Vegetation cover change assessment on Yarraloola and Red Hill - Remote Sensing monitoring program report 2019

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Vegetation cover change monitoring for Rio Tinto

July 2020

GOVERNMENT OF WESTERN AUSTRALIA

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Summary

The aim of this project is to identify changes to current vegetation cover compared with 1988-2014 levels across Yarraloola and Red Hill stations using Landsat satellite data. Results indicate that across Yarraloola and Red Hill 269 km sq (14.1%) experienced an increase above baseline levels (1988 – 2014) and 319 km sq (17.9%) experienced a decrease below baseline levels.

Examination of time series graphs within areas of significant change and field investigations are required to determine the cause of vegetation cover change from baseline levels and whether the change represents an improvement or reduction in condition. A significant reduction in vegetation cover, below the 1988 to 2014 mean, was observed at sites YL-15 and YL-16 (see Figure 4).

1 Methodology

1.1 Landsat imagery

Imagery from the Landsat satellite series is used in this analysis (https://landsat.usgs.gov/). The Landsat satellites began capturing data in the 1970's with regular captures from 1988. Imagery is collected at 30 m pixel size across 6 spectral bands. Landsat data are fundamental to monitoring long term vegetation change globally (Hansen et al., 2013). The Landsat archive has recently been made available to download free of charge from the United States Geological Survey (USGS). In this project Landsat imagery from 1988 to 2019 is being used to map and monitor changes to vegetation cover.

All Landsat imagery covering Yarraloola and Red Hill (scene 114/075, Figure 1) available for download from the USGS from 1988 to the beginning of 2020, with less than 30% cloud cover, was acquired. This ensured complete and comprehensive coverage of the stations. The imagery was corrected for variable sun angle and distance using the CSIRO software "Sun_Correct" (Wu and Danaher, 2001) to enable comparisons through time.

Figure 1 Landsat image extent for scene location 114/075.

1.2 Vegetation cover index

The Landsat imagery was converted from digital counts of reflectance to a vegetation cover index. The index is an estimate of vegetation cover generated from field data supplied by Rio Tinto. The index was created using field measures assessing total cover (%) from 29 plots within Red Hill and Yarraloola. The field measures were regressed against their associated i35 index ((Landsat red band + Landsat short wave infrared band 1)/2).

The i35 index was developed in the south west of Western Australia (Caccetta et al., 2000) and has been applied across the continent to monitor change in woody vegetation cover (Lehmann et al., 2013). Along with vegetation cover the reflectance of soil or rock will heavily influence the index value. As a result areas of low cover can have a range of index values which may appear as outliers in a regression. Cook's distance was used to identify outliers which are particularly influential on the regression of total cover against the i35 index. Cook's distance plots the residual (distance from a model) with leverage (the points influence on the model) (Crawley, 2007). Using this method two field sites were identified as outliers and were removed from the analysis (Figure 2).

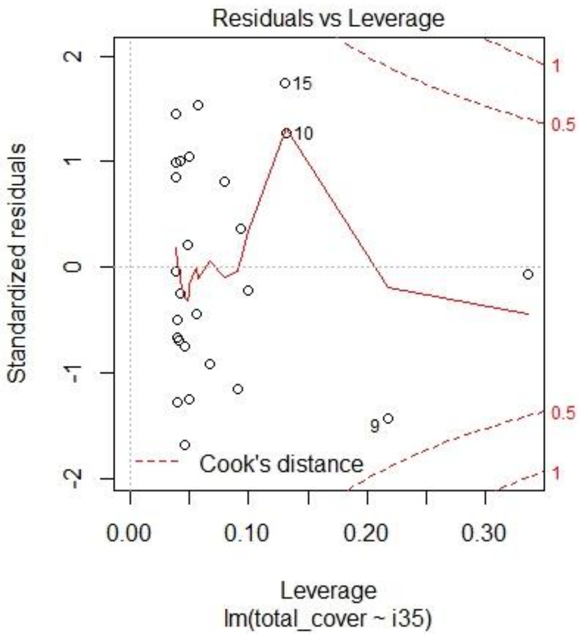


Figure 2 Cook's distance assessment of points in the i35 to vegetation cover regression (point 9 is RH-x, and point 15 is YESG01).

The regression of total cover against the i35 index is shown in Figure 3. A moderate relationship ($r^2 = 0.469$) was recorded.

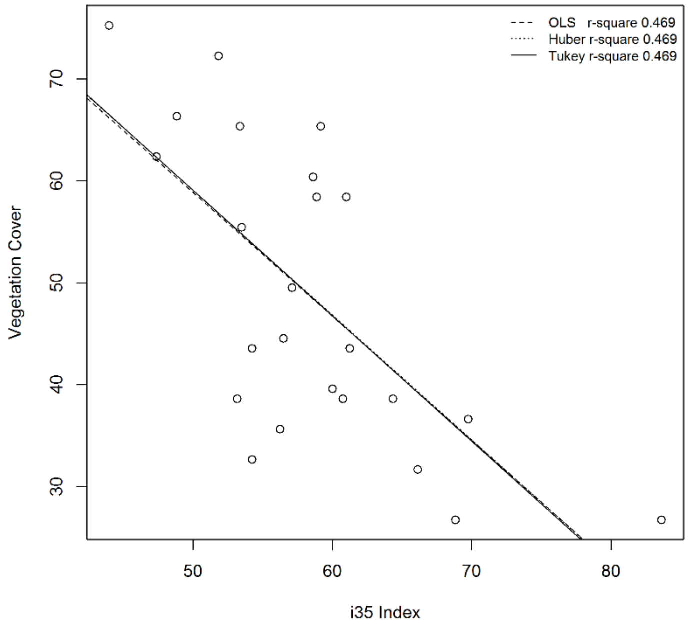


Figure 3 Regression of field measures of vegetation cover against the i35 index.

The ordinary least squared regression line followed the equation y = -1.2154x + 119.64. This equation was then applied to the i35 index to create the vegetation cover index images which are summarized in the time series plots (presented in Sections 2.3 and 2.4). Note that areas where the i35 index is greater than the maximum value used in the training data will return a cover index value less than 0.

1.3 Cover change images and graphs

The methodology used to examine vegetation cover change is adapted from Zhu et al., (2012) and Gove et al., (2013). Zhu et al., (2012) used all available Landsat imagery to detect forest disturbance at high temporal frequency, while Gove et al., (2013) demonstrated the utility of using control charts as a means of detecting shifts in time series data. The analysis technique involved plotting vegetation cover values from annual Landsat imagery and applying the Cumulative Sum (CUSUM) test (Gove et al., 2013).

The change image represents change in perennial cover as the satellite imagery used is dry season imagery. One Landsat image per year from 1988 to 2019 from the end of the dry season (around November) was selected. This imagery was then put into a “stack” and the CUSUM formula applied. The use of dry season imagery means that changes in ephemeral plant cover are excluded.

To apply the CUSUM formula, baseline periods need to be identified. The 1988 to 2014 period was used as a baseline for Yarraloola and Red Hill. Changes in vegetation cover above or below the mean of the baseline period can then be detected. This technique was utilised to produce a spatial representation of significant vegetation cover change which was classified into 5 classes (Table 1). The cause of change can then be attributed by examining time series plots and field validation.

The vegetation change classes listed in Table 1 are consistent with those used in previous Department of Biodiversity, Conservation and Attractions (DBCA) projects (van Dongen and Huntley, 2016). However, they are subjective and may be adjusted if fieldwork demonstrates that they are insensitive or overly sensitive to change.

Table 1 Thresholds used to identify areas of change.

	Cusum threshold
Large increase	> 50
Moderate increase	> 25 and < = 50
Stable	> -25 and <= 25
Moderate decrease	> -50 and < = -25
Large decrease	<-50

Areas of significant change in vegetation cover from the baseline identified in the vegetation cover change map were identified further using check points. At each check point satellite derived vegetation cover estimates for the period 1988 to 2020 were graphed. The mean baseline vegetation cover level for each point and standard deviations are also shown. This allows recent changes in vegetation cover to be examined in relation to the range of values observed during the baseline period (1988 – 2014).

2 Results

Examples of how the resultant graphs and images can be interrogated are shown in Figures 4 to 6. Figure 4 displays aerial photography from August 2007 (Figure 4a) and July 2014 (Figure 4b) (© Landgate (2018)), a change in vegetation cover is evident in these photographs. This area is shown in the vegetation cover change map (Figure 4c) as having regions of moderate and large decreases in vegetation cover.

The time series graph shows the change in vegetation cover at this point over the 1988 to 2020 time period. The graph indicates that cover levels are currently low and outside the normal range observed during the baseline period. The imagery indicates that this significant change occurred around June 2017.

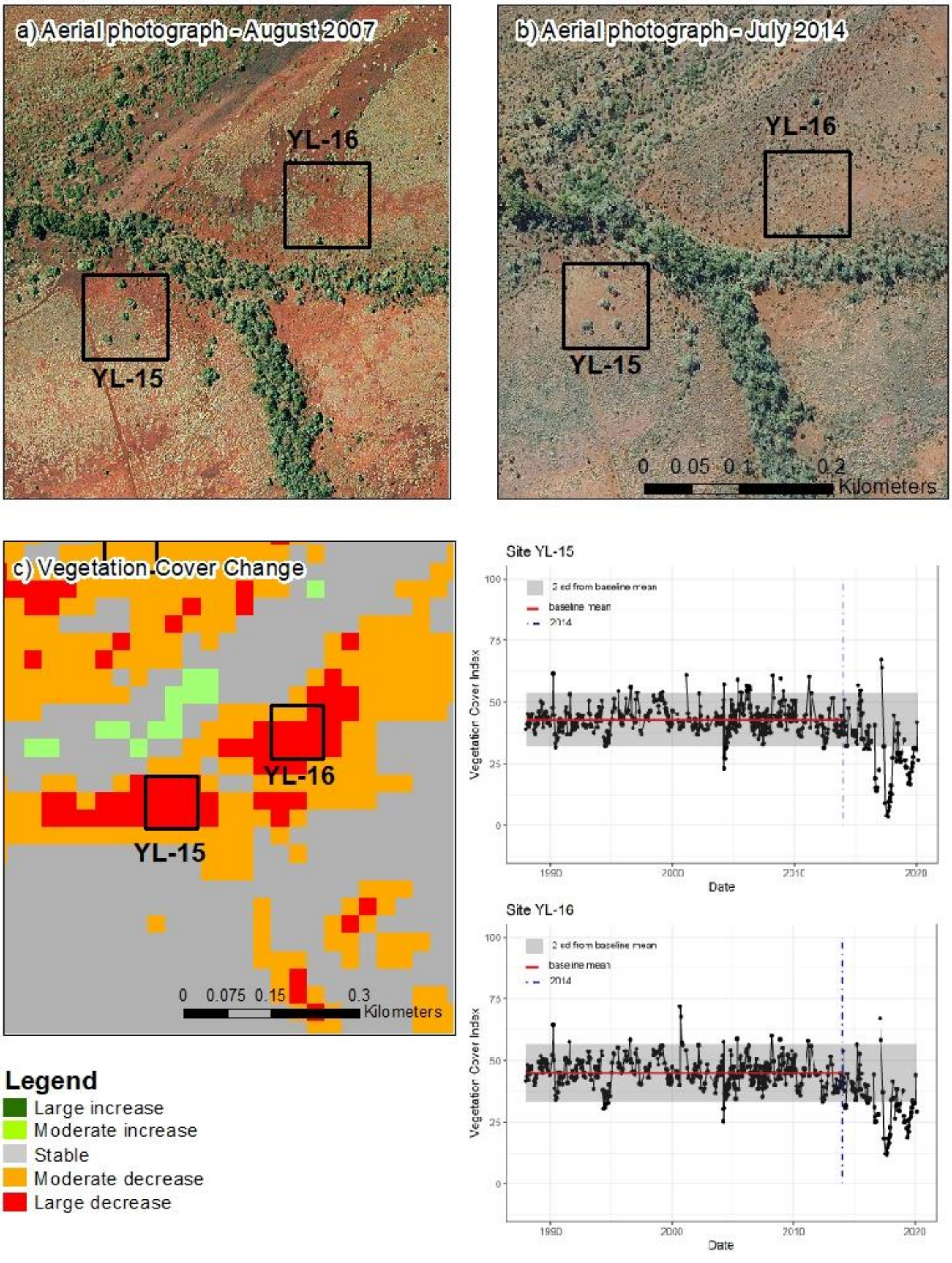


Figure 4 An example of an area of vegetation cover decline in Yarraloola. This includes aerial photography from August 2007 and July 2014 (© Landgate (2018)), a vegetation cover change image and a time series graph. The dashed blue vertical line is at 1/1/2014, the baseline mean is a solid red line and the range within 2 standard deviations of the baseline mean is shaded in grey.

Figure 5 includes aerial photography from November 2005 (Figure 5a) and August 2012 (Figure 5b) (© Landgate (2018)), these photographs provide an example of changes in vegetation cover at the site . This area is shown in the vegetation cover change map (Figure 5c) as having a large increase in vegetation cover. The time series graph shows the change in vegetation cover at this point over the 1988 to 2020 time period. The large increase in cover recorded at this site appears due to the current long period since fire. In comparison there are three fires in the baseline period.

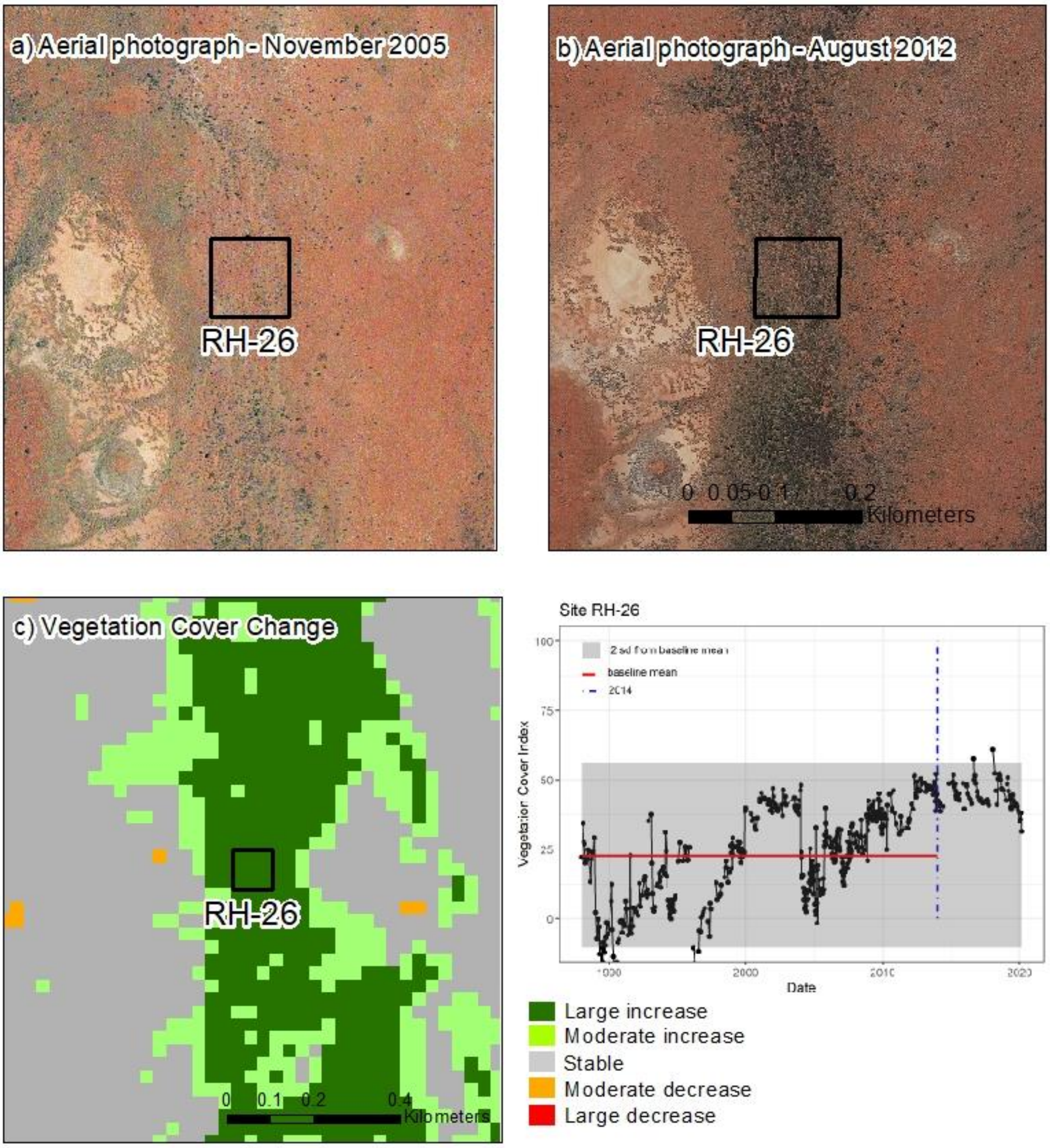


Figure 5 An example of an area of vegetation cover increase in Red Hill. This includes aerial photography from November 2005 and August 2012 (© Landgate (2018)), a vegetation cover change image and a time series graph. The dashed blue vertical line is at 1/1/2014, the baseline mean is a solid red line and the range within 2 standard deviations of the baseline mean is shaded in grey.

Figure 6 includes an area where the vegetation cover in the 2015 to 2018 period is consistent with the mean from the 1988 to 2014 time period. It is evident from the time series graph that cover has large, regular annual fluctuations. This seasonal variance may explain the difference in appearance of the 2007 and 2015 aerial photographs (© Landgate (2018)).

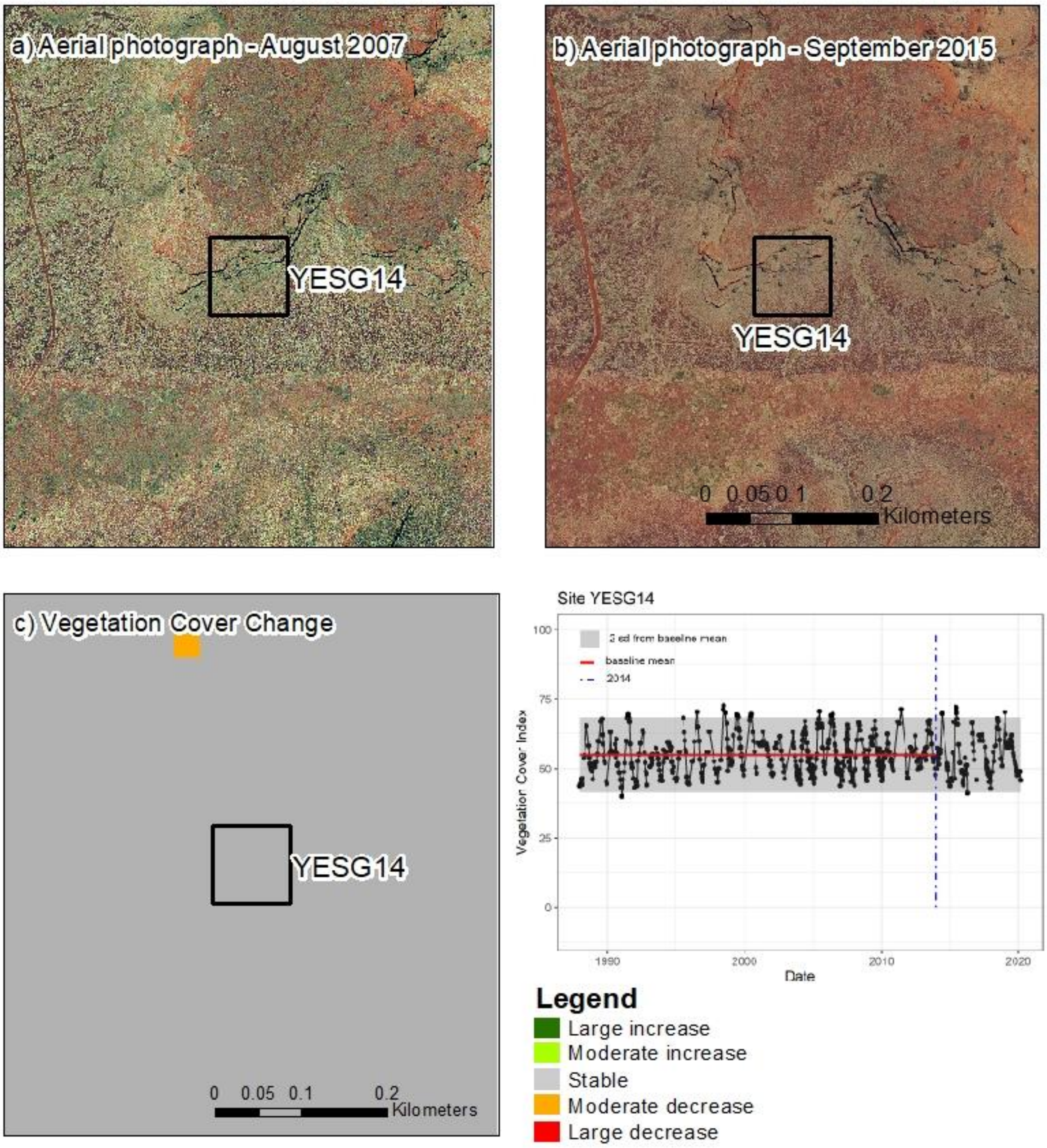


Figure 6 An example of an area where vegetation cover has not changed from the pre 2014 mean in Yarraloola. This includes aerial photography from 2007 and 2015 (© Landgate (2018)), a vegetation cover change image and time series graphs. The dashed blue vertical line is at 1/1/2014, the baseline mean is a solid red line and the range within 2 standard deviations of the baseline mean is shaded in grey.

2.1 Vegetation cover change maps

The areas where vegetation cover change has changed to 2019 compared to baseline levels, and the location of check points, are displayed in figure 7 for both Red Hill and Yarraloola.

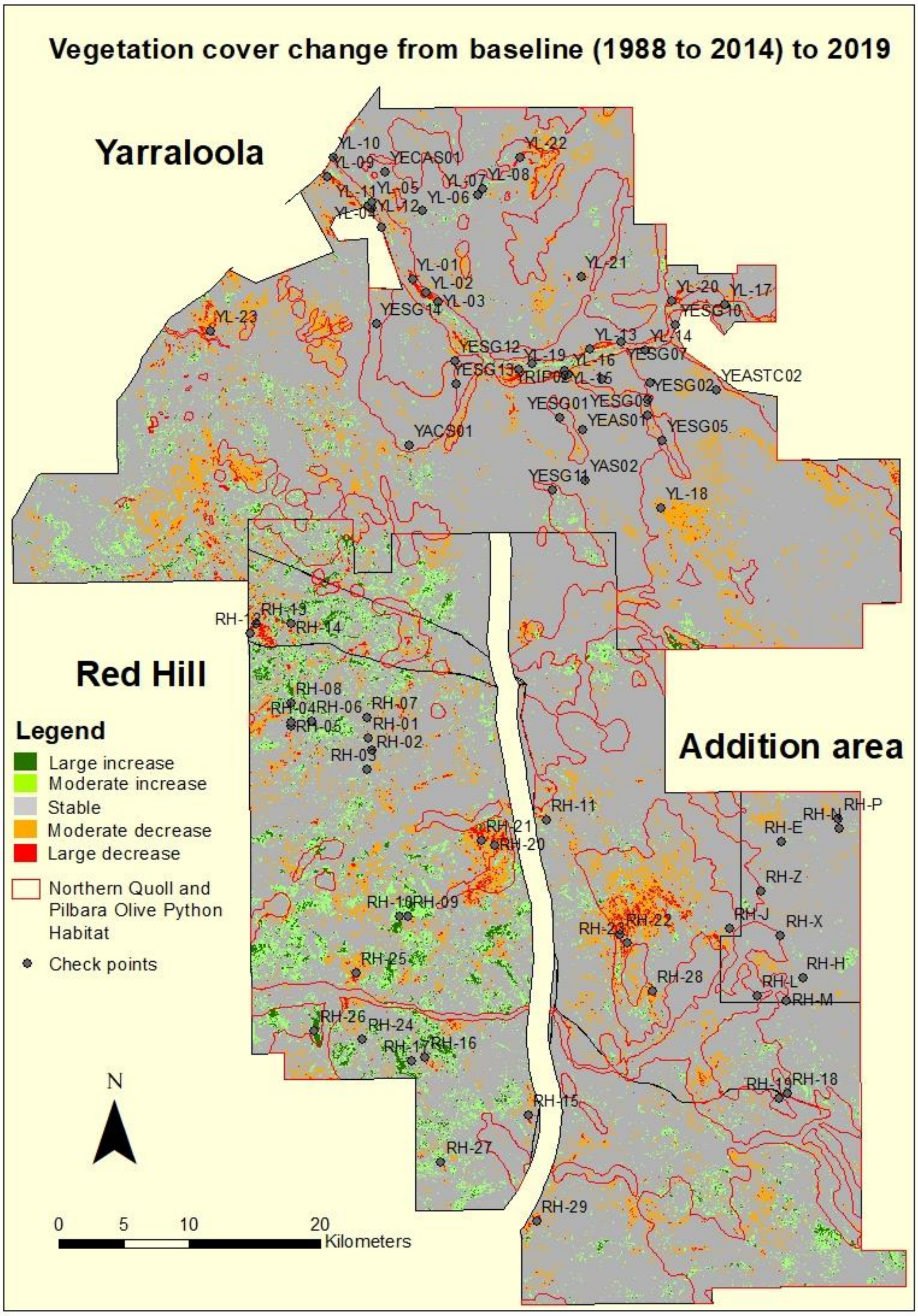


Figure 7 A map of vegetation cover change from the 1988 to 2014 baseline across Yarraloola and Red Hill. The location of check points is also shown.

The area of change within each property and change class displayed in Figure 7 can be calculated. Area and percentage figures are shown in Table 2.

Table 2 The percentage area of vegetation cover change from baseline values from Yarraloola and Red Hill.

	Red Hill		Yarraloola	
Class	sq km	Area %	sq km	Area %
Large increase	37.05	1.82	5.46	0.35
Moderate increase	171.48	8.41	54.78	3.52
Stable	1660.84	81.49	1347.12	86.51
Moderate decrease	145.60	7.14	133.76	8.59
Large decrease	23.14	1.14	16.07	1.03
Water	0.00	0.00	0.01	0.00

The area of change within northern quoll (NQ) and pilbara olive python (POP) habitat on each property are shown in Table 3.

Table 3 The percentage area of vegetation cover change from baseline values from northern quoll and pilbara olive python habitat on Yarraloola and Red Hill.

	Red Hill – NQ and POP habitat		Yarraloola – NQ and POP habitat	
Class	sq km	Area %	sq km	Area %
Large increase	3.96	0.59	1.47	0.23
Moderate increase	32.34	4.79	13.25	2.07
Stable	570.98	84.57	555.53	86.68
Moderate decrease	57.78	8.56	63.87	9.97
Large decrease	10.07	1.49	6.78	1.06
Water	0.00	0.00	0.01	0.00

2.2 Time series graphs at check points

Time series graphs of all check points are shown below. A summary of the number of check points added to each property in each cover change class is shown in Table 4.

Table 4 The number of check points in each change class and property.

	Red Hill		Yarraloola	
Class	Number of check points	Number of check points per sq km	Number of check points	Number of check points per sq km
Large increase	6	0.16	5	0.92
Moderate increase	4	0.02	2	0.04
Stable	15	0.01	17	0.01
Moderate decrease	0	0.00	2	0.01
Large decrease	13	0.56	16	1.00
Grand Total	38	0.02	42	0.03

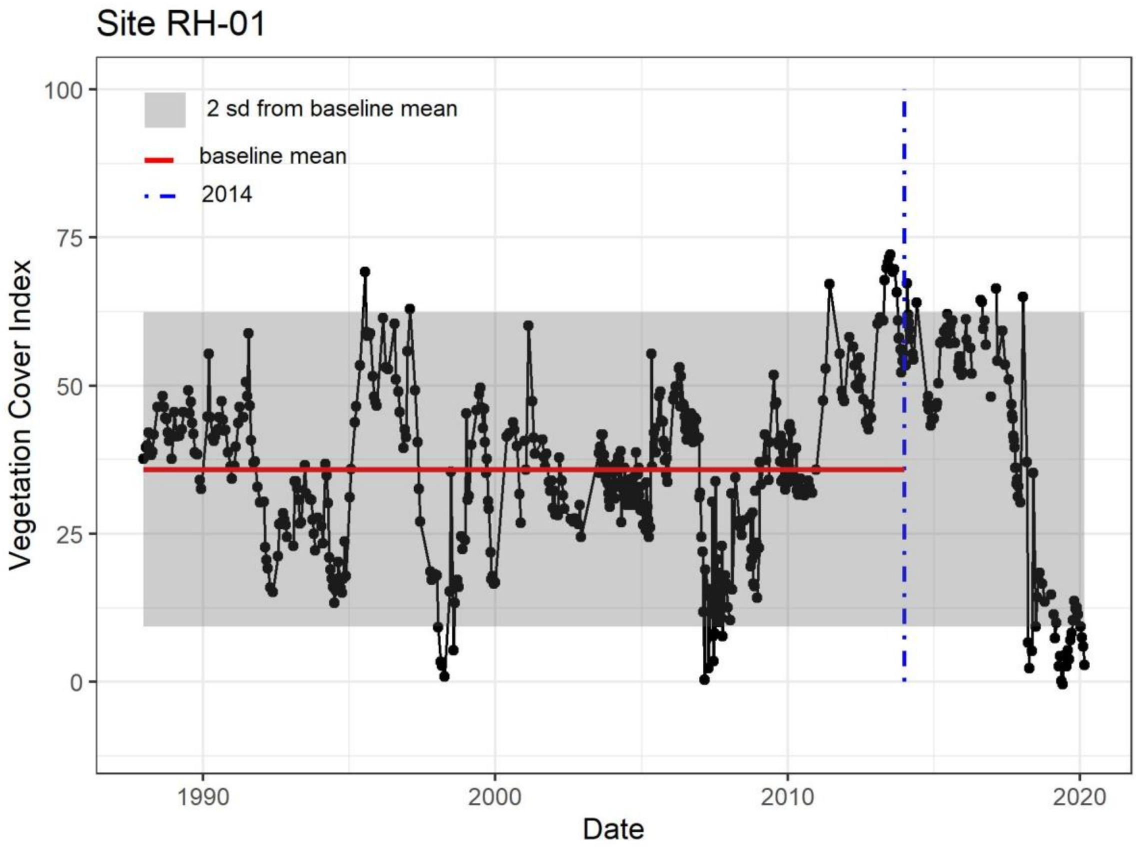
A summary of the number of check points, within northern quoll (NQ) and pilbara olive python (POP) habitat, on each property in each cover change class is shown in Table 5.

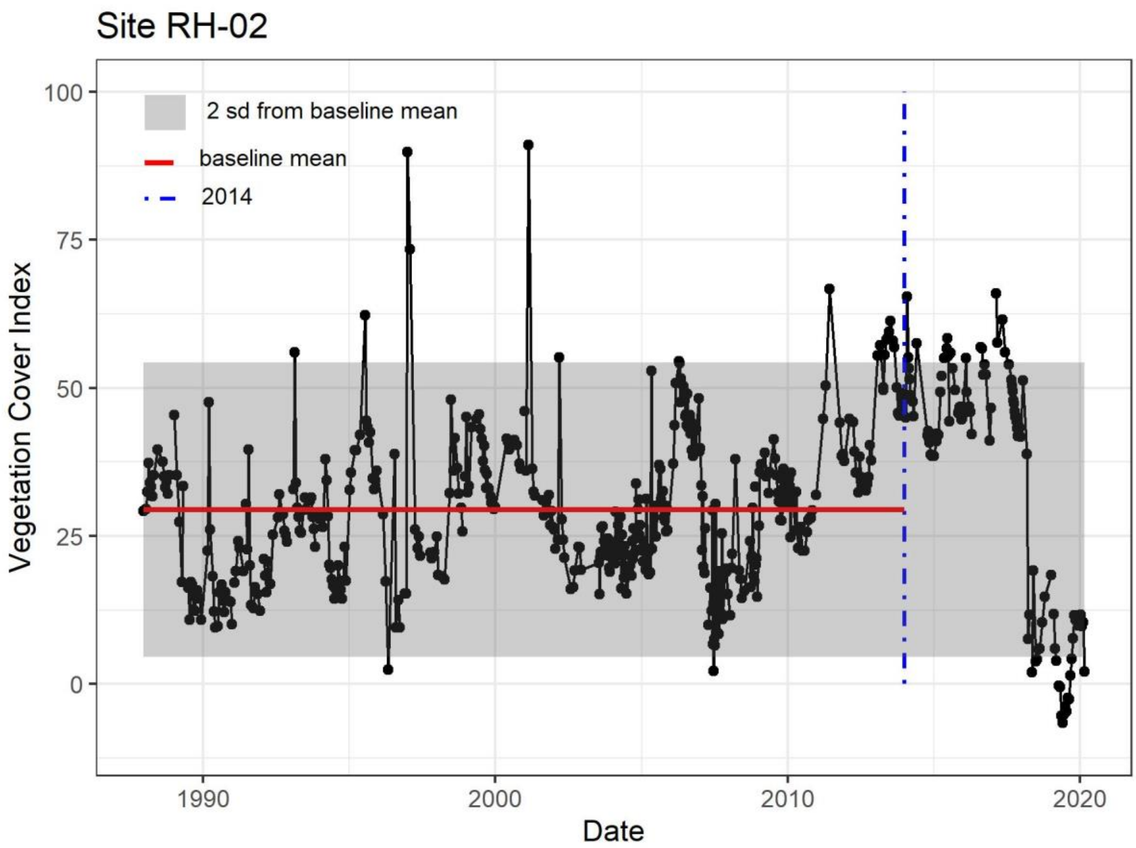
Table 5 The number of check points in each change class and property within northern quoll and pilbara olive python habitat.

