FOREST DISTURBANCE ANALYSIS BY PHENOLOGY OF FOREST COVERS IN MEXICO USING TIME SERIES NDVI DATA FOR THE PERIOD OF 2014-2016

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ABSTRACT

Land surface phenology reflects seasonality patterns, and provides information about vegetation dynamics due to disturbances such as deforestation and forest degradation. It has been applied in studies of climate change, carbon cycle analysis, crop health assessment, drought monitoring, and wildfire risks assessment. We want to find out if land surface phenology can be used to study forest disturbance. We compared phenological parameters of conserved and degraded forest covers derived from time series MODIS NDVI images for an area in the east of Michoacán state, Mexico during 2014-2016. The vegetation types are: oak forest, pine forest, tropical dry forest, and *Abies* (fir) forest. NDVI time series data was filtered in Timesat by Savitsky-Golay, least-squared fitting and the asymmetric Gaussian algorithms to remove the noises in the data. Phenological parameters, such as start of season, end of season, length of season, base value, and small seasonal integral, were extracted for each forest cover. To validate the results derived from MODIS time series NDVI data, time series NDVI data from Landsat 8 for the same period were obtained and processed to extract the phenological parameters. This research shows that phenological parameters such as, NDVI Peak values and base values can be used to differentiate between conserved and degraded forest covers, and thus might contribute to evaluating forest disturbance. Start of season and End of season in tropical dry forest, and pine forest derived from Landsat and MODIS could also make distinguish between conserved and degraded forest.

1. INTRODUCTION

Forest disturbance such as deforestation and forest degradation contributes to greenhouse gas emissions (Meneses-Tovar 2011). Remote sensing has played an important role in characterizing forest disturbance. Remote sensing data from MODIS sensor aboard Terra and Aqua satellite provides high frequency measurements of land surface properties since 2000, and it represents an excellent basis for regional scale studies of land surface phenology at various temporal and spatial scales, which supports the study of trends in phenology and the detection and characterization of vegetation disturbances (Serbin 2013). Land surface phenology has been studied for the changes in recurring cycles of land surfaces and vegetation using time-series vegetation indices (Galiano et al. 2015). NDVI, abbreviated from normalized difference vegetation index, is an index of the absorptive and reflective characteristics of vegetation in red and near infrared proportion of the electromagnetic spectrum. Changes in NDVI time series data are often related to changes in vegetation conditions, proportional to the absorption of photosynthetically active radiation. Affected by clouds, aerosol and other atmospheric contamination there are often noises in time series data (Chen et al. 2004). To reduce the noise, algorithms such as Savitzky-Golay, Asymmetric Gaussian, and Double logistic filter are often applied. Timesat (Jönsson & Eklundh 2004) provides elementary tools to eliminate inconsistencies in time series data such as missing values or outliers caused mostly by clouds and atmospheric variability, and it provides phenological parameters for trend analysis and furthermore it has been tested using MODIS data (Jönsson & Eklundh 2002; Jayawardhana et al. 2015; Hentze et al. 2016).

In this paper, we compare the phenology of conserved and degraded forest covers using MODIS NDVI for temperate forests (Fir forest, pine forest, oak forest, pine and oak forest), and tropical dry forest. We intend to find answers for the following questions: 1) does forest cover phenology described by time-series NDVI allow the detection of forest degradation? 2) what is the difference in phenological parameters of conserved and degraded forests?

2. METHODOLOGY

2.1 The study area

The study area is located in two watersheds, Cuitzeo and Balsas in Michoacán state, Mexico (figure 1). Its altitude ranges from 400-3400 meters above sea level (asl). The average annual rainfall is 850mm, and the temperature ranges from 8-31 degrees (INEGI). Altitude of the tropical dry forest (TDF) ranges from 200-1,000 m asl, fir forest ranging from around 2500-3700 m asl, oak forest from 1200 - 3200 m asl, and pine forest 2000-3400 m als.

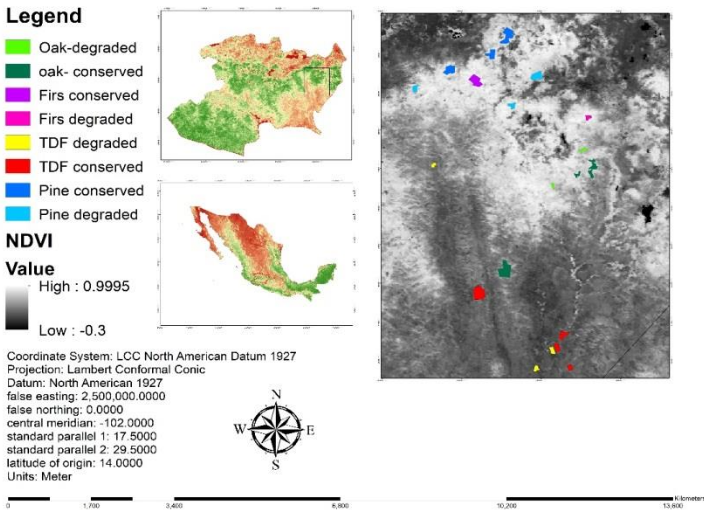

Figure 1. The map showing the location of the study area. The left side is the legend showing the land cover types in the study area, the value range of NDVI, and the coordinate system used for the projection of the study area. The two maps in the middle showing Mexico (lower map) and Michoacán state (upper map). The map on the right side shows the location of the sampled vegetation.

