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BFAST: A replacement of climate indicators for monitoring time-series using MODIS

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Introduction

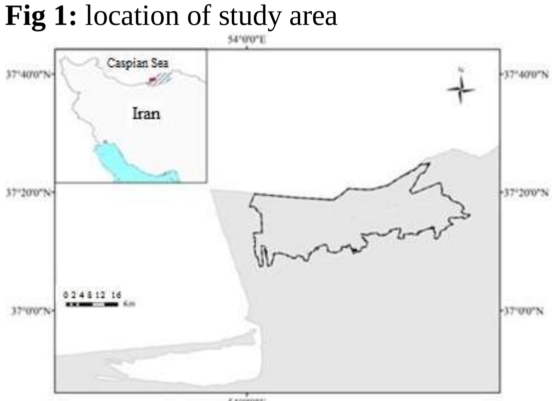
Monitoring changes is critical information for rangeland management because vegetation is seasonally fluctuating green base protection of soil, therefore it is necessary to evaluate it at long-term period. In this study, abrupt and gradual trend changes were detected using BFAST and EVI-16 days of MODIS production. Time series results showed that 2000-2003 period was *stable history* and abrupt changes included 2003 onwards on *monitoring history*. The most negative trends were situated at center above of area with salty soil. Other parts of study area had positive and moderate trend. Our results suggest that BFAST is an automatic and repeatable method that can be used for a more accurate time of disturbance and breakpoints estimation. Using these, we can provide best grazing management for rangeland.

Rangelands are affected on fodder livestock, soil erosion and carbon cycle. So, it is needed to monitor and evaluate changes at the long term. In order to investigate ecological and driving forces on vegetation changes, time series would be best indicator. Detection of gradual and abrupt trend changes can be the first step understanding mechanism of factors affecting on vegetation (Waylen *et al*., 2014). Therefore it is critical to detect changes, understand change processes and their impact in terrestrial ecosystems. Satellite sensors provide consistent and repeatable measurements that enable capturing effects of many processes that cause change, including natural and anthropogenic disturbances (Forkel *et al*., 2013). BFAST integrates the decomposition of time series into trend, seasonal, and remainder components with methods for detecting and characterizing abrupt trend changes within the trend and seasonal components (Verbesslet *et al*., 2013). BFAST monitor provides functionality to detect disturbance in near real-time and is flexible approach that handles missing data without interpolation. The objectives of our study were to: (1) demonstrate seasonally rainfall disturbances and (2) assess change dynamics on vegetation. To achieve these objectives, field samplings were conducted on rangeland of NE–Iran which is located between arid and humid zones.

Materials and Methods

Study area: Investigation of times series on rangelands was carried out as rectangular at satellite images in NE–Iran (54°10’20”E and 37°15’15”N, figure 1). This is 112752 ha area about -21 above sea level. The average annual precipitation in the area is 180 mm/yr and means annual temperature is 17° C. Rainfall mostly occurs during autumn, winter and early spring (October-April). 113°34’20”E, altitude: 972 m) (Fig. 1). The study site has flat topography and uniform vegetation distribution. The vegetation is dominated by *Halocnemun strobilacium*, *Halostachys caspica* and annual grasses. The site base Abrejheh and Domartan methods has arid and semiarid climate.

Fig 1: location of study area



Data derived from satellite: To detect changes in greenness of rangelands during a long periods (2000-2012), a times series of enhanced vegetation index was used (EVI) as derived MODIS on NASA's TERRA satellite (MOD13Q1) in time intervals of 16 days at a spatial resolution of 250 m, 27 images per year (Helman *et al*., 2014; Wallace *et al*., 2013). The area was at (h05, v22) tiles. Images were converted at MRT software from HDF format to UTM format. In order to investigation changes Breaks For Additive Season and Trend package (BFAST) was used in R. BFAST iteratively estimates the time and number of abrupt trend changes within time series, and characterizes change by its magnitude and direction. It provides stable history period and monitoring period in time series (Verbesslet *et al*., 2013). Detection was applied to classify changes which explain trend of effective forces on growing vegetation. Mann-Kendal method was performed to determine significant at each segment in trend component. Classification analysis was used to expand the map derived from TMNB across EVI–16 days time series. Maximum silhouette coefficient was achieved by standardized and plotting. Then final map which showed total variability.