	Red Hill – NQ and POP habitat		Yarraloola – NQ and POP habitat	
Class	Number of check points	Number of check points per sq km	Number of check points	Number of check points per sq km
Large increase	0	0.00	2	1.36
Moderate increase	0	0.00	2	0.15
Stable	10	0.02	13	0.02
Moderate decrease	0	0.00	2	0.03
Large decrease	3	0.30	8	1.18
Grand Total	13	0.02	27	0.04

2.3 Time series plots from Red Hill

The time series vegetation cover graphs for Red Hill are shown below. The red line is the baseline (1988 to 2014) mean, the grey area shows the range within two standard deviations from this mean and the blue dashed line indicates the end of the baseline period (2014).

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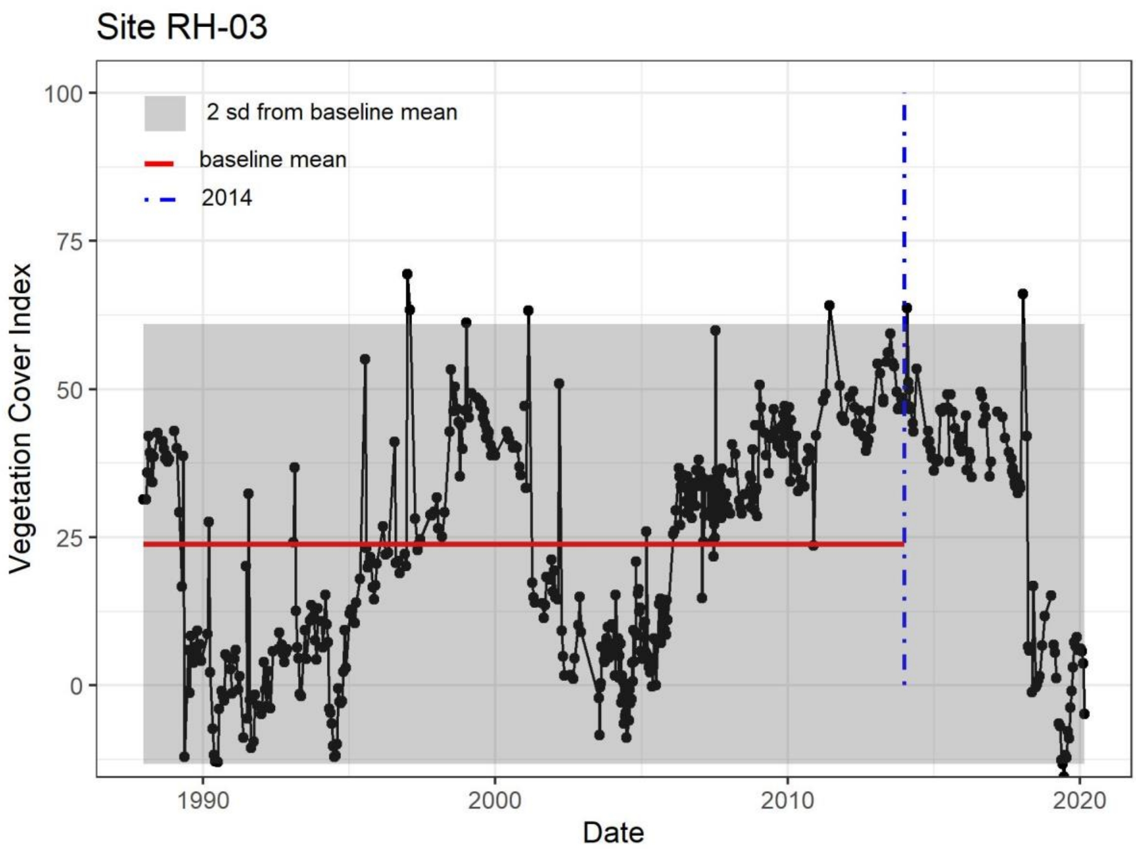
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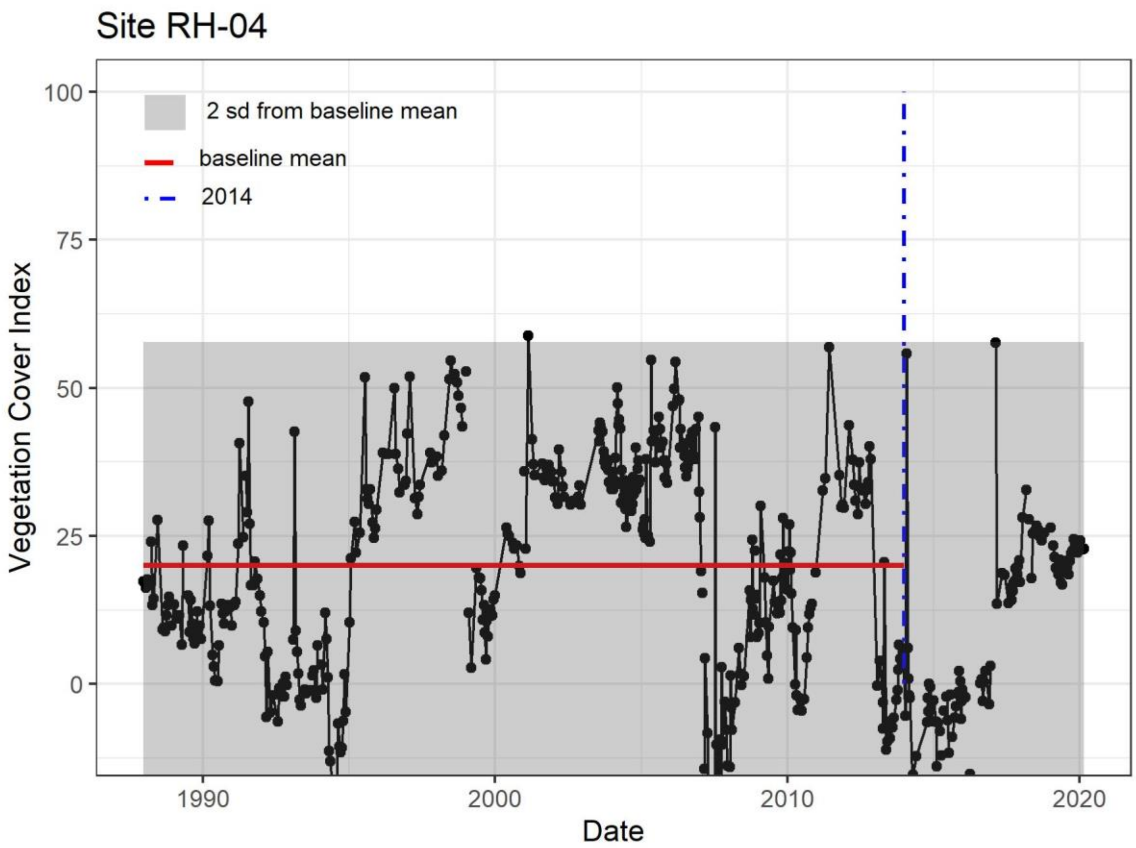
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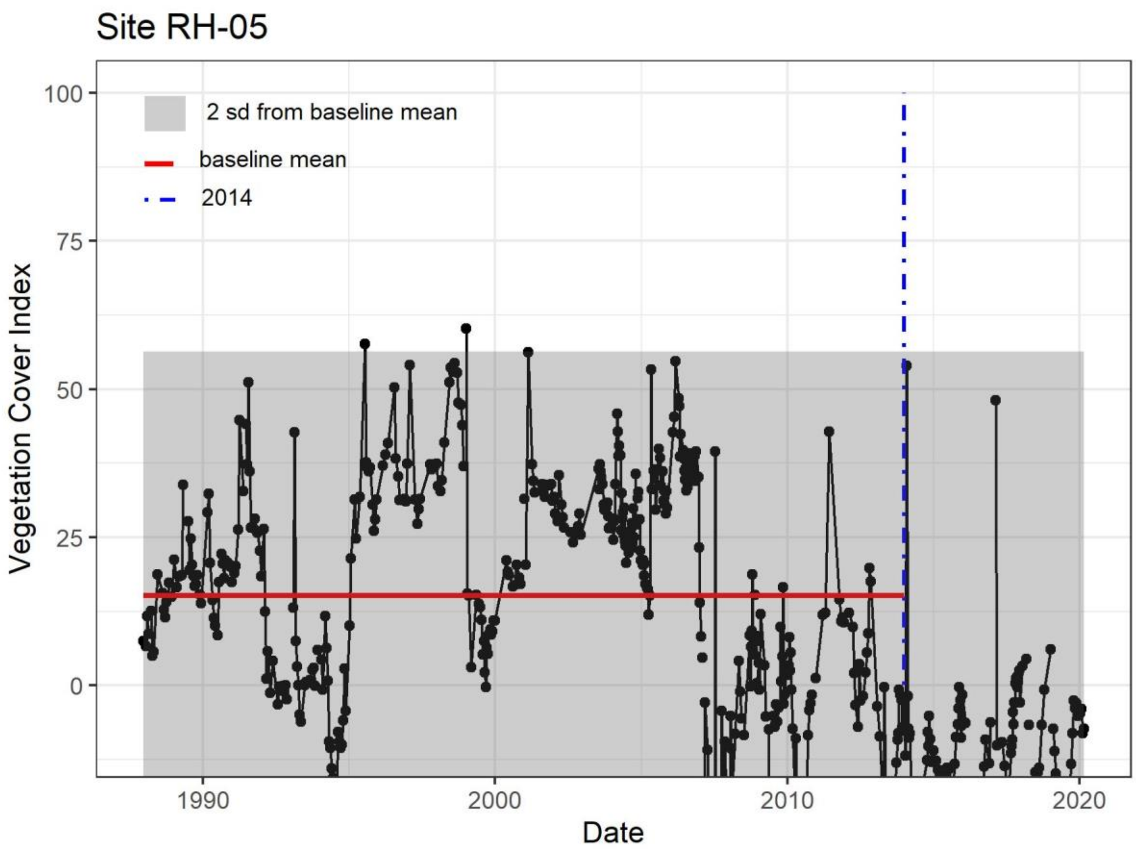
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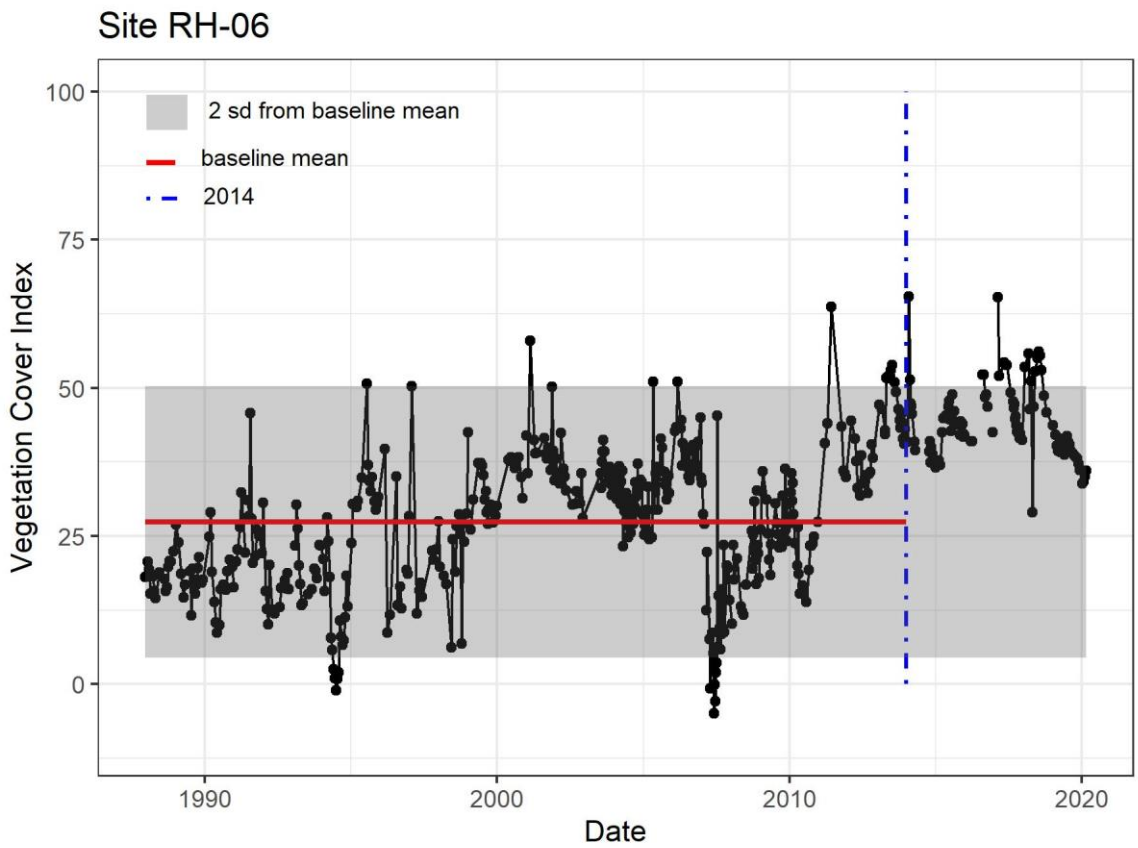
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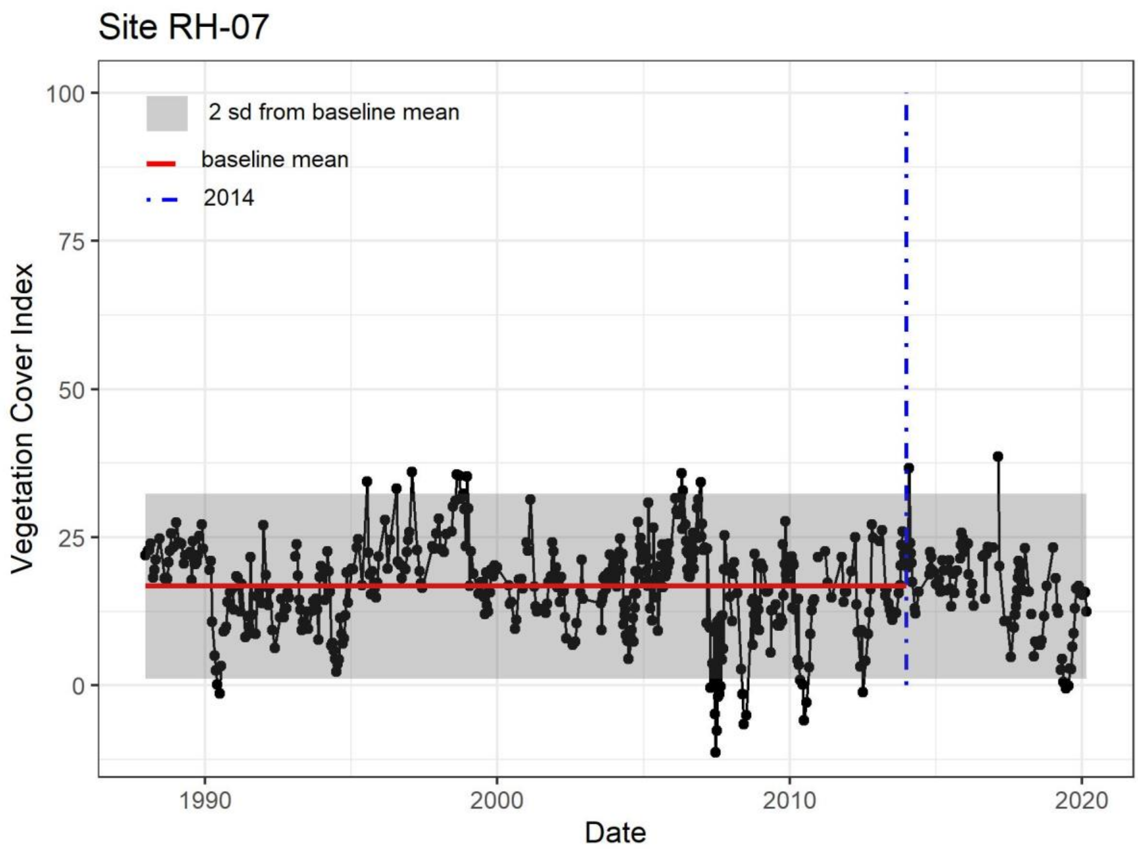
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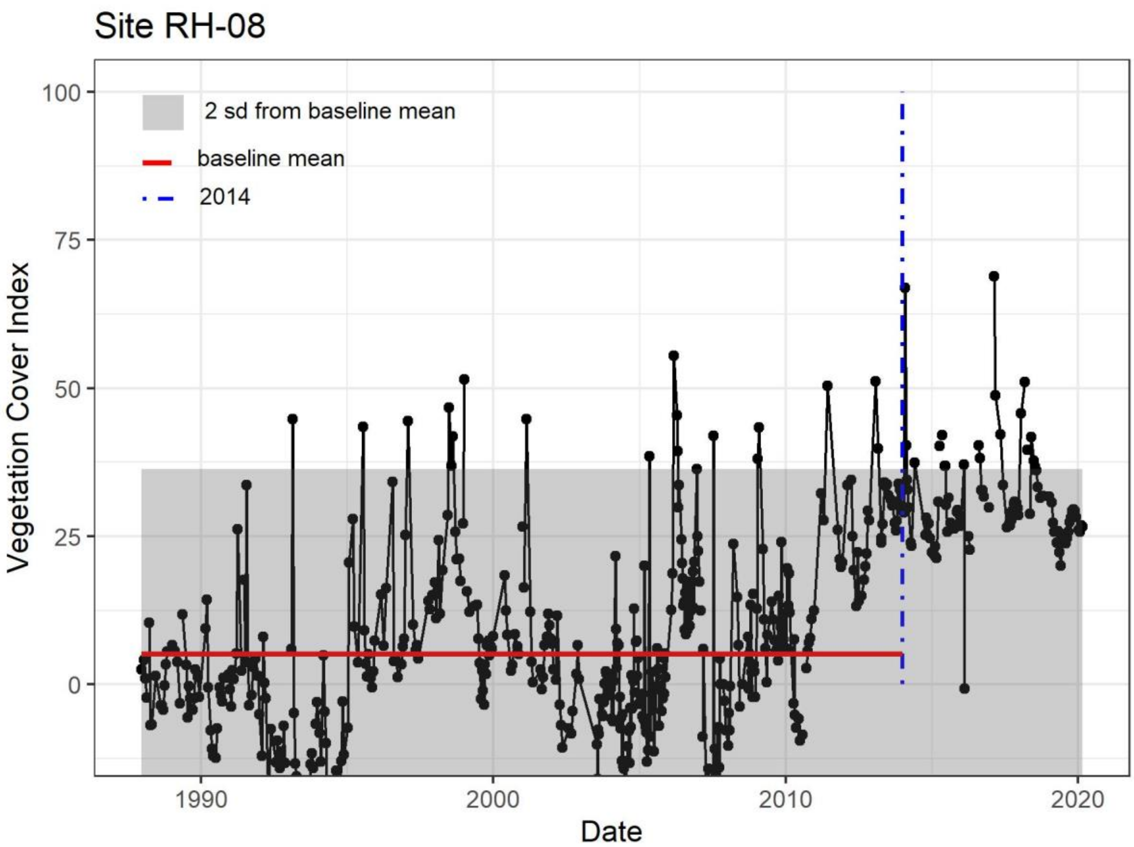
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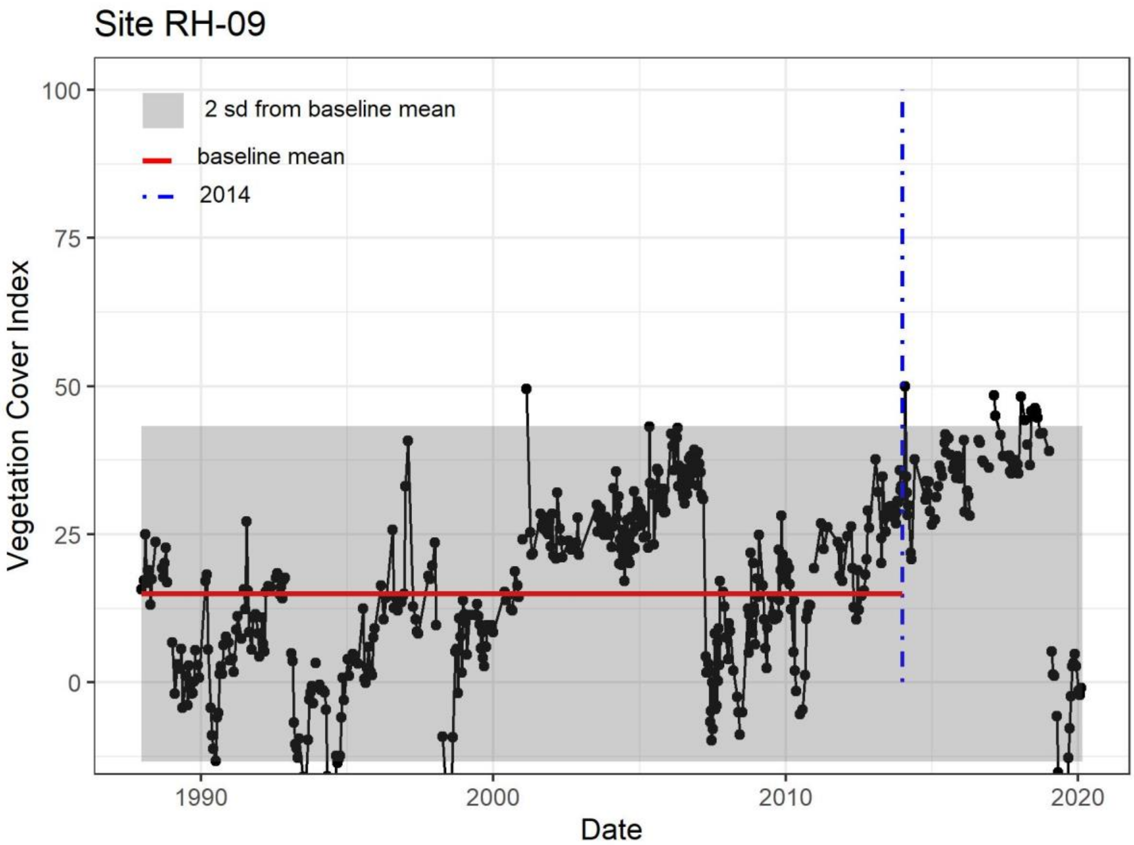
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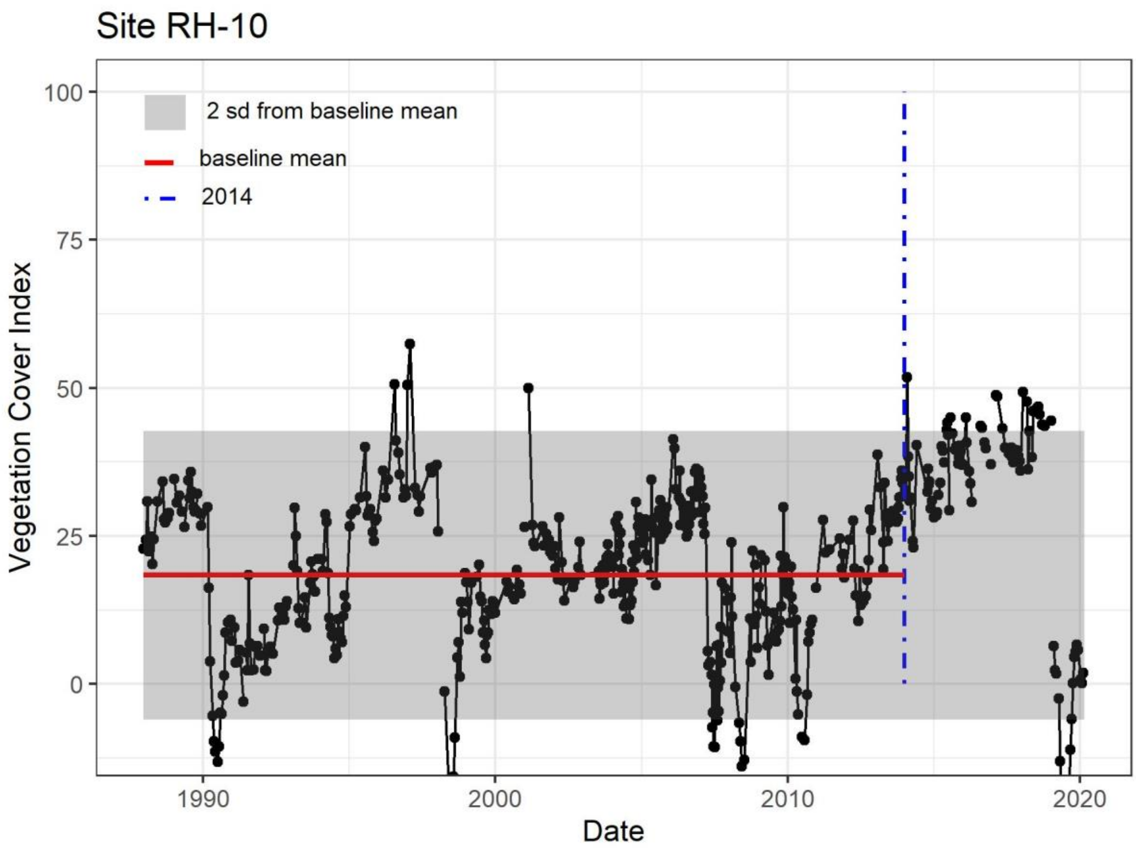
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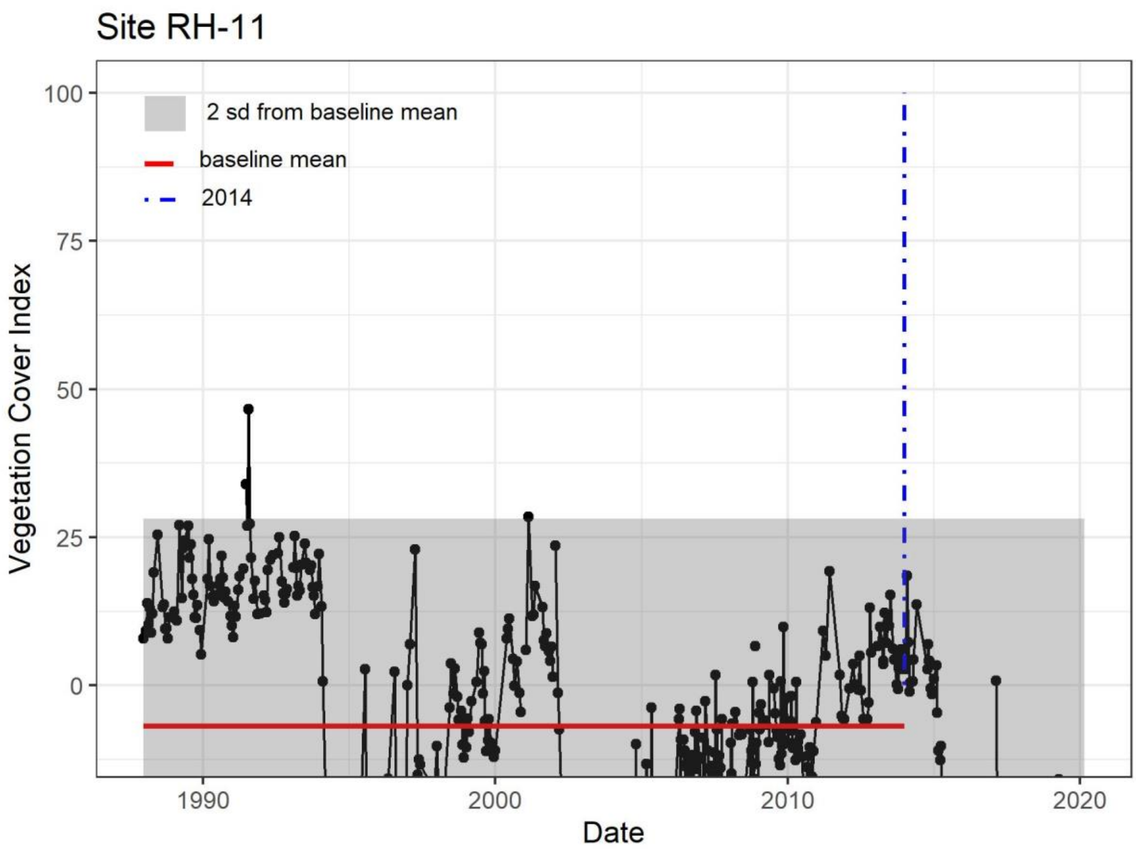
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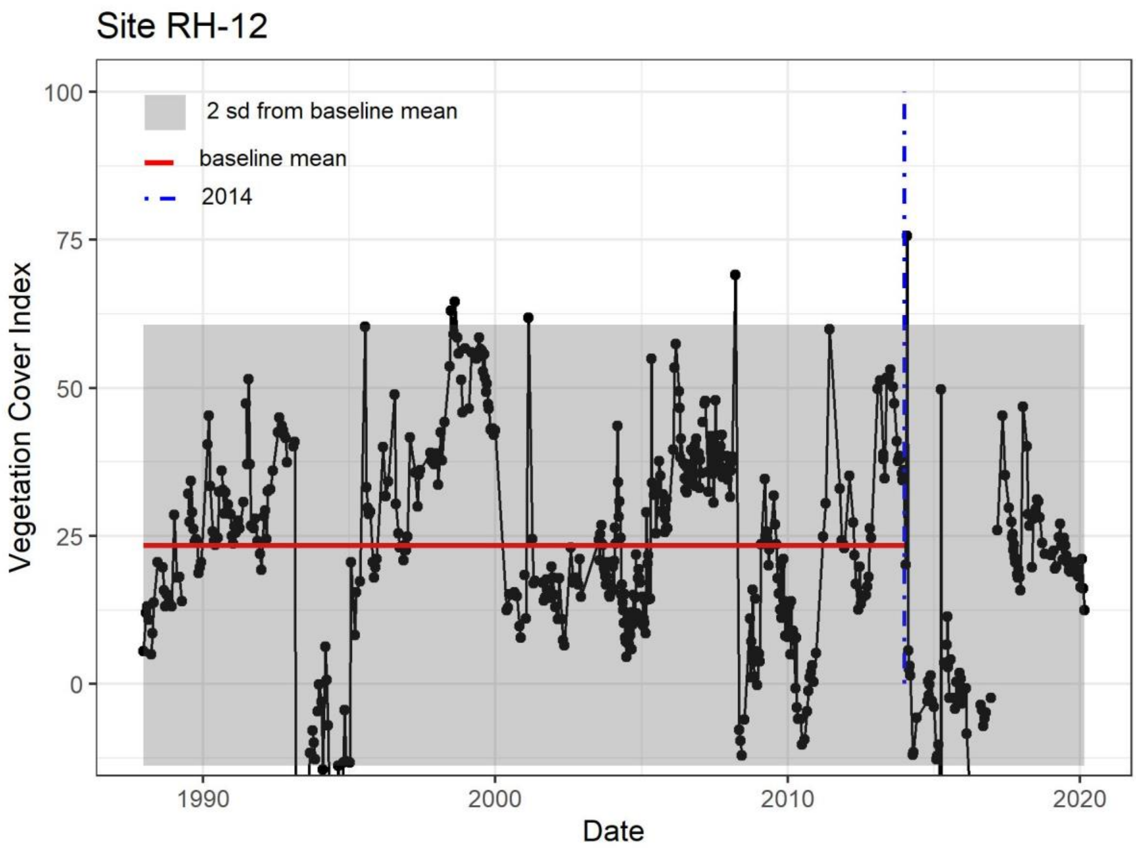
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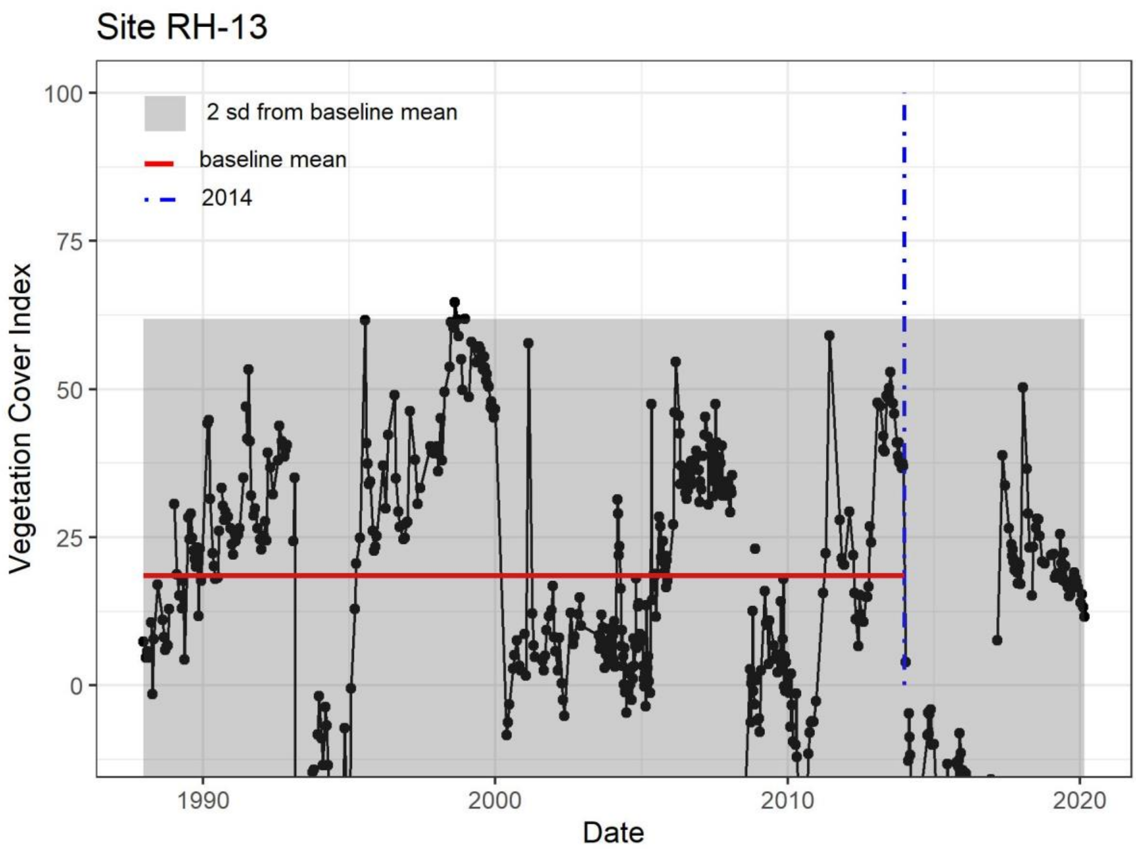
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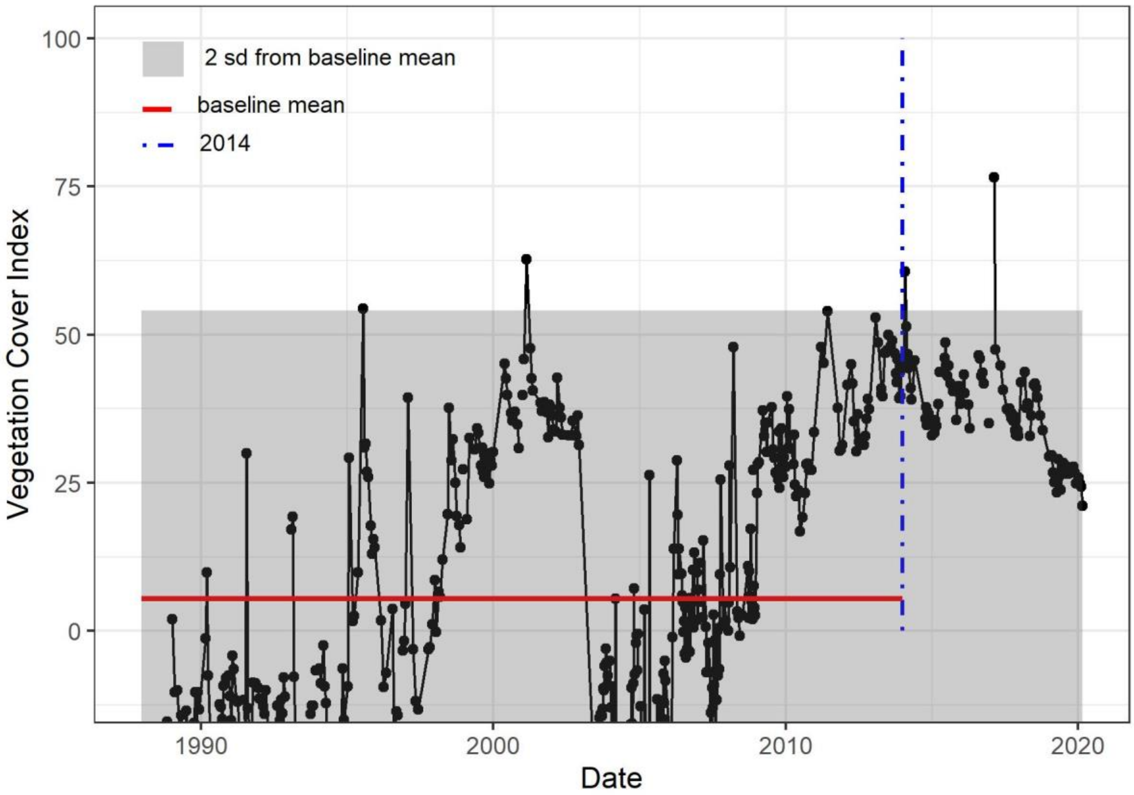