2.2 DATA

Normalized Difference Vegetation Index (NDVI), covering the period from January 2014 to December 2016 of sensor MODIS (product MOD13Q1), was obtained from Earth observation system data and information system (EOSDIS Reverb Echo *https://reverb.echo.nasa.gov*). This vegetation index is a product of 16-day composites with a spatial resolution of 250m with reduced noises by aerosols and clouds. The data was reprojected from Sinusoidal to Lambert conic conformal with datum NAD27 through MODIS Reprojection Tool (MRT *https://lpdaac.usgs.gov/tools/modis_reprojection_tool*). Based on the land cover and vegetation maps from Instituto Nacional de Estadística y Geografía (INEGI) (http://www.inegi.org.mx/geo/contenidos/recnat/usosuelo/) and images of Google Earth, four types of forest classes were identified (Fir forest, pine forest, oak forest, and tropical dry forest) for both conserved and degraded conditions. Five polygons were selected randomly for each forest class covering different ecoregions of Mexico. NDVI values were extracted for each polygon of forest classes and these data were converted into format of ASCII, as the input data for Timesat (Eklundh & Jönsson, 2004), Time series NDVI data were smoothed and phenological parameters were calculated.

2.3 Applied filters for noise removal

Savitzky Golay Filter

The Savitzky Golay is one of the most efficient filters to reduce contaminations in time series data, caused by clouds and atmospheric conditions (Chen et al 2004). It can be applied to any consecutive data with fixed and uniform interval, which is the case for time-series satellite images (Eklundh & Per Jönsson 2015).

$$Y_j * = \frac{\Sigma_{i=-m}^{i=m} c_i \; Y_j + i}{N} \qquad (1)$$

Where Y_j is the original NDVI value, Y_j* is the resultant NDVI value, C_i is the coefficient for the i_{th} NDVI value of the filter, and N is the number of convoluting integers and is equal to the smoothing window size

(2m+1). The Index *j* is the running index of the original ordinate data table, and *m* is the half-width of the smoothing window.

Asymmetric Gaussian Filter

This approach is effective and flexible in obtaining a high-quality time-series by removing the noises. However, in data from areas where seasonality is not clear, it may be hard to identify a reasonable or consistent maxima and minima to which the local functions can be fitted (Chen et al. 2004). The basis function is a Gaussian type:

$$g(t; x_1, x_2, \ldots, x_5) = \begin{cases} \exp\left[-\left(\frac{t-x_1}{x_2}\right)^{x_3}\right] & if \ \ t > x_1 \\ \exp\left[-\left(\frac{x_1-t}{x_4}\right)^{x_5}\right] & if \ \ t < x_1 \end{cases} \quad (2)$$

Where x_1 determines the position of the maximum or minimum with respect to the independent time variable t, while x_2 and x_3 determine the width and flatness of the right half of the function, and x_4 and x_5 determine the width and flatness of the left half (Eklundh & Per Jönsson 2015).

Double Logistic filter:

Double logistic function has been used to monitor land surface phenology in previous research (Sobrino and Julien 2010).

$$g(t; x_1, \ldots, x_4) = \frac{1}{1+\exp(\frac{x_1-t}{x_2})} - \frac{1}{1+\exp(\frac{x_3-t}{x_4})} \quad (3)$$

In which x_1 determines the position of the left inflection point while x_2 gives the rate of change, x_3 determines the position of the right inflection point while x_4 gives the rate of change at this point.

2.4 Determination of the number of seasons

It is difficult to set the number of seasons based on data for only one year, and thus convenient to include data from surrounding years to reduce incorrect determination. Considering just one full season per year, during a period of n-years, there may in general case be n-1 full seasons (Eklundh & Jönsson 2004). In this work, we could only obtain 2 full seasons with the data from November 2013 to February 2017, and we duplicated the time series data to have 4 full seasons.

Phenological Parameters

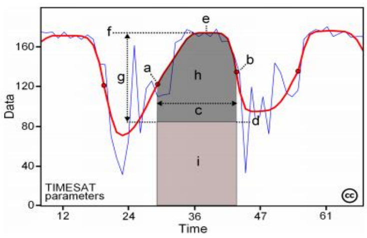

Figure 4: illustration of phenological parameters, adopted from user Manual of Timesat (Eklundh & Jönsson, 2004). The phenological characteristics are the following: (a) start of season, (b) end of season, (c) length of season, (e) peak value, (f) time of peak value, (d) base value, (h) small integral, (g) amplitude.

The parameters used are explained in the following (Tucker 2001, Schwartz 2002, White 2009): Start of season: the rapid and sustained increase in greenness after the longest annual period of photosynthesis senescence; end of season: end of greenness period; length of season: time from the start of season to the end of season; base value: defined as the average of the left and right minimum values; time of peak of value: day of the season when maximum value is reached; peak value: maximum value of time series; seasonal amplitude: difference between maximum NDVI value and the base level; small integral: difference between the function describing the season and the base level from season start to end.

2.4 **Validation**

To validate our work we used Landsat 8 data with 30 m spatial resolution, downloaded for the period of Nov 2013 - Feb 2017 from Land Viewer (*https://lv.eosda.com*). We calculated NDVI with red band (band 4: 0.656-0.673µm), and Near infrared band (band 5: 0.851-0.879µm), applying the next formula:

NDVI=$\frac{NDVI_{band\,5} - RED_{band\,5}}{NDVI_{band\,5} + RED_{band\,4}}$ (4)

3. RESULTS

3.1. Oak forest

3.1.1. results from time series MODIS NDVI data. The phenology of degraded Oak forest (figure 5) has more noise with bigger range of NDVI values than conserved oak forest (figure 6). Table 1 presents the phenological parameters. The *start of season* and the *end of season* for degraded oak forest (SOSD, EOSD) was later than conserved oak forest (SOSC, EOSC). The degraded oak forest has longer *length of season* (LD) than conserved oak forest (LC). As for *time of peak value* (TP): in season 1, 2, 3, 4 the degraded oak forest has the *time of peak value* earlier and in season 5, conserved oak forest has *the time of peak value* earlier. We also found that the *base value* (BV) and *peak value* (PV) for conserved oak forest was greater in all seasons. *Small integral* (SI) values were greater in degraded oak forest.