Results and Discussion

Initial maps of analysis included three layers named: Time, Magnitude, and Number of Breaks (TMNB). Breakpoints on time series are related to factors such as low precipitation. Next important output is Figure 2 which first panel showed total time series. Second, seasonality component with one break point illustrated phonological changes. Third one is trend component which was divided into six segment and five break points, including gradual and abrupt trend changes. Last component is residual or noise base on generalized least square (GLS). It calculated autocorrelation of residual in time series.

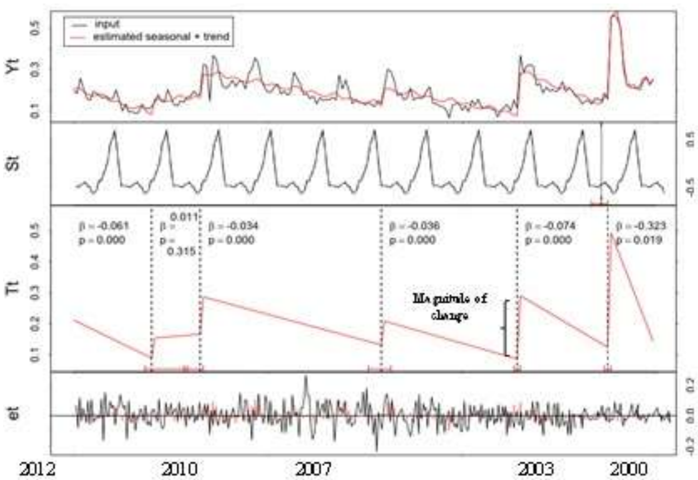


Fig 2: BFAST analysis was done with 5 breakpoints at trend and seasonal component, interval confidence (Red line) and approximate time of change (dash line). Yt component is total input to the model. The model can be detected by three abrupt trend changes at trend component and phonological changes at seasonal component.

Inspection of additional result revealed maximum structure change (OLS) in time series (α<0.05). *Stable period* was identified in *stable history* during 2000–2003 periods. It was used for prediction of normal variance of expected data and distribution detection in *monitoring period* (new observation, red curve). *Monitoring period* is taken into account from 2004 onwards with a negative magnitude. The negative magnitude is clearly shown by the lack of seasonality and major decrease in NDVI (probability of detection was 60%, more than two observations in the *monitoring period*) (Verbesslet *et al*., 2013). These results imply that for 8 or 16 days composites reduce effects of cloud and improves noise-signal ratio.

BFAST clustering data: TMNB map was applied to classify changes at each part of rangelands. EVI showed that at 9 cluster had 87.37% separability for detecting changes in area. The output of Zonal algorithm in clustering was table to mention positive or negative trends (table 1). In respect to this table, around Gomishan channel, central part of area toward Caspian sea, Inche-Broun and Sofikam was showed without changes. Positive trend with moderat changes during 2001-2005 periods was almost in central, above of Inche-Broun and down of Gomishan channel. Negative trend with moderat changes was only above salty part of Gomishan where soil is salty completely. Finally, positive trend with sever changes was at center to east.

Table 1: Properties of each category using EVI-TMNB

level	characteristic	Range change	Date	No. Breaks	Magnitude
1	Non-change	0	2000-09-13	2	0.0
2	Pre, positive	1	2002-09-30	2	0.1
3	Pre, positive	1	2002-09-30	3	0.1
4	Pre, positive	1	2002-09-30	3	0.1
5	Non-change	0	2002-09-30	2	0.0
7	Non-change	0	2006-09-30	3	0.0
9	Pre, negative	-1	2004-09-29	3	-0.1

Conclusion

Minimum number of observation between two breakpoints was acquired at 48 monthly observations (4 years). One of the most important results is an automatic and repeatable method that can be used for a more accurate time of disturbance and breakpoints estimation. The final map and table revealed that area was situated at drought years. Magnitude of changes was dependent on density of shrubs in this area (Verbesslet *et al*., 2013).

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