Impact of near-surface wind speed variability on wind erosion in the eastern agro-pastoral transitional zone of Northern China, 1982-2016

Gangfeng ZHANG Faculty of Geography, Beijing Normal University, Beijing, China
Cesar AZORIN-MOLINA Department of Earth Sciences, University of Gothenburg, Gothenburg, Sweden
Peijun SHI Faculty of Geography, Beijing Normal University, Beijing, China
Degeng LIN College of Geography and Environmental Sciences, Zhejiang Normal University, Zhejiang, China
Jose A. GUIJARRO State Meteorological Agency, Balearic Islands office, Palma de Mallorca, Spain
Feng KONG School of Public Policy and Management, Tsinghua University, Beijing, China
Deliang CHEN Department of Earth Sciences, University of Gothenburg, Gothenburg, Sweden

Corresponding author: Gangfeng Zhang, Beijing Normal University, Email: **zhanggf15@foxmail.com**

ABSTRACT: The Wind erosion in arid and semi-arid areas is an important global environmental issue, and changes in wind speed trends over time play a key role in wind erosion dynamics. In a warming climate, scientists have recently observed a widespread decline in wind speed, termed “stilling”. Here, we apply the **Revised Wind Erosion Equation Model (RWEQ)** to simulate the variability of wind erosion and quantify the impact of wind speed changes on soil degradation dynamics over the **eastern agro-pastoral transitional zone of Northern China (EANC)** from 1982 to 2016. Our results show that a significant (i.e., $p<0.05$) decrease (-0.007 m s^{-1} $year^{-1}$) of near-surface wind speed was observed annually, with significant declining trends in spring (-0.010 m s^{-1} $year^{-1}$) and autumn (-0.009 m s^{-1} $year^{-1}$). At the same time, wind erosion simulations reveal a negative trend for the annual **soil loss from wind erosion (SLWE**, -6.20 t $hectare^{-2}$ $year^{-1}$, $p<0.05$; affecting 99.8% of the study region), with significant declining trends in all seasons, particularly in spring (-3.49 t $hectare^{-2}$ $year^{-1}$) and autumn (-1.26 $hectare^{-2}$ $year^{-1}$). Further, we isolate the **effects of wind variability on wind erosion (SLWED)** from 1982 to 2016 by the model variable control method. This shows that wind speed variability strongly weakens wind erosion at -8.14 t $hectare^{-2}$ $year^{-1}$ ($p<0.05$) annually, with the strongest stilling recorded in spring leading to major decreases of wind erosion in spring (-4.77 t $hectare^{-2}$ $year^{-1}$, $p<0.05$). Meanwhile, the weakest stilling in summer had the opposite influence on wind erosion (+0.40 t $hectare^{-2}$ $year^{-1}$, $p<0.10$). To summarize, our findings have shown a significant impact of wind stilling on the decline of soil erosion rates in Northern China.

1. Data and methods

Table 1. Data required for the wind erosion model RWEQ and the assessment of climate variability. Note: ‘N/A’ means not applicable.

Data types	Temporal resolution	Spatial resolution	Time period
Wind speed	3-hour	N/A	1982-2016
Soil moisture	Daily	0.25º latitude x longitude	1982-2016
Snow depth	Daily	25-km	1982-2016
Fractional vegetation cover	Daily	1-km	1999-2016
NDVI	Daily	8-km	1982-1998
Temperature	Daily	0.5º latitude x longitude	1982-2016
Dust storm frequency	Daily	N/A	1982-2007
Precipitation	Daily	0.5º latitude x longitude	1982-2016

- **Homogenization method**: R package CLIMATOL version 3.0 (http://www.climatol.eu/).
- **Wind erosion assessment**: Revised Wind Erosion Equation Model (RWEQ; https://www.lbk.ars.usda.gov/wewc/rweq/readme.htm)