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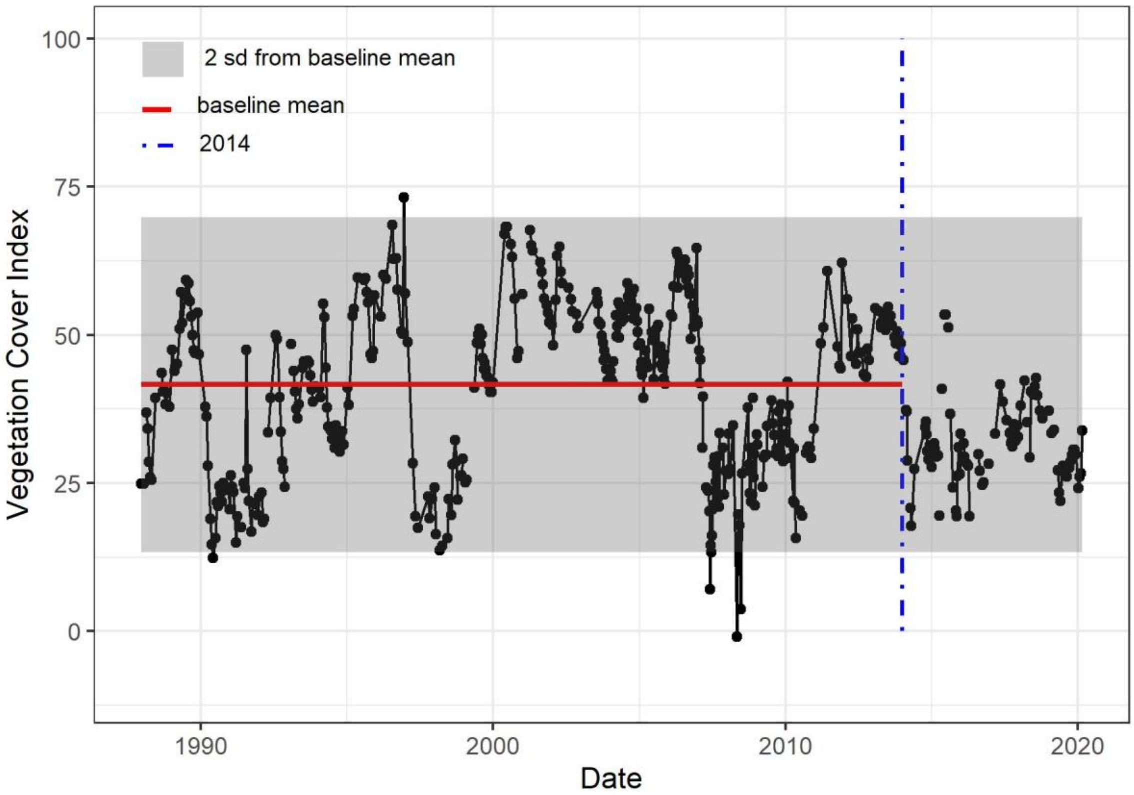

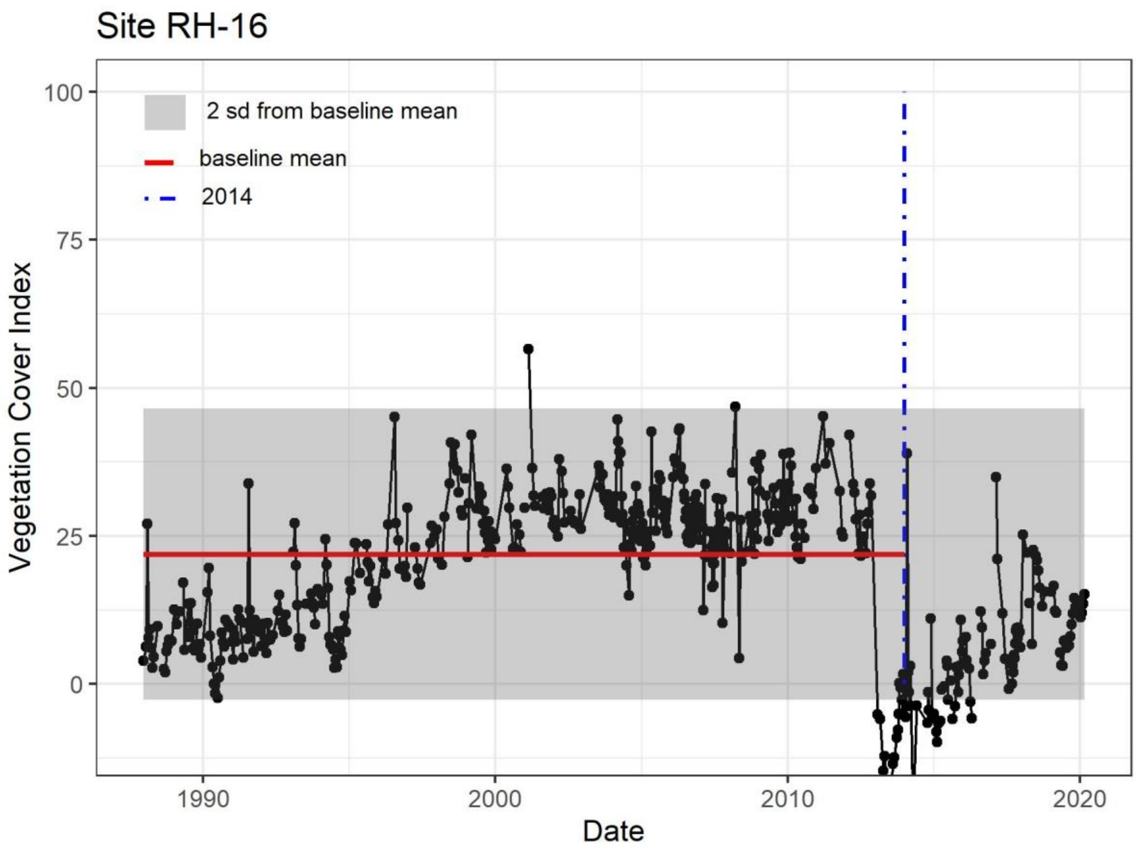
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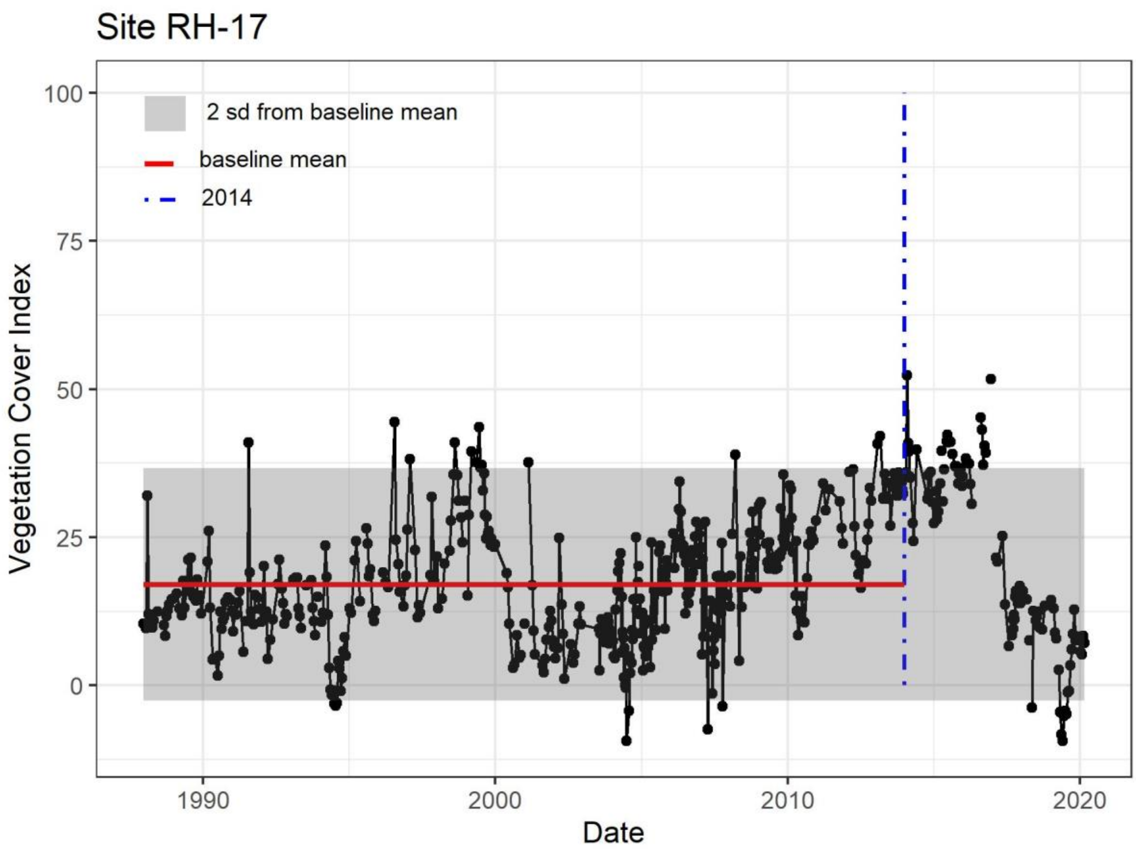
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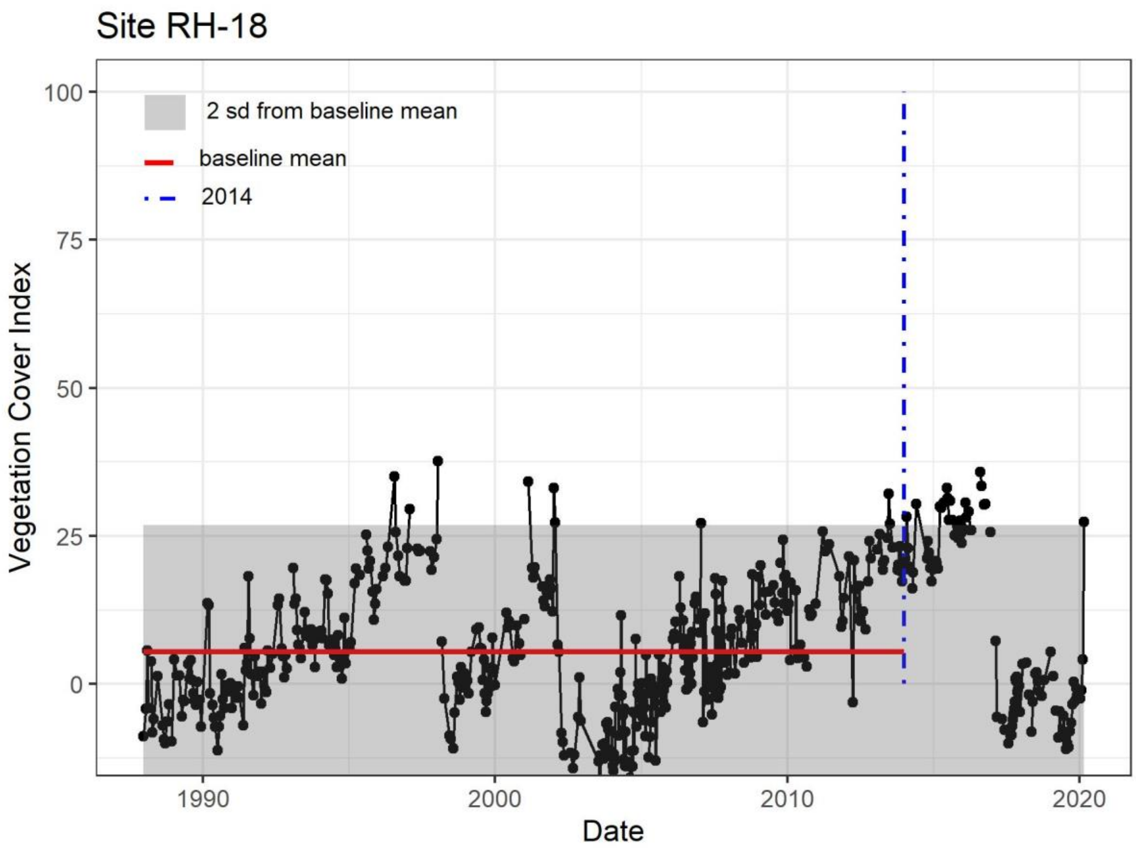
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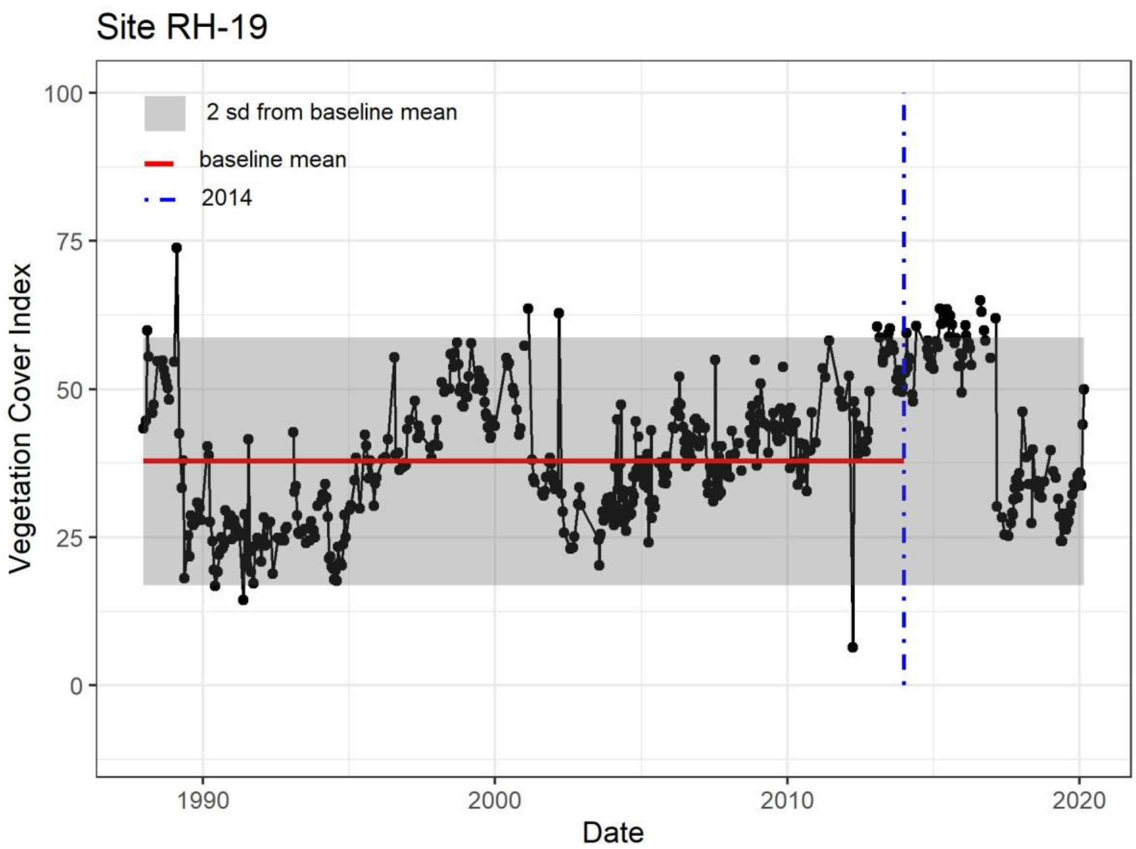
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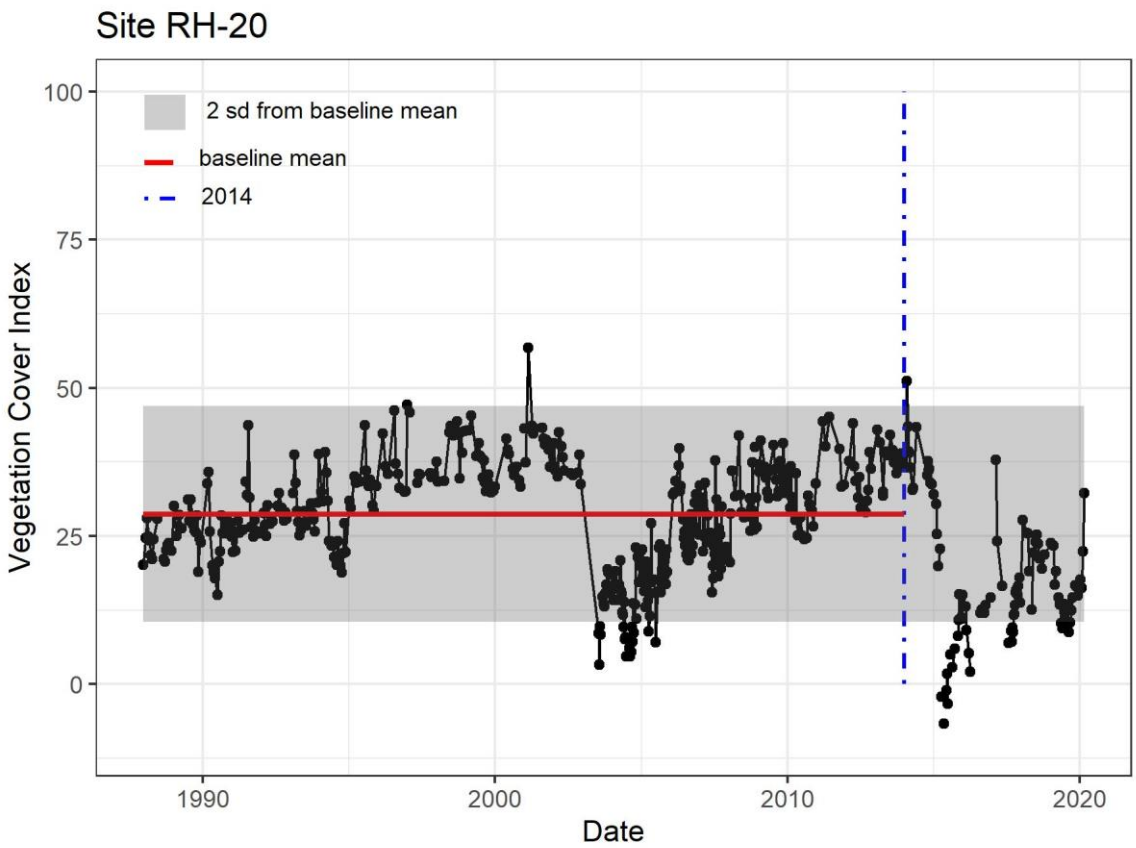
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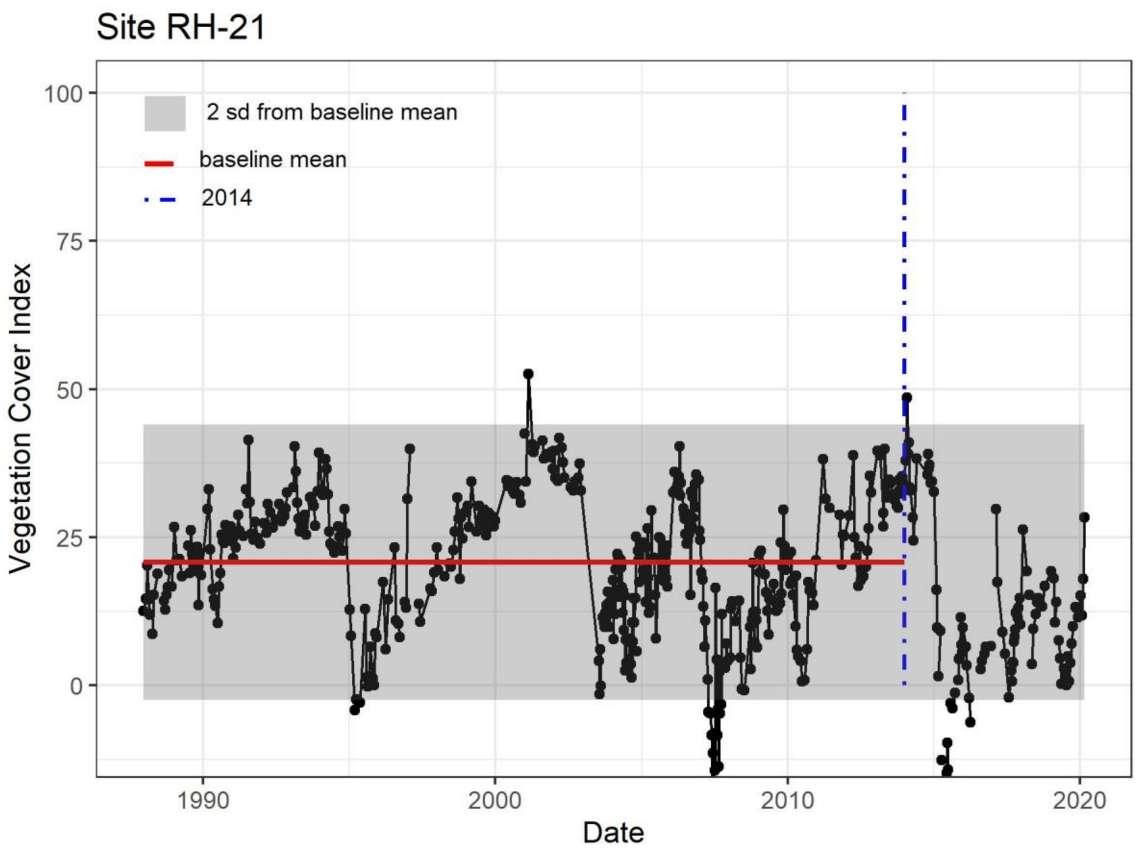
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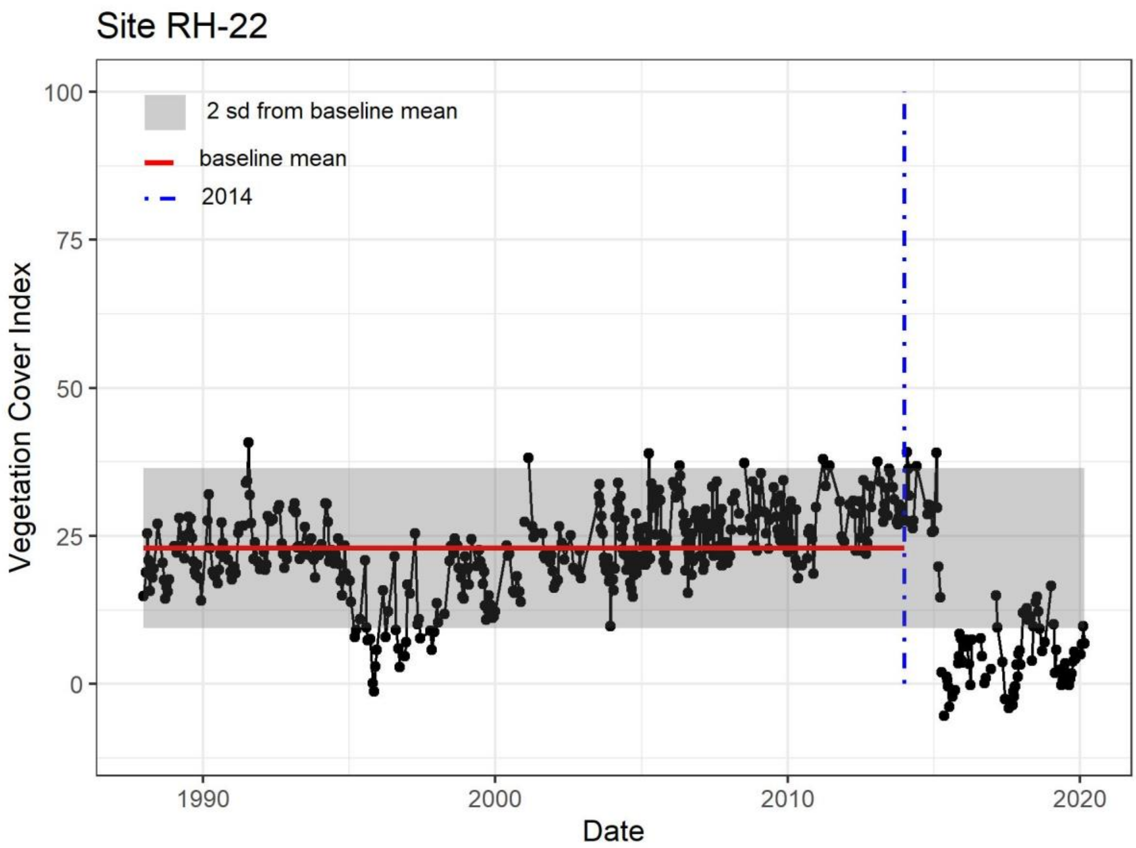
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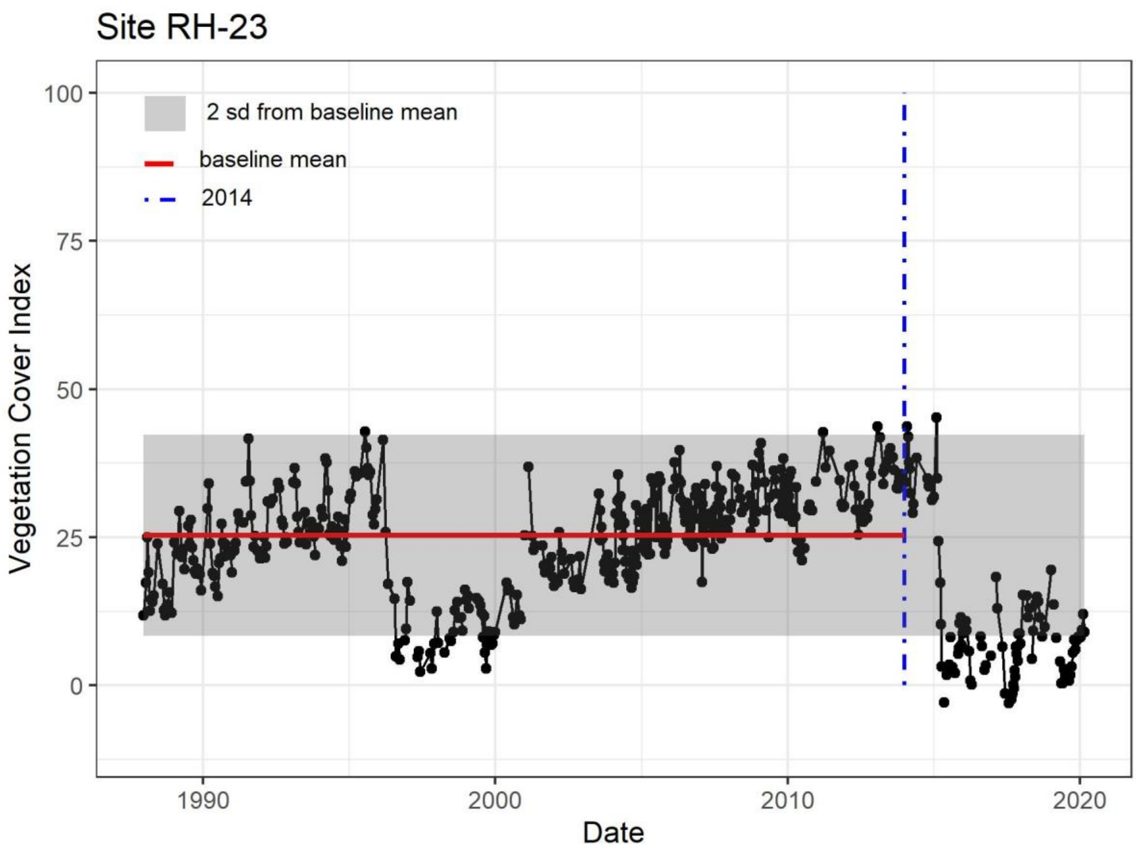
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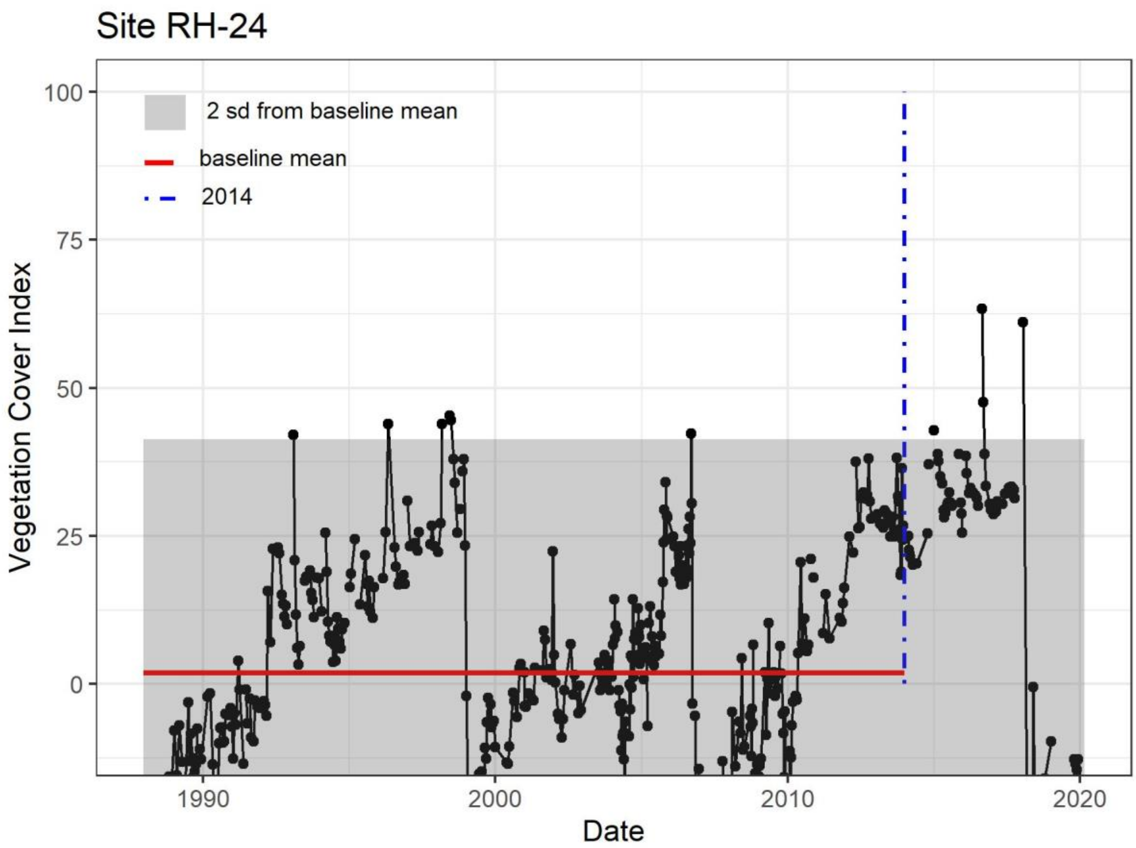
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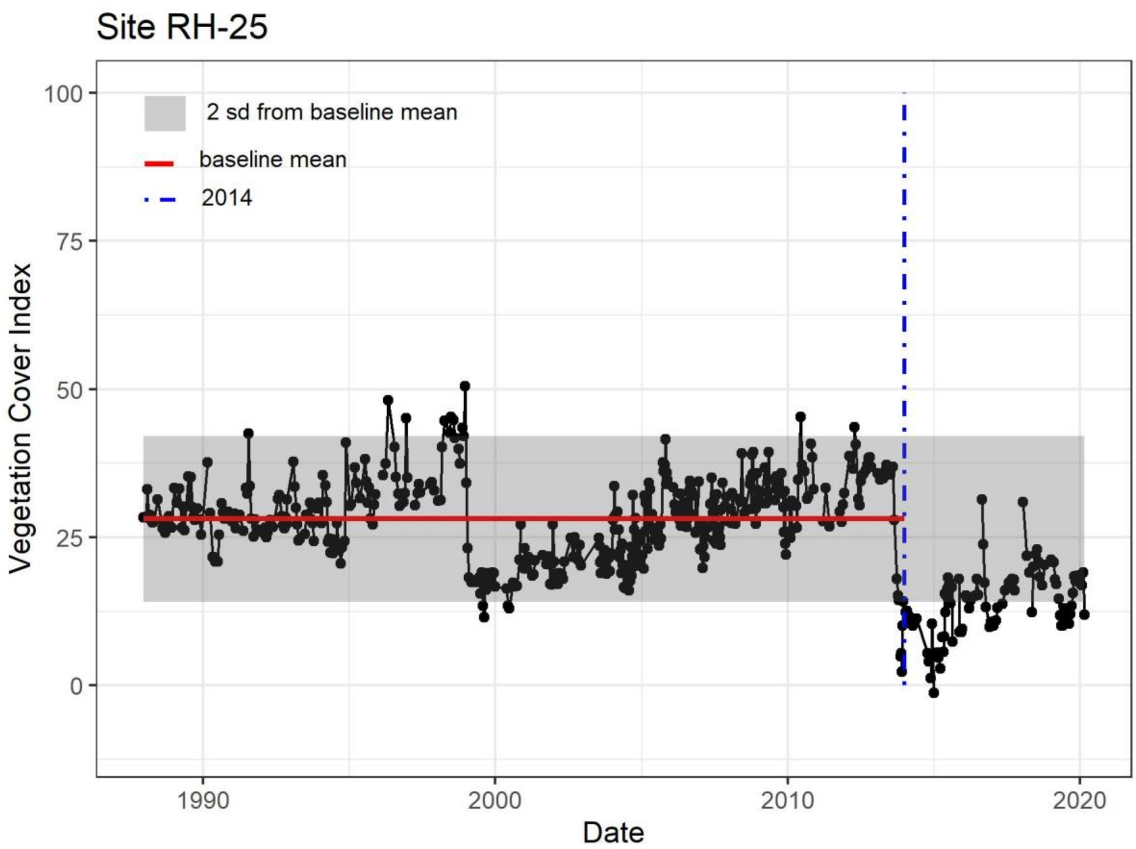
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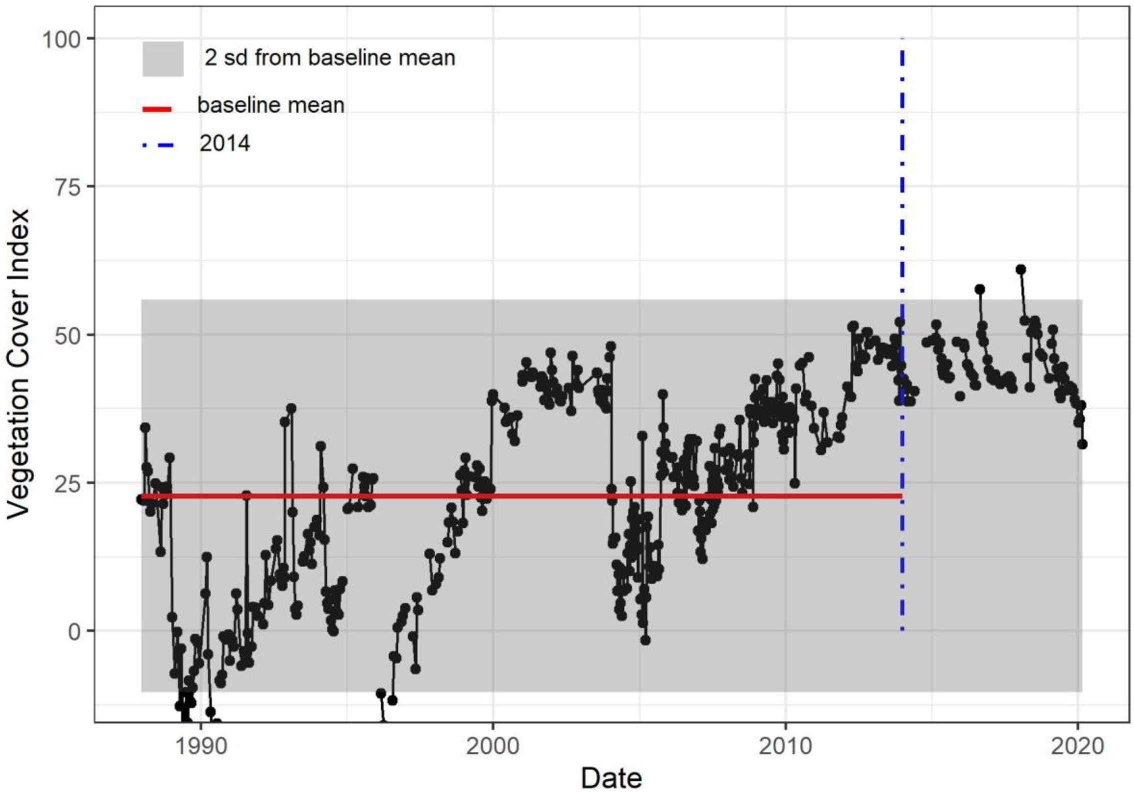

