Tornado disaster assessment of rubber plantation in western Hainan Island using Landsat and Sentinel-2 time series images

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1. Introduction
Rubber plantation (RP) in China

• About 1,157,000 ha in 2017, rank 3rd in the world;
• Three production bases: Hainan (47%), Yunnan (50%), Guangdong (3%);
• All regions face serious natural disaster threats.
2019/8/29, **Podul** triggered **tornado** (EF2 level, 49-74m/s) in Hainan, killed 8 people, destroyed many rubber plantation, damage reached $2.27 million.
Disaster assessment, challenges and opportunities

**Remote sensing** is the most important way for large scale disaster assessment.

**Opportunities**
- Increased satellites
- Improved resolution
- More open-access big data
- Cloud computation

**Challenges**
- Cloud contamination in optical images
- Limited SAR data
- Fragment landscape
- Land use change
Objectives

A case study of monitoring damage of rubber plantation caused by Tornado using remote sensing big data.

Why monitor Tornado?

- Latest disaster with Landsat 7/8 and twin satellite of Sentinel-2A/B
  - S2-A/B revisiting every 5 days
  - Landsat revisiting every 16 days
  - Spatial resolution 10, 20, 30-m
- Damage characteristics are similar to typhoons
  - Fast physical destruction

1. **When** is the ideal monitoring time?
2. **How** to using the dense time series images?
3. **What** are the best monitoring indicators?
2. Material and methods
Field survey were carried quickly in the next days (8/29 and 8/30).
Study area and field survey
Mark damage plantations using Google Earth

Plantations in **red polygon** were updated between 2019/8/29 and 2019/11/17

Plantations in **blue polygon** were updated between 2019/11/17 and 2020/1/15
Satellite imagery

Landsat 7/8 Collection 1 TOA reflectance, from USGS
- 30-m resolution
- Revising every 16 days

Sentinel-2 A/B L1C TOA, from ESA
- 10, 20, 60-m resolution
- Revising every 5 days

- Landsat 7, lunched in 1999
- Landsat 8, lunched in 2015
- Sentinel-2A, lunched in 2015
- Sentinel-2B, lunched in 2017

Image count during 2015-2019 in the study area (40 x 70 km)
Imagery pre-processing

**Quality controlling**
- Cloud masking and scan-off line excluding (ETM+)
- Bands harmonization

**Vegetation indices calculation**
- $NDVI = \frac{\rho_{NIR} - \rho_{Red}}{\rho_{NIR} + \rho_{Red}}$
- $LSWI = \frac{\rho_{NIR} - \rho_{SWIR_1}}{\rho_{NIR} + \rho_{SWIR_1}}$
- $EVI = 2.5 \times \frac{\rho_{NIR} - \rho_{Red}}{\rho_{NIR} + 6 \times \rho_{Red} - 7.5 \times \rho_{Blue} + 1}$
- $NBR = \frac{\rho_{NIR} - \rho_{SWIR_2}}{\rho_{NIR} + \rho_{SWIR_2}}$