2. Observed wind stilling

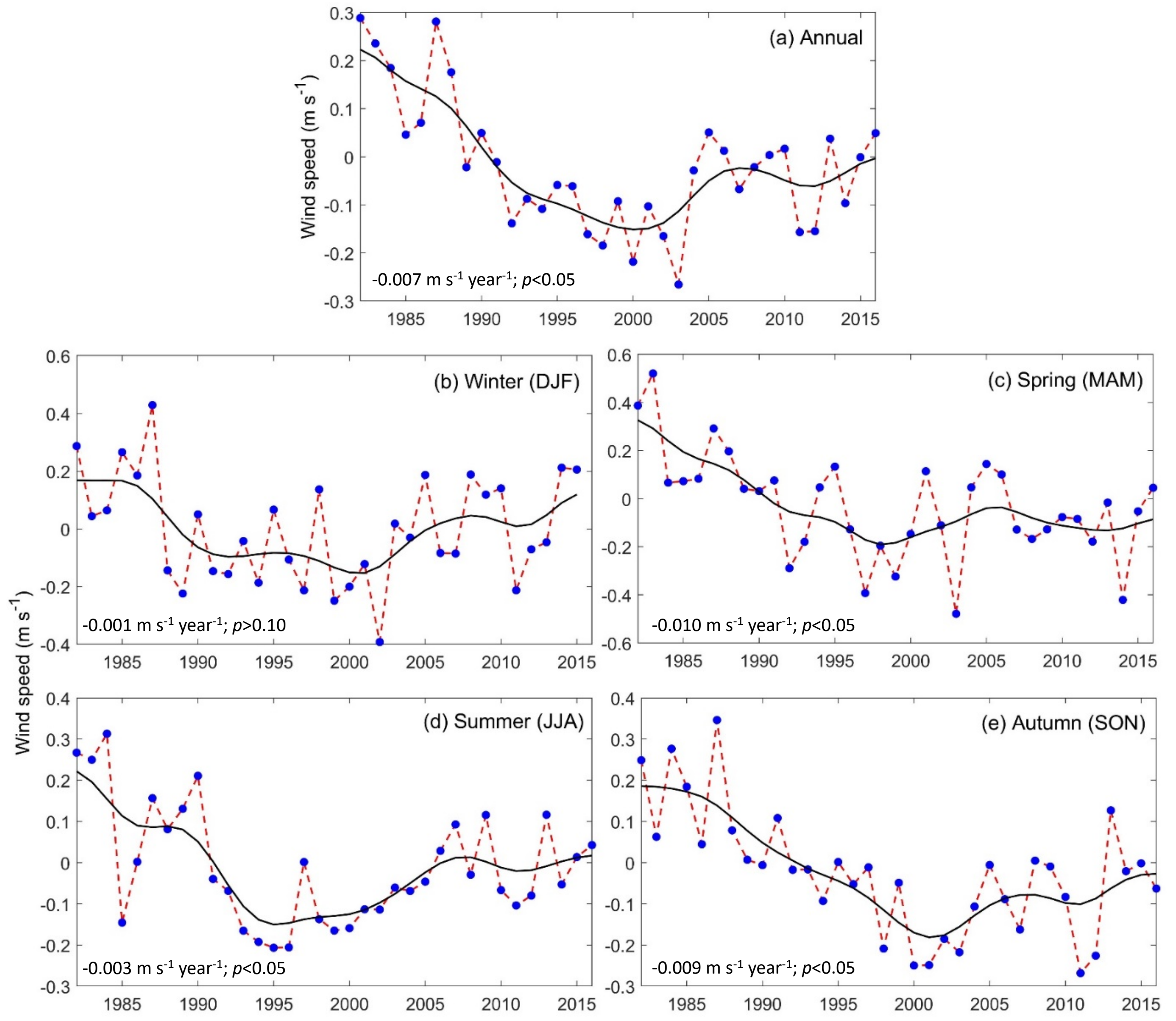

Figure 1. Annual and seasonal average wind speed anomaly across EANC from 1982 to 2016. The 11-year Gaussian low-pass filter is shown with a solid black line.