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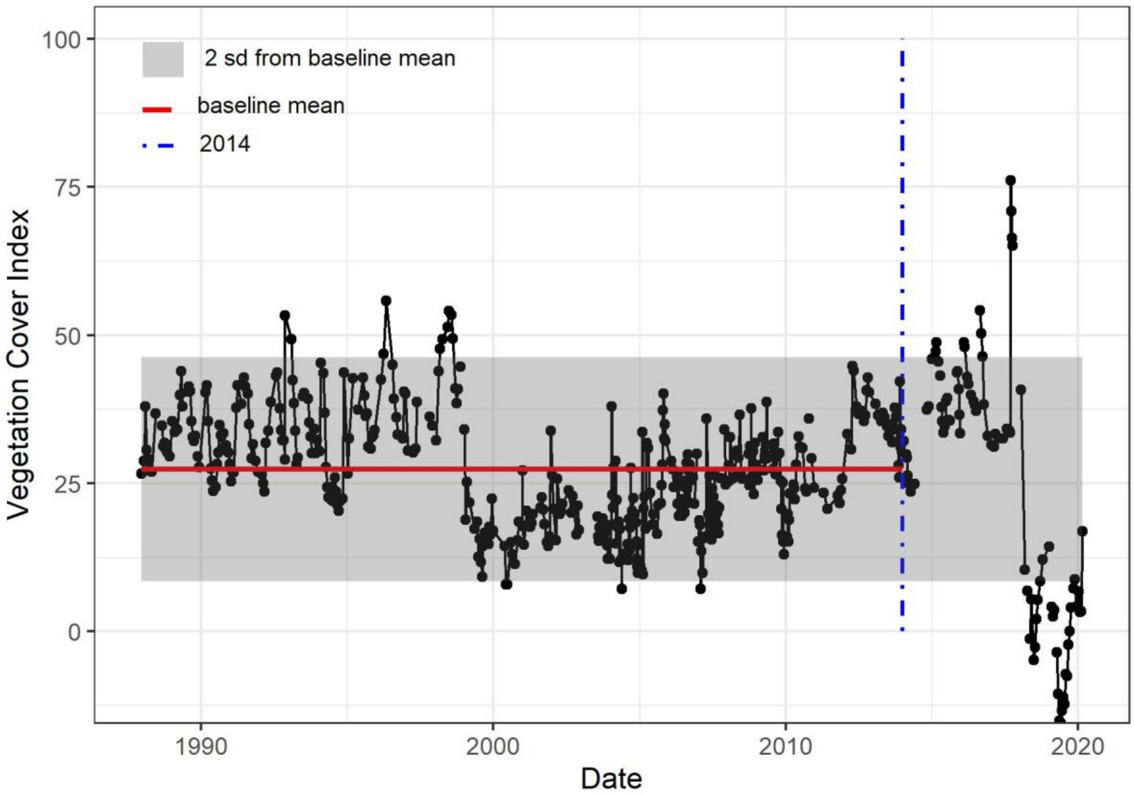

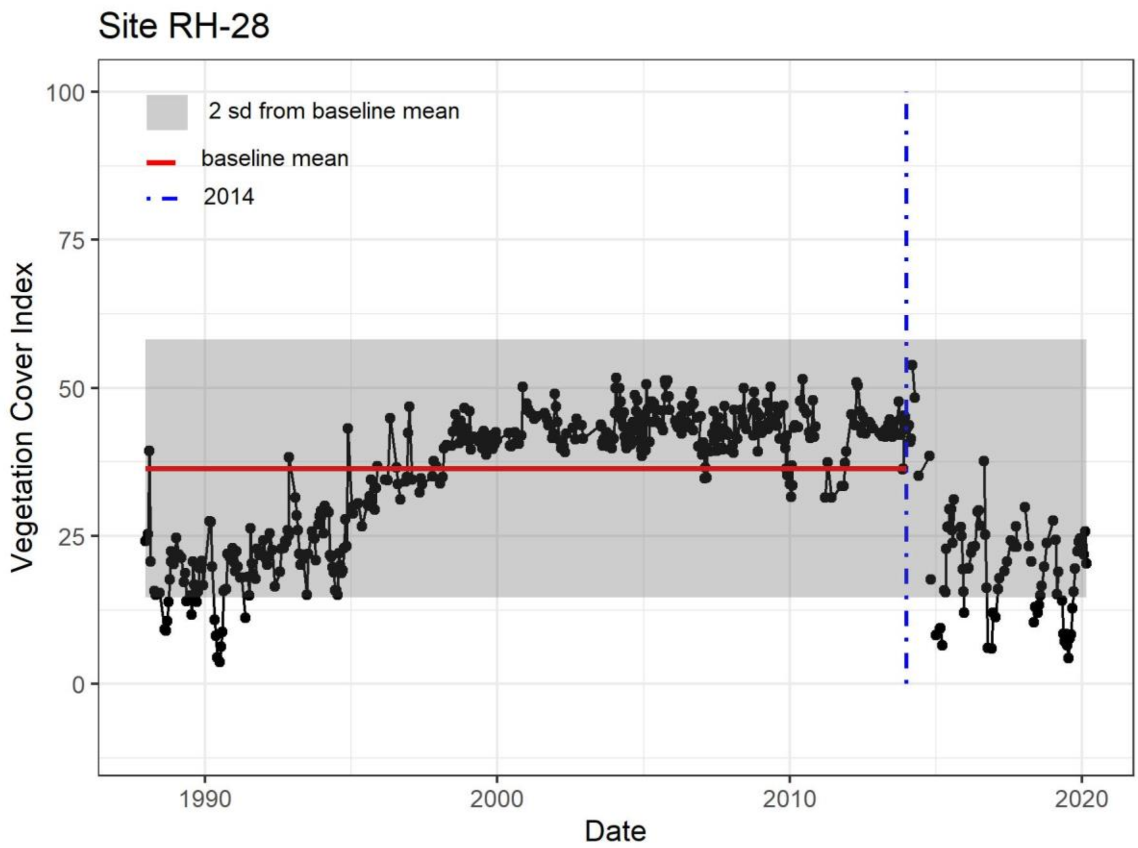
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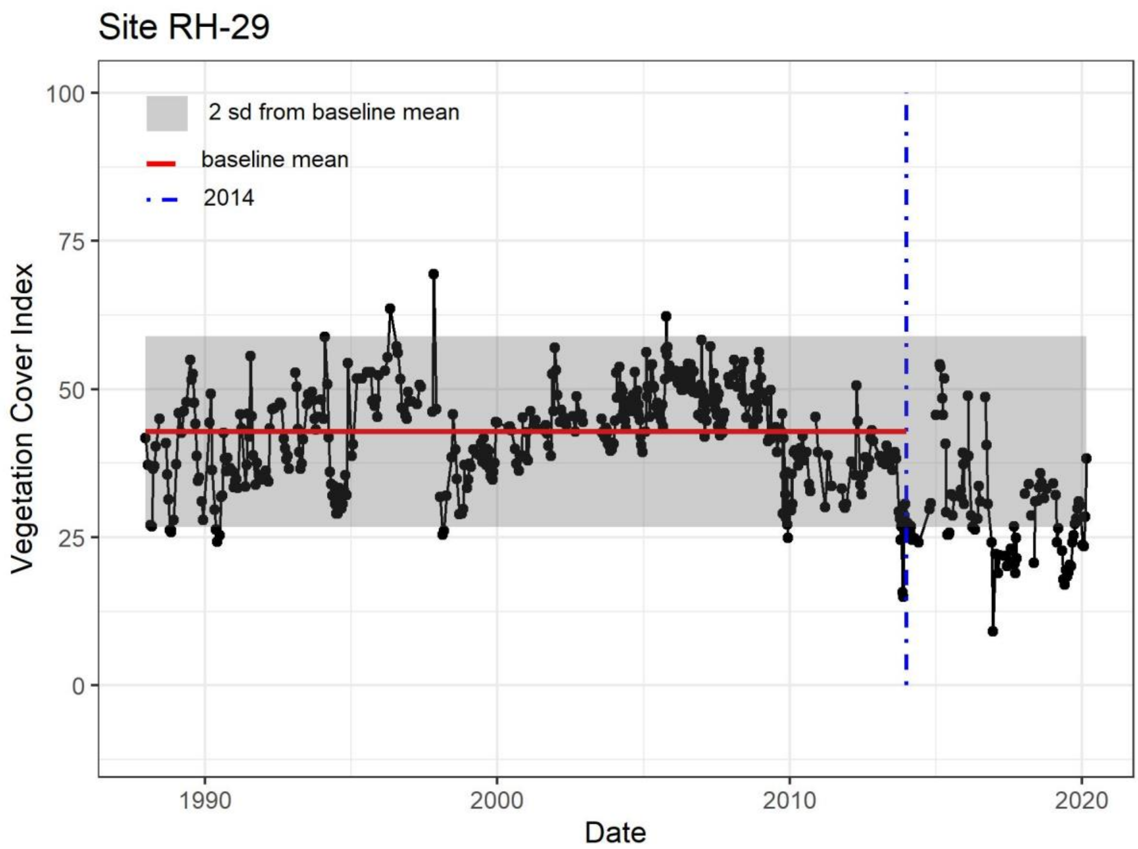
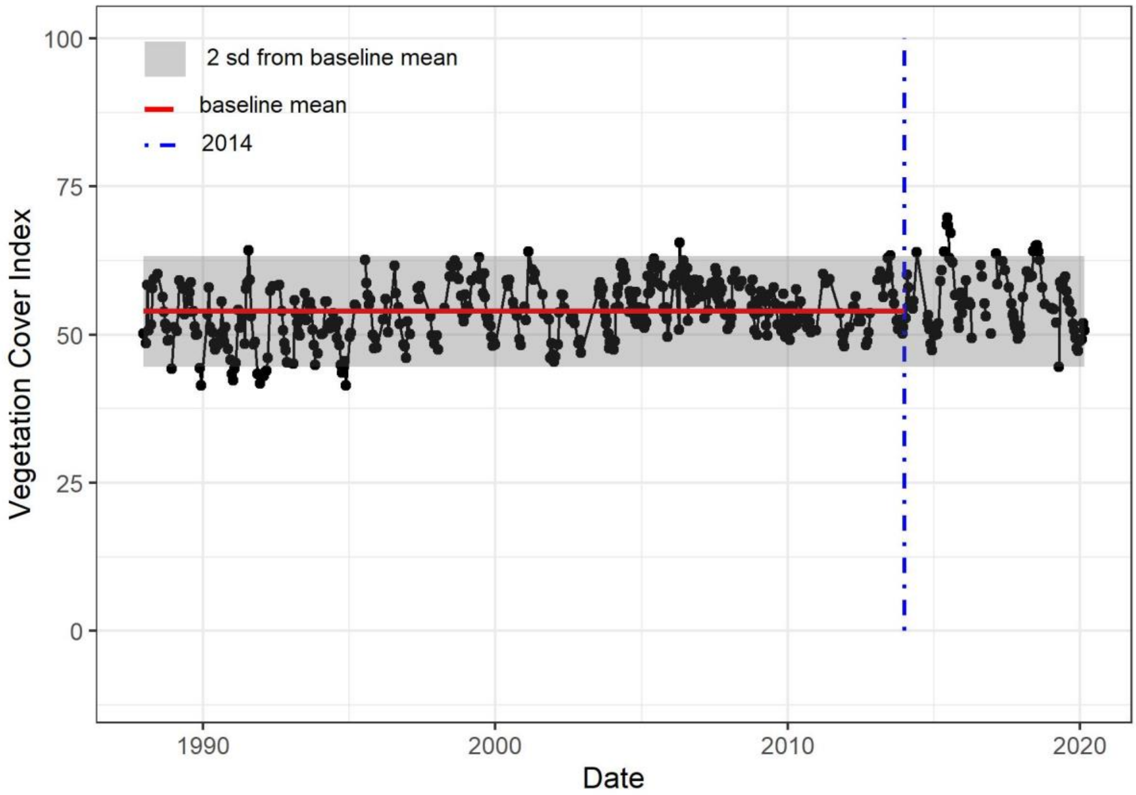
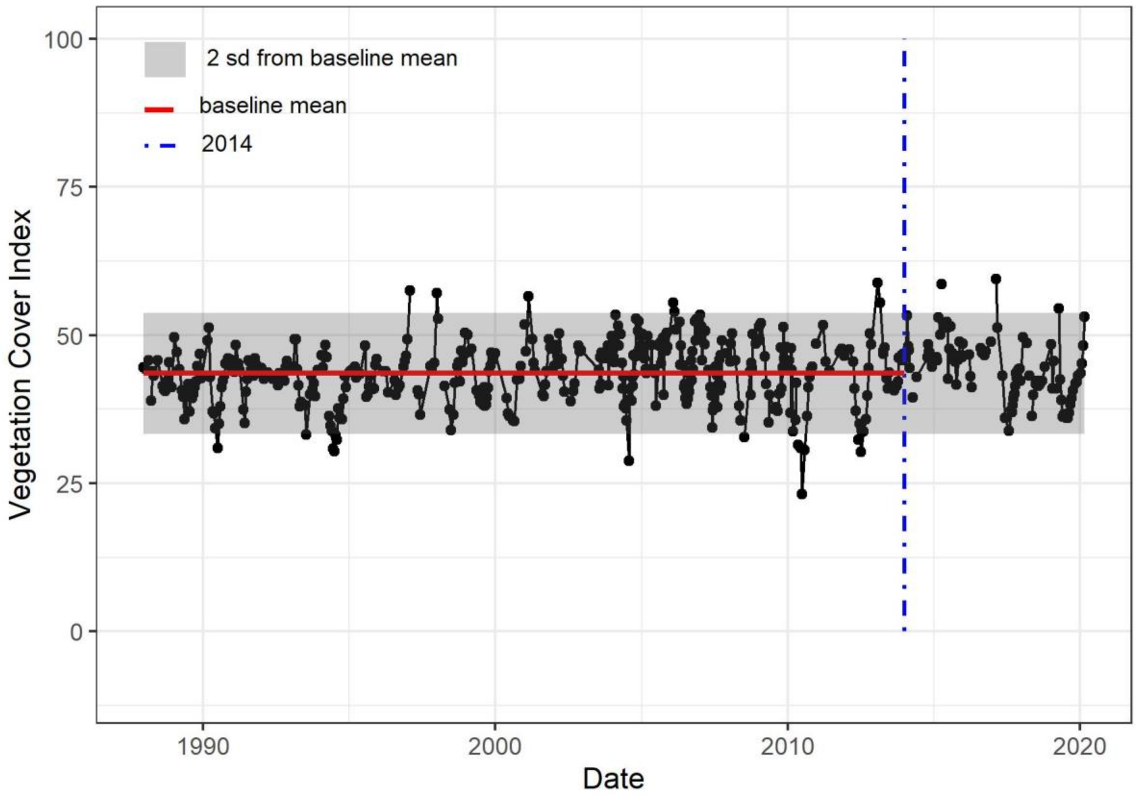
2020
Date

