



# Supplementary Materials: Spatiotemporal Characteristics of Droughts and Their Propagation during the Past 67 Years in Northern Thailand

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**Table S1.** the drought propagation ratios in the study period. (The first row is the result calculated from the original formula of drought propagation ratios in Apurv et al. (2017); the second row is the result calculated from the formula herein proposed by the authors)

Propagation Ratio	Duration	Area	Severity
Original Formula	1.00	1.02	1.06
New Formula	0.94	0.83	0.92

**Table S2.** The historical meteorological droughts in the study period. (MNo refers to the code of meteorological droughts.T refers to return period and the unit is year.)

MNo	T <sub>Duration</sub>	T <sub>Area</sub>	T <sub>Severity</sub>	T <sub>A-S</sub>	T <sub>S-D</sub>	T <sub>D-A</sub>	T <sub>D-A-S</sub>	Duration (month)	Area (km <sup>2</sup> )	Severity (km <sup>2</sup> month)	Begin	Finish
1	8	4	3	8	8	4	9	6	2.00×10 <sup>5</sup>	9.15×10 <sup>6</sup>	Januray 1948	June 1948
2	51	47	72	51	72	72	112	9	3.66×10 <sup>5</sup>	4.98×10 <sup>7</sup>	October 1948	June 1949
3	10	38	43	38	43	43	75	6	3.61×10 <sup>5</sup>	3.98×10 <sup>7</sup>	Decembe r 1949	May 1950
4	3	17	14	17	14	17	28	5	3.26×10 <sup>5</sup>	2.32×10 <sup>7</sup>	Decembe r 1950	April 1951
5	1	1	1	1	1	1	1	3	3.38×10 <sup>4</sup>	1.99×10 <sup>6</sup>	Januray 1951	March 1951
6	8	3	4	8	8	4	9	6	1.53×10 <sup>5</sup>	1.09×10 <sup>7</sup>	Decembe r 1951	May 1952
7	1	1	1	1	1	1	2	3	6.56×10 <sup>4</sup>	3.01×10 <sup>6</sup>	July 1953	September 1953
8	3	2	3	3	3	3	4	5	1.08×10 <sup>5</sup>	7.78×10 <sup>6</sup>	Febrary 1954	June 1954
9	6	7	8	7	8	8	9	6	2.49×10 <sup>5</sup>	1.67×10 <sup>7</sup>	August 1954	Janurary 1955
10	2	2	2	2	2	2	2	4	1.13×10 <sup>5</sup>	5.53×10 <sup>6</sup>	July 1955	October 1955
11	1	1	1	1	1	1	1	3	2.75×10 <sup>4</sup>	1.17×10 <sup>6</sup>	Septemb er 1955	November 1955
12	2	3	2	3	2	3	3	4	1.50×10 <sup>5</sup>	6.04×10 <sup>6</sup>	August 1958	November 1958
13	1	1	1	1	1	1	1	3	5.44×10 <sup>4</sup>	2.18×10 <sup>6</sup>	April 1959	June 1959
14	1	1	1	1	1	1	1	3	3.56×10 <sup>4</sup>	1.45×10 <sup>6</sup>	Febrary 1960	April 1960