3. Changes in soil loss from wind erosion

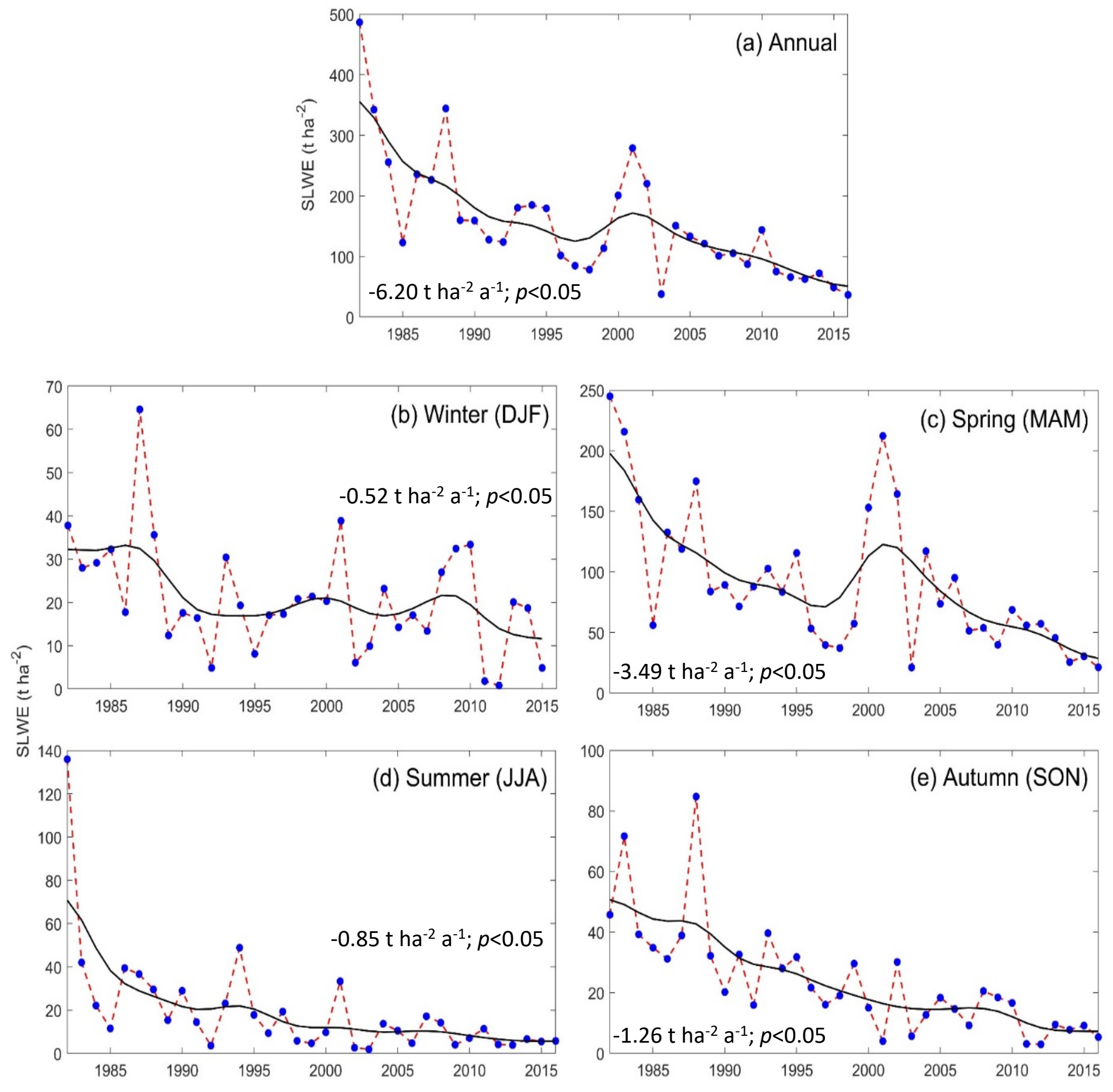

Figure 2. Annual and seasonal variability of SLWE across EANC from 1982 to 2016. The 11-year Gaussian low-pass filter is shown with a solid black line.