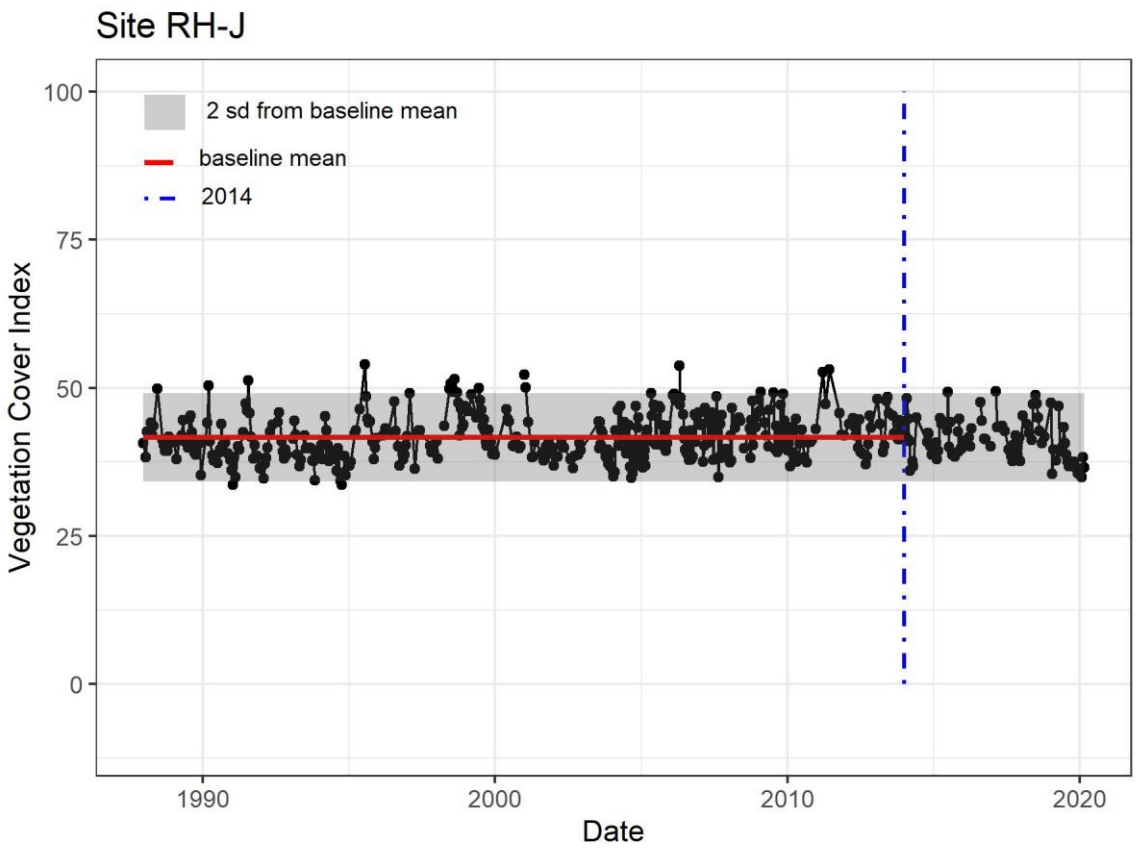

Site RH-29
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

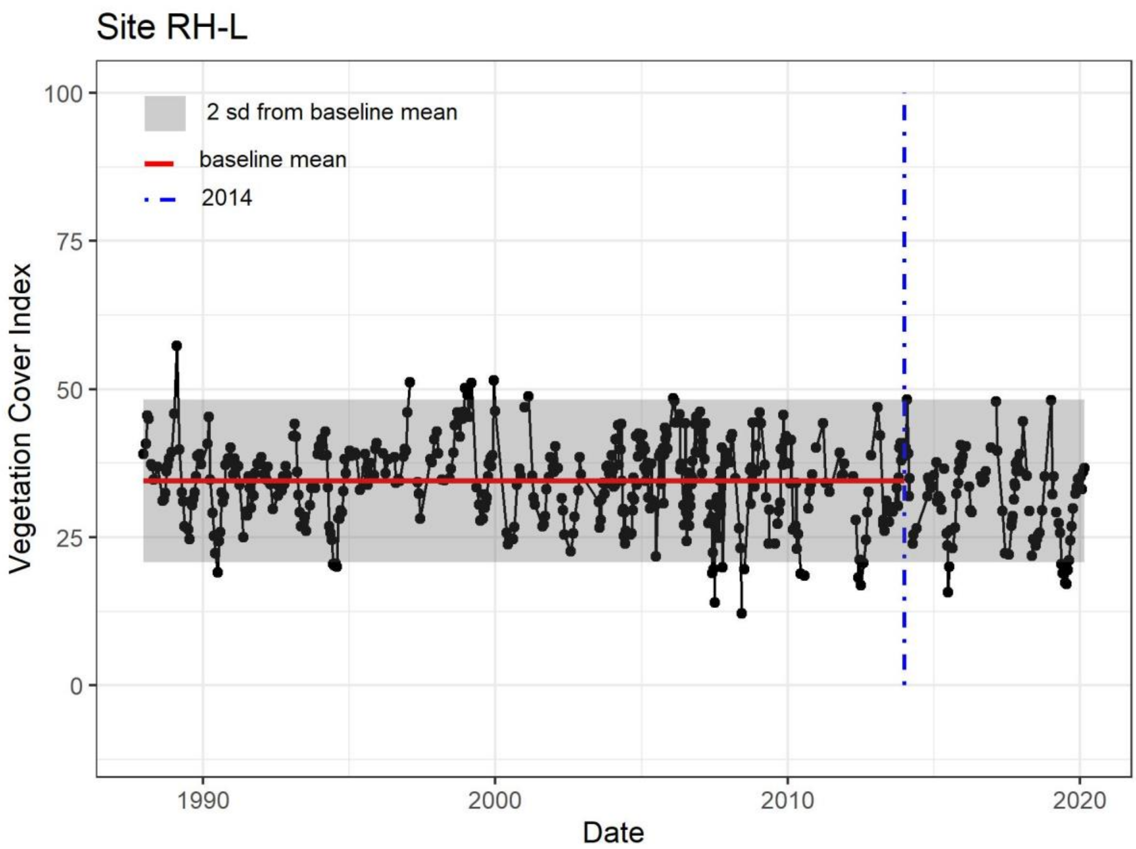
Site RH-E

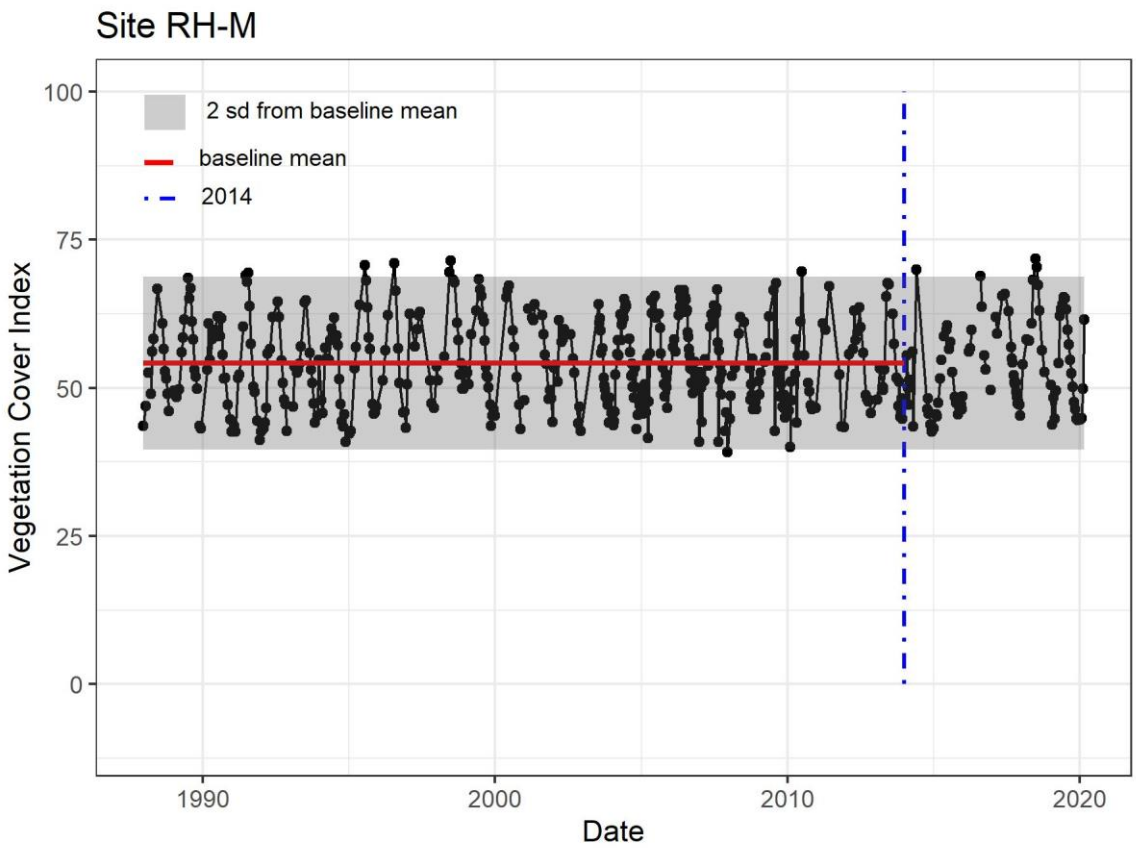


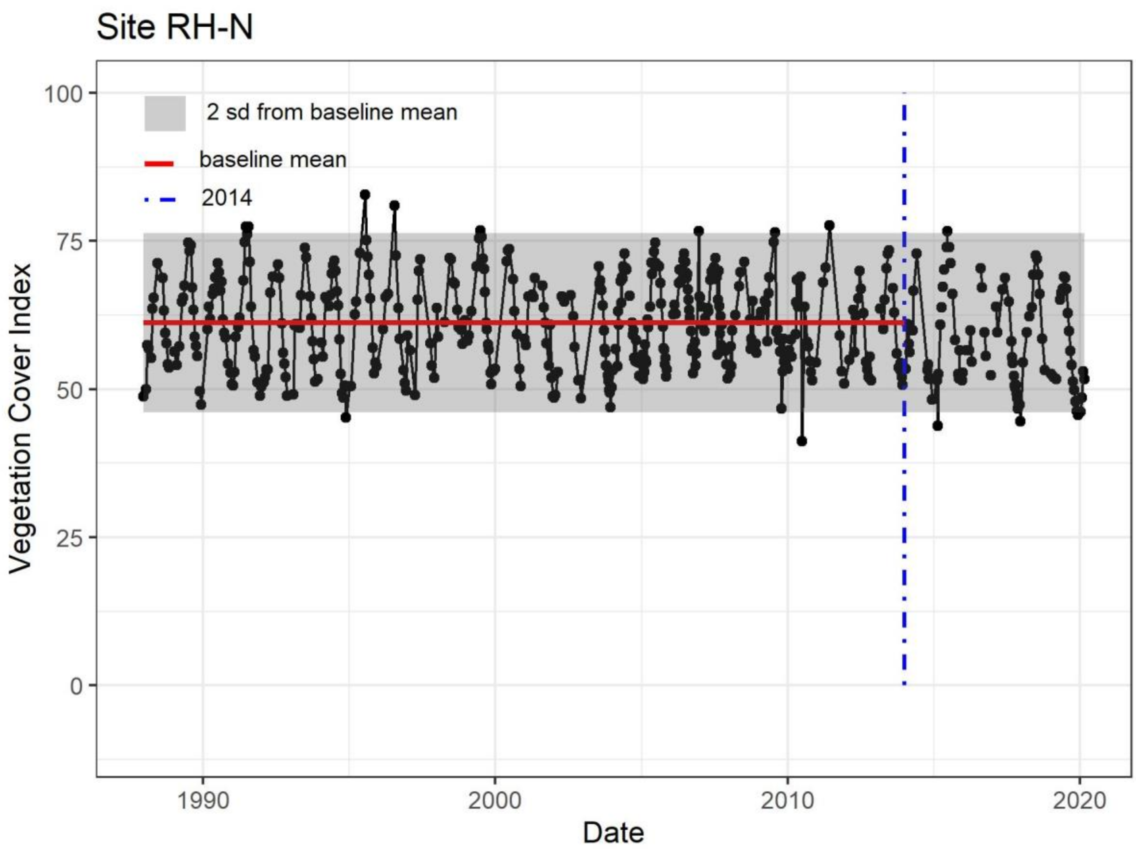
Site RH-H

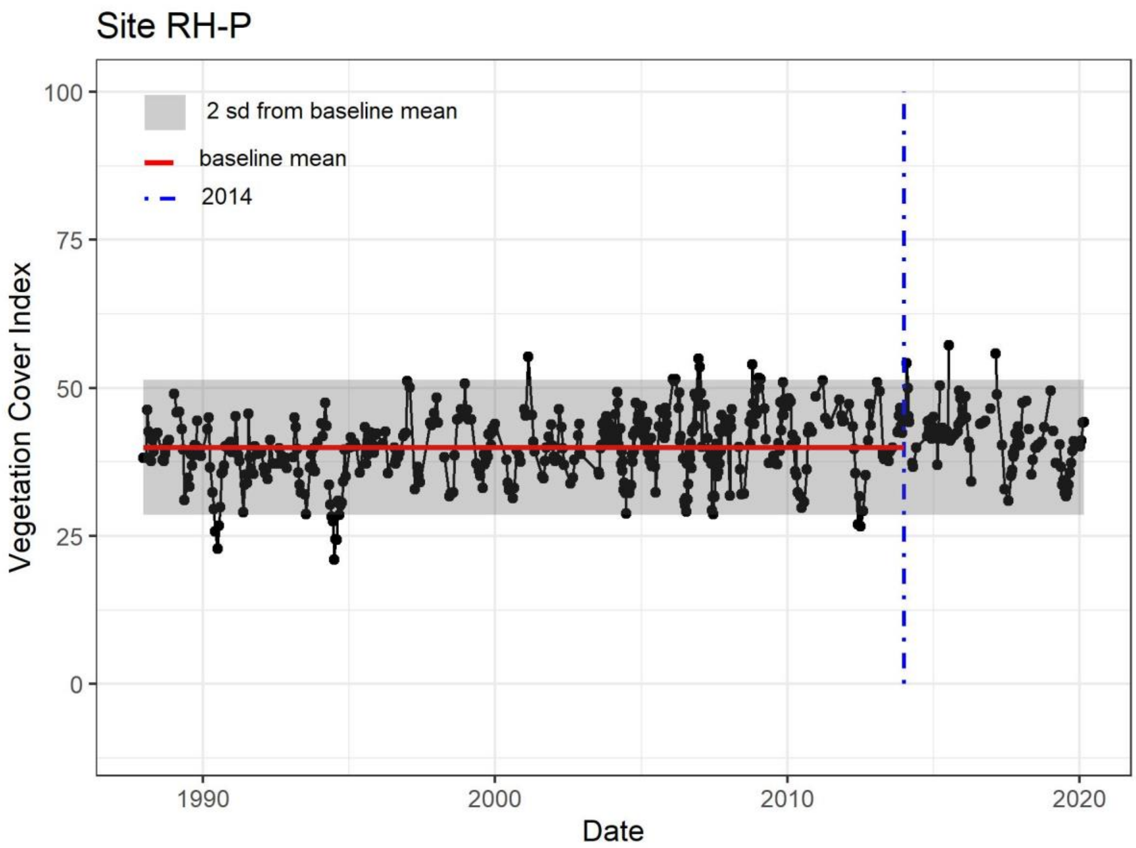


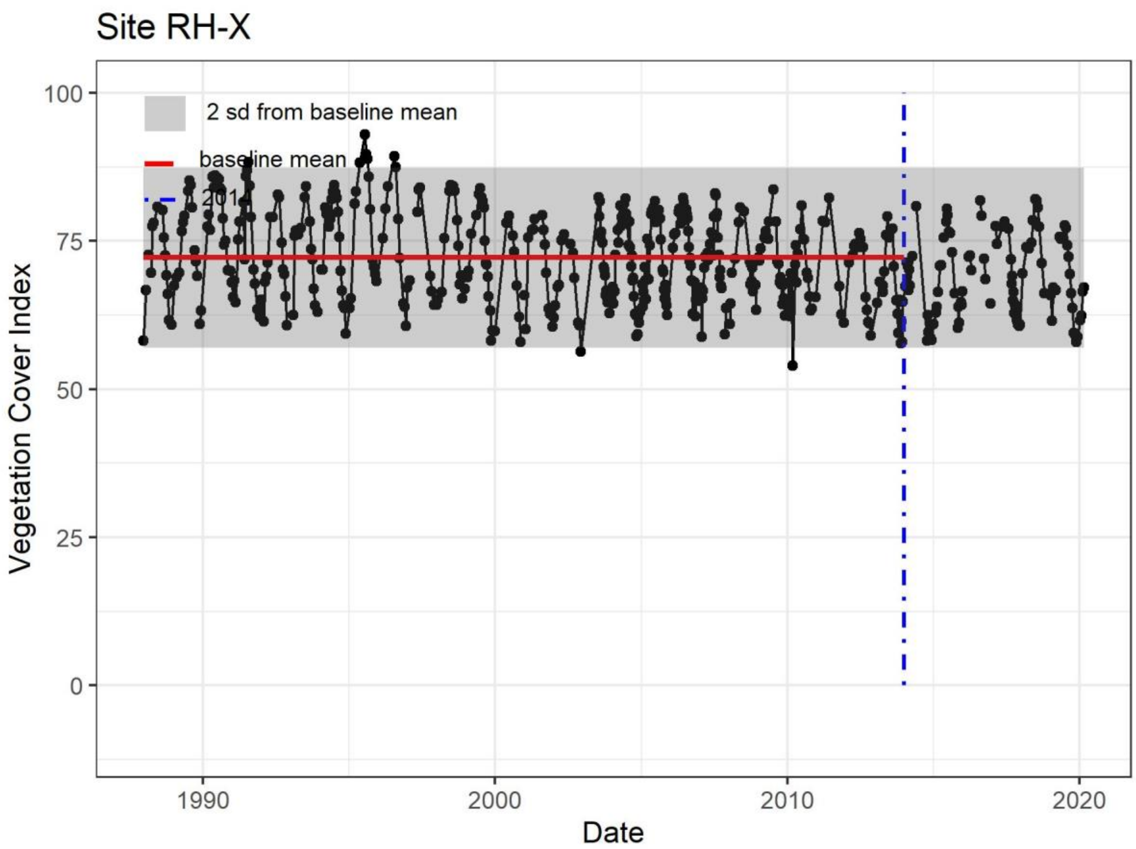

Site RH-J
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

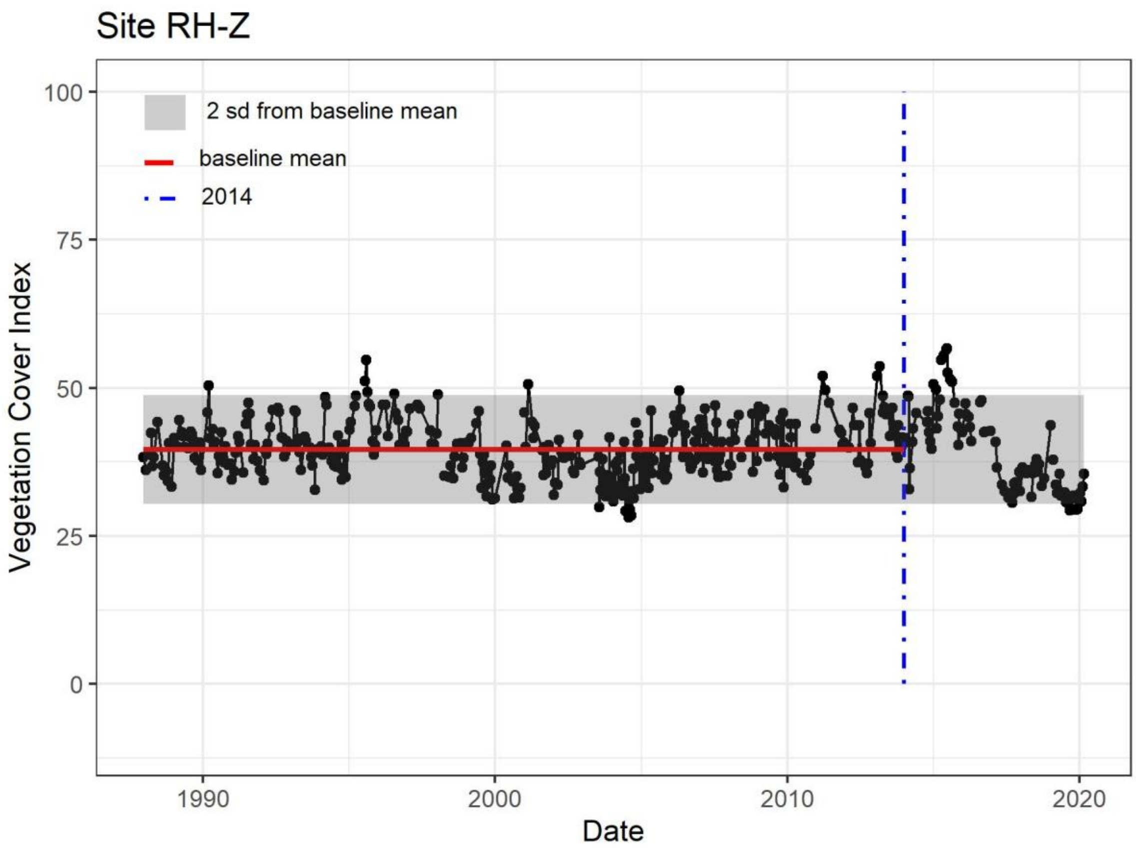

Site RH-L
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date


Site RH-M
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date


Site RH-N
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

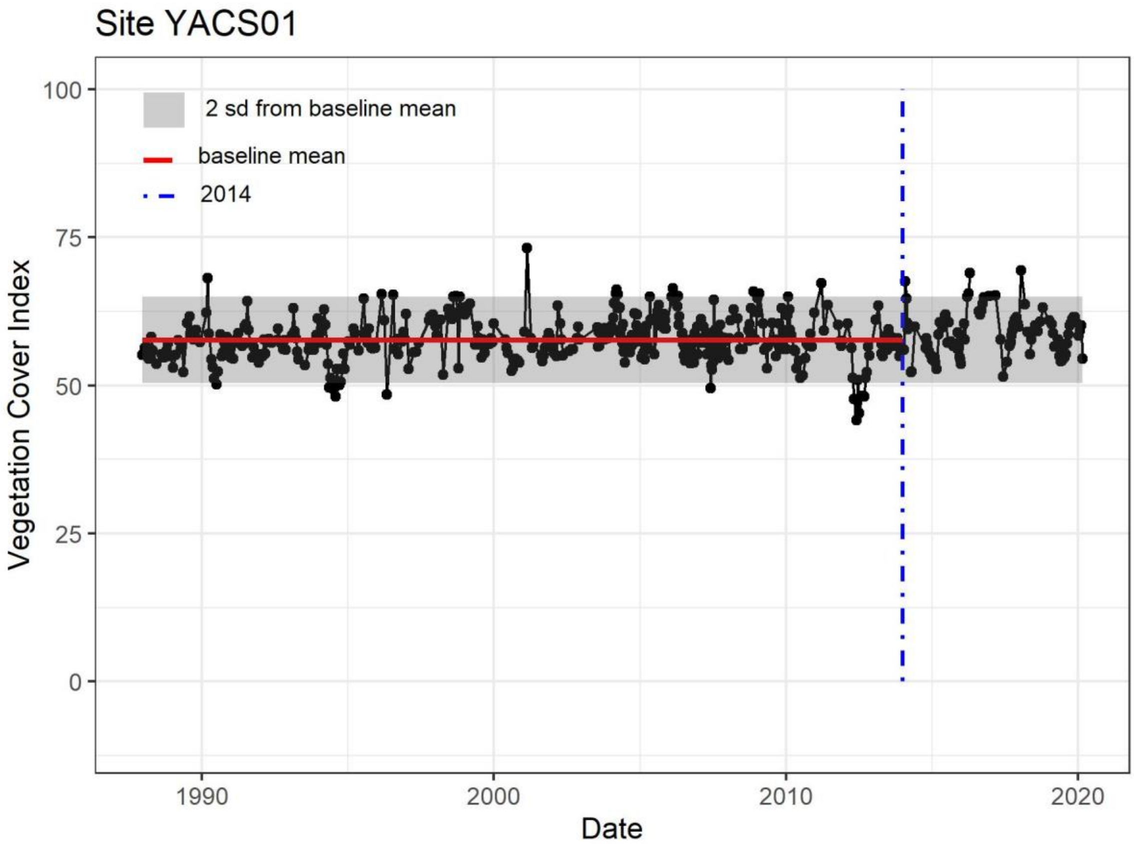

Site RH-P
100
75
50
25
0
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
1990
2000
2010
2020
Date


Site RH-X
100
75
50
25
0
2 sd from baseline mean
baseline mean
Vegetation Cover Index
1990
2000
2010
2020
Date

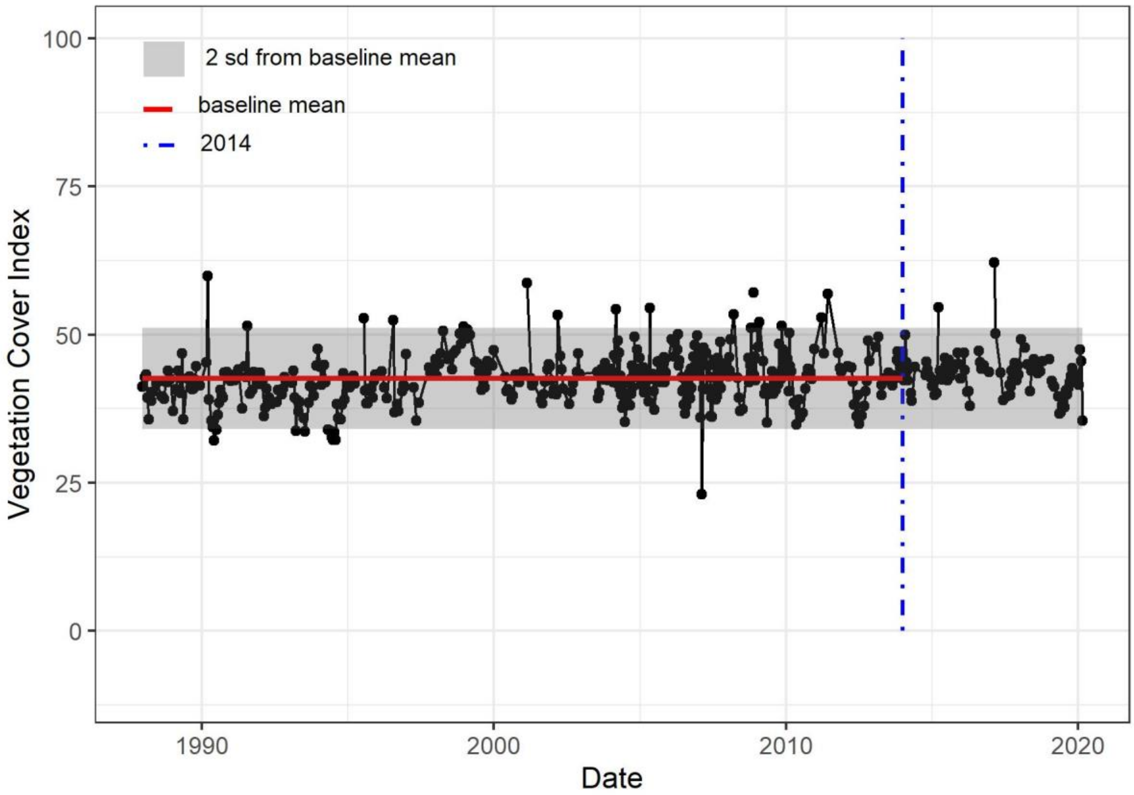

Site RH-Z
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

2.4 Time series plots from Yarraloola

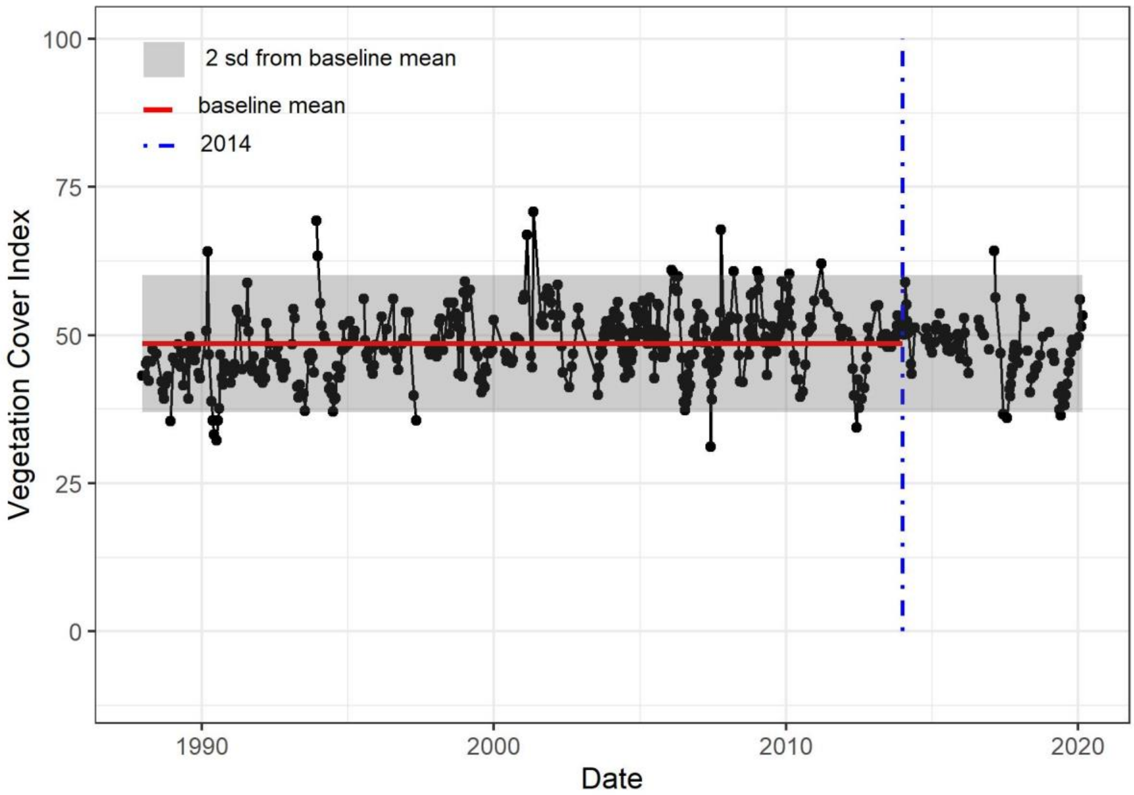
The time series vegetation cover graphs for Yarraloola are shown below. The red line is the baseline (1988 to 2014) mean, the grey area shows the range within two standard deviations from this mean and the blue dashed line indicates the end of the baseline period (2014).