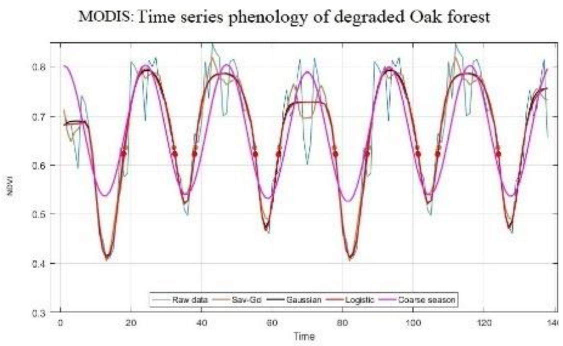

Figure 5: Time series phenology of conserved Oak forest Derived from MODIS data

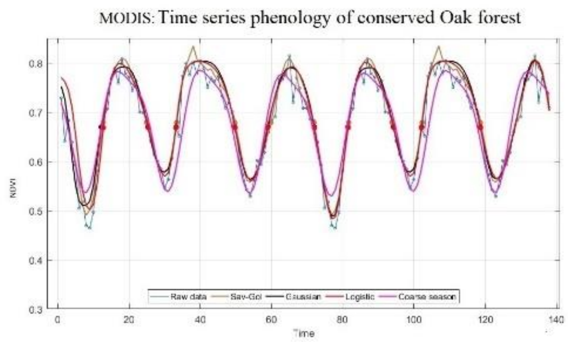

Figure 6. Time series phenology of conserved Oak forest derived from MODIS

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Phenological parameters of Oak forest derived from MODIS NDVI time series data														
Season	SOSD	SOSC	EOSC	EOSD	LC	LD	TPC	TPD	PVD	PVC	BVC	BVD	SIC	SID
1	334.95	167.48	350.18	523.74	182.70	218.84	254.90	97.10	0.80	0.83	0.54	0.49	2.90	4.30
2	341.04	149.21	383.67	563.33	234.47	246.25	248.83	109.24	0.81	0.83	0.57	0.50	3.40	4.70
3	334.95	188.79	386.72	566.37	197.93	261.47	279.17	103.17	0.80	0.83	0.52	0.46	3.20	4.90
4	347.13	164.43	350.18	578.55	185.75	249.29	248.83	106.21	0.80	0.83	0.53	0.49	3.00	4.30
5	182.70	121.80	383.67	310.59	261.87	310.19	254.90	303.45	0.81	0.84	0.57	0.52	3.40	4.40

Table 1. SOS: start of season, (columns 2,3); EOS: End of season (Colum 4,5); LS: Length of season (columns 6,7); TP: Time of peak value (columns 8,9); PV: Peak values (columns 10,11), BV: base values (columns 12,13), SI: small integral (columns 14,15). SOS, EOS and TP represented as day of the year. LS, represented as the number of days, PV & BV represents NDVI values. Letter "C" at the end of capital letters correspond to conserved forest, letter "D" to degraded forest.

3.1.2. results from time series LANDSAT NDVI.

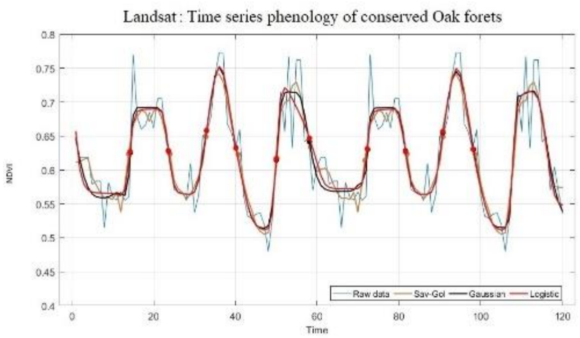

Figure 7. Time series phenology of conserved Oak forest derived from Landsat 8

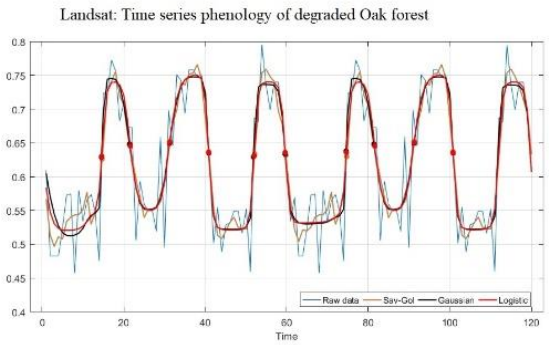

Figure 8. Time series phenology of degraded Oak forest derived from Landsat 8

Time series NDVI values derived from Landsat imagery for degraded Oak forest (figure 8) presents more noise, especially in the lower NDVI values, than conserved Oak forest (figure 7). The calculated phenology parameters (table 2) for Oak forest show that *the start of season* for degraded was sooner than the in conserved ones. As for end of season (EOS), it was slightly different between conserved and degraded Oak forest. In seasons 1 and 3, end of season for conserved forest is later than degraded forest, and for season 2, 3 and 5, end of season for conserved forest is earlier than degraded forest. As for the length of season (LS), the degraded oak forest has shorter length of season than conserved oak forest. As for time of peak value (TP): in season 2, 3, 4, 5 the conserved oak forest has the time of peak value earlier than the degraded ones and in season 5, conserved oak forest has the time of peak value later than the degraded ones. The *base value* (BV) and *peak value* (PV) for conserved oak forest was greater in all seasons. As for the small integral (SI), in season 1 & 4, conserved forest has bigger value than degraded forest, and in seasons 2, 3, and 5, conserved forest has smaller values.