15	2	1	1	2	2	1	2	4	$5.19 \times 10^4$	$2.65 \times 10^6$	March 1960	June 1960
16	1	1	1	1	1	1	1	3	$1.88 \times 10^4$	$9.72 \times 10^5$	March 1963	May 1963
17	1	1	1	1	1	1	1	3	$3.81 \times 10^4$	$1.91 \times 10^6$	March 1963	May 1963
18	1	1	1	1	1	1	1	3	$3.88 \times 10^4$	$2.06 \times 10^6$	July 1965	September 1965
19	1	2	2	2	2	2	2	3	$9.94 \times 10^4$	$4.13 \times 10^6$	Januray 1967	March 1967
20	6	2	2	6	6	2	7	6	$1.13 \times 10^5$	$6.33 \times 10^6$	August 1967	Januray 1968
21	2	4	3	4	3	4	4	4	$1.79 \times 10^5$	$9.36 \times 10^6$	July 1968	October 1968
22	2	2	1	2	2	2	2	3	$7.63 \times 10^4$	$2.78 \times 10^6$	Decembe r 1969	Febrary 1970
23	2	5	3	5	3	5	6	4	$2.09 \times 10^5$	$8.80 \times 10^6$	Septemb er 1971	December 1971
24	4	4	5	4	5	5	5	5	$1.84 \times 10^5$	$1.32 \times 10^7$	Decembe r 1972	April 1973
25	2	13	4	13	4	13	16	3	$3.08 \times 10^5$	$1.04 \times 10^7$	October 1973	December 1973
26	1	2	1	2	1	2	2	3	$9.31 \times 10^4$	$3.23 \times 10^6$	May 1974	July 1974
27	15	6	12	15	15	12	19	7	$2.39 \times 10^5$	$2.20 \times 10^7$	Decembe r 1976	June 1977
28	4	1	1	4	4	1	5	5	$5.38 \times 10^4$	$2.94 \times 10^6$	May 1977	September 1977
29	1	1	1	1	1	1	1	3	$3.19 \times 10^4$	$1.53 \times 10^6$	August 1977	October 1977
30	2	2	2	2	2	2	2	3	$8.88 \times 10^4$	$3.40 \times 10^6$	Januray 1979	March 1979
31	76	133	58	133	76	133	157	10	$3.76 \times 10^5$	$4.56 \times 10^7$	June 1979	March 1980
32	1	2	2	2	2	2	2	3	$8.94 \times 10^4$	$3.45 \times 10^6$	July 1981	September 1981

33	4	7	5	7	5	7	7	5	$2.45 \times 10^5$	$1.17 \times 10^7$	Januray 1983	May 1983
34	3	1	1	3	3	1	3	4	$3.50 \times 10^4$	$2.10 \times 10^6$	March 1983	June 1983
35	1	1	1	1	1	1	1	3	$6.06 \times 10^4$	$3.11 \times 10^6$	Decembe r 1985	Febrary 1986
36	3	4	3	4	3	4	4	4	$1.79 \times 10^5$	$7.69 \times 10^6$	Decembe r 1985	March 1986
37	1	1	1	1	1	1	1	3	$5.88 \times 10^4$	$2.56 \times 10^6$	June 1986	August 1986
38	1	2	2	2	2	2	3	3	$1.24 \times 10^5$	$4.32 \times 10^6$	July 1986	September 1986
39	1	1	1	1	1	1	1	3	$6.88 \times 10^4$	$2.12 \times 10^6$	May 1987	July 1987
40	2	1	1	2	2	1	2	3	$5.81 \times 10^4$	$1.92 \times 10^6$	June 1989	August 1989
41	1	1	1	1	1	1	1	3	$3.25 \times 10^4$	$1.50 \times 10^6$	May 1990	July 1990
42	2	16	14	16	14	16	26	4	$3.24 \times 10^5$	$2.38 \times 10^7$	Febrary 1992	May 1992
43	1	2	1	2	1	2	2	3	$8.69 \times 10^4$	$3.28 \times 10^6$	April 1993	June 1993
44	6	1	2	6	6	2	7	6	$6.88 \times 10^4$	$3.74 \times 10^6$	May 1993	October 1993
45	3	3	3	3	3	3	3	5	$1.64 \times 10^5$	$8.64 \times 10^6$	August 1993	December 1993
46	9	5	5	9	9	5	13	6	$2.24 \times 10^5$	$1.22 \times 10^7$	April 1997	September 1997
47	2	1	1	2	2	1	2	3	$2.88 \times 10^4$	$1.37 \times 10^6$	Febrary 1998	April 1998
48	58	2	3	59	59	3	67	9	$7.25 \times 10^4$	$7.71 \times 10^6$	Febrary 1998	October 1998
49	3	2	2	3	3	2	6	4	$9.38 \times 10^4$	$5.76 \times 10^6$	May 1998	August 1998
50	1	1	1	1	1	1	1	3	$3.50 \times 10^4$	$1.41 \times 10^6$	July 2000	September 2000
51	1	1	1	2	2	1	2	3	$5.75 \times 10^4$	$1.88 \times 10^6$	June 2001	August 2001