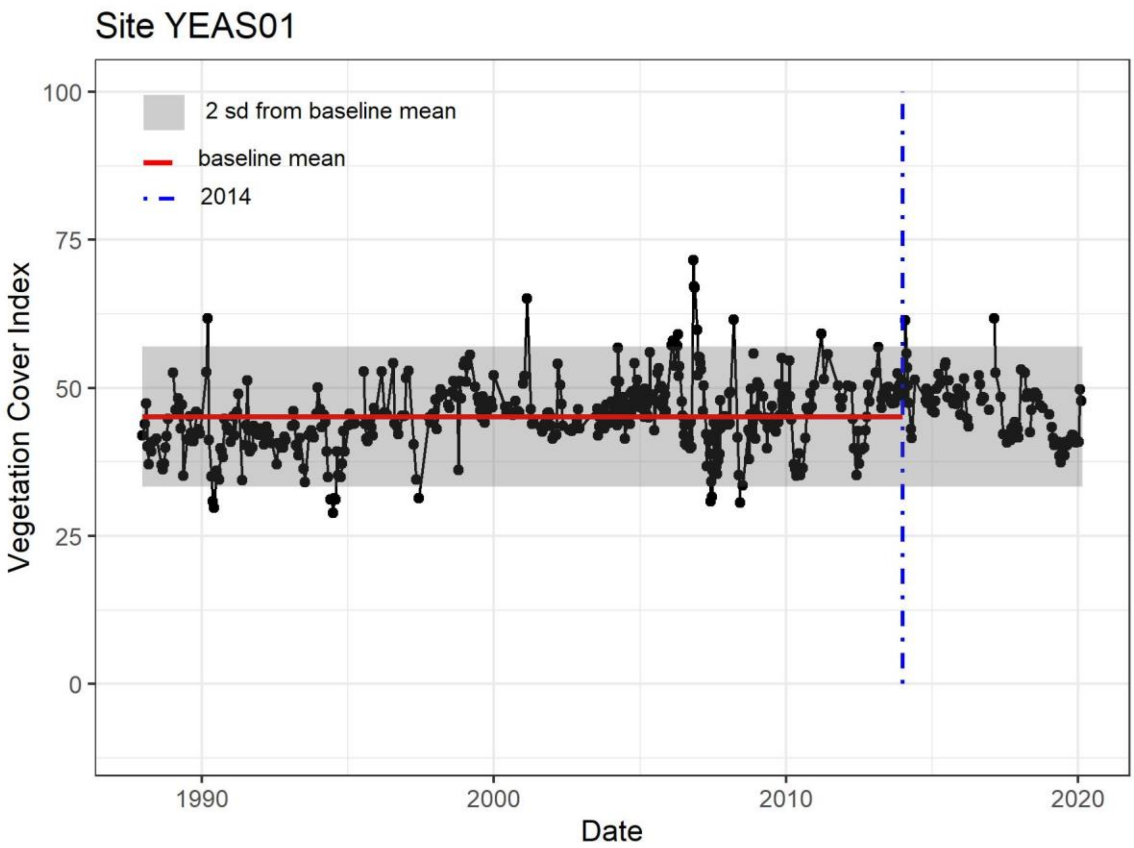


Site YAS01

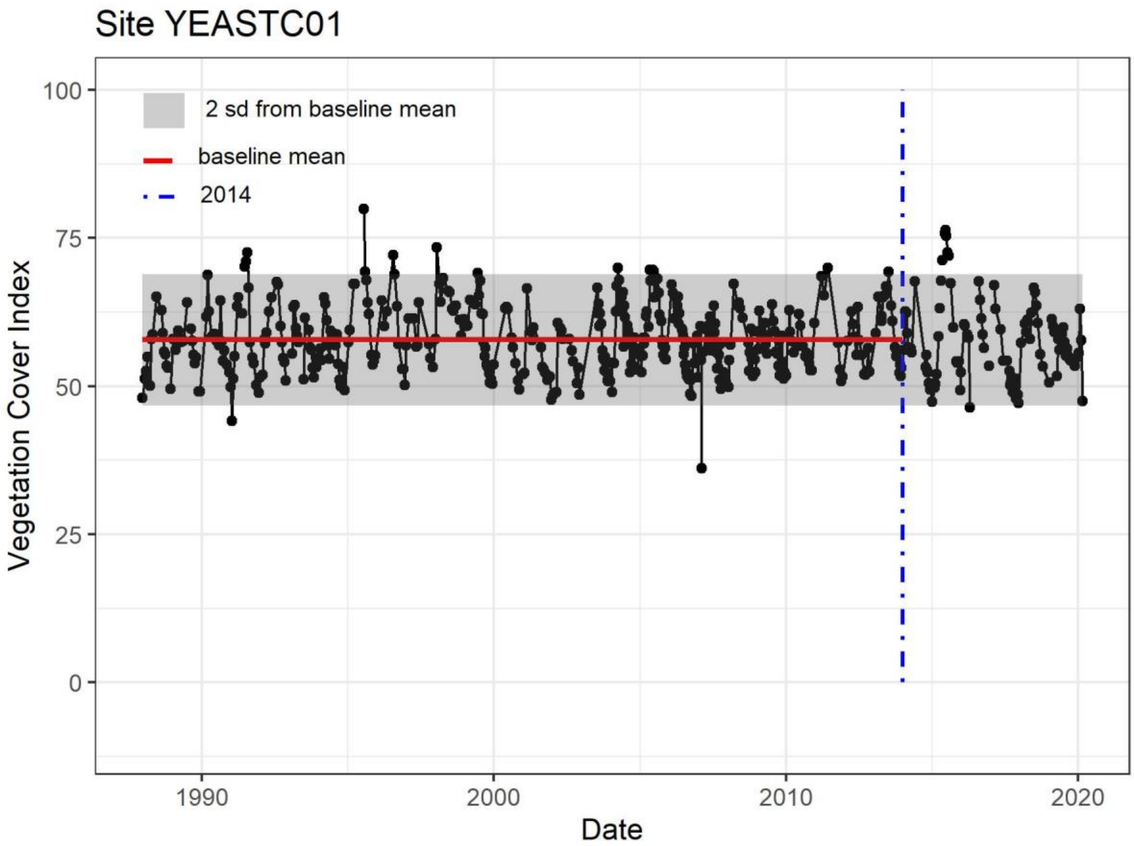


Site YAS02

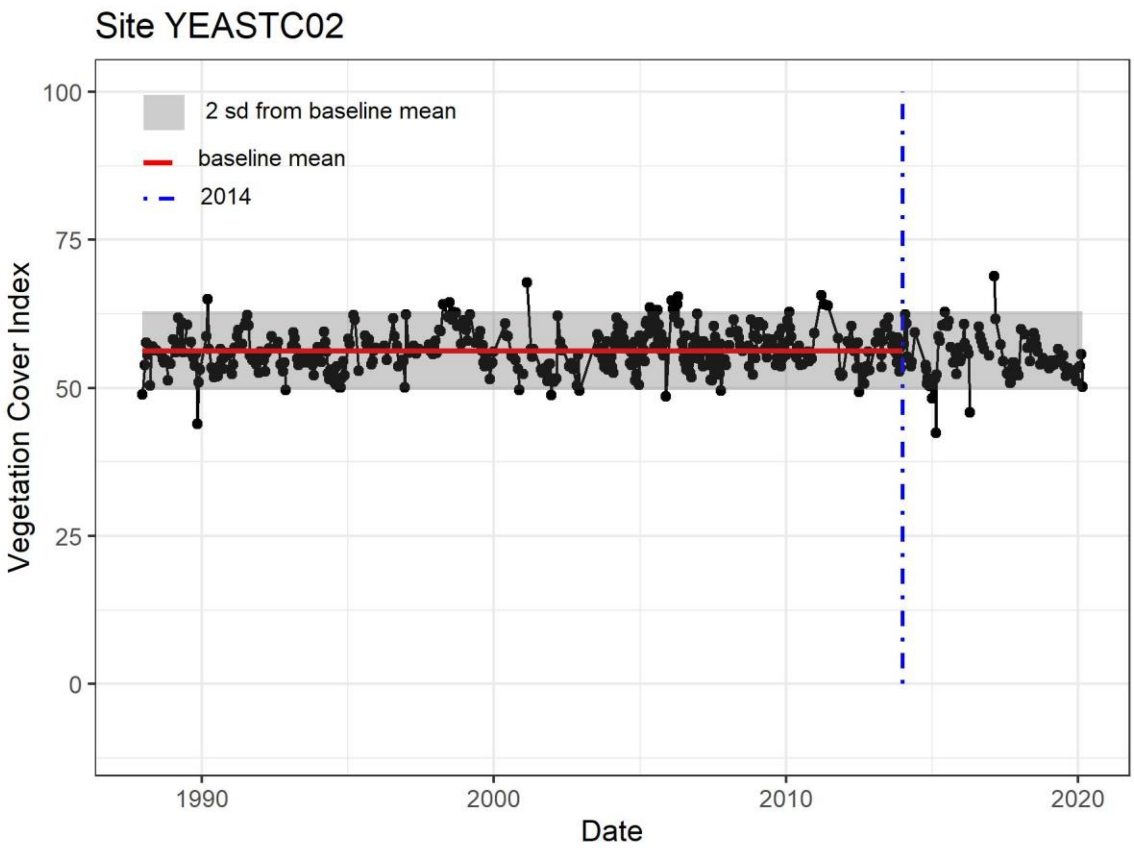


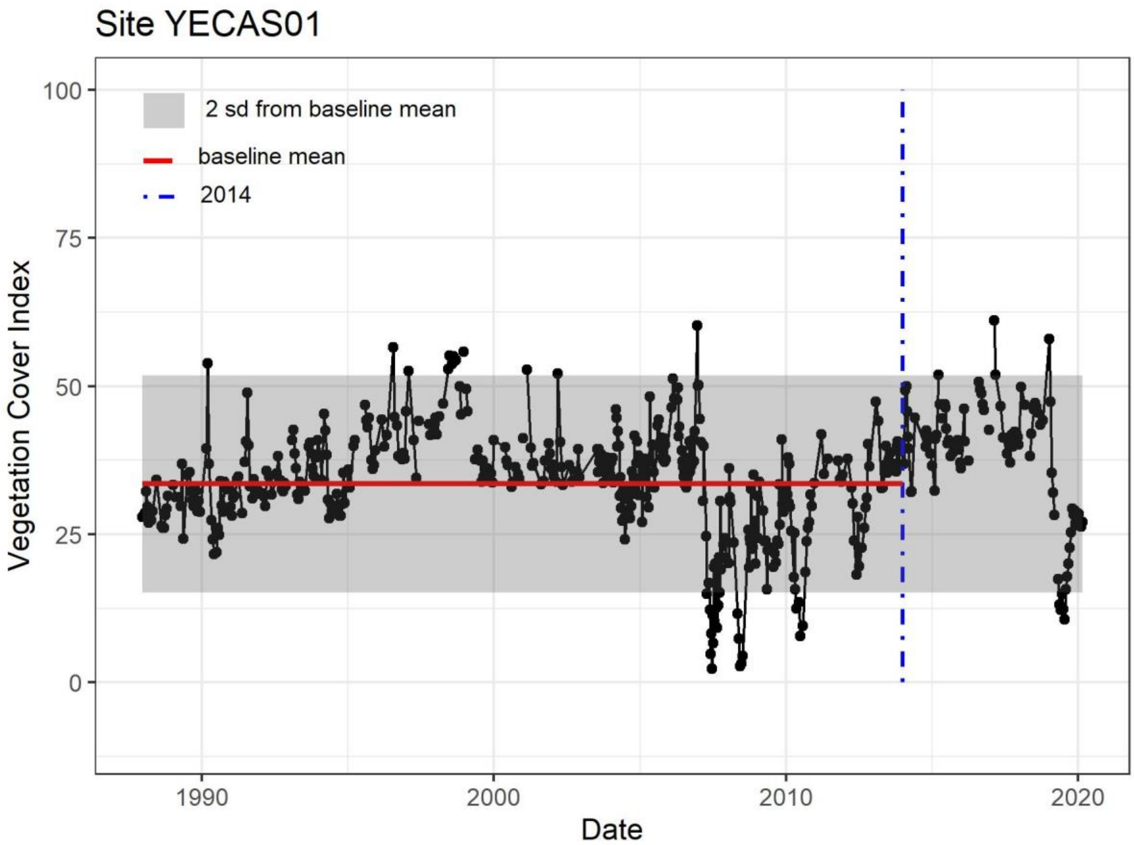


Site YEAS01
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

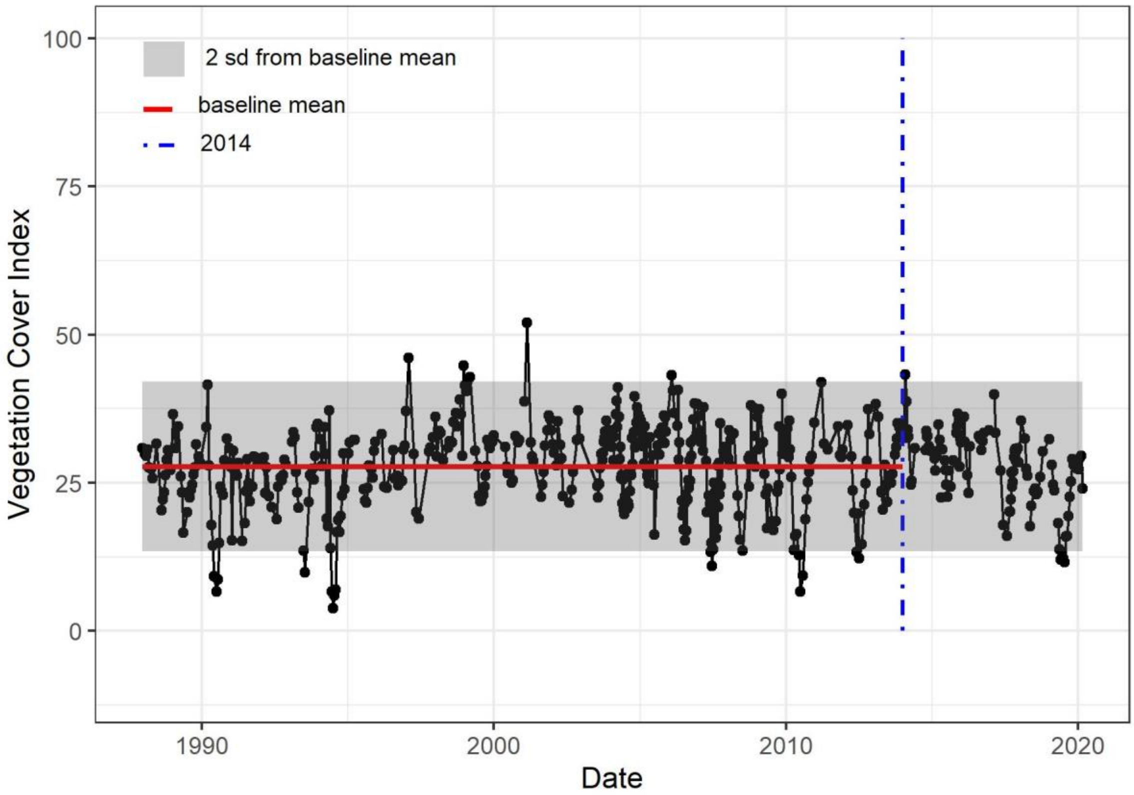


Site YEASTC01
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

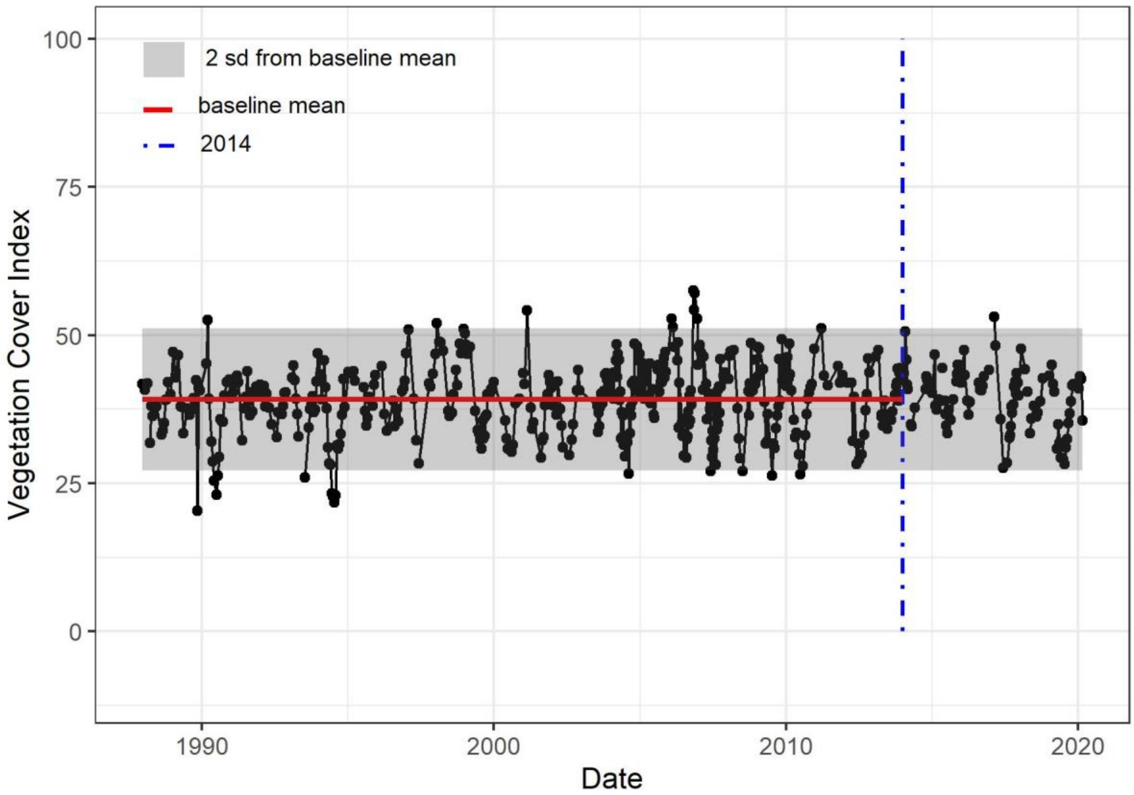

Site YEASTC02
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

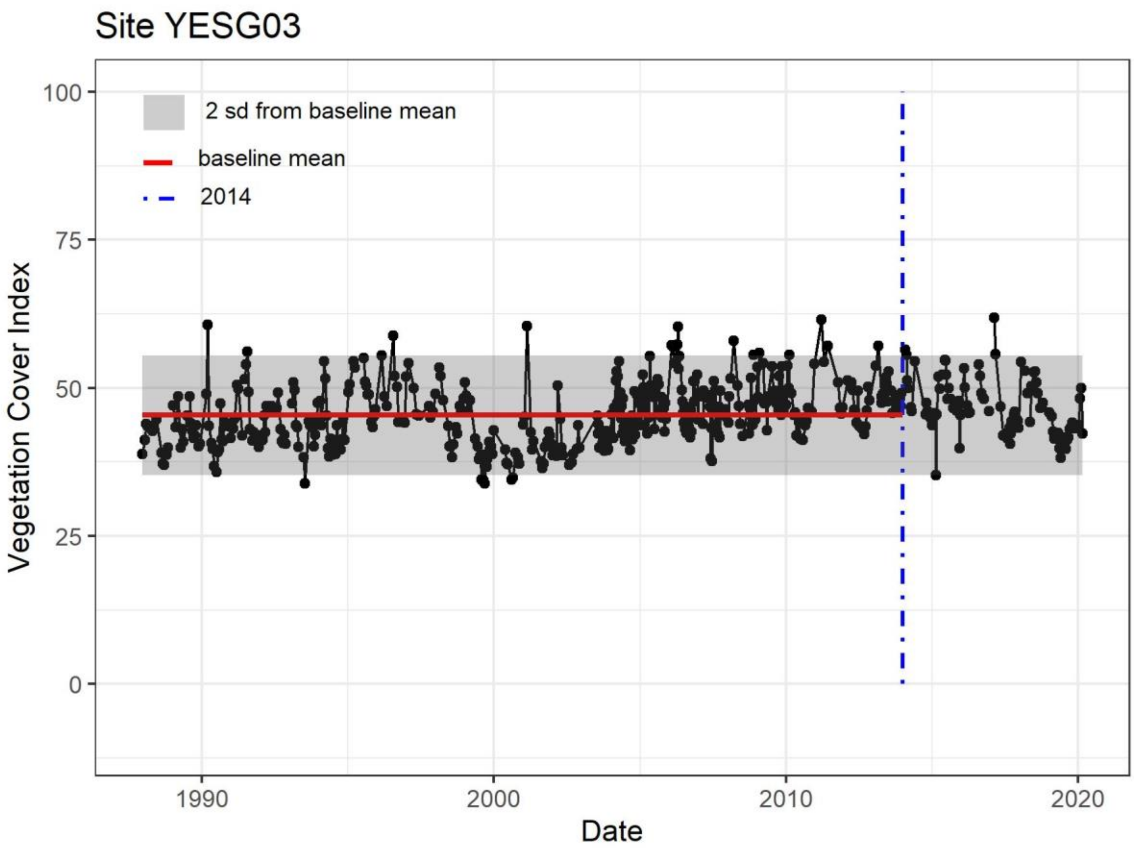

Site YECAS01
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

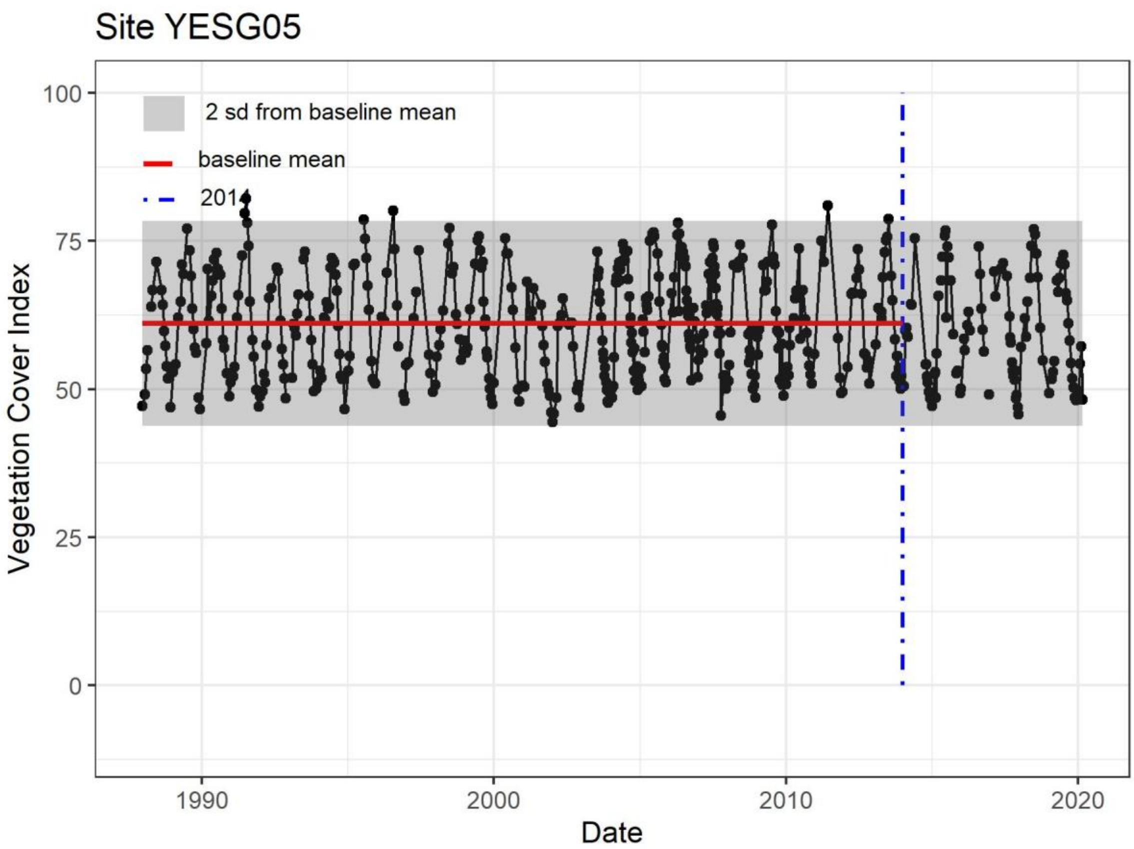
Site YESG01



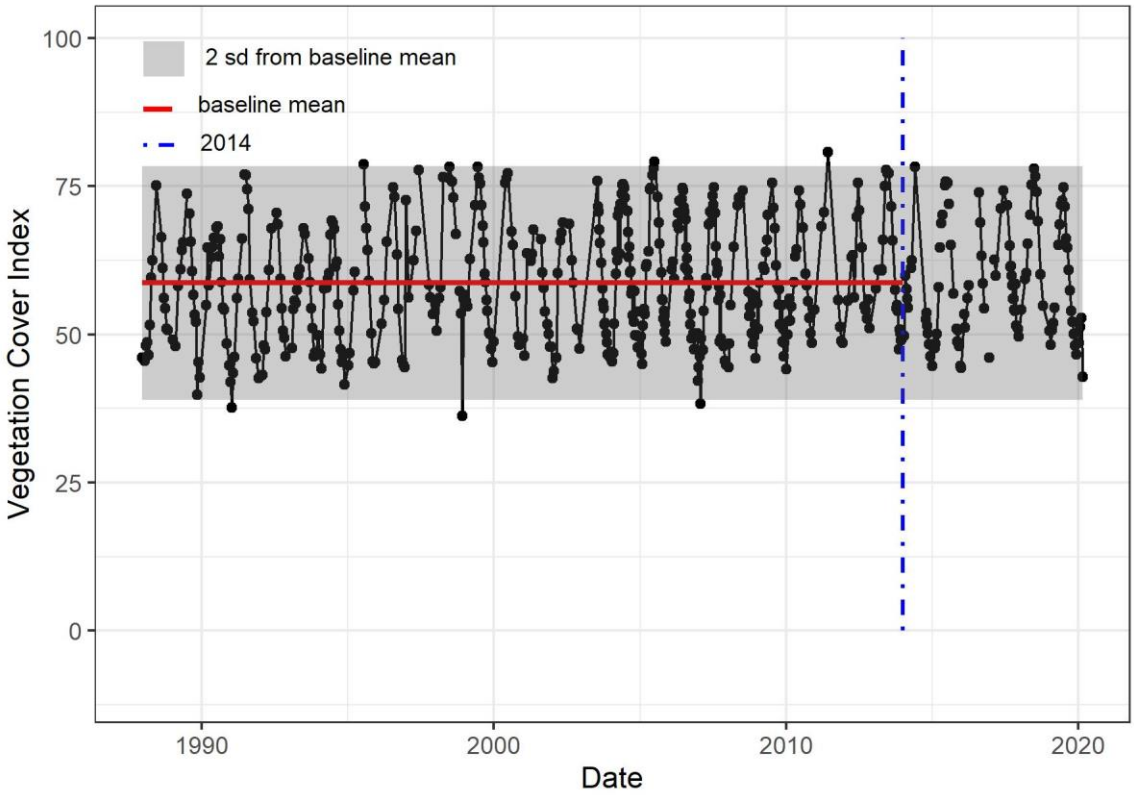
Site YESG02



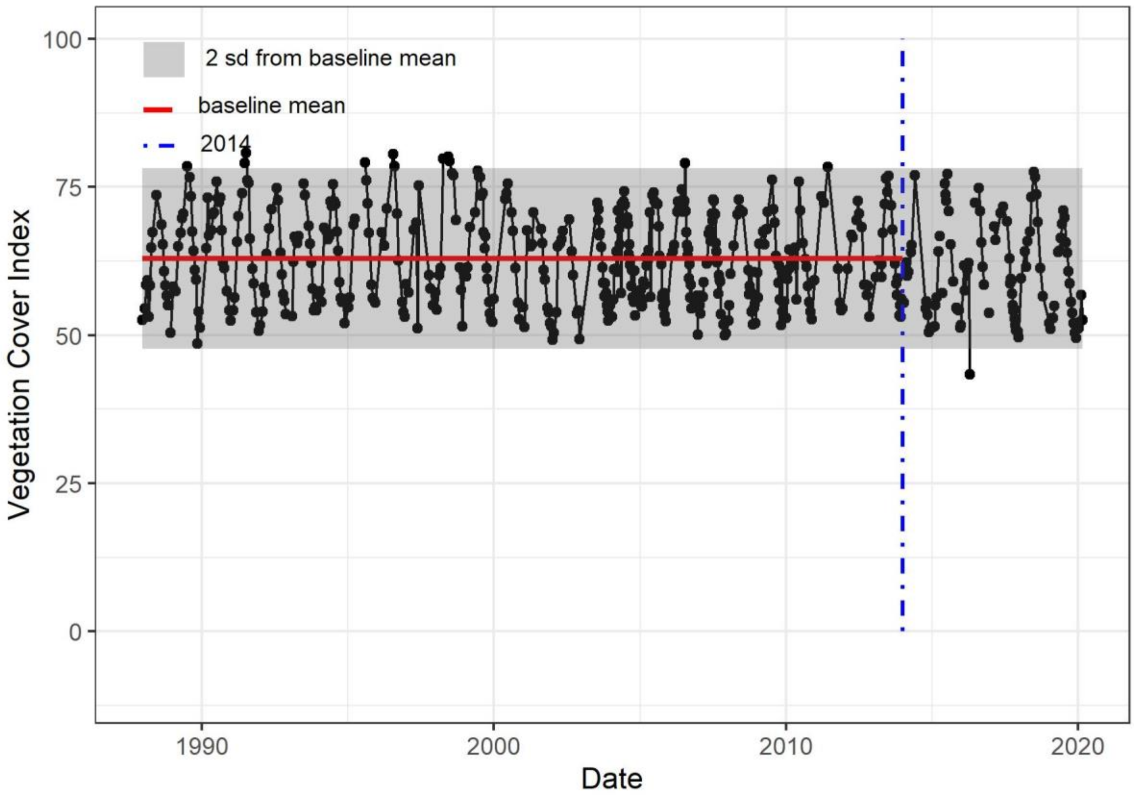

Site YESG03
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

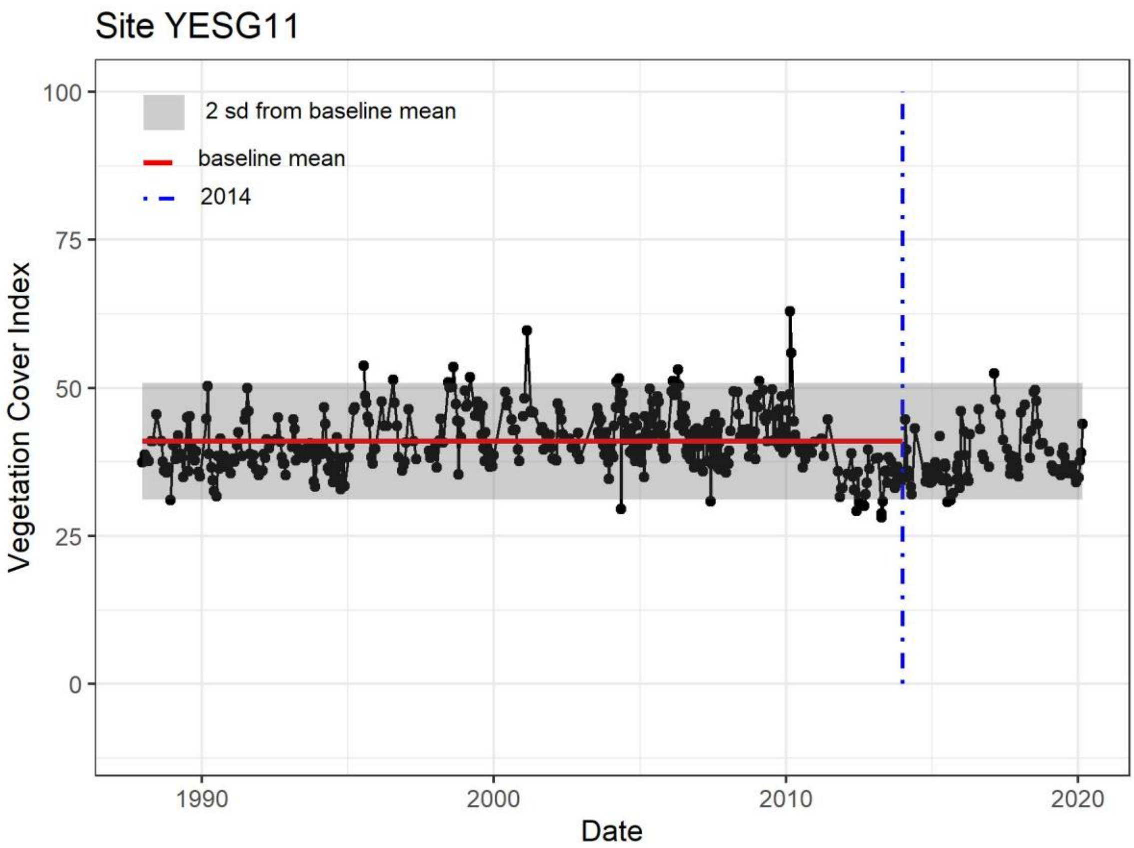

Site YESG05
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

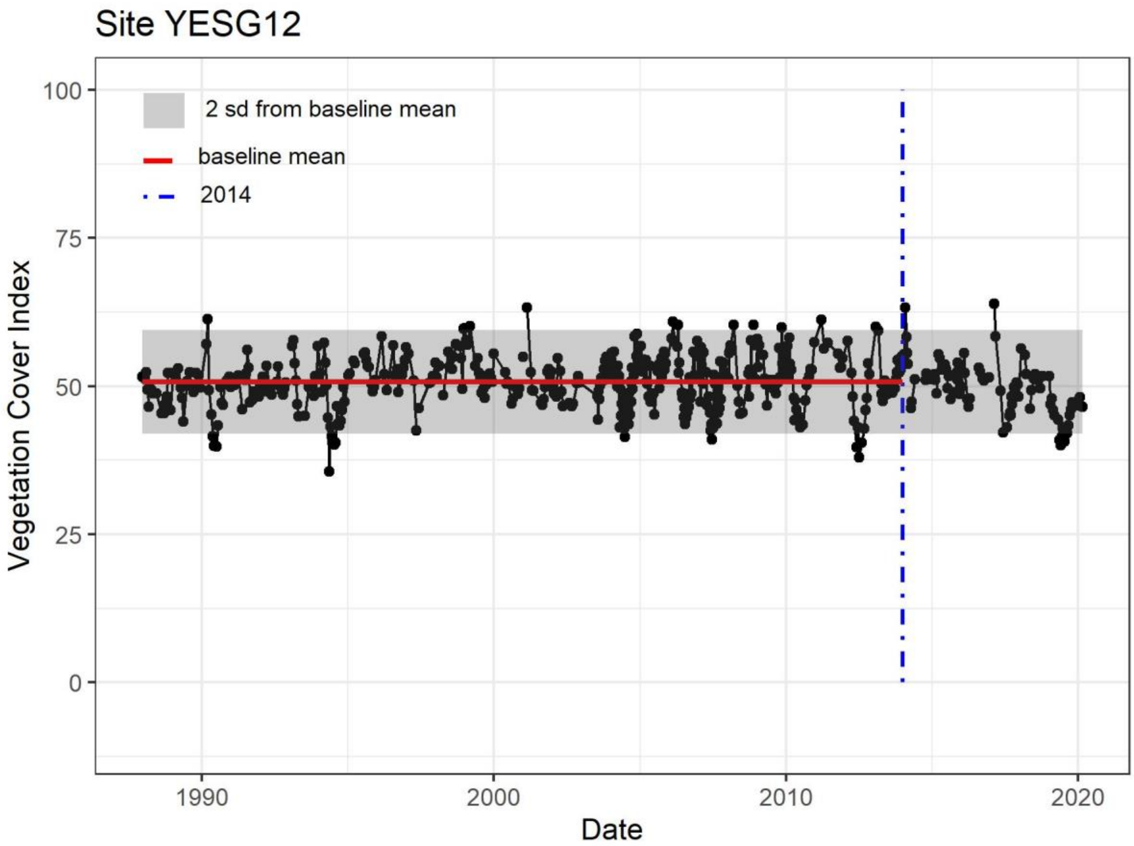
Site YESG07



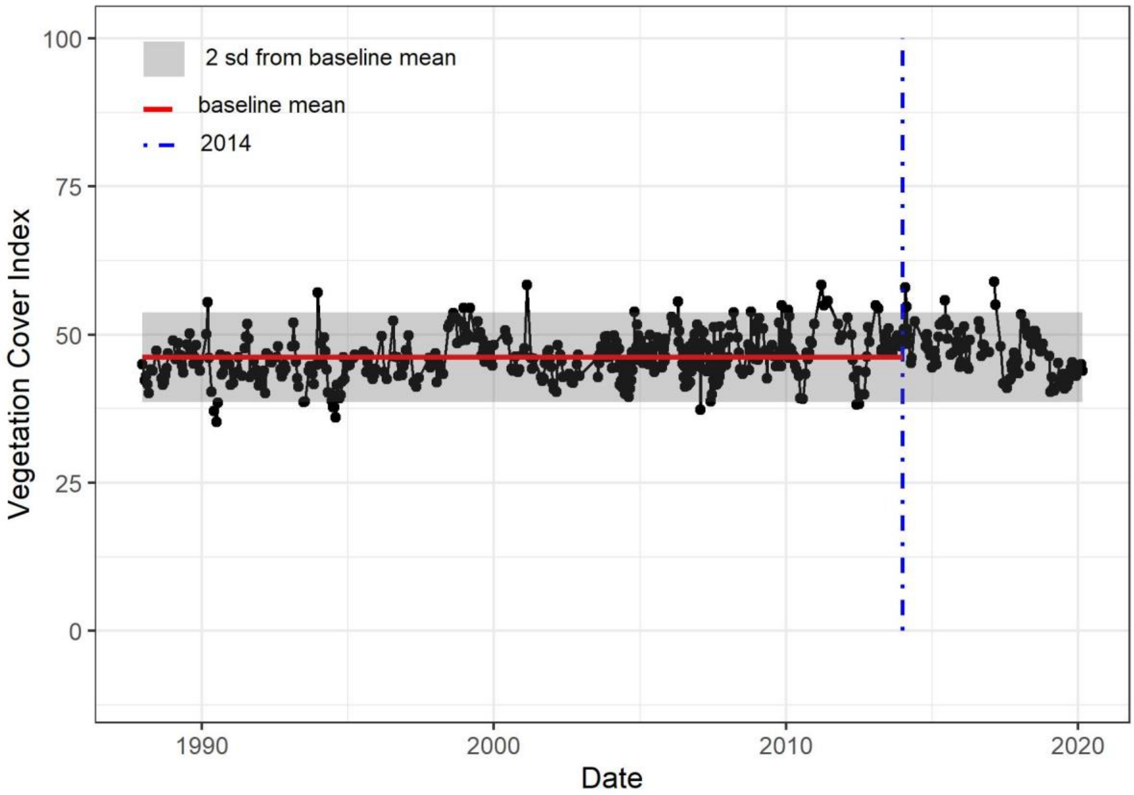
Site YESG10



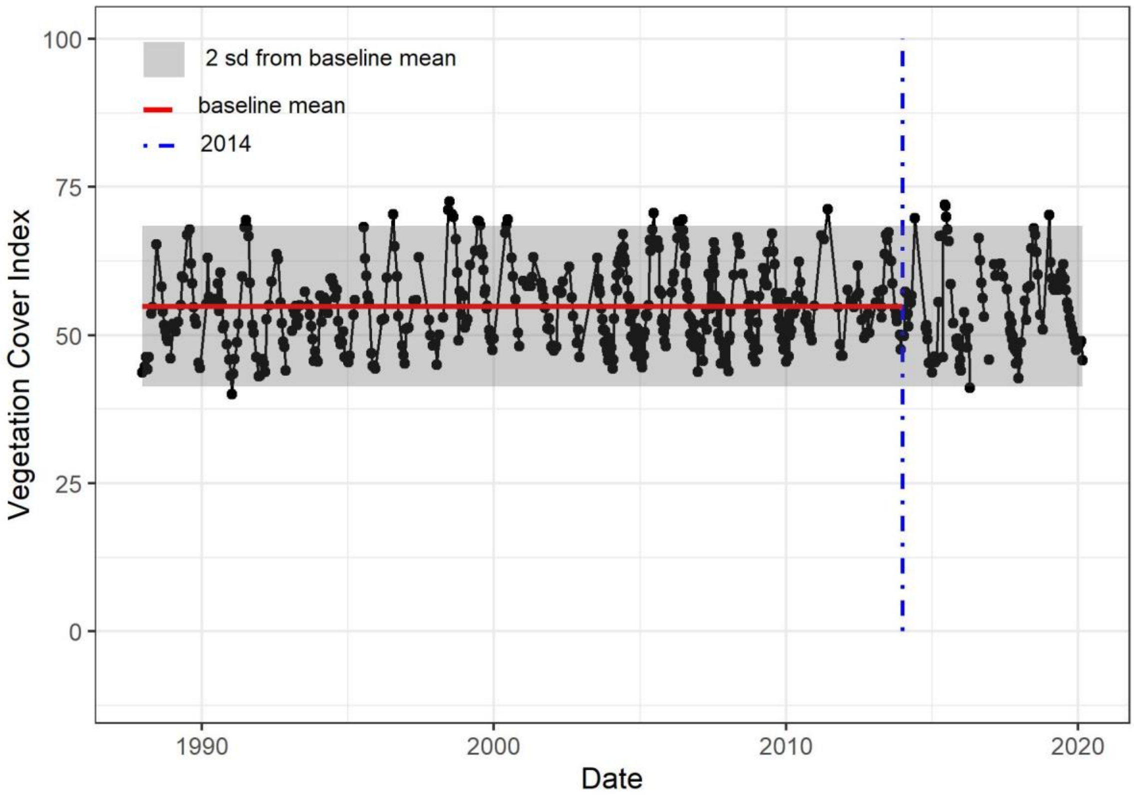

Site YESG11
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date


Site YESG12
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

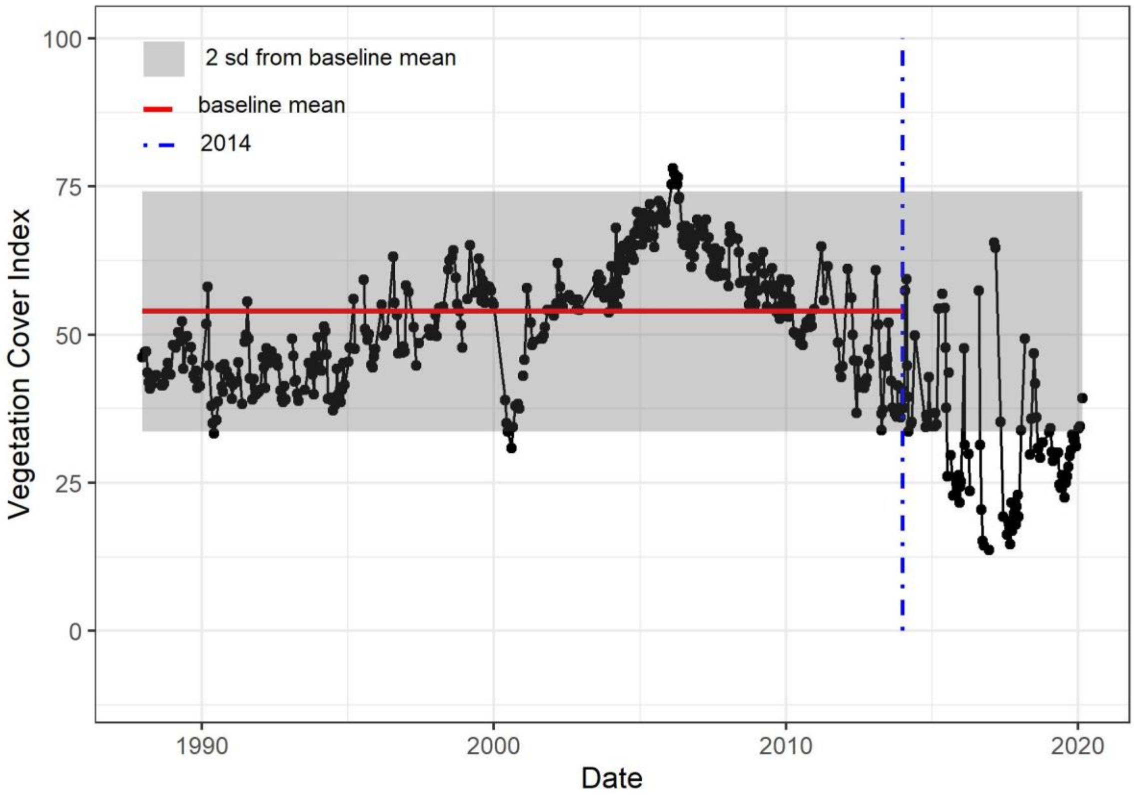
Site YESG13



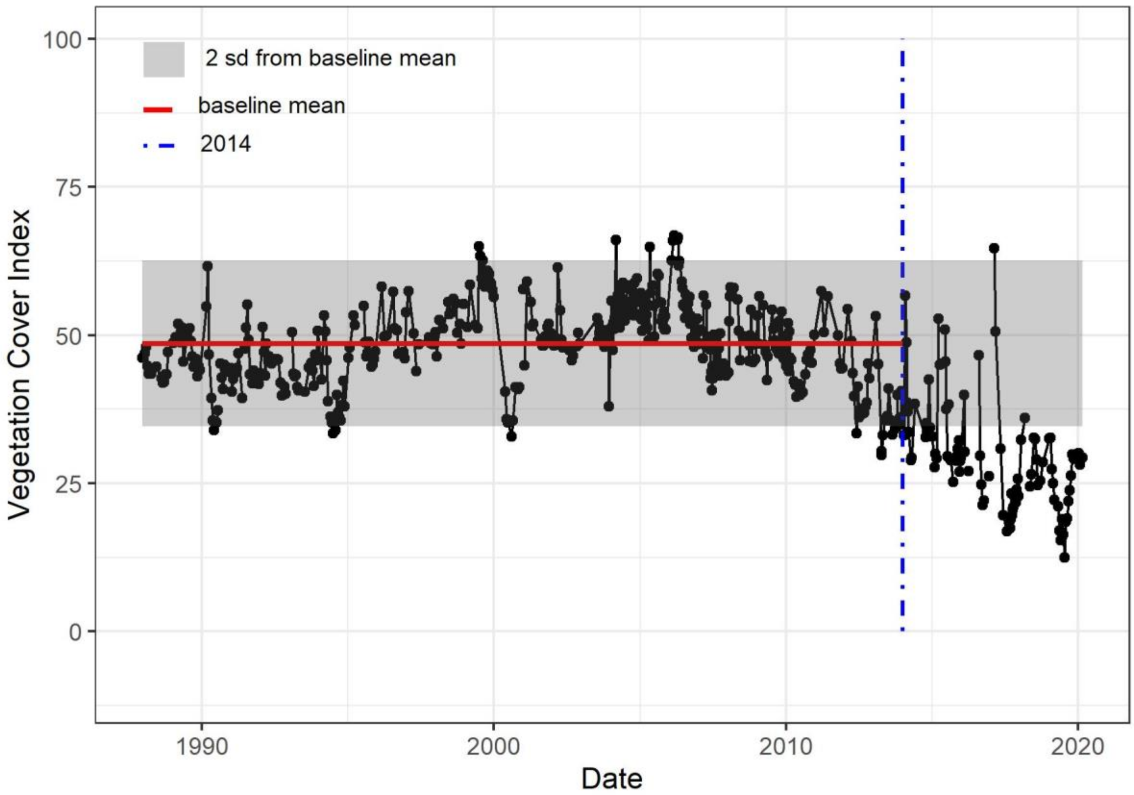
Site YESG14