Phenological parameters of Oak forest derived from Landsat8														
Season	SOSD	SOSC	EOSC	EOSD	LC	LD	TPC	TPD	pvd	pvc	SIC	SID	BVC	BVD
1	228.38	243.60	392.81	350.18	164.43	121.80	325.82	280.14	0.74	0.84	1.25	1.07	0.61	0.55
2	228.38	200.97	365.40	374.54	152.25	146.16	283.19	286.23	0.79	0.85	1.47	1.94	0.59	0.56
3	213.15	274.05	392.81	395.85	213.15	182.70	301.46	338.00	0.77	0.85	1.42	1.68	0.58	0.54
4	179.66	227.77	368.45	341.04	185.75	161.39	274.05	280.14	0.74	0.84	1.21	1.03	0.61	0.56
5	182.70	188.79	307.55	344.09	307.55	161.39	231.42	277.10	0.79	0.85	1.47	1.97	0.59	0.55

Table 2. Phenological parameters of oak forest derived from Landsat NDVI time series data. The detailed explainations for the abbreviations are in table 1.

3.2. Tropical dry forest

3.2.1. results from time series MODIS NDVI data

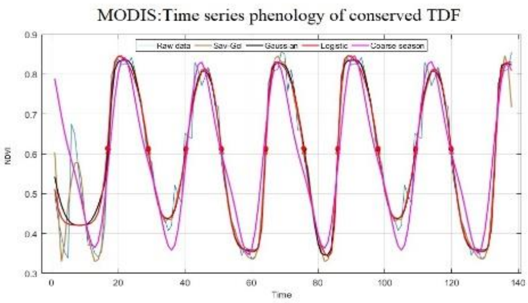

Figure 9. Time series phenology of conserved TDF derived from MODIS

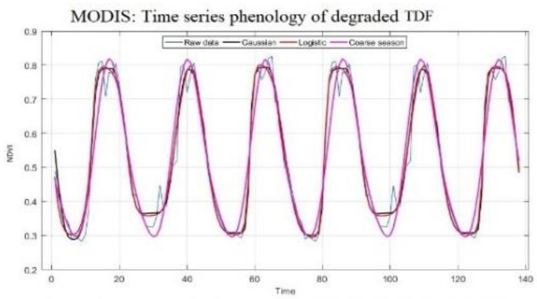

Figure 10. Time series phenology of degraded TDF derived from MODIS

Time-series MODIS NDVI for conserved and degraded oak forest is presented in figure 9 & 10. NDVI values in figure 10 are lower than in figure 10. Time series phenology derived Table 3 presents the phenological parameters, and shows that the start of season (SOS) for degraded TDF was sooner than conserved ones, and the end of season (EOS) for degraded forest was also sooner than conserved forest. As for the length of season (LS), the degraded tropical dry forest has shorter length than conserved TDF. As for time of peak value (TPV), the degraded tropical dry forest has the time of peak value earlier than the conserved ones. We also found that the base value (BV) and peak value (PV) for conserved oak forest was greater in all seasons. Small Integral (SI) values were greater in conserved TDF that in degraded one.

Phenological parameters of TDF derived from MODIS														
Season	SOSD	SOSC	EOSC	EOSD	LC	LD	TPC	TPD	pvd	pvc	SIC	SID	BVC	BVD
1.00	161.69	244.87	440.31	339.28	195.44	177.59	314.65	228.38	0.79	0.84	4.29	4.67	0.19	0.12
2.00	184.83	246.69	431.20	342.75	184.51	157.92	319.73	254.77	0.79	0.81	4.09	3.80	0.17	0.14
3.00	168.69	258.88	465.77	344.93	206.89	176.23	334.95	234.47	0.80	0.83	5.38	4.70	0.17	0.13
4.00	152.25	230.55	428.55	329.56	197.99	177.31	309.58	228.38	0.79	0.84	4.90	4.59	0.19	0.16

5.00	183.31	244.56	429.07	341.23	184.51	157.92	324.80	250.71	0.79	0.81	4.08	3.80	0.17	0.15

Table 3. Phenological parameters of Tropical Dry Forest derived from MODIS NDVI time series data.

