A COMPARATIVE STUDY OF THREE ALGORITHMS FOR FOREST FIRE DETECTION IN IRAN

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ABSTRACT:

Fire as a natural disaster plays a major role in deforestation; is a major source of trace gases, aerosols and carbon fluxes. Approximately 7 percent of Iran area is covered by forests/and wooded lands. According to the ECE/FAO database on forest/other wooded land fires in Iran (1982-1995), the number of fires per year is 130 and the average area burnt per year is 5400 ha, but fires are not largely monitored and enough detection facilities are not available. The use of remote sensing is now a useful alternative, especially in vast and remote areas. The objective of this paper is to inspect the applicability of using MODIS imagery for forest fire detection in Iran, so a comparative study between a graph-based algorithm proposed by Byun et al. (2005) and two contextual algorithms developed by Giglio et al. (2003) and Wang et al. (2007) using MODIS data acquired over Kerman shah province in summer 2006 is present. The results were compared with ground-based observations collected with GPS. It implies that the algorithm developed by Giglio et al. (2003), MODIS version 4 contextual algorithm, performed best with the least commission and omission errors; has potential to be applied in detecting the fire pixels that start in or around forests and are mainly surface fires and seldom crown fires. As a result, using daily MODIS data, it is possible to track fire development in Iran.

1. INTRODUCTION

Biomass burning is a major source of trace gases, aerosols and carbon fluxes. Fire as a natural disaster also plays a major role in deforestation (Kaufman et al., 1998). Every year Iran experiences fires that impinge upon the sparse forest resources. Allard (2003) states that approximately 7 percent of Iran area is covered by forests/and wooded lands and the fire season depends on location and associated climatic conditions. Fire season in the northern part of Iran is from August until the end of December, in the eastern part of Iran is in summer and winter, and in the central and southern part of Iran is from March until September (Allard, 2003). According to the ECE/FAO database on forest/other wooded land fires in Iran (1982-1995), the number of fires per year is 130 and the average area burnt per year is 5400 ha (Allard, 2003), but fires are not largely monitored and enough detection facilities are not available. Standard forms, filled by field survey, are used for documentation of when and where fires occurred. It is mentionable that these forms are incomplete especially from a spatial point of view. Duo to aforementioned shortcomings, monitoring of fires is inevitable. To meet this need, the use of remote sensing is now a useful alternative, especially in vast and remote areas. For example, MODIS imagery from the Terra with continuous near daily coverage can be a good candidate. MODIS on Terra, launched in December 18, 1999, has 36 spectral bands, ranging from 0.4 to 14 μm with three spatial resolutions, 250m (2 bands), 500m (5bands), and 1km (29bands). Other advantages of MODIS for forest fire monitoring are high positional accuracy, high radiometric resolution, moderate spatial resolution modes, and high saturation level (Kaufman et al., 1998). In recent years, several algorithms have been developed for global fire detection with MODIS data (e.g. Kaufman et al., 1998; Byun et al., 2005; Giglio et al. 2003; Wang et al., 2007). The objective of this paper is to inspect the applicability of using MODIS imagery for forest fire detection in Iran, so a comparative study between a graph-based algorithm and two contextual algorithms (Giglio et al., 2003; Byun et al., 2005; Wang et al., 2007) using MODIS data acquired over Kerman shah province in summer 2006 is present.

2. DATA AND METHODS

2.1.Remote Sensing Data

The remote sensing data used in this paper is a set of imageries acquired over Iran in summer 2006 by NASA's Terra satellite.

num	Date	Time (GMT)	
		Start	End
1	2006-07-24	07:42:44	07:45:28
2	2006-07-26	07:30:46	07:33:17
3	2006-07-27	08:13:19	08:16:16

