monitoring of forest fire using IFEMS. Black, dark grey, light grey, and white represent burned area, fire front, area beneath flames and area burned completely between two consecutive images t-1 & t, respectively. If this fire has been monitored carefully, the huge fire can be prevented.