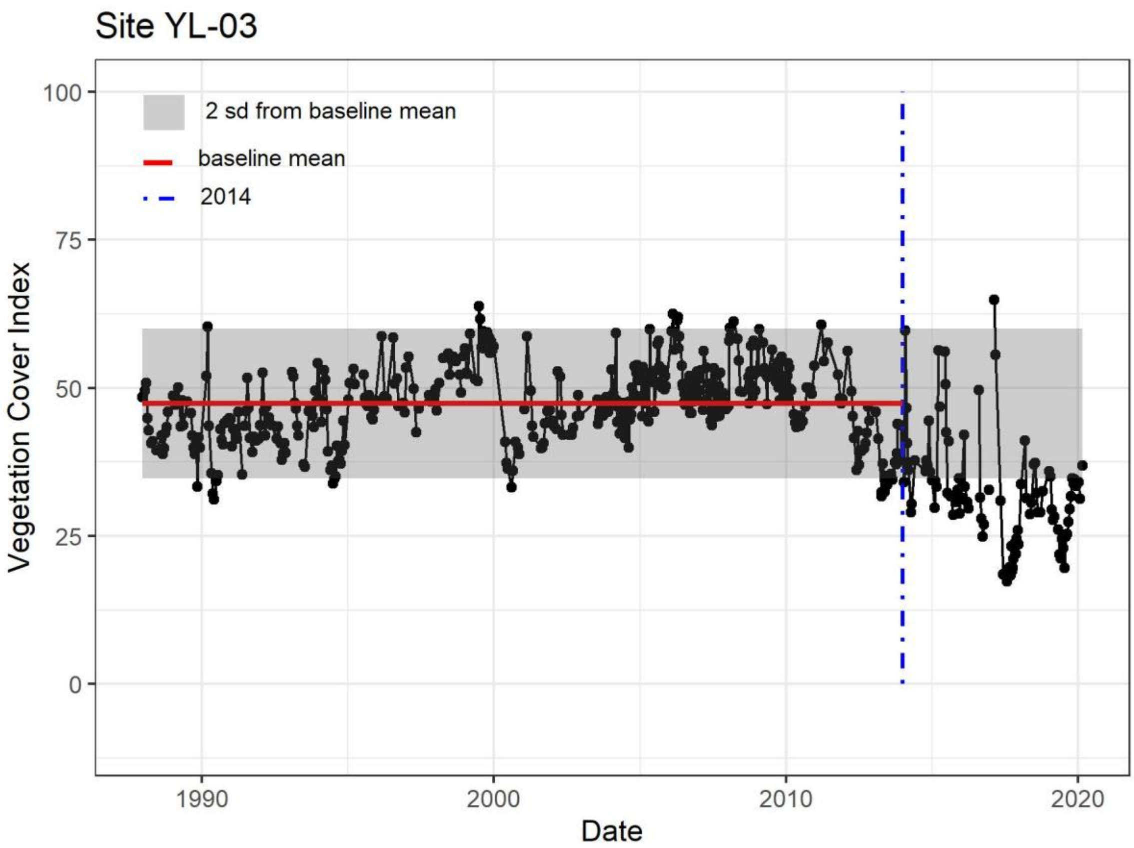


Site YL-01

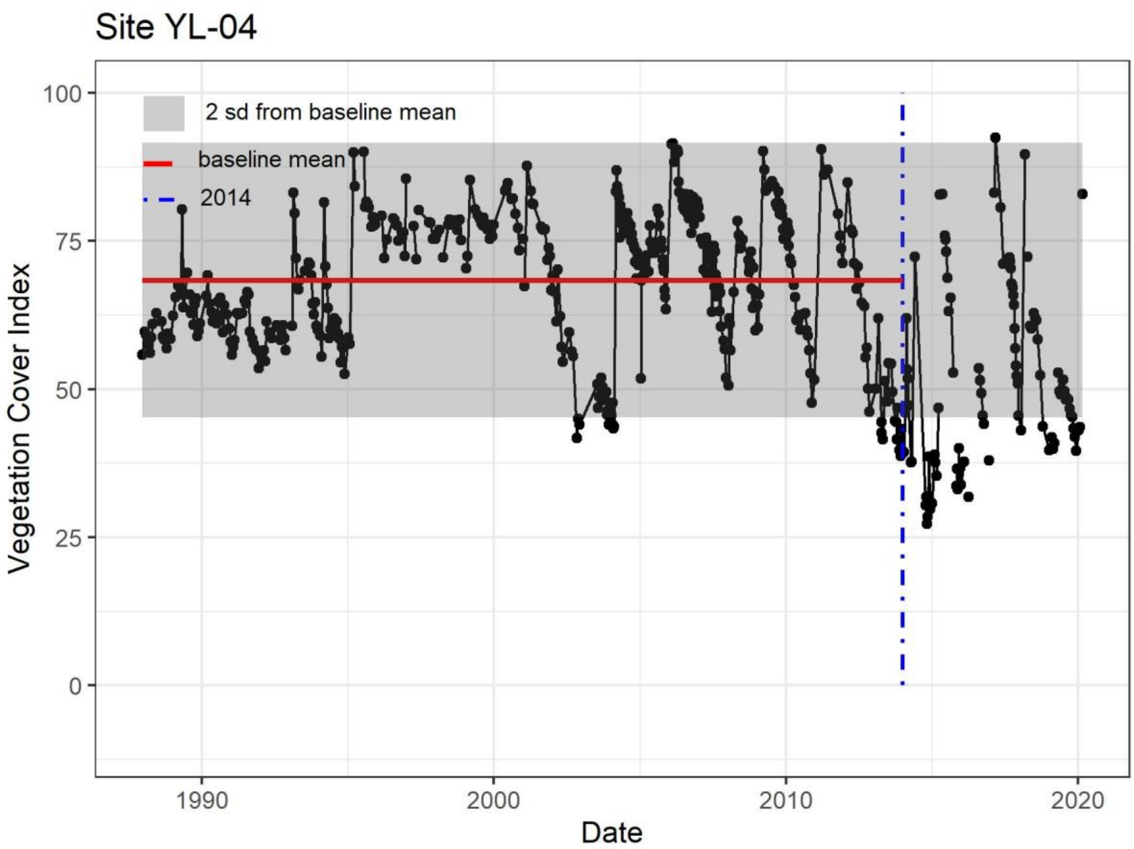


Site YL-02

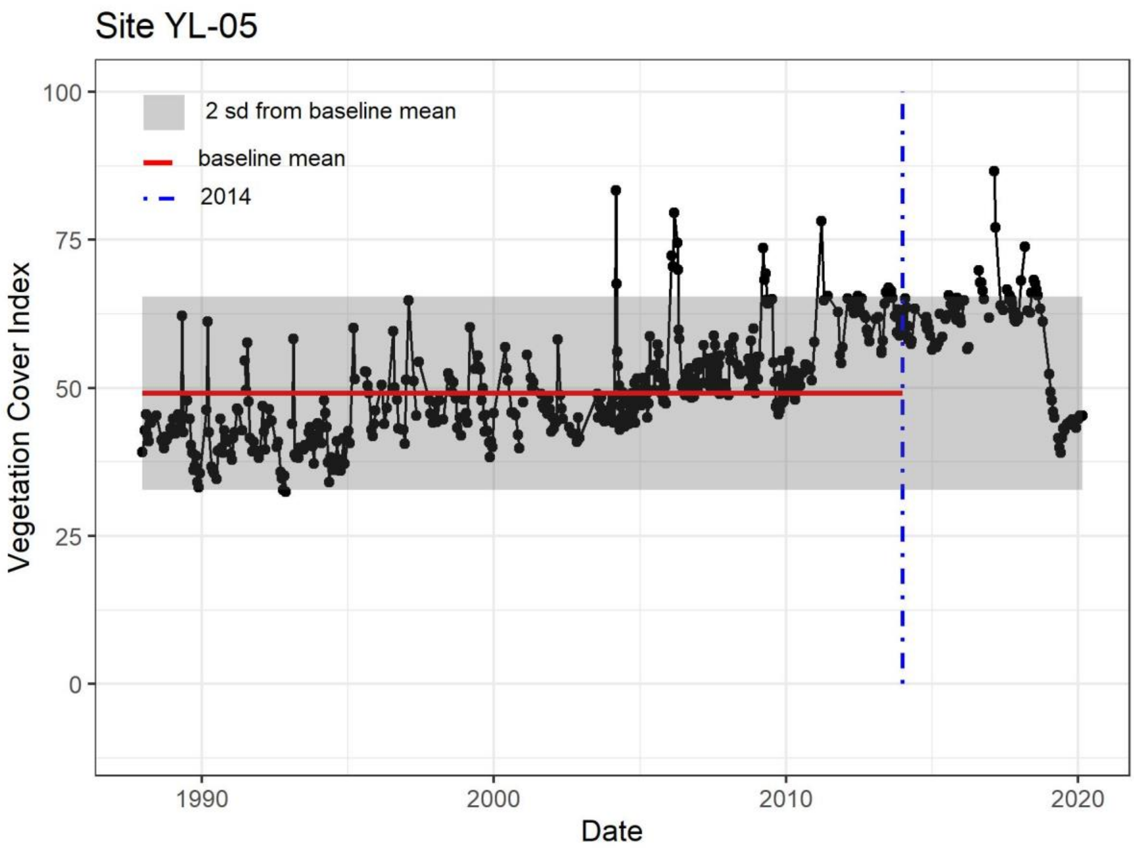


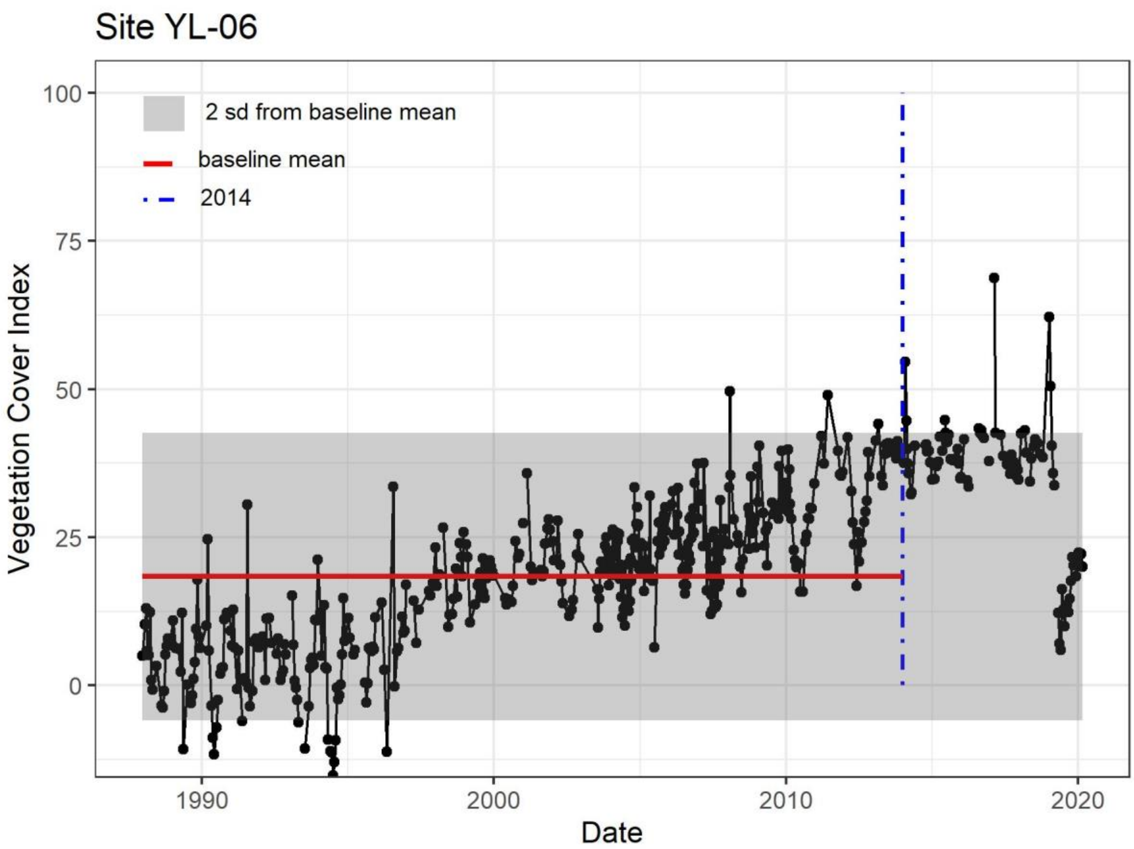


Site YL-03
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

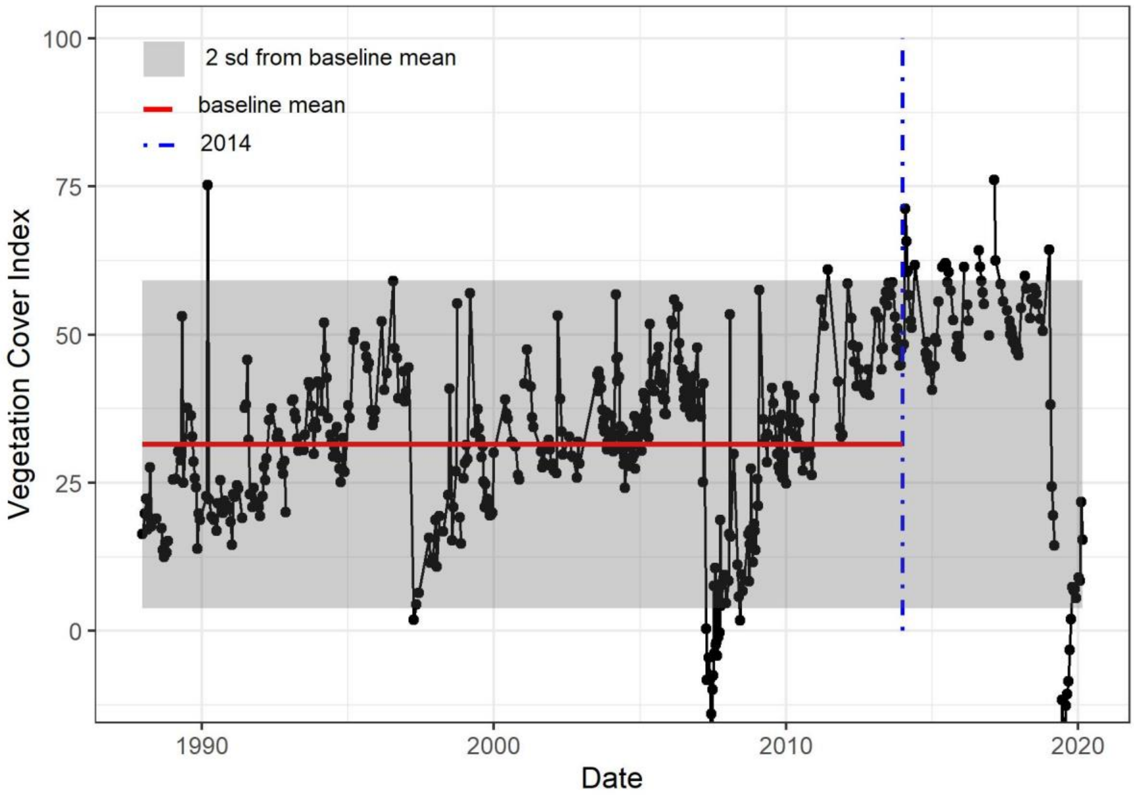


Site YL-04
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

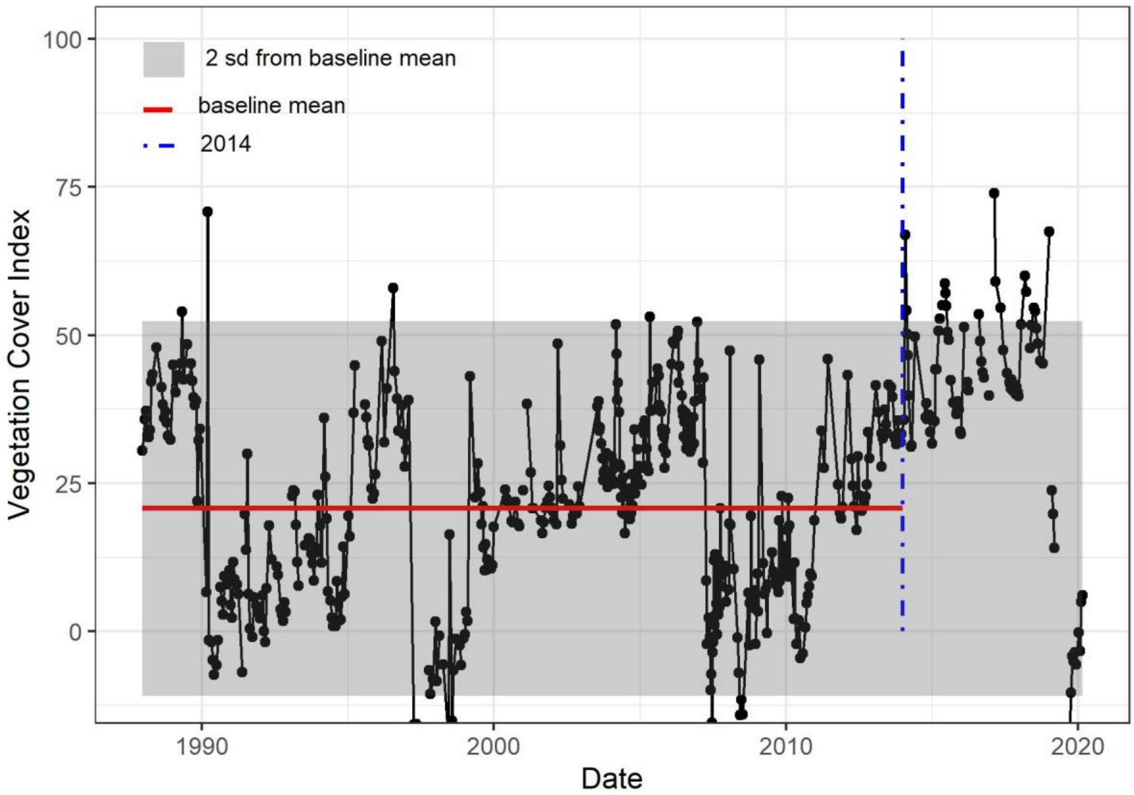

Site YL-05
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

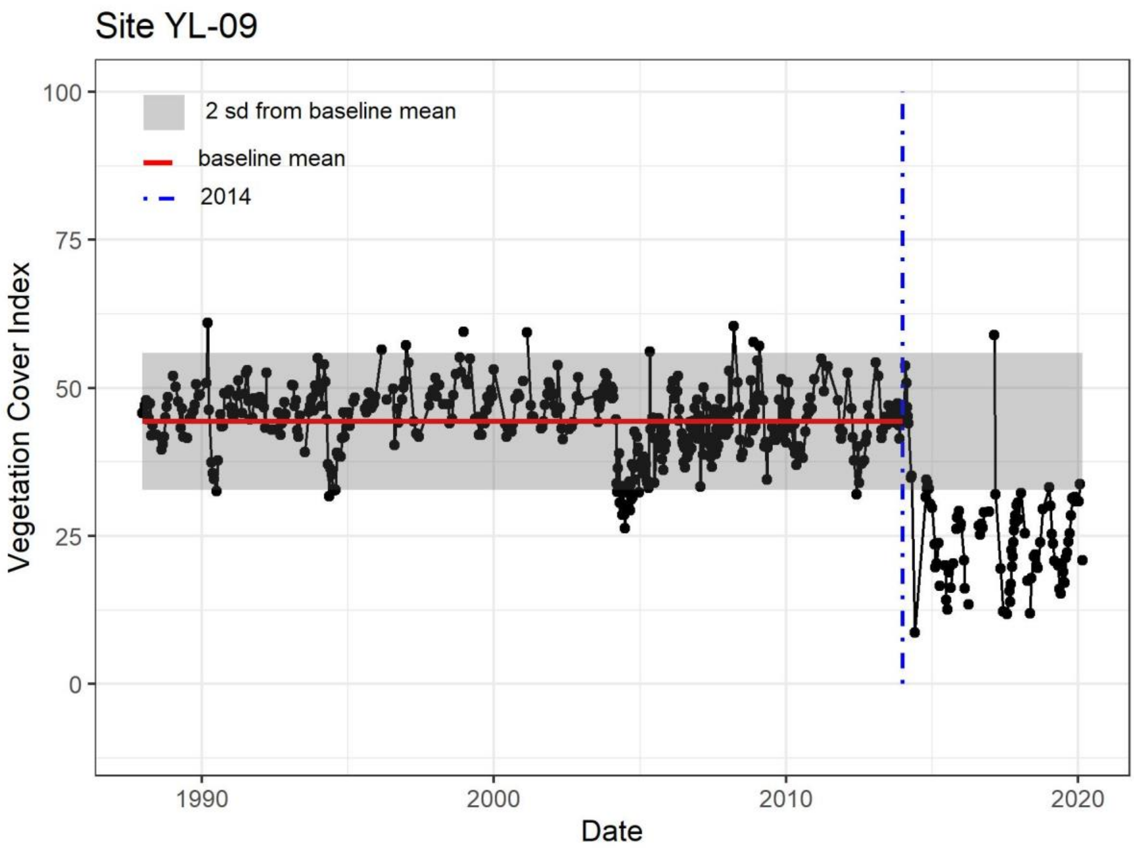

Site YL-06
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

Site YL-07



Site YL-08




Site YL-09
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
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50
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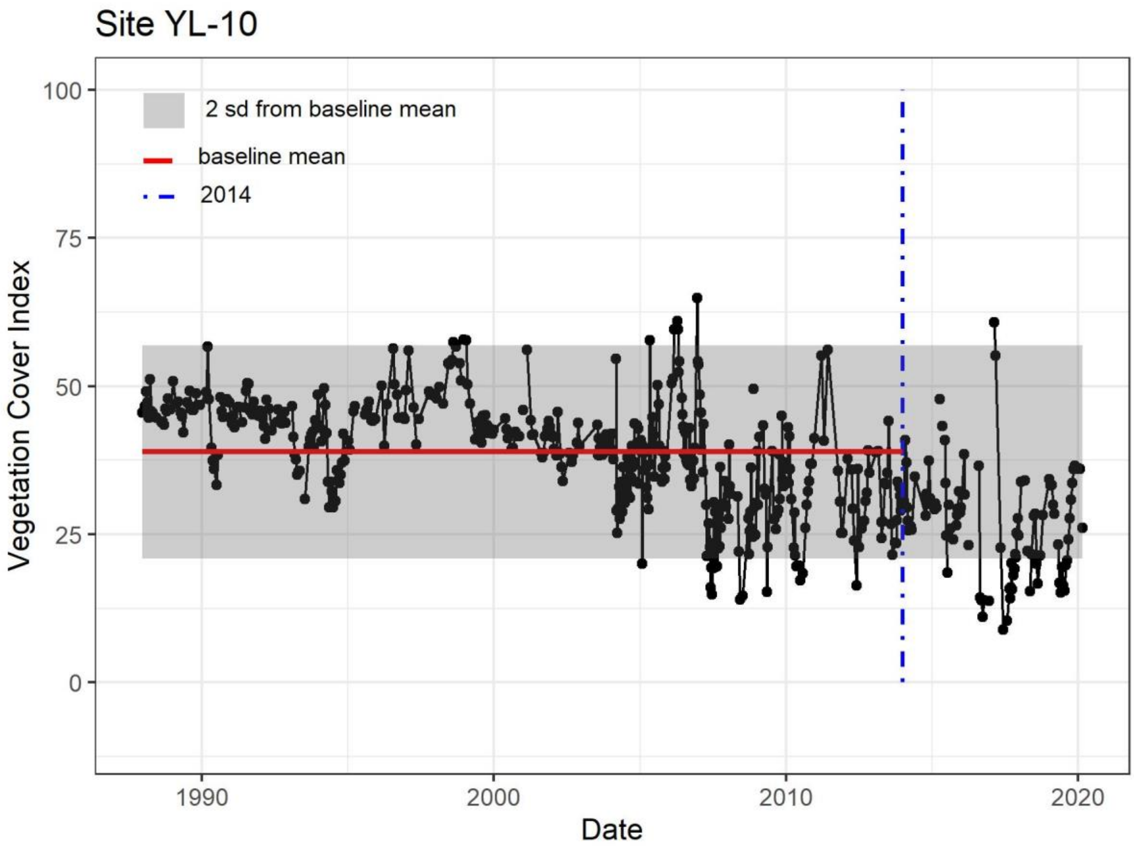
0
1990
2000
2010
2020
Date


Site YL-10
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
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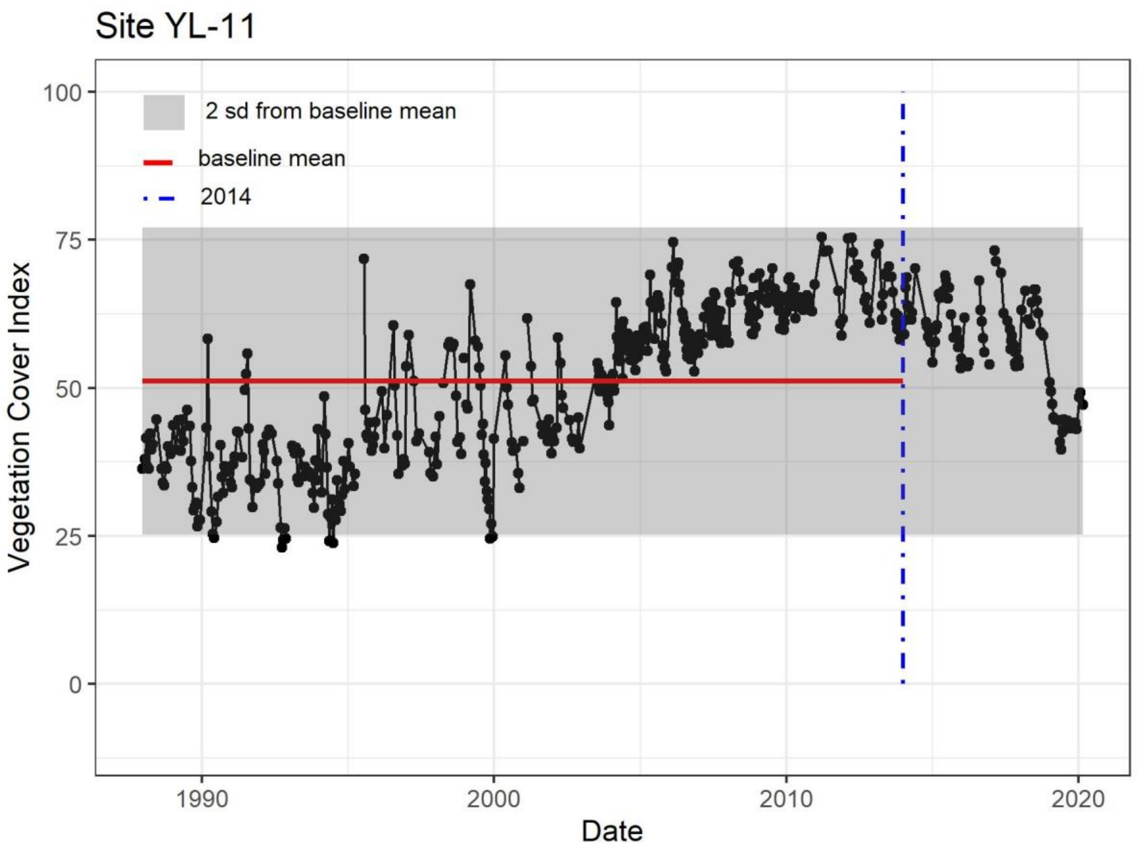
50
25
0
1990
2000
2010
2020
Date


Site YL-11
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
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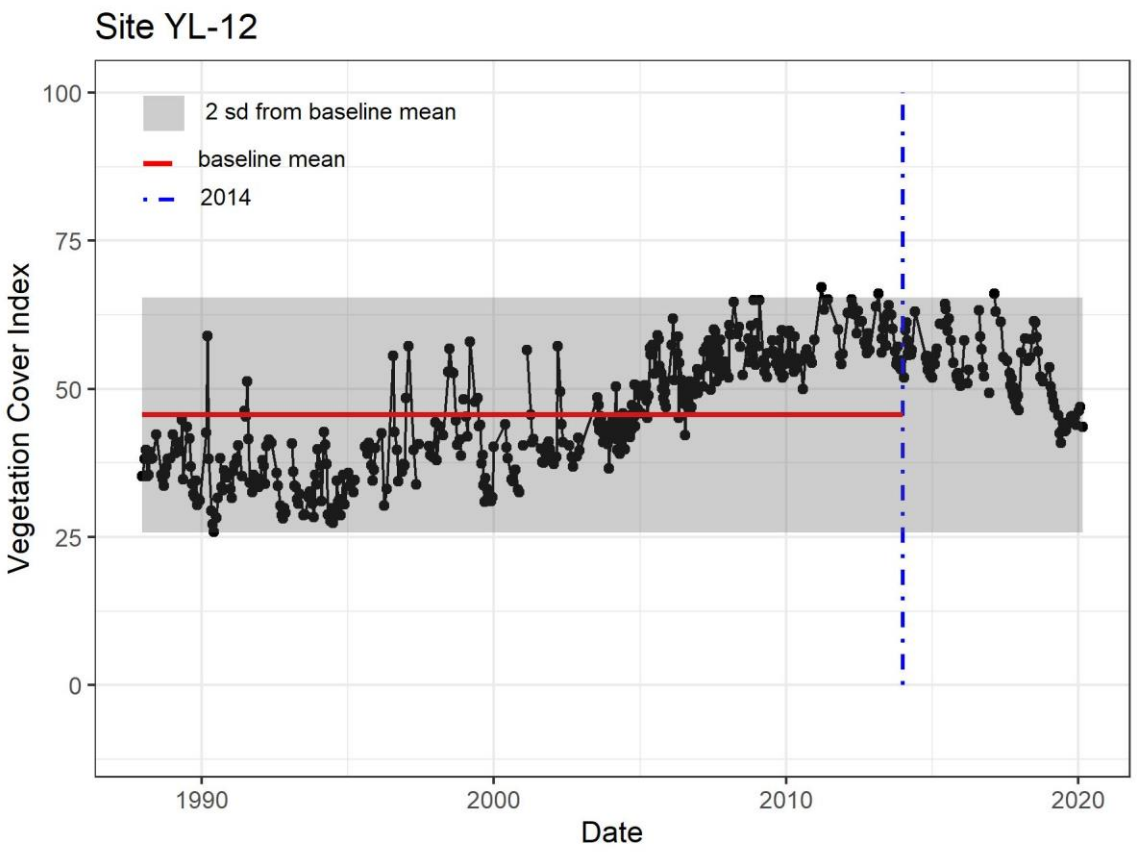
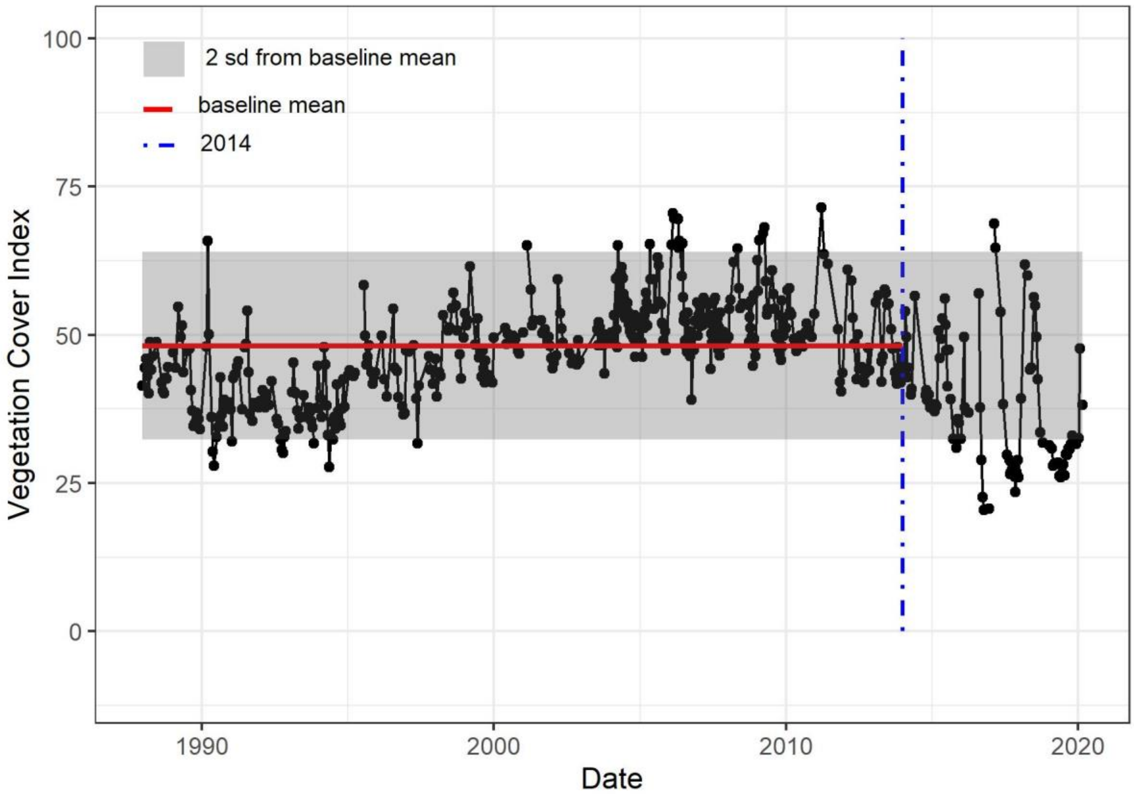
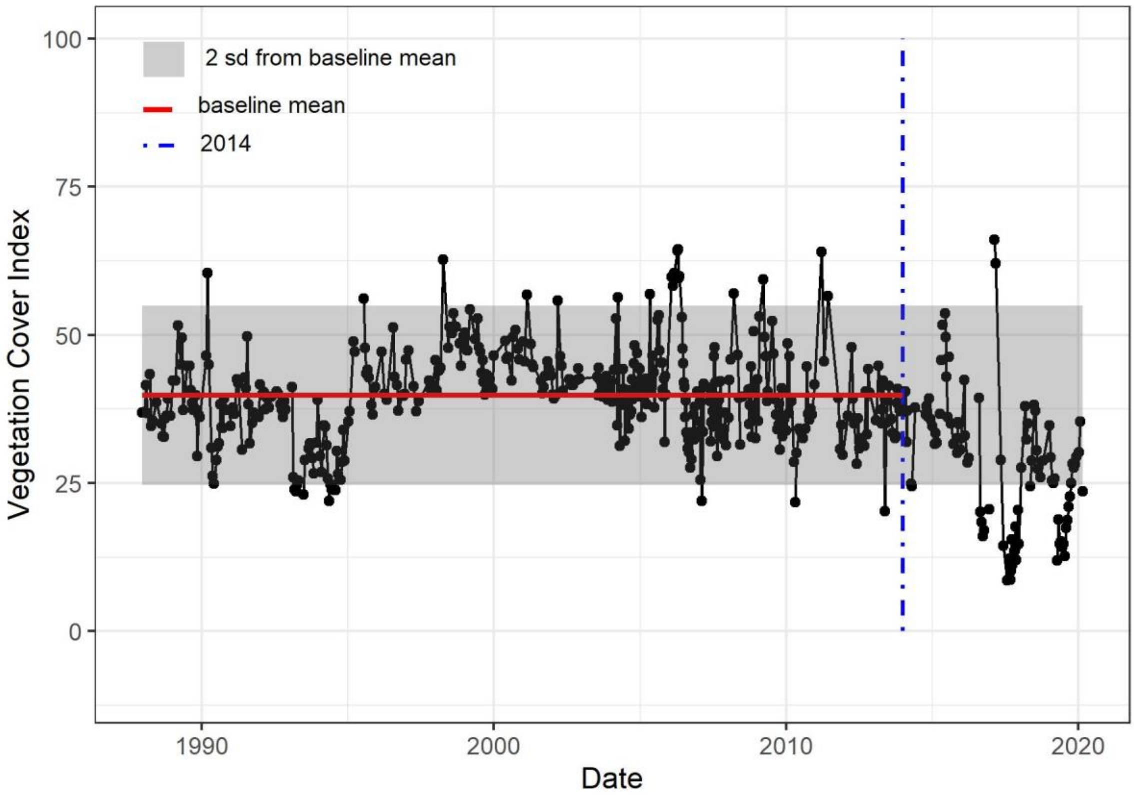
0
1990
2000
2010
2020
Date