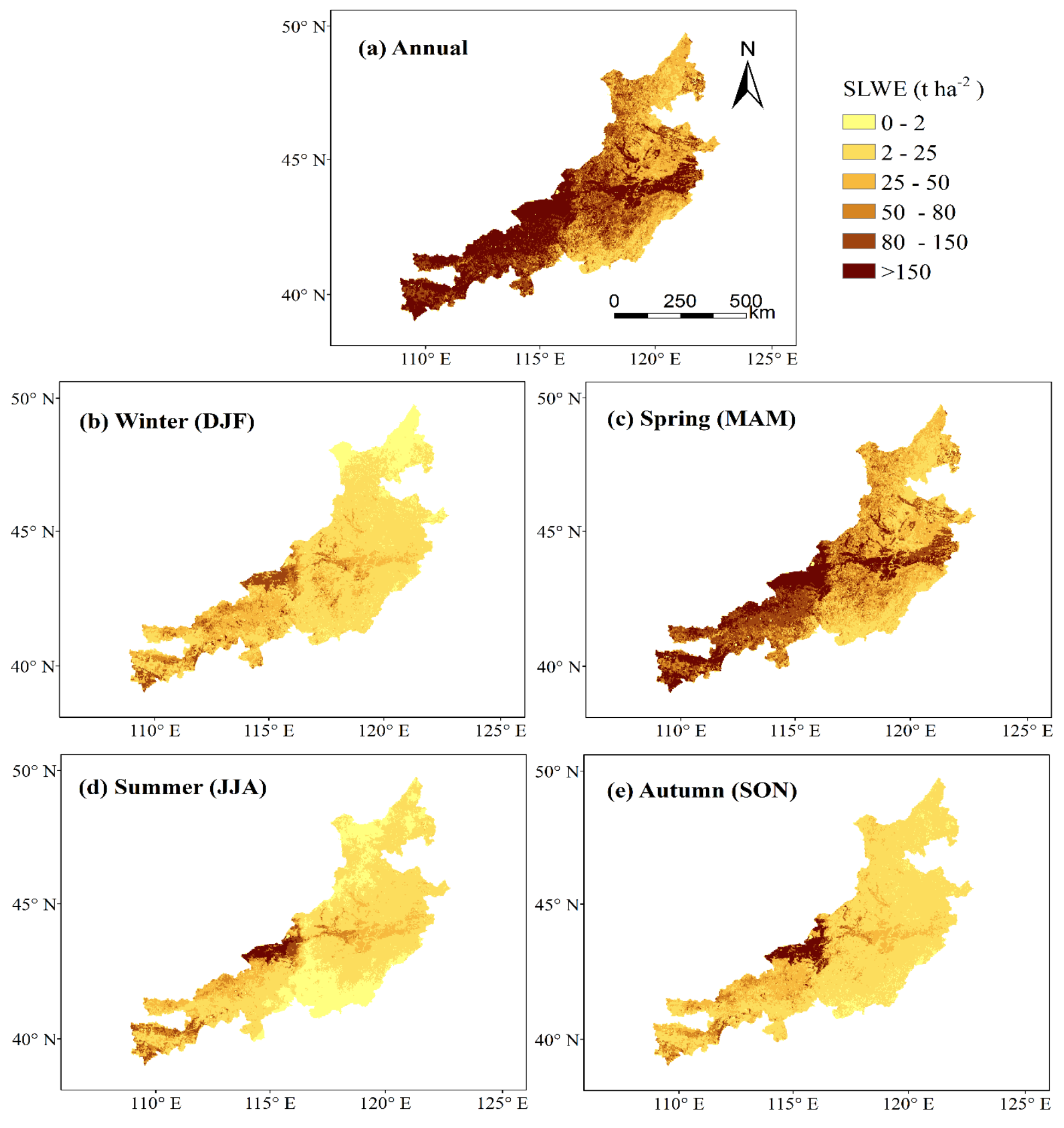

Figure 3. Spatial distribution of annual and seasonal SLWE across EANC from 1982 to 2016.