Table 1. Specifications of MODIS imageries used

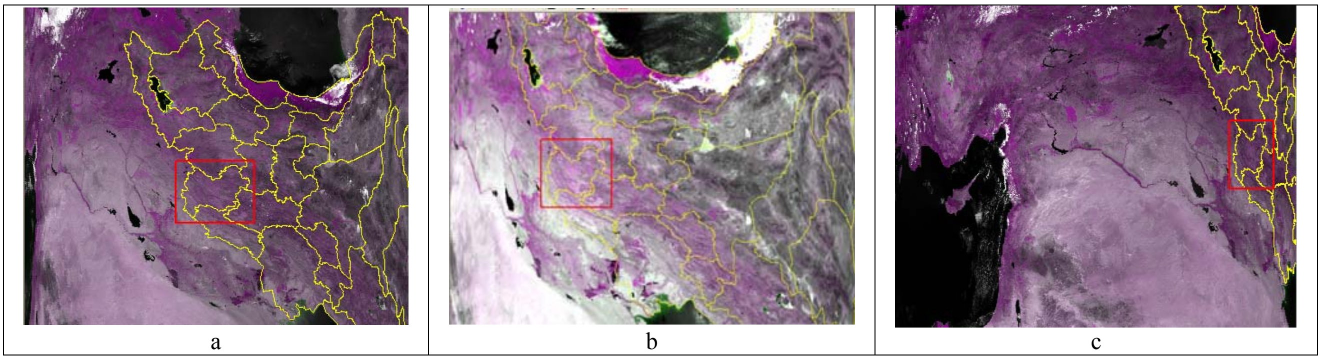

Figure 1. MODIS imageries on a) July 24, 2006, b) July 26, 2006, and c) July 27, 2006 used in this study

We used three imageries taken on 24th, 26th, and 27th September of 2006 (figure 1, table 1). In figure 1, the selected window shows our study area, Kerman shah province. Before fire detection, reflectance values for visible and NIR bands and brightness temperature values for MIR and TIR bands are computed using MODIS level 1B 1 km earth view data product. The bands used in our study are listed in Table 2.

Band number	Band width (μm)
1	0.620 – 0.670
2	0.841 – 0.876
3	0.459 – 0.479
7	2.105 – 2.155
8	0.405 – 0.420
9	0.438 – 0.448
19	0.915 – 0.965
21	3.930 – 3.989
22	3.930 – 3.989
28	7.175 – 7.475
31	10.780 – 11.280
32	11.770 – 12.270

Table 2. MODIS bands used in our study

2.2.Fire Detection Algorithms

Three algorithms used in this paper are classified as either 'contextual' or 'graph-based' (Giglio et al., 2003; Byun et al., 2005; Wang et al., 2007). The contextual algorithms used are based on the original MODIS contextual algorithm (Kaufman et al., 1998), but offer superior sensitivity to smaller, cooler fires and have yielded fewer blatant false alarms over this version (Giglio et al., 2003; Byun et al., 2005). The first contextual algorithm is divided in the following steps (Giglio et al., 2003):

1. Cloud and water masking
2. Identification of potential fire pixels to eliminate obvious non-fire pixels
3. Background characterization using the neighboring pixels to estimate the radiometric signal of the potential fire pixel in the absence of fire
4. Tentative fire detection using a series of contextual threshold tests
5. Sun glint, desert boundary, and coastal false alarm rejection

It uses MODIS geolocation product, reflectance values in 0.65μm, 0.86μm and 2.1μm and brightness temperature values in 4μm, 11μm and 12μm. The second one (Wang et al., 2007) comprises the aforesaid 1st - 4th steps with some changes and an additional step of identifying potential fire areas, before the 2nd step. The latter step uses reflectance values in 0.47μm, 2.1μm, 0.41μm, 0.44μm and 0.94μm; identifies smoke pixels and then calculates potential fire area around them to form a potential fire area mask. As Wang et al. (2007) mention, that is because tests used to detect potential fire pixels use fixed thresholds. It increases the risk of omitting small, cool fires that do not emit sufficient TIR radiation to penetrate dense canopies and cannot be easily distinguished from non-fire background radiation; however, most fires emit smoke and smoke plumes from small and cool fires stay near ground in high concentrations (Wang et al., 2007). As a result, smoke can be a good indicator for this type of fires in solar reflective channels. In comparison to the former, this algorithm uses reflectance values in 0.47μm, 0.41μm, 0.44μm and 0.94μm and brightness temperature values in 7.3μm too. On the other hand, the graph-based algorithm (Byun et al., 2005) is based on spatial outlier detection method. That is because forest fire pixels can be treated as thermal anomaly in TIR bands (Byun et al., 2005). This algorithm doesn't need the step for determining the threshold empirically according to the target regions. In this method, after the implementation of a potential fire test, brightness temperature in 4μm was used as a single spatial variable in the ordinary scatter plot and Moran's scatter to detect fire pixels. Each of these three algorithms was coded in MATLAB 7.1.