52	12	3	6	14	15	6	16	7	$1.43 \times 10^5$	$1.43 \times 10^7$	August 2003	February 2004
53	1	2	1	3	2	2	4	3	$1.18 \times 10^5$	$3.33 \times 10^6$	September 2003	November 2003
54	6	2	2	7	7	2	8	6	$7.38 \times 10^4$	$4.87 \times 10^6$	October 2003	March 2004
55	7	32	22	37	24	33	66	6	$3.56 \times 10^5$	$2.92 \times 10^7$	July 2004	December 2004
56	8	15	15	21	19	18	42	6	$3.18 \times 10^5$	$2.46 \times 10^7$	September 2006	February 2007
57	2	1	1	2	2	1	2	4	$4.50 \times 10^4$	$2.17 \times 10^6$	June 2007	September 2007
58	1	1	1	1	1	1	2	3	$2.75 \times 10^4$	$1.35 \times 10^6$	July 2007	September 2007
59	3	6	5	8	6	6	9	4	$2.37 \times 10^5$	$1.18 \times 10^7$	October 2007	January 2008
60	1	2	2	2	2	2	3	3	$1.12 \times 10^5$	$5.33 \times 10^6$	November 2008	January 2009
61	2	2	3	3	4	3	7	4	$1.20 \times 10^5$	$8.62 \times 10^6$	November 2008	February 2009
62	3	2	2	4	3	2	6	4	$1.17 \times 10^5$	$5.54 \times 10^6$	November 2008	February 2009
63	1	2	1	2	1	2	2	3	$7.38 \times 10^4$	$2.09 \times 10^6$	August 2009	October 2009
64	3	9	13	11	13	13	15	5	$2.80 \times 10^5$	$2.22 \times 10^7$	January 2010	May 2010
65	2	2	3	3	3	3	6	4	$1.06 \times 10^5$	$7.10 \times 10^6$	February 2010	May 2010
66	1	1	1	1	1	2	2	3	$6.81 \times 10^4$	$2.75 \times 10^6$	January 2011	March 2011
67	2	3	3	4	4	4	6	4	$1.58 \times 10^5$	$9.28 \times 10^6$	January 2013	April 2013

<b>68</b>	1	1	1	2	2	1	2	3	$6.56 \times 10^4$	$2.63 \times 10^6$	February 2013	April 2013
<b>69</b>	2	3	4	4	5	5	7	4	$1.57 \times 10^5$	$1.14 \times 10^7$	February 2013	May 2013
<b>70</b>	2	2	2	2	2	2	3	4	$8.00 \times 10^4$	$4.68 \times 10^6$	Januray 2014	April 2014

**Table S3.** The historical soil droughts in the study period. (MNo refers to the code of meteorological droughts.T refers to return period and the unit is year.)

SNo	T <sub>Duration</sub>	T <sub>Area</sub>	T <sub>Severity</sub>	T <sub>A-S</sub>	T <sub>S-D</sub>	T <sub>D-A</sub>	T <sub>D-A-S</sub>	Duration (month)	Area (km <sup>2</sup> )	Severity (km <sup>2</sup> month )	Begin	Finish
1	21	10	7	21	21	10	27	7	2.23×10 <sup>5</sup>	1.07×10 <sup>7</sup>	Januray 1949	July 1949
2	2	4	4	4	4	4	5	3	1.31×10 <sup>5</sup>	7.50×10 <sup>6</sup>	March 1950	May 1950
3	10	19	23	19	23	23	29	6	2.79×10 <sup>5</sup>	2.33×10 <sup>7</sup>	Decemb er 1954	May 1955
4	2	2	2	2	2	2	2	3	6.06×10 <sup>4</sup>	3.85×10 <sup>6</sup>	Decemb er 1956	February 1957
5	2	3	3	3	3	3	3	3	1.01×10 <sup>5</sup>	5.40×10 <sup>6</sup>	Decemb er 1956	February 1957
6	3	2	2	3	3	2	3	4	4.88×10 <sup>4</sup>	2.74×10 <sup>6</sup>	March 1958	June 1958
7	4	4	3	4	4	4	5	4	1.17×10 <sup>5</sup>	5.38×10 <sup>6</sup>	Decemb er 1958	March 1959
8	9	9	10	9	10	10	12	5	2.12×10 <sup>5</sup>	1.42×10 <sup>7</sup>	February 1960	June 1960
9	4	2	2	4	4	2	4	4	7.13×10 <sup>4</sup>	3.02×10 <sup>6</sup>	April 1963	July 1963
10	2	2	2	2	2	2	2	3	4.81×10 <sup>4</sup>	1.63×10 <sup>6</sup>	February 1967	April 1967
11	2	2	2	2	2	2	2	3	6.94×10 <sup>4</sup>	2.48×10 <sup>6</sup>	Januray 1968	March 1968
12	6	2	2	6	6	2	6	5	5.75×10 <sup>4</sup>	3.08×10 <sup>6</sup>	Decemb er 1968	April 1969