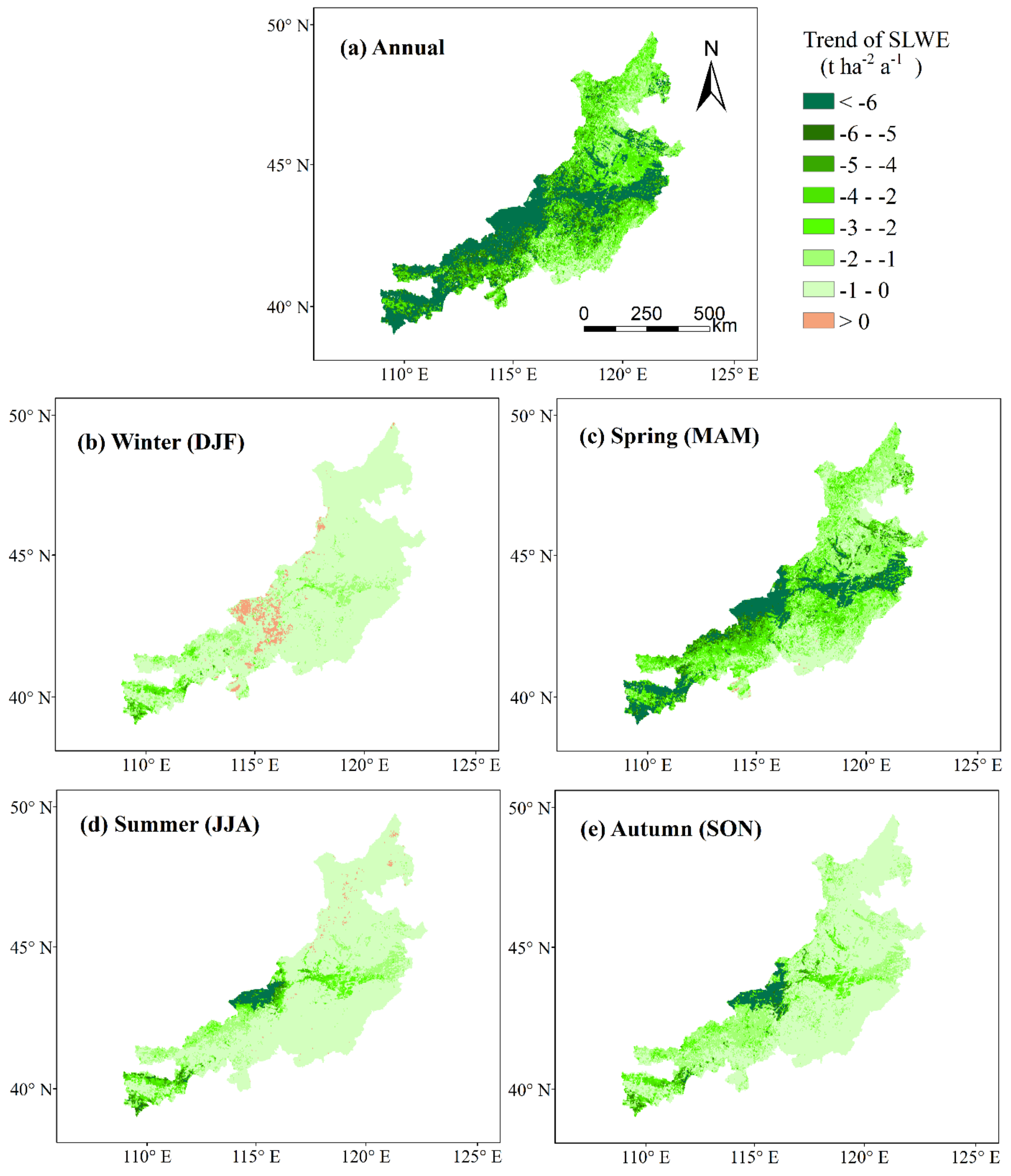

Figure 4. Spatial distribution of annual and seasonal trends of SLWE across EANC from 1982 to 2016.