3. RESULTS

Three algorithms were applied to the data (table 1, figure 1). Figure 2 shows the results of MODIS version 4 contextual algorithm (Giglio et al., 2003). The results were compared with ground-based observations collected with GPS by Forest, Range and Watershed management organization (table 3, figure 3). The MODIS images were observed in the morning i.e. at 07:42:44 - 07:45:28 GMT on July 24, 2006, 07:30:46 – 07:33:17 GMT on July 26, 2006, and 08:13:19 - 08:16:16 GMT on July 27, 2006. On the other hand, according to ground-based observations, the fire events took place in the afternoon. As a result, it is likely to miss fire events duo to limited satellite diurnal sampling. Nonetheless the fire spot detected in image 3 (figure 2(c)) was reported to be an active fire in the afternoon (i.e. approximately 3 hours later). This proves the advantage of using remote sensing imagery for fire detection. Fire spot detected in image 2 (figure 2(b)) wasn't reported as an active fire, but considering images 1 and 3 with respect to image 2, this pixel has potential to be an active fire. The algorithm developed by Wang et al. (2007) detected no fire spots in the images. Figures 4-5 show the results of the graph-based algorithm developed by Byun et al. (2005). As can be seen, in comparison to the first algorithm, the omission and commission errors in this algorithm are notable. But, it is worth nothing that using this algorithm, the fire spots detected in image 2 and 3 (i.e. figures 2(b) and 2(c)) by the former, are reported to be active fires (figure 4(b) and 5(b-c)).

Num	Region	Date	Area (ha)	Spatial coordinate of fire		Time (Local)	
				Latitude	Longitude	Start	End
1	Sahneh, Bide Sorkh defile	2006-7-26	15	34:26:10 N	47:28:51 E	16:30	18:30
2	Eslam Abad Gharb, Haroon Abad	2006-7-26	5	34:43:00 N	46:33:00 E	13:00	15:00
3	Eslam Abad Gharb	2006-7-27	10	34:05:00 N	46:31:00 E	14:00	20:00
4	Salase Babajani	2006-7-27	1	34:41:16 N	46:13:12 E	16:30	17:20
5	Gilane Gharb	2006-7-27	20	-	-	17:00	20:30