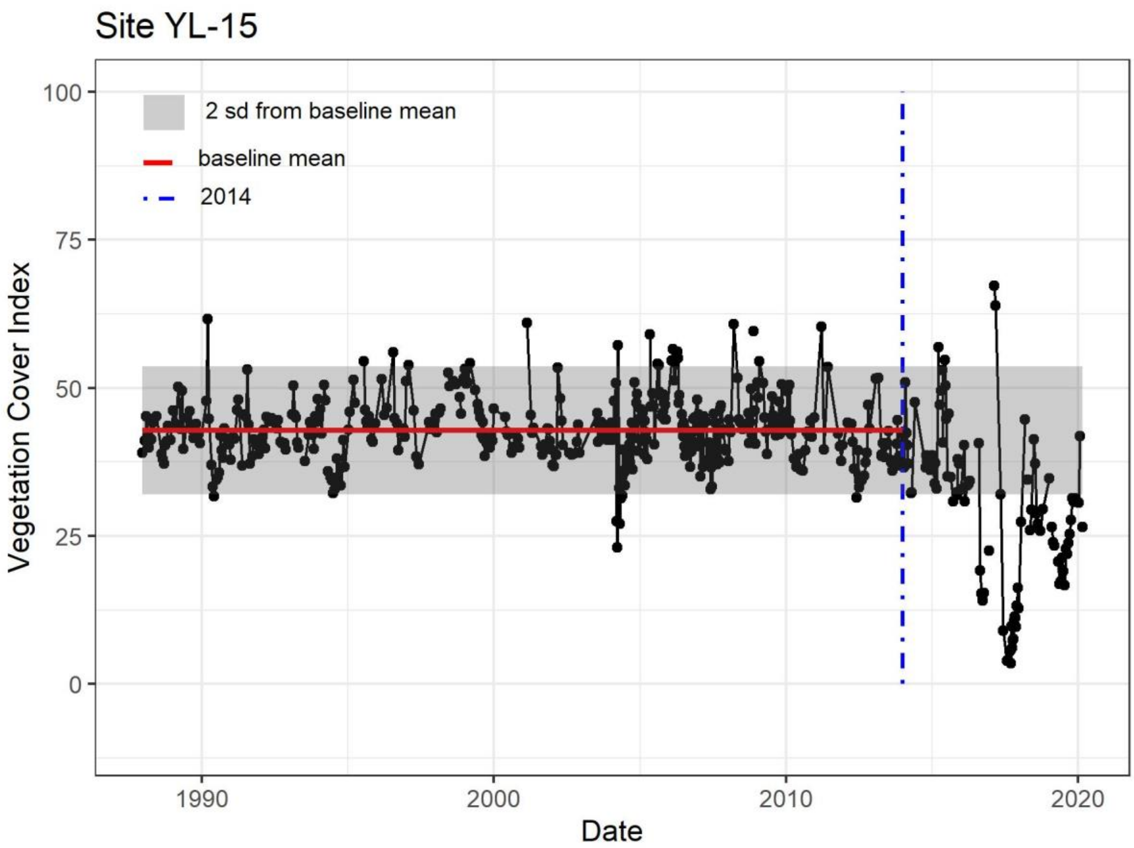

Site YL-12
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

Site YL-13



Site YL-14




Site YL-15
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
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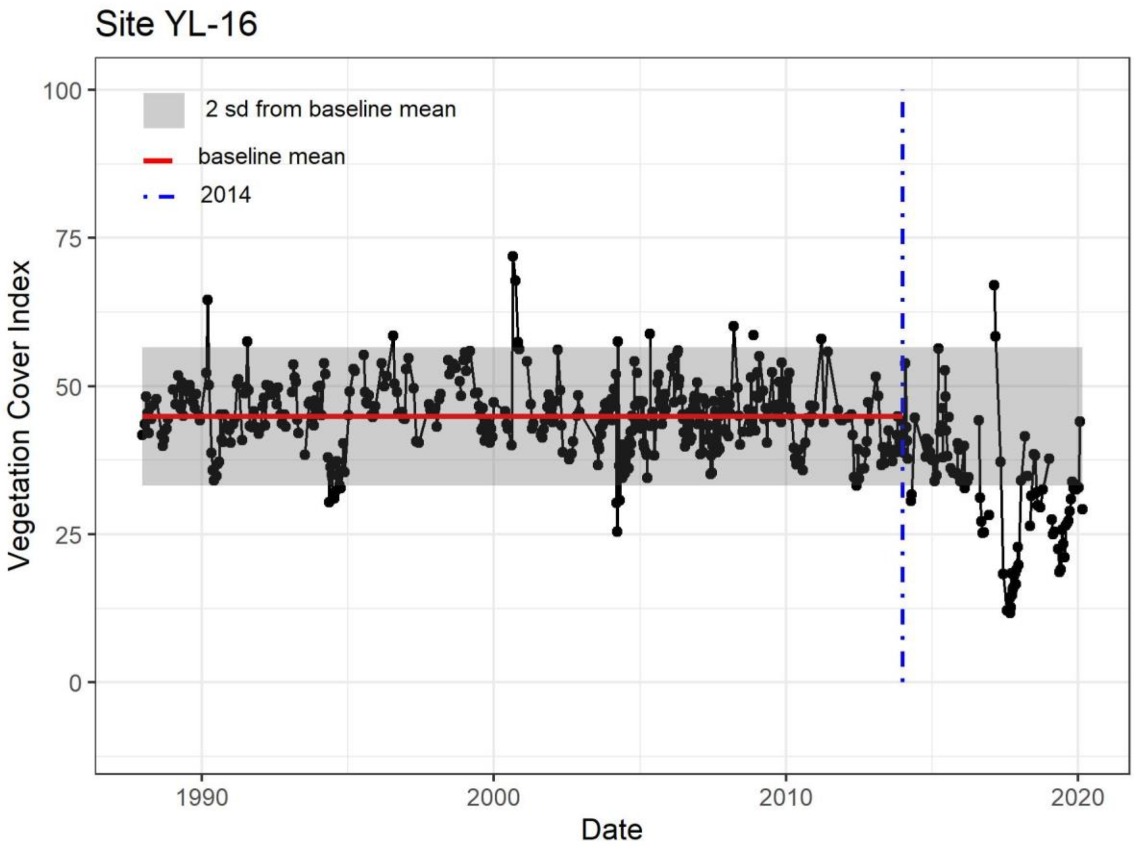
25
0
1990
2000
2010
2020
Date


Site YL-16
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
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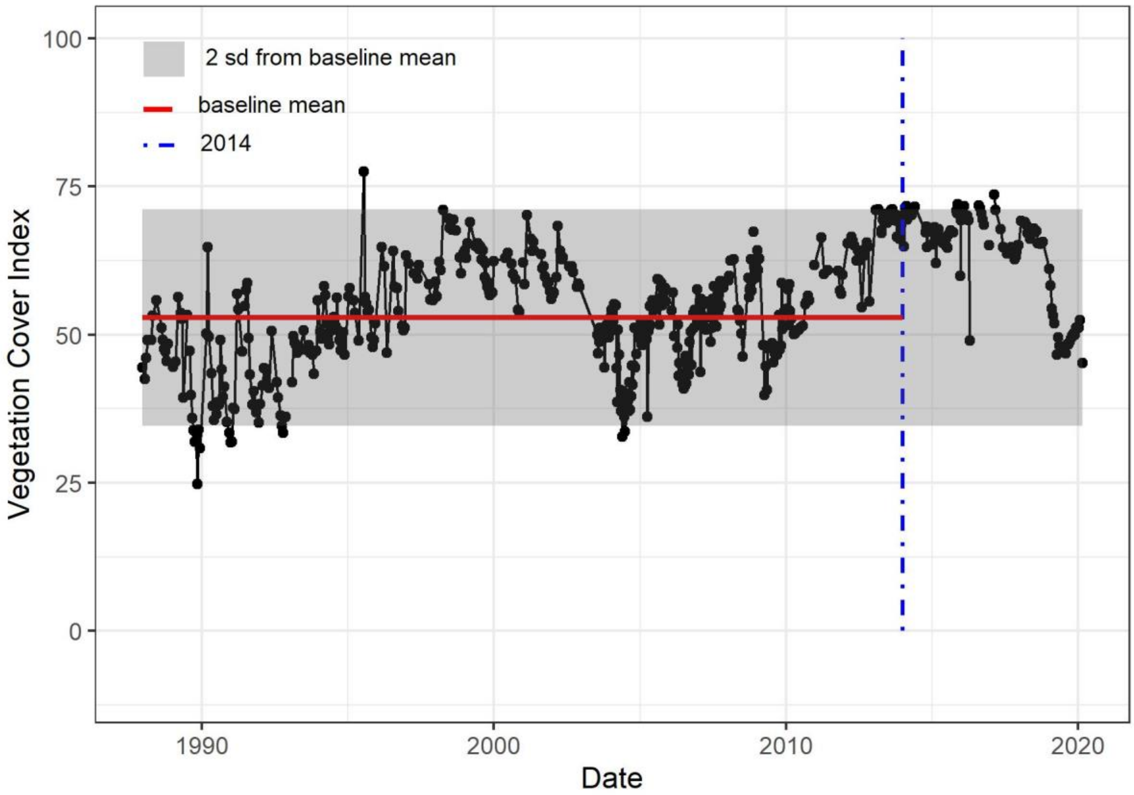
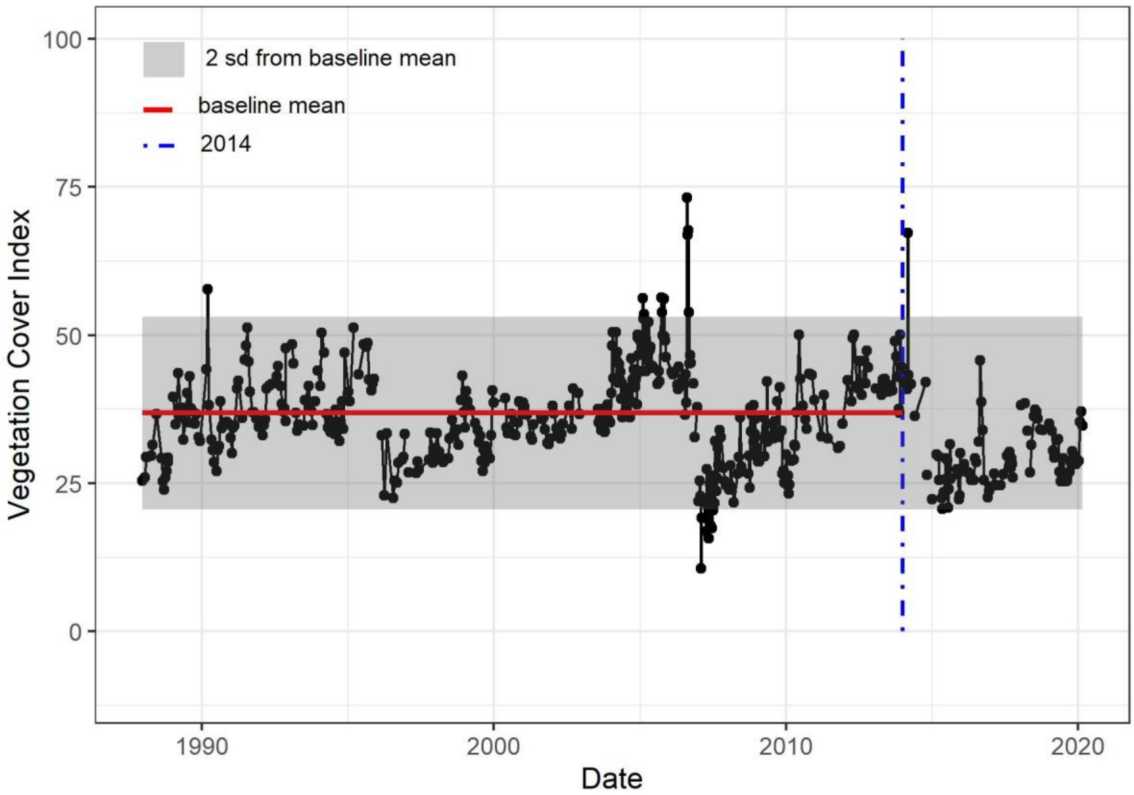
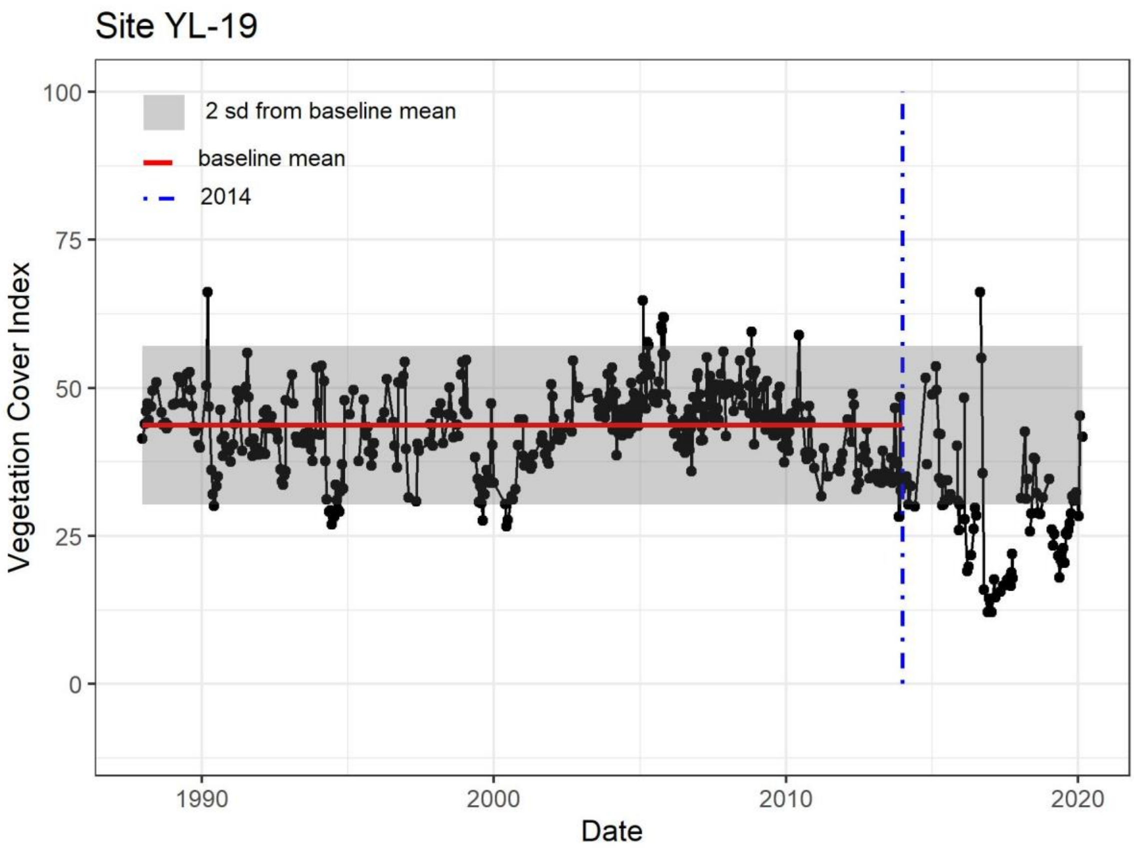
50
25
0
1990
2000
2010
2020
Date

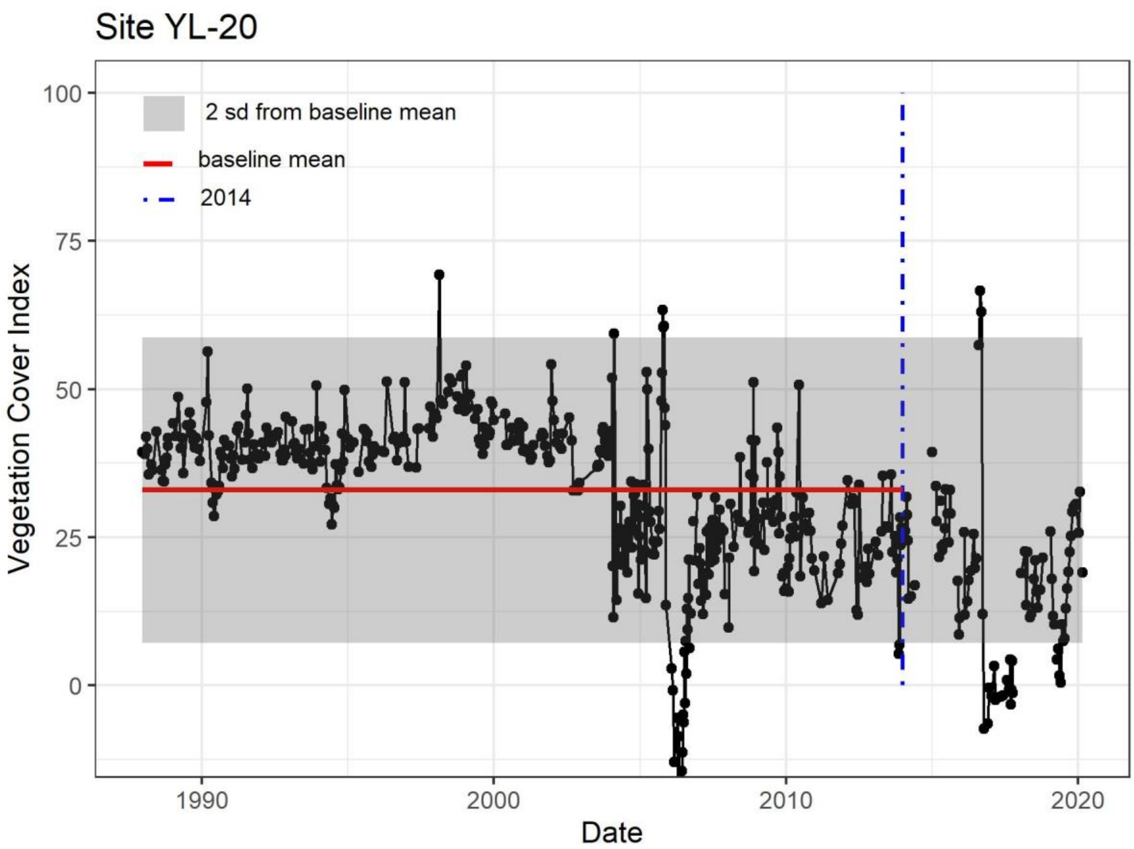
Site YL-17

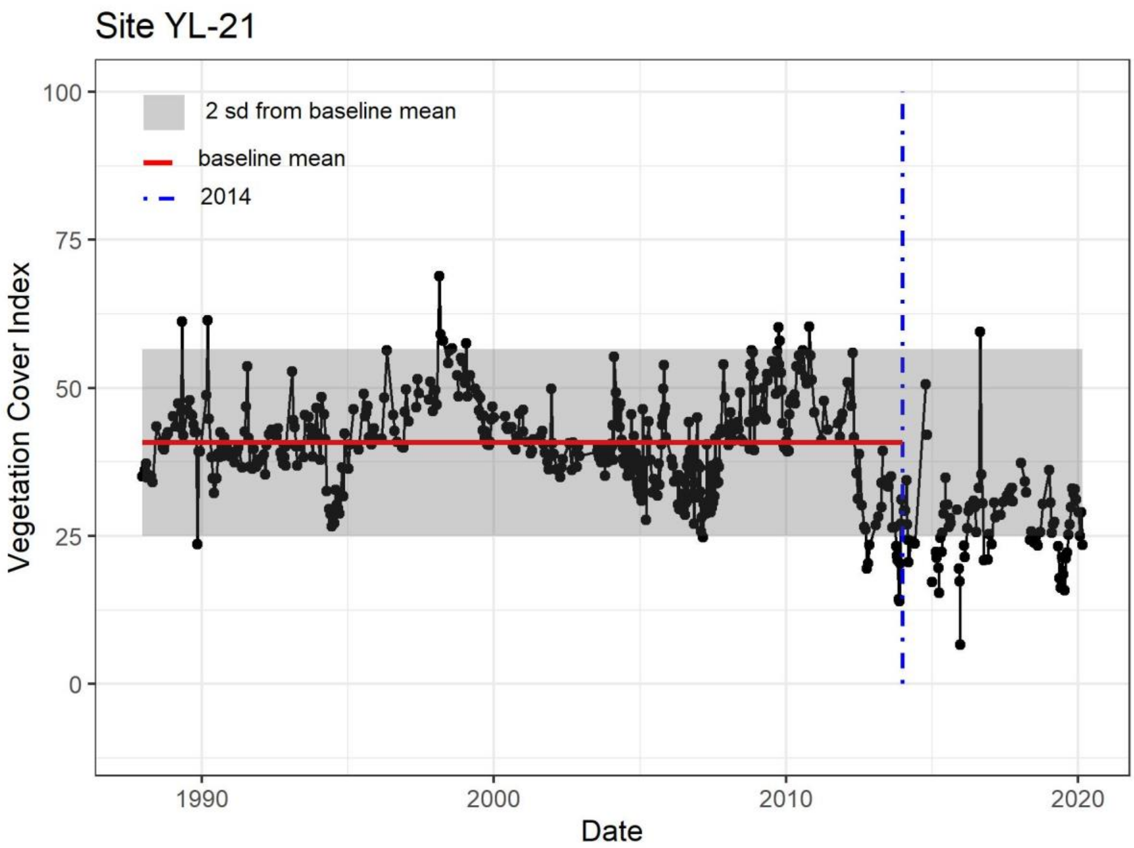


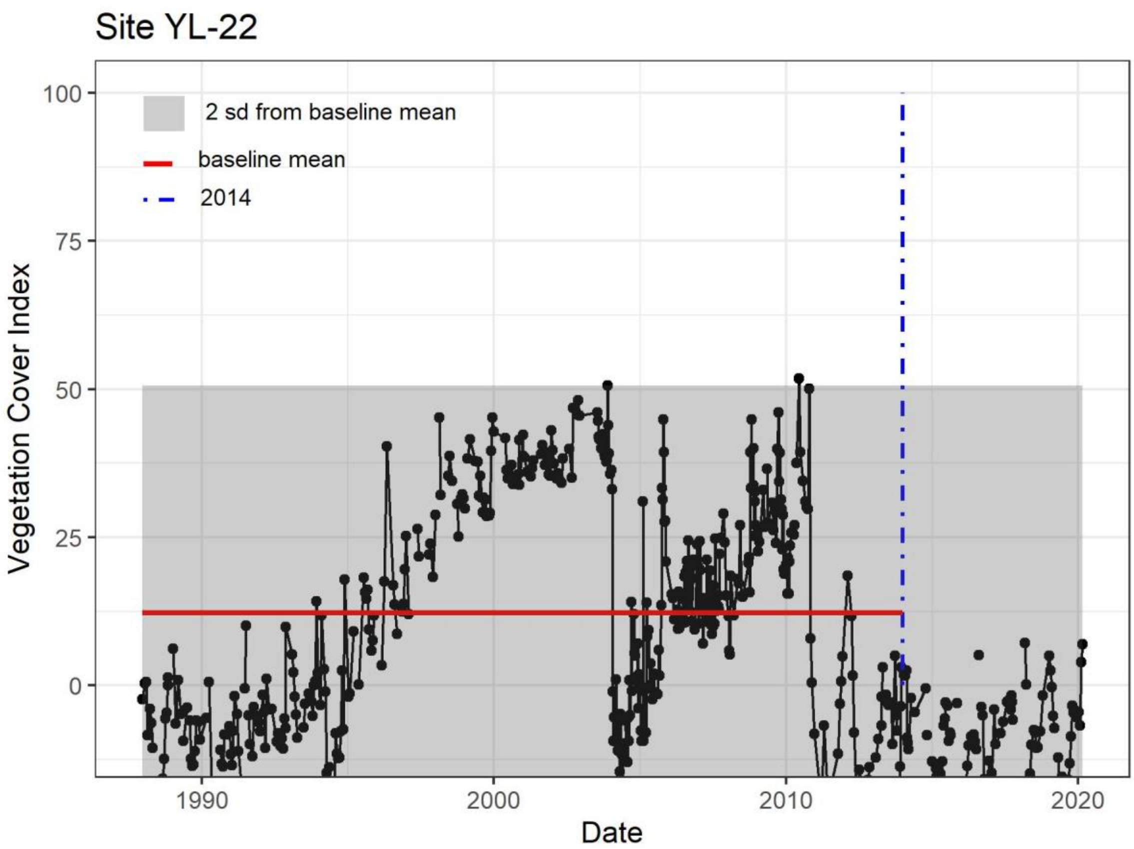
Site YL-18

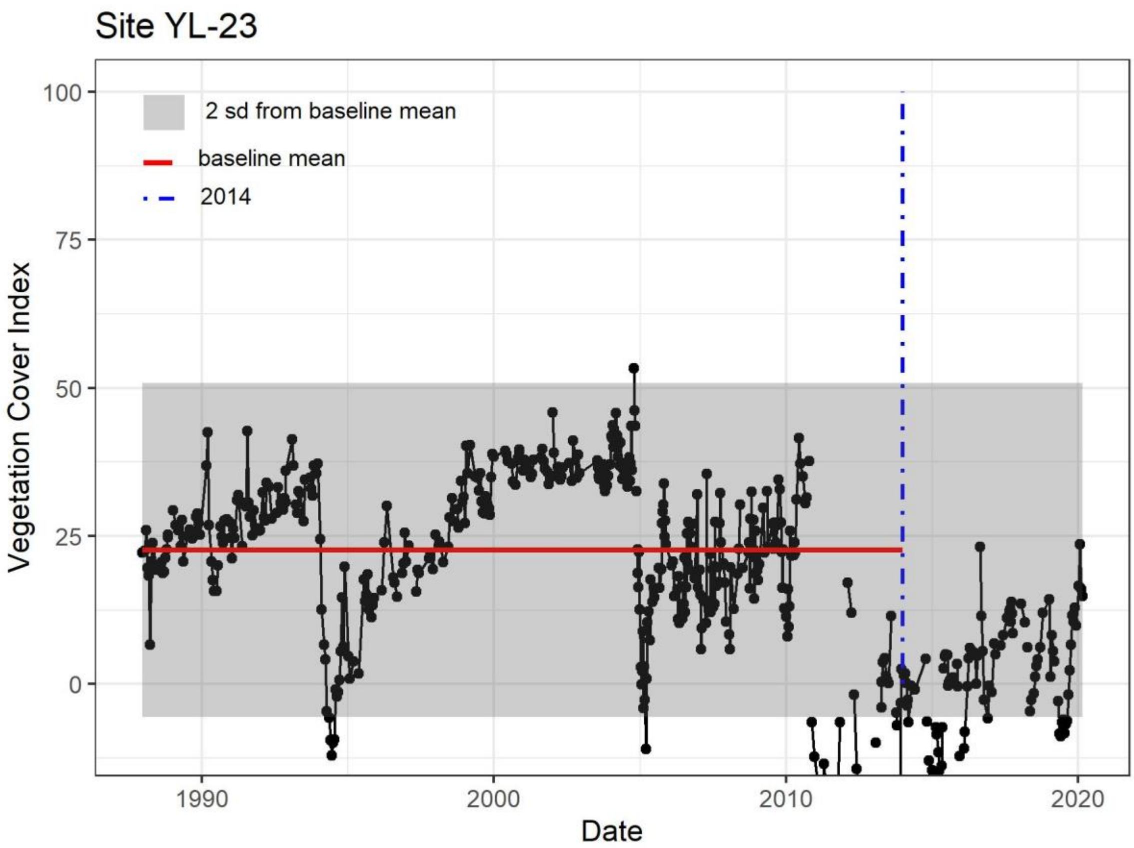



Site YL-19
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

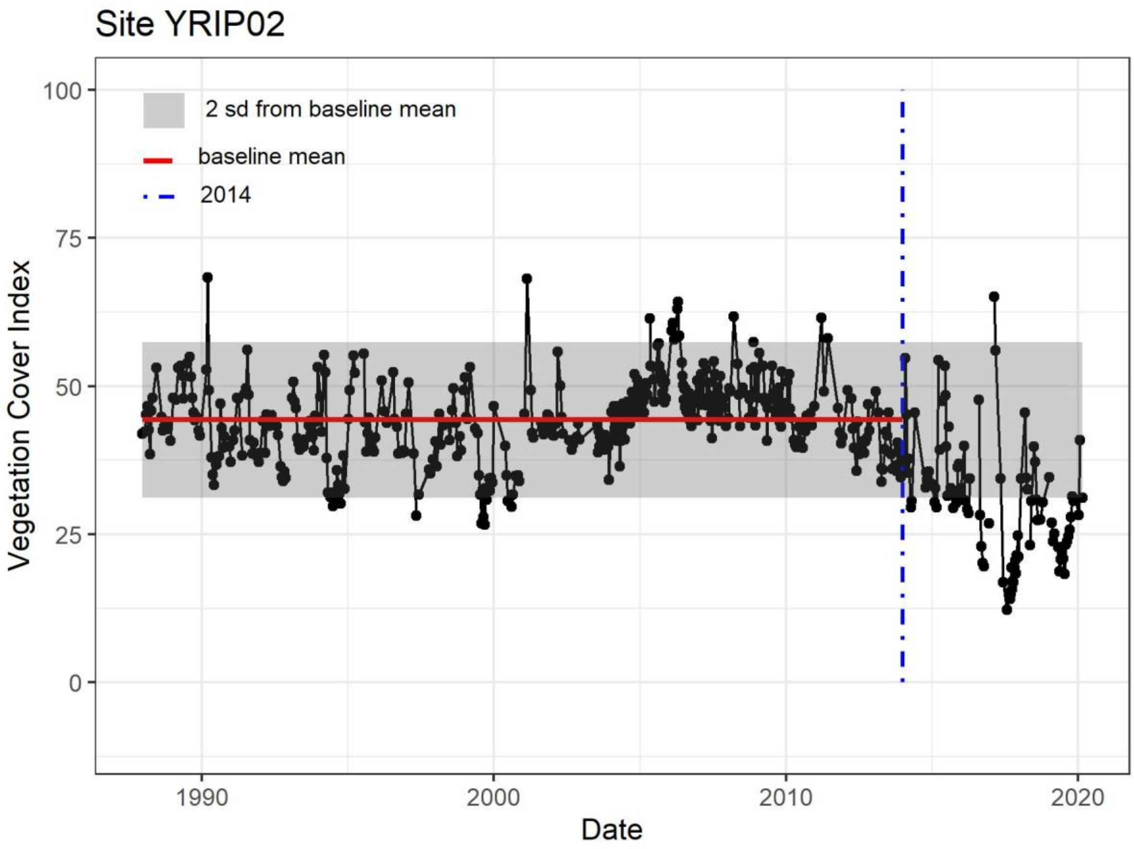

Site YL-20
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date


Site YL-21
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

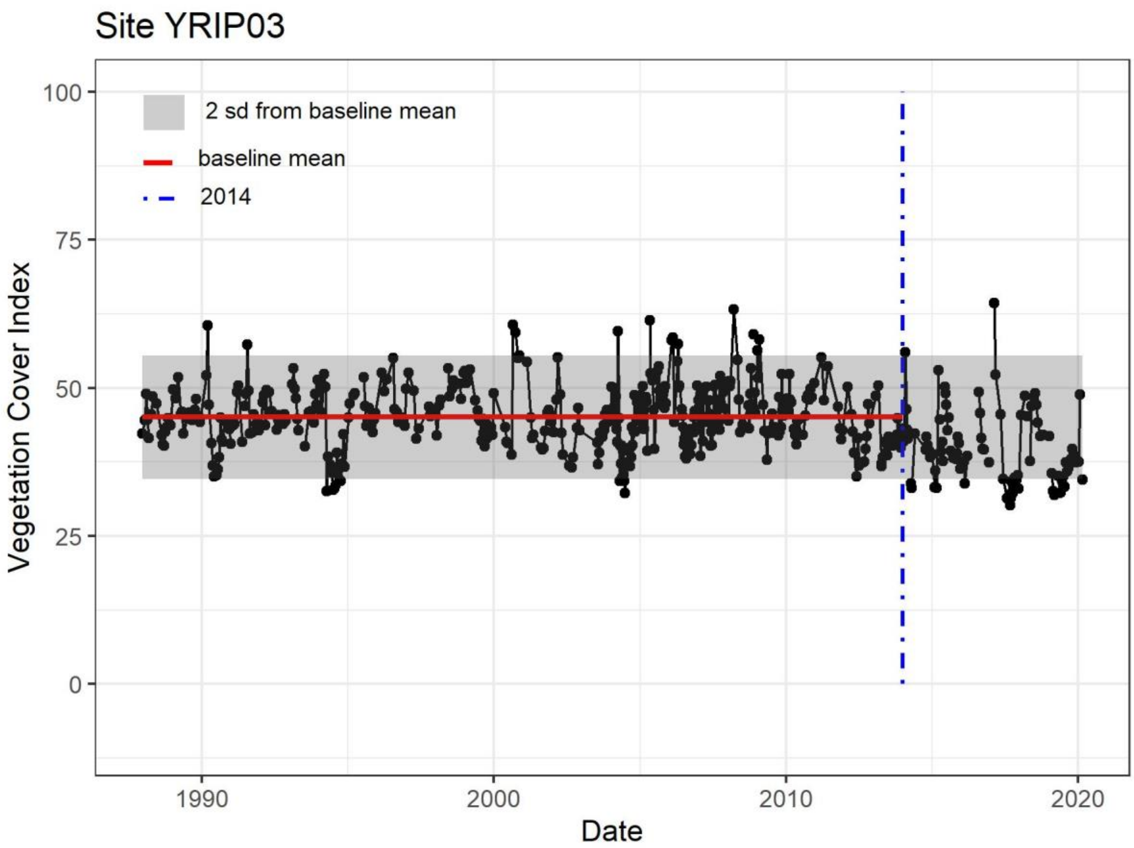

Site YL-22
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date



Site YL-23
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date



Site YRIP02
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date


Site YRIP03
2 sd from baseline mean
baseline mean
2014
Vegetation Cover Index
100
75
50
25
0
1990
2000
2010
2020
Date

3 References

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