4. Validation of RWEQ

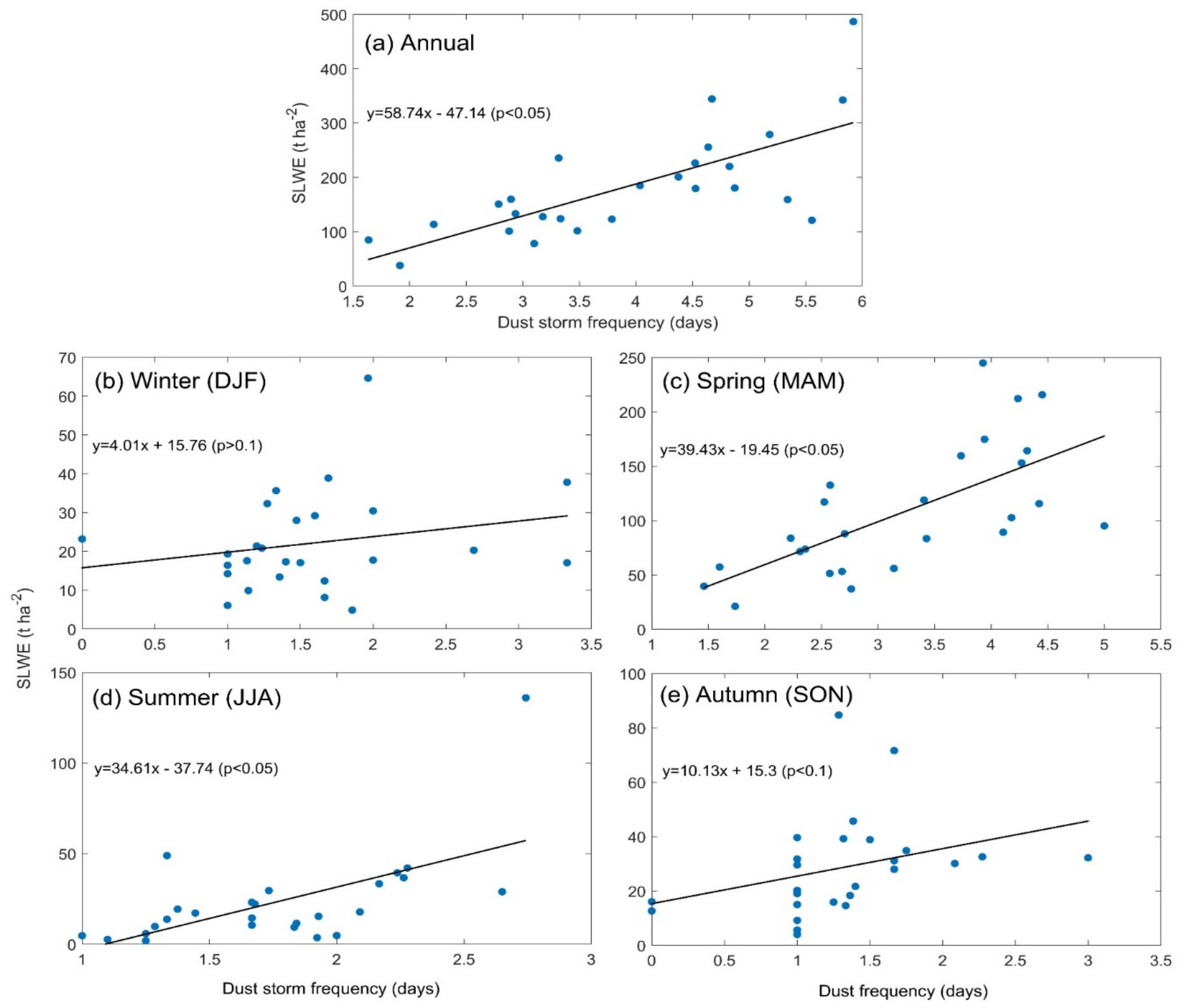

Figure 5. Annual and seasonal relationship between SLWE and dust storm frequency across EANC from 1982 to 2007. The linear regression model and fitted curve between SLWE and dust storm frequency also displayed in each plot.