Table 3. Specifications of ground based measurements

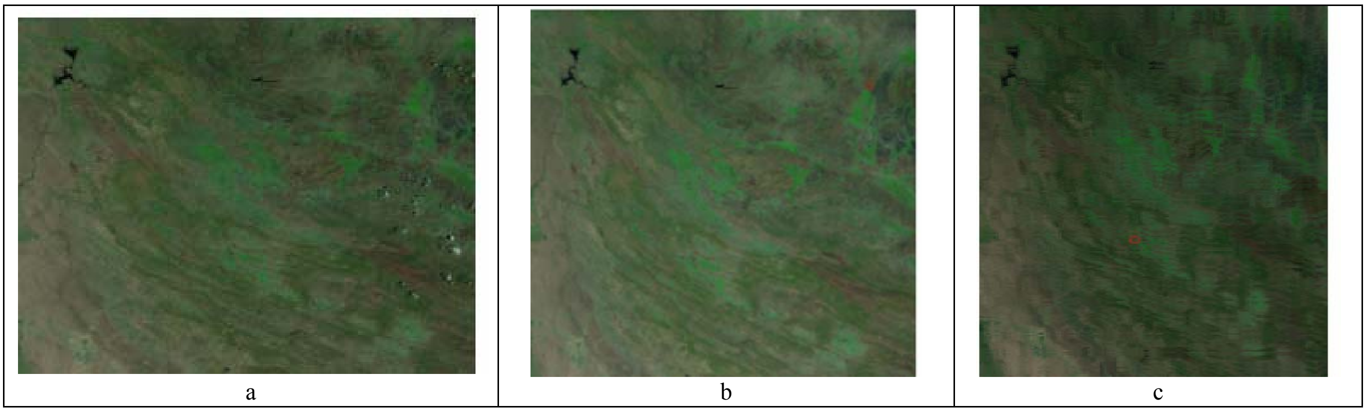

Figure 2. Fire events detected by algorithm developed by Giglio et al. (2003) on a) July 24, 2006, b) July 26, 2006, and c) July 27, 2006. The red enlarged dots represent the fires detected.

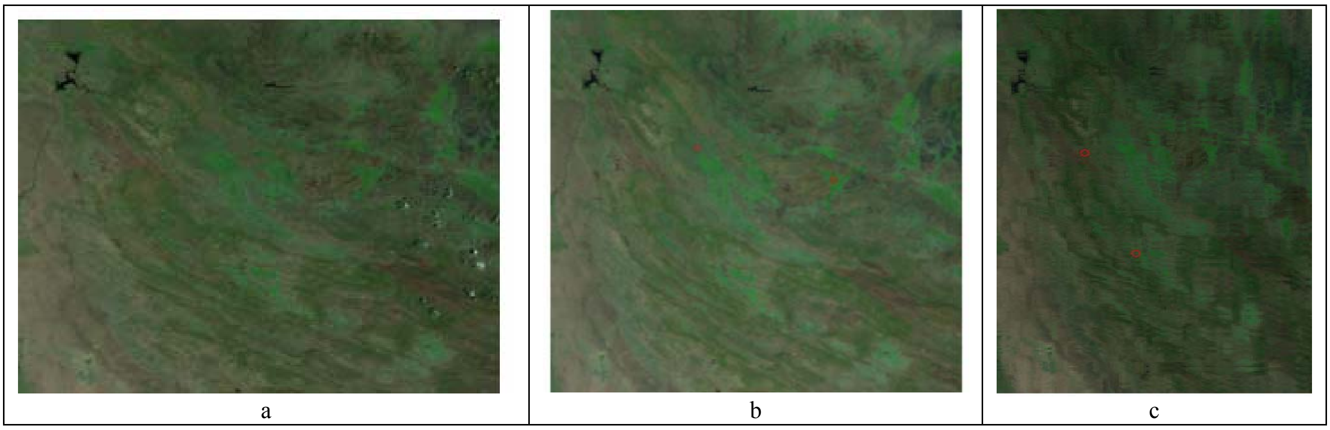

Figure 3. Ground-based measurements on a) July 24, 2006, b) July 26, 2006, and c) July 27, 2006 used in this study. The red enlarged dots represent the fires reported.