3.2.2. results from time series Landsat NDVI data

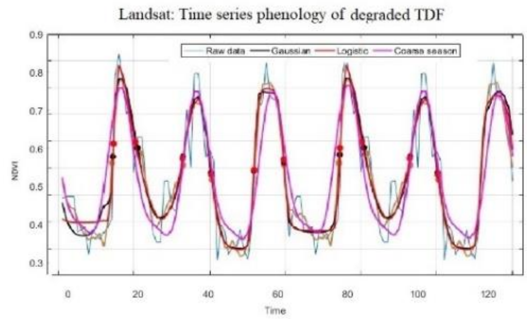

Figure 11. Time series phenology of degraded TDF

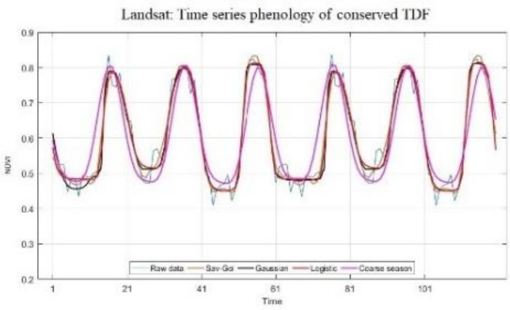

Figure 12. Time series phenology of conserved TDF

Time-series Landsat NDVI for degraded and conserved tropical dry forest is presented in figure 11 & 12. Degraded TDF has more noise and bigger data range than conserved one (figure 11). The calculated phenology parameters for TDF are summarized in table 4 and shows that the start of season for degraded TDF was sooner than conserved ones in season 2, 3, & 5, and later in season 1 and 4. The end of season for degraded forest was sooner than conserved forest. As for the length of season, the degraded TDF is shorter than conserved TDF. As for time of peak value, the degraded TDF is earlier than the conserved ones. We also found that the base value (BV) and peak value (PV) for conserved TDF was greater in all seasons. Small Integral values were greater in conserved TDF.

Season	**SOSD**	**SOSC**	**EOSC**	**EOFSD**	**LSC**	**LSD**	**PTC**	**PTD**	**PVD**	**PVC**	**BVD**	**BVC**	**SIC**	**SID**
1	262	250	388.85	369.05	136.4	128.4	323.68	315.15	0.76	0.81	0.39	0.45	3.16	1.98
2	213	231	373.6	362.95	147.3	139.3	302.3	287.75	0.73	0.81	0.37	0.44	3.22	2.61
3	210	198	394.97	366	129.25	121.25	304.5	287.752	0.77	0.80	0.35	0.43	2.76	2.59
4	271	265.	376.67	359.9	136.47	128.47	320.63	315.15	0.76	0.83	0.38	0.46	1.37	1.14
5	198	207	361.5	347.7	153.22	145.22	284.09	272.55	0.78	0.85	0.37	0.45	1.56	2.51

Table 4. Phenological parameters of tropical dry forest derived from Landsat NDVI time series data. Headers were explained in Table 1.

3.3 Pine forest

3.3.1. results from time series MODIS NDVI data

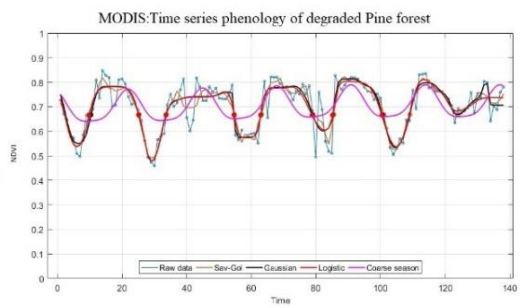

Figure 13. Time series phenology of degraded Pine forest derived from MODIS

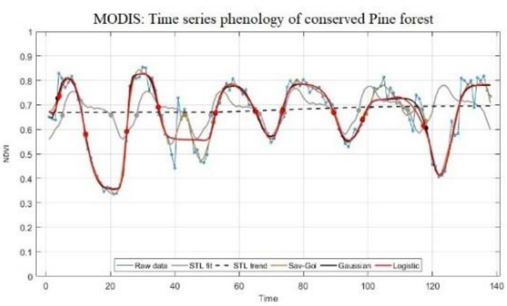

Figure 14. Time series phenology of conserved Oak forest derived from MODIS.

Time-series MODIS NDVI for degraded and conserved pine forest is presented in figure 13 & 14. The crest of degraded pine forest is flatter than conserved ones and presents more noises (13). The calculated phenology parameters for pine forest are summarized in table 5. Both the start and the end of season for degraded pine forest was sooner than the conserved ones. As for the length of season, the degraded pine forest has shorter length in seasons 3,4 & 5 than conserved one. The degraded pine forest has earlier time of peak value than the conserved ones. We also found that the peak values and base value for conserved pine were greater in all seasons, the base values were greater in degraded pine forest. Small Integral values were greater in conserved Oak forest.

Season	**SOSD**	**SOSC**	**EOSC**	**EOSD**	**LSC**	**LSD**	**TPD**	**TPC**	**PVC**	**PVD**	**BVC**	**BVD**	**SIC**	**SID**
1.00	30.45	219.24	158.34	109.62	133.41	238.35	91.35	334.95	0.81	0.79	0.51	0.71	2.62	1.15
2.00	36.54	234.47	204.02	124.85	201.15	271.31	94.40	341.04	0.83	0.81	0.44	0.72	3.90	1.10
3.00	70.04	231.42	267.96	106.58	200.91	113.03	176.61	365.40	0.79	0.81	0.55	0.69	2.98	0.50
4.00	54.81	258.83	295.37	310.59	252.75	159.89	164.43	213.15	0.79	0.53	0.56	0.47	3.53	1.33
5.00	76.13	255.78	380.63	127.89	303.31	256.96	200.97	334.95	0.81	0.75	0.52	0.70	3.70	1.31

Table 5. Phenological parameters of Pine forest derived from MODIS NDVI time series data.