5. Influence of wind stilling on SLWE

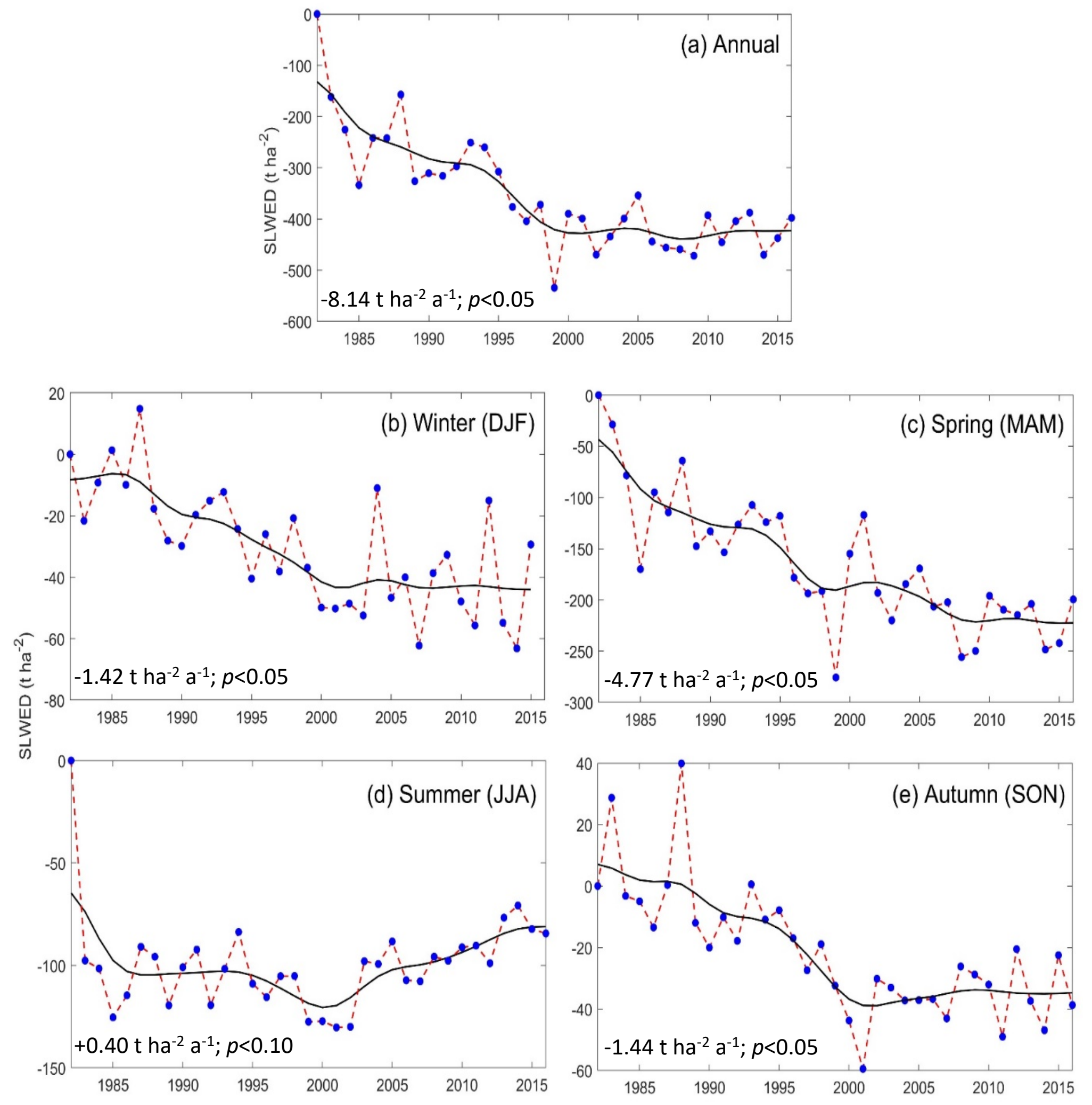

Figure 6. Annual and seasonal SLWED across EANC from 1982 to 2016. The 11-year Gaussian low-pass filter is shown with a solid black line.