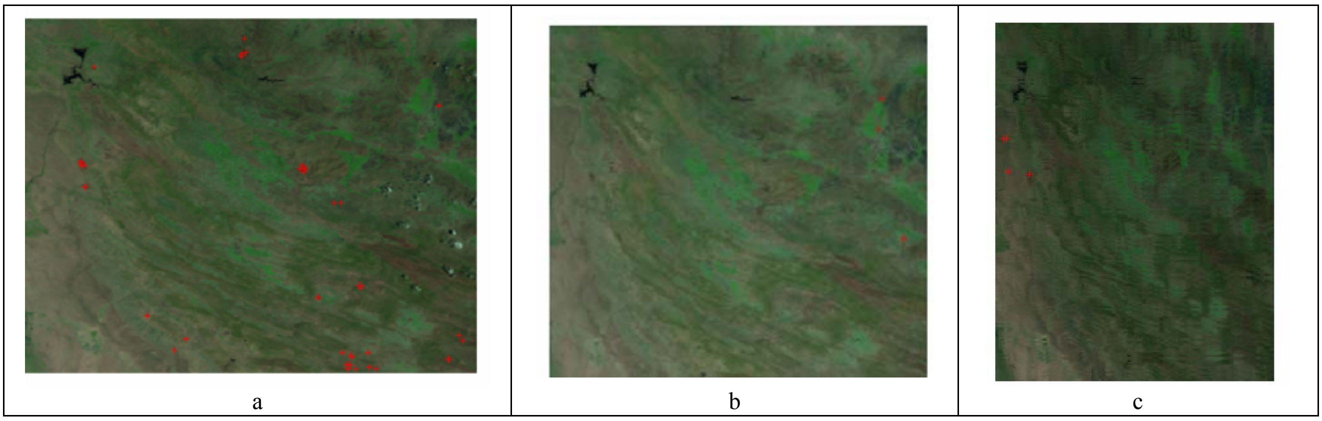

Figure 4. Fire events detected by algorithm developed by Byun et al. (2005) using ordinary scatter plot on a) July 24, 2006, b) July 26, 2006, and c) July 27, 2006. The red enlarged plus signs represent the fires detected.

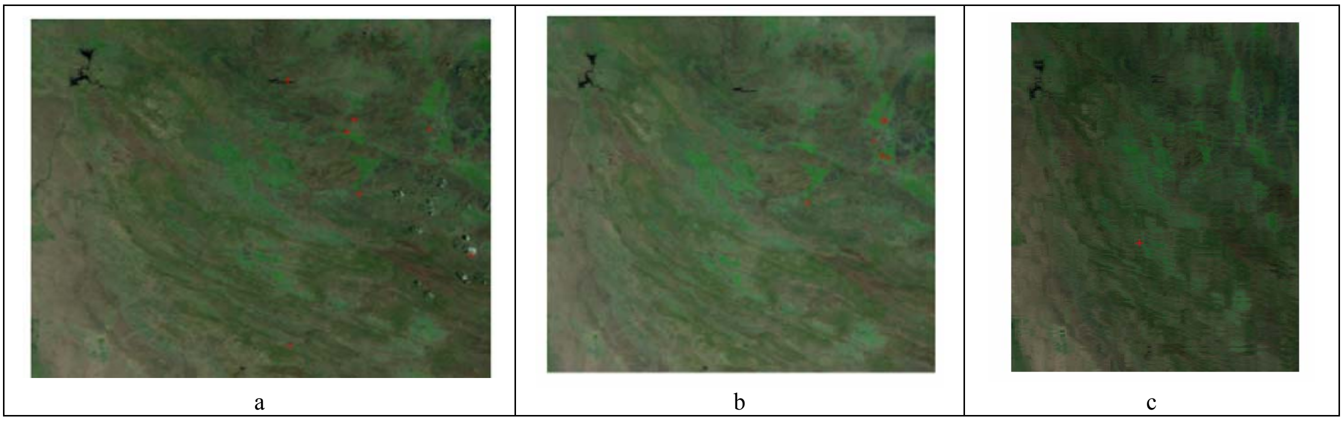

Figure 5. Fire events detected by algorithm developed by Byun et al. (2005) using Moran's scatter plot on a) July 24, 2006, b) July 26, 2006, and c) July 27, 2006. The red enlarged plus signs represent the fires detected.

4. CONCLUSION

Three fire detection algorithms developed by Byun et al. (2005), Giglio et al. (2003), and Wang et al. (2007) have been implemented and tested with MODS data and ground-based measurements acquired over Kerman Shah Province in Iran on July 24, 26, and 27 2006. This study implies that MODIS version 4 contextual algorithm (Giglio et all, 2003) has potential to be applied in detecting the fire pixels that start in or around forests and are mainly surface fires and seldom crown fires in Iran. Using this algorithm, the results entitled decrease in omission and commission errors in comparison to the other two algorithms.

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Byun, Y. Gi., et al., 2005, Evaluation of graph-based analysis for forest fire detections, Proceedings of World Academy of Science, Engineering and Technology, Vol. 10, pp. 24-29