3.3.2. results from time series Landsat NDVI data

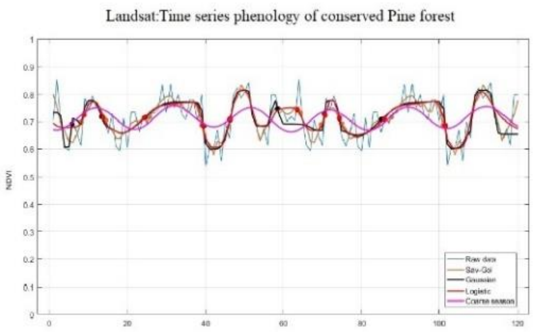

Figure 15. Time series phenology of conserved pine forest derived from Landsat 8

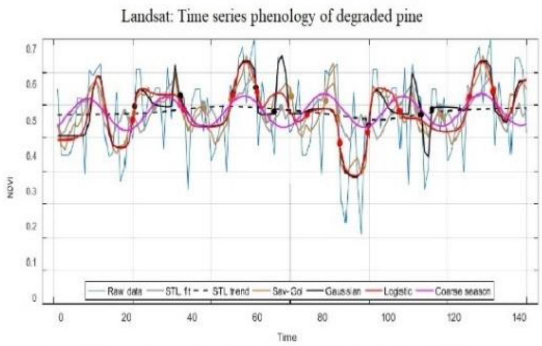

Figure 16. Time series phenology of degraded pine forest derived from Landsat8

Time-series Landsat NDVI for conserved and degraded pine forest is presented in figure 15 & 16. Degraded pine forest presents a lot of noise compared with conserved one. Unlike that of tropical dry forest, the phenological pattern of pine forest is disorganized. Table 6 shows that the start of season for conserved pine forest was sooner than degraded ones in season 1, 2, and 4, and it was earlier in season 3 & 5 and the end of season for degraded forest was sooner than conserved forest in seasons 2, 3 & 5. As for the length of season, the degraded tropical dry forest has shorter length in seasons 2, 4 & 5 than conserved pine forest. As for time of peak value, the degraded pine forest has the time of peak value earlier than the conserved ones. We also found that peak values for conserved pine were greater in all seasons, the base values (BV) were greater in degraded pine forest. Small Integral values were greater in conserved Oak forest.

Phenological parameters of Pine forest derived from Landsat 8														
Season	SOSD	SOSC	EOSC	EOSD	LC	LD	TPC	PTD	pvd	pvc	bvc	bvd	SIC	SID
1	359.31	121.8	216.2	313.64	102.37	188.16	176.61	130.94	0.66	0.77	0.63	0.53	0.8	0.8
2	106.58	85.26	359.31	36.54	213.28	92.75	219.24	176.61	0.67	0.79	0.61	0.55	2.17	0.51
3	127.89	137.03	380.63	137.03	293.6	265.28	200.97	137.03	0.59	0.83	0.6	0.52	2.68	1.08
4	313.64	106.58	228.38	210.11	82.43	213.92	155.3	66.99	0.65	0.75	0.63	0.52	0.57	1.42
5	88.31	124.85	362.36	207.06	213.6	249.6	231.42	152.25	0.67	0.79	0.61	0.56	2.17	1.15

Table 6. Phenological parameters of Pine forest derived from Landsat 8NDVI time series data. Headers were explained above in Table 1.

3.4. Fir FOREST

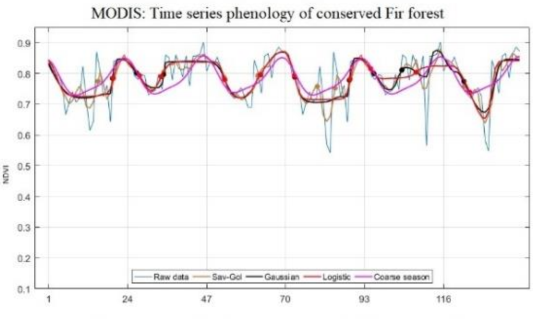

Figure 17. Time series phenology of conserved Fir forest derived from MODIS

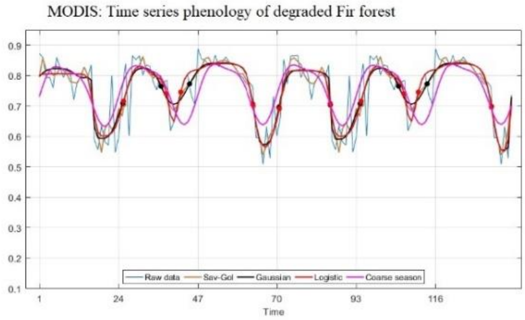

Figure 18. Time series phenology of degraded fir forest derived from MODIS

3.4.1. results from time series MODIS NDVI

Time-series MODIS NDVI for degraded and conserved fir forest is presented in figure 17 & 18. Degraded time series have the troughs formed with smaller NDVI values than conserved fir forest. The crest presents in figure 17, are more irregular than conserved ones. The calculated phenology parameters for fir forest are summarized in table 5, the start of season (SOS) and the end of season (EOS) for conserved fir forest was sooner than conserved ones. As for the length of season (LS), the fir forest has shorter length in seasons III & IV in degraded fir forest than conserved fir forest. As for time of peak value (TPV), the conserved fir forest has the time of peak value earlier than the degraded ones. We also found that peak values (PV) for conserved fir forest were greater in all seasons, the base values (BV) were greater in degraded fir forest. Small Integral (SI) values were greater in degraded fir forest that in conserved one.

Season	SOSD	SOSC	EOSC	EOSD	LSC	LSD	TPC	TPD	PVC	PVD	BVC	BVD	SIC	SID
1	258.825	152.25	315.59	459.8	163.25	201.07	228.37	334.0	0.85	0.79	0.64	0.44	2.15	4.13
2	261.87	182.7	289.275	429.	95.45	167.3	261.8	341.0	0.82	0.75	0.7	0.32	0.6	4.8
3	295.365	140.07	353.22	442.7	217.01	147.3	222.2	334.9	0.83	0.8	0.71	0.32	1.4	3.93
4	280.14	146.16	365.4	478.46	273.6	198.32	255.7	334.9	0.82	0.81	0.67	0.34	2.05	4.7
5	337.995	249.69	392.805	519.8	164.77	181.8	334.95	392.80	0.79	0.86	0.69	0.41	0.88	4.64

Table 7. Phenological parameters of Fir forest derived from MODIS NDVI time series data. Headers were explained above in Table 1.