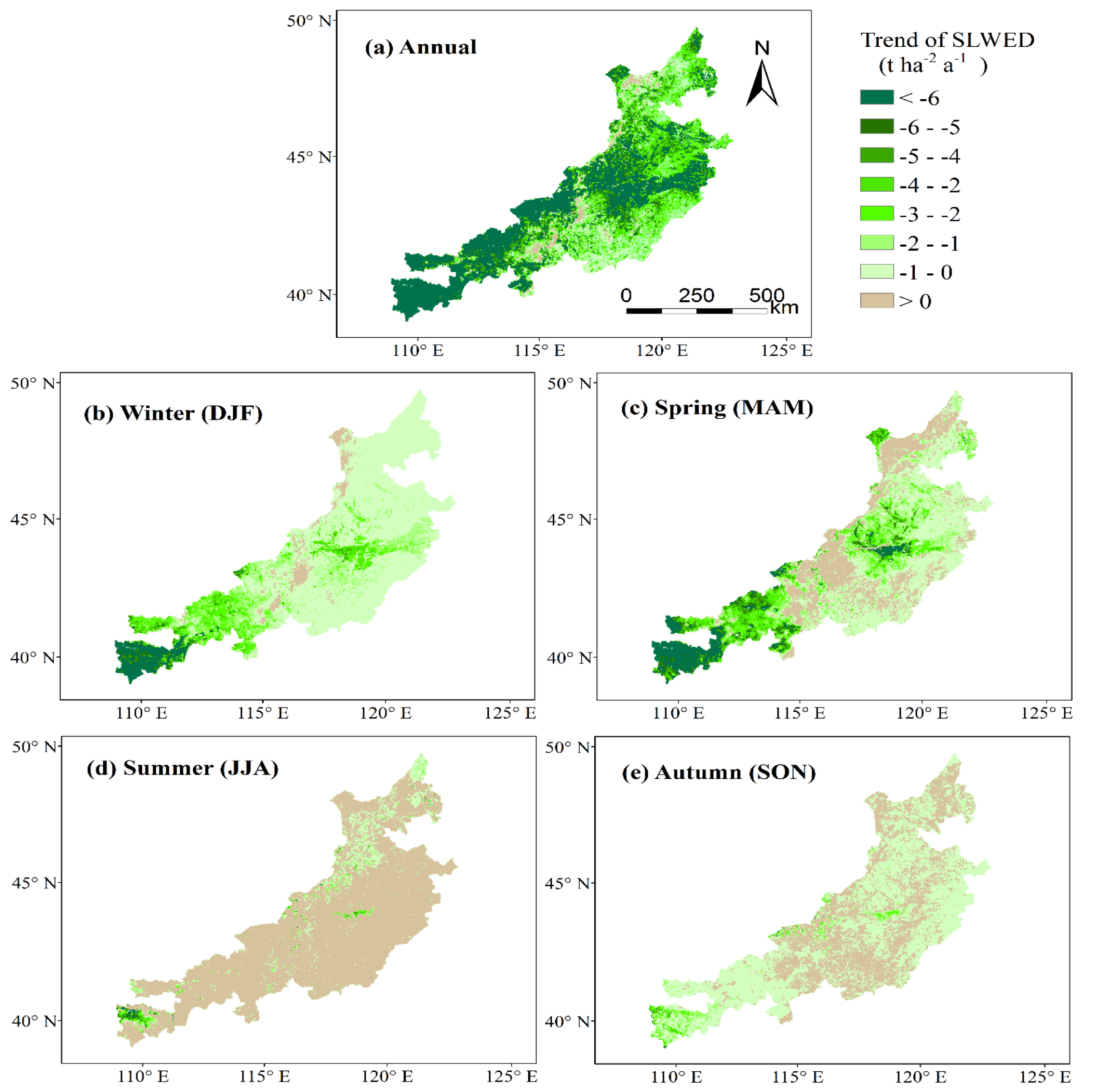

Figure 7. Spatial distribution of annual and seasonal SLWED across EANC from 1982 to 2016.

6. Conclusion

1. **Wind stilling was observed** with significant declines annually and seasonally (spring and autumn) from 1982 to 2016.

2. Simulations of **soil loss from wind erosion also exhibited significant declining trends;** validated with observed dust storm frequency data.

3. **A significant impact of wind speed variability on wind erosion was found**, with a distinct seasonality; stilling in spring resulted in the strongest soil loss rates, whereas the weakest stilling in summer derived in even increases of erosion.

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