<b>13</b>	2	2	2	2	2	2	2	3	$4.13 \times 10^4$	$2.20 \times 10^6$	March 1969	May 1969
<b>14</b>	2	3	3	3	3	3	4	3	$1.07 \times 10^5$	$5.50 \times 10^6$	March 1973	May 1973
<b>15</b>	4	2	2	4	4	2	4	4	$6.63 \times 10^4$	$3.59 \times 10^6$	March 1977	June 1977
<b>16</b>	3	2	2	3	3	2	3	4	$5.00 \times 10^4$	$2.86 \times 10^6$	December 1978	March 1979
<b>17</b>	6	14	12	14	12	14	17	5	$2.53 \times 10^5$	$1.59 \times 10^7$	January 1979	May 1979
<b>18</b>	97	129	135	129	135	136	179	8	$3.70 \times 10^5$	$5.68 \times 10^7$	November 1979	June 1980
<b>19</b>	4	10	12	10	12	12	15	4	$2.16 \times 10^5$	$1.56 \times 10^7$	March 1983	June 1983
<b>20</b>	6	3	4	6	6	4	7	5	$1.01 \times 10^5$	$7.23 \times 10^6$	March 1983	July 1983
<b>21</b>	2	2	2	2	2	2	2	3	$4.63 \times 10^4$	$1.67 \times 10^6$	February 1985	April 1985
<b>22</b>	2	6	6	6	6	6	8	3	$1.75 \times 10^5$	$9.17 \times 10^6$	March 1986	May 1986
<b>23</b>	2	2	2	2	2	2	2	3	$5.94 \times 10^4$	$2.75 \times 10^6$	March 1987	May 1987
<b>24</b>	5	5	5	5	5	5	6	5	$1.44 \times 10^5$	$7.74 \times 10^6$	February 1991	June 1991
<b>25</b>	5	20	26	20	26	26	30	5	$2.84 \times 10^5$	$2.49 \times 10^7$	March 1992	July 1992
<b>26</b>	6	2	2	6	6	2	7	5	$4.38 \times 10^4$	$4.10 \times 10^6$	March 1992	July 1992

<b>27</b>	2	2	2	2	2	2	2	3	$4.06 \times 10^4$	$2.35 \times 10^6$	November 1993	January 1994
<b>28</b>	2	7	5	7	5	7	10	3	$1.82 \times 10^5$	$8.37 \times 10^6$	December 1993	February 1994
<b>29</b>	2	2	2	2	2	2	2	3	$7.00 \times 10^4$	$3.09 \times 10^6$	December 1993	February 1994
<b>30</b>	17	5	9	17	17	9	23	6	$1.49 \times 10^5$	$1.28 \times 10^7$	December 1994	May 1995
<b>31</b>	12	3	3	12	12	3	12	6	$9.75 \times 10^4$	$5.31 \times 10^6$	December 1994	May 1995
<b>32</b>	5	2	3	5	5	3	6	5	$7.88 \times 10^4$	$4.37 \times 10^6$	May 1997	September 1997
<b>33</b>	3	3	4	3	4	4	4	4	$1.10 \times 10^5$	$6.20 \times 10^6$	March 1998	June 1998
<b>34</b>	3	2	2	3	3	2	3	4	$3.13 \times 10^4$	$2.19 \times 10^6$	November 1998	February 1999
<b>35</b>	4	2	2	4	4	2	4	4	$7.56 \times 10^4$	$3.70 \times 10^6$	February 2001	May 2001
<b>36</b>	2	9	5	9	5	9	12	3	$2.15 \times 10^5$	$8.47 \times 10^6$	March 2002	May 2002
<b>37</b>	44	22	24	44	44	24	50	7	$2.91 \times 10^5$	$2.36 \times 10^7$	November 2003	May 2004
<b>38</b>	44	136	87	136	87	136	144	7	$3.71 \times 10^5$	$4.61 \times 10^7$	November 2004	May 2005

<b>39</b>	6	5	6	6	6	6	8	5	$1.53 \times 10^5$	$9.37 \times 10^6$	December 2006	April 2007
<b>40</b>	3	3	3	3	3	3	3	4	$1.11 \times 10^5$	$5.19 \times 10^6$	February 2007	May 2007
<b>41</b>	2	3	3	3	3	3	4	3	$1.08 \times 10^5$	$5.56 \times 10^6$	April 2010	June 2010
<b>42</b>	3	2	3	3	3	3	4	4	$6.25 \times 10^4$	$4.30 \times 10^6$	April 2010	July 2010
<b>43</b>	2	3	3	3	3	3	3	3	$9.13 \times 10^4$	$4.60 \times 10^6$	April 2013	June 2013
<b>44</b>	2	4	3	4	3	4	4	3	$1.31 \times 10^5$	$4.65 \times 10^6$	March 2014	May 2014



## 1. The Impacts of Climate Indices on Drought Propagation

The stepwise regression of drought propagation ratios to Phase Index (PI) and Climate Seasonality Index (CSI) are shown as the following figures. X1 refers to the detrended normalized Phase Index (PI), and X2 refers to the detrended normalized CSI.

PI and CSI are calculated as follows:

The monthly PET and monthly precipitation are fitted by sine curves as:

$$E_p(t) = \overline{E_p} \left[ 1 + \delta_E \sin \frac{2\pi(t - s_E)}{\tau} \right] \quad (S1)$$

$$P(t) = \overline{P} \left[ 1 + \delta_P \sin \frac{2\pi(t - s_P)}{\tau} \right] \quad (S2)$$

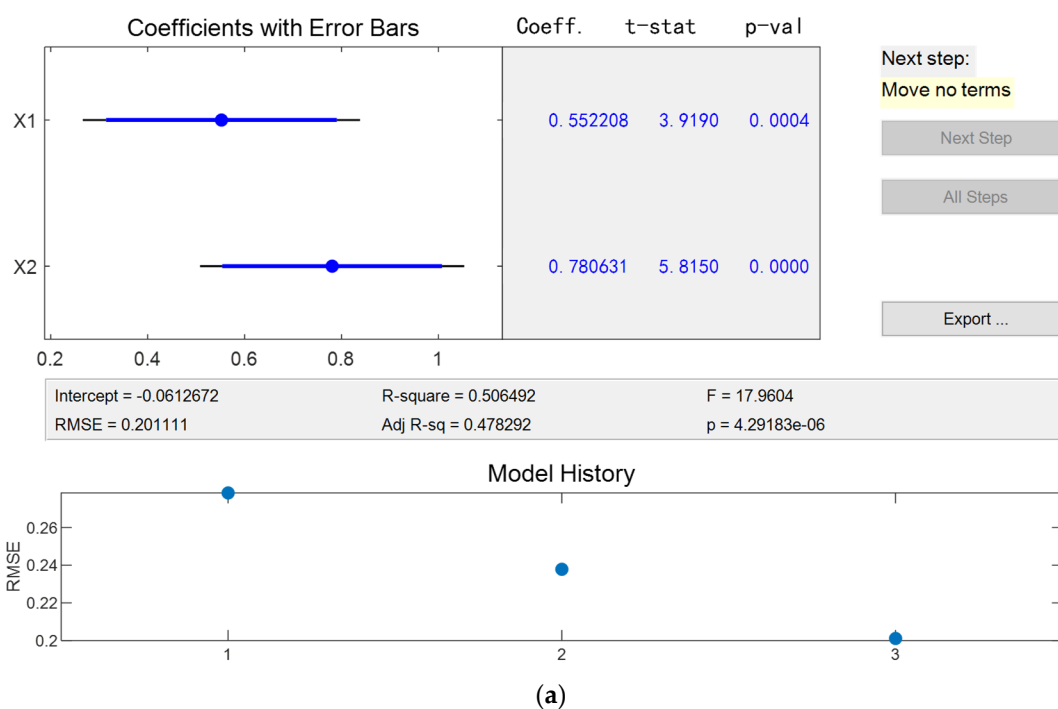
Then PI is calculated as:

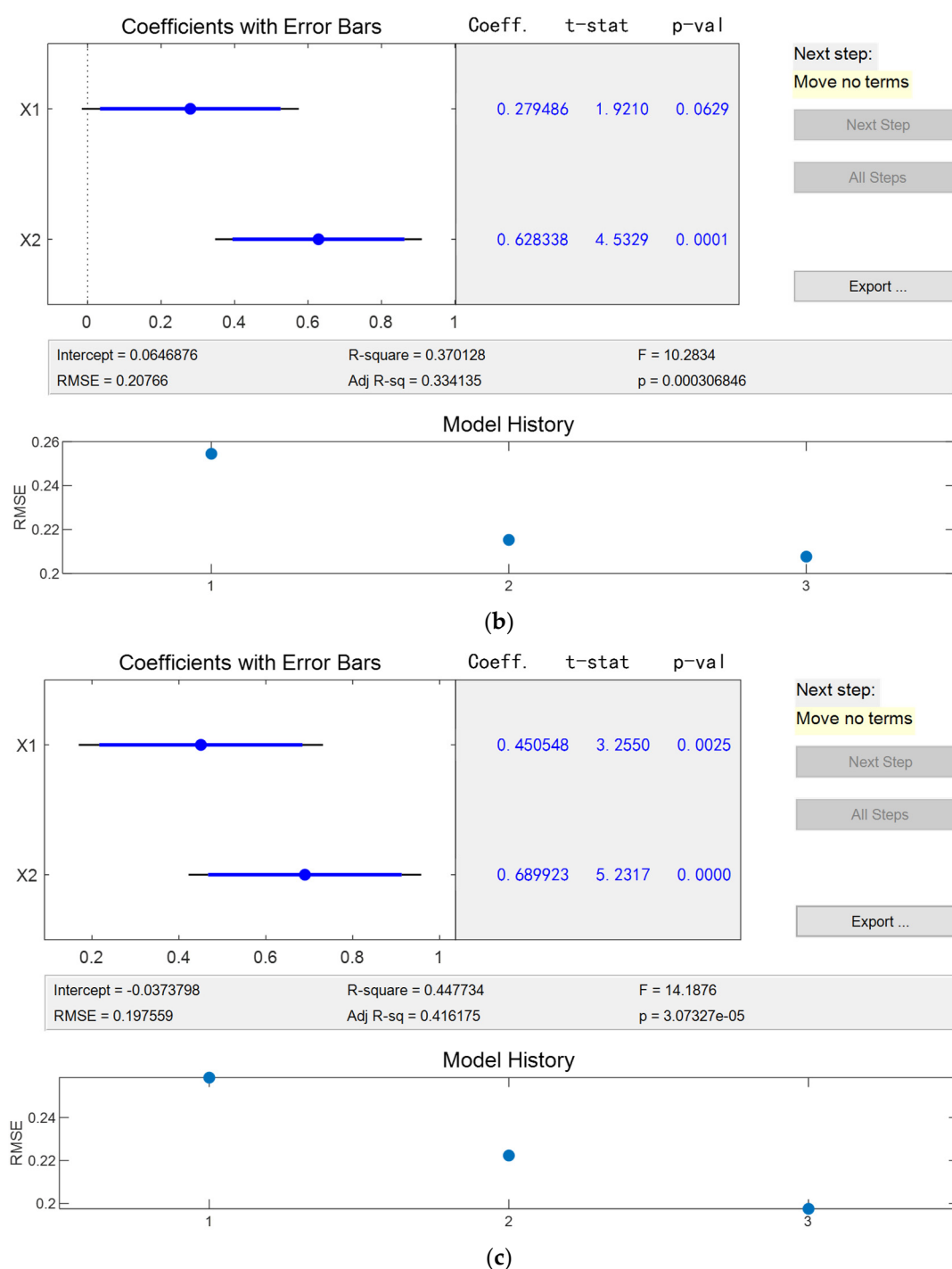
$$PI = \delta_P \delta_E \cos \left( \frac{2\pi(s_P - s_E)}{\tau} \right) \quad (S3)$$

CSI is calculated as:

$$CSI = |\delta_P - \delta_E \Phi| \quad (S4)$$

where  $\Phi$  is the aridity index ( $\overline{E_p}/\overline{P}$ )





**Figure S1.** Regression results. (a) is the regression result of drought duration, (b) is the regression result of drought area, and (c) is the regression result of drought severity.

The stepwise regression is applied using Matlab R2018b. The threshold of p-value for accepting candidate variable is 0.05, and the threshold of p-value for rejecting accepted variable is 0.10.