3.4.2. results from time series Landsat NDVI data

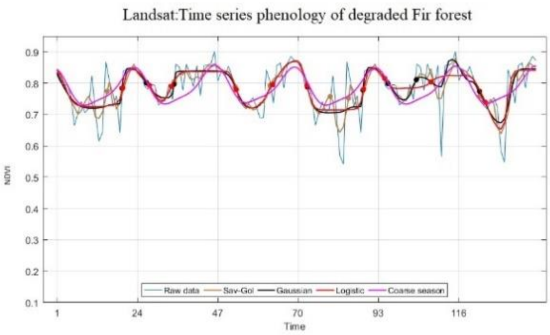

Figure 19. Time series phenology of degraded fir forest derived from Landsat 8.

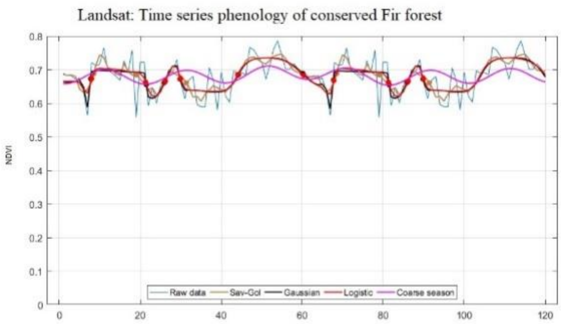

Figure 20. Time series phenology of conserved Fir forest derived from Landsat 8

Time-series Landsat NDVI for degraded and conserved fir forest is presented in figure 19 & 20. Degraded time series have the troughs formed with smaller NDVI values, and presents more noise than conserved fir forest. In both Time series there is no clear patterns of seasons. The calculated phenology parameters for fir forest are summarized in table 8, the start of season (SOS) for conserved fir forest was sooner than conserved ones, and the end of season (EOS) for conserved forest was sooner than degraded fir forest. As for the length of season (LS), the conserved fir forest has shorter length in seasons than conserved fir forest. As for time of peak value (TPV), the conserved pine forest has the time of peak value earlier than the conserved ones. We also found that peak values (PV) for conserved fir forest were greater in all seasons, the base values (BV) were greater in degraded fir forest. Small Integral(SI) values were greater in degraded fir forest that in degraded one.

Season	SOSD	SOSC	EOSC	EOSD	LSC	LSD	TPC	TPD	PVD	PVC	BVC	BVD	SIC	SID
1	124.85	140.07	362.36	386.72	222.29	261.87	235.99	271.01	0.69	0.71	0.71	0.67	0.87	1.49
2	88.31	94.40	200.97	344.09	106.58	255.78	141.59	222.29	0.65	0.71	0.71	0.72	0.32	1.12
3	179.66	155.30	392.81	392.81	237.51	213.15	298.41	261.87	0.71	0.74	0.74	0.68	1.53	2.17
4	106.58	110.49	356.27	380.63	255.78	274.05	234.47	237.51	0.69	0.71	0.71	0.70	0.92	1.65
5	79.17	78.31	185.75	319.73	107.44	240.56	127.89	208.58	0.65	0.71	0.71	0.70	0.32	1.12

Table 8. Phenological parameters of Fir forest derived from Landsat 8 NDVI time series data. Headers were explained above in Table 1.

4. DISCUSSION

Peak values and base value were the best parameters to distinguish between conserved and degraded forest for all tested vegetation classes (Pine forest, Oak forest, Fir forest and Tropical dry forest), with higher NDVI values for conserved forest types than the degraded ones.

For tropical dry forest and pine forest, *start of season* is a good indicator to distinguish conserved and degraded forest. We found the similarity in derived phenological parameters in time-series NDVI for both MODIS and Landsat for tropical dry forest, and pine forest. For example, both *start of season* and *end of season* for degraded forest are sooner in TDF; *length of season* for conserved is greater than degraded; *time of peak value* is sooner in degraded than in conserved; small integral is greater in conserved than in degraded; base value and peak value are both greater in conserved than in degraded. For degraded TDF and pine forest, the *start of season* and *end of season* are sooner than the conserved forests. The possible reason could be that these degraded forests have secondary vegetation such as shrubs with no access to deep surface water and respond faster to first inputs of water than conserved forest covers (Huete et al 2006; Koltunov et al.2009).

It is important to mention that for both MODIS and Landsat imagery, the time-series NDVI data for fir forest and pine forest have more noise than tropical dry forest and Oak forest. The climate condition for both fir and pine forests is more humid and thus has frequent cloud cover, which affects the quality and reliability of the images obtained and affects the phenological parameters (Bojnowski 2009). For oak forest, it is different the phenological parameters from Landsat and MODIS. The composition of oak forest changes by latitude and altitude (Nixon 1993), and most of oak species are phonologically desynchronized because they response differently to weather conditions (Nixon 1993). It is important to know the species composition within the pixels measured. Since possibly the phenological data derived from MODIS could be affected by composition of different oak species with different phenological patterns. Also, is important to assess the influence of spatial and temporal resolution to plant phenology. *Small integral* is related with vegetation net productivity (Davis 2017). It measures vegetation productivity only in growing season and it is related with the *length of season*. Conserved tropical dry forest and pine forest have greater value of *Small integral*, nevertheless in Oak and Fir forest this pattern is reversed. Conserved fir forest does not show much variety in NDVI for the observed period, and thus coincide with low *Small integral* value.

5. CONCLUSION

Conserved forest and degraded forest have different vegetation composition which causes the difference in phenology presented in time series NDVI images (Koultunov 2009). This research shows that phenological parameters such as, NDVI Peak values and base values can be used to differentiate between conserved and degraded forest covers, and thus might contribute to evaluating forest disturbance. Start of season and End of season in tropical dry forest, and pine forest derived from Landsat and MODIS could also make distinguish between conserved and degraded forest. Other parameters did not show a clear result to detect forest disturbance. Time series phenology of tropical dry forest derived both from Landsat and MODIS have less noise that allow us to create a more accurate time series and obtain reliable parameters. Tropical dry forest is a deciduous forest cover type, and is to sensitive to rainfall. For future work, combine climate data such as temperature and rainfall, cloud help to validate and understand the obtained patterns from NDVI Time series data.

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REFERENCES

Chen, J., Eklundh, L., Jonsson, P., Matsushita, B., Chen, J., & Chen, L. (2004) A simple method for reconstructing a high-quality NDVI time-series data set based on the Savitzky-Golay filter. Remote Sensing Of Environment, 91(3-4), 332-344

Davis, C., Hoffman, M., & Roberts, W. (2017). Long-term trends in vegetation phenology and productivity over Namaqualand using the GIMMS AVHRR NDVI3g data from 1982 to 2011. South African Journal of Botany, 11176-85

Eklundh, L., & Jönsson, P. (2015). TIMESAT: A software package for time-series processing and assessment of vegetation dynamics. In *Remote Sensing Time Series* (pp. 141-158). Springer International Publishing.

Hentze, K., Thonfeld, F., & Menz, G. (2016). Evaluating Crop Area Mapping from MODIS Time-Series as an Assessment Tool for Zimbabwe’s “Fast Track Land Reform Programme”. Plos ONE, 11(6), 1-22.

Herold, M., Kooistra, L., DeVries, B., Verbesselt, J., DeVries, B., Verbesselt, J., & ... Herold, M. (n.d). Robust monitoring of small-scale forest disturbances in a tropical montane forest using Landsat time series. Remote Sensing Of Environment, 161107-121.

Jedrzej Bojnowski . (2009). Noise reduction of NDVI time-series: a robust method based on Savitzky-Golay filter. Annals of Geomatics , VII, 12-21

Jonsson, P., & Eklundh, L. (2002). Seasonality extraction by function fitting to time-series of satellite sensor data. *IEEE transactions on Geoscience and Remote Sensing*, *40*(8), 1824-1832.

Jönsson, P., & Eklundh, L. (2004). TIMESAT—a program for analyzing time-series of satellite sensor data. *Computers & Geosciences*, *30*(8), 833-845.10.Koppen climate classification | climatology". 1918 Encyclopedia Britannica. Retrieved 2017-08-04.

Kou, W; et al. Phenology-based method for mapping tropical evergreen forests by integrating of MODIS and Landsat imagery. Forests. 8, 2, Jan. 1, 2017.

Meneses-Tovar, C. (2011). NDVI as indicator of degradation. Unasylva, 62(238), 39-46

Misra, G., Buras, A., & Menzel, A. (2016). Effects of Different Methods on the Comparison between Land Surface and Ground Phenology-A Methodological Case Study from South-Western Germany. Remote Sensing, 8(9), 753.

Nguy-Robertson, A., Suyker, A.)., & Xiao, X.). (2015). Modeling gross primary production of maize and soybean croplands using light quality, temperature, water stress, and phenology. Agricultural And Forest Meteorology, 213160-172

Oeser, J., Pflugmacher, D., Senf, C., Heurich, M., & Hostert, P. (2017). Using Intra-Annual Landsat Time Series for Attributing Forest Disturbance Agents in Central Europe. Forests (19994907), 8(7), 1-24.

Rzedowski, J. 1978. Vegetación de México. Limusa. México, D.F. 432 p.

Rodriguez-Galiano, V. F., Rodriguez-Galiano, V. F., Dash, J., & Atkinson, P. M. (n.d). Intercomparison of satellite sensor land surface phenology and ground phenology in Europe. Geophysical Research Letters, 42(7), 2253-2260.

Serbin, S., Townsend, P., Isaacson, B. N., Serbin, S. P., & Townsend, P. A. (2013). Detection of relative differences in phenology of forest species using Landsat and MODIS. Landscape Ecology, 27(4), 529-543.

Tang, X., Wang, X., Wang, Z., Liu, D., Jia, M., Dong, Z., & ... Liu, X. (2013). Influence of vegetation phenology on modelling carbon fluxes in temperate deciduous forest by exclusive use of MODIS time-series data. International Journal of Remote Sensing, 34(23)

Zexing, Tao, Wang Huanjiong, Liu Yachen, Xu Yunjia, and Dai Junhu. 2017. "Phenological response of different vegetation types to temperature and precipitation variations in northern China during 1982-2012." *International Journal Of Remote Sensing* 38, no. 11: 3236-3252. *Inspec*, EBSCO*host* (accessed September 23, 2017)

Zhang, X., Tan, B., ganguly, s., Ganguly, S., Friedl, M. A., Verma, M., & ... Zhang, X. (n.d). Land surface phenology from MODIS: Characterization of the Collection 5 global land cover dynamics product. Remote Sensing of Environment, 114(8), 1805-1816.

Zhu, W., Jiang, N, & Chen, G (2013). Estimating carbon flux phenology with satellite-derived land surface phenology and climate drivers for different biomes: A synthesis of AmeriFlux observations. Plos ONE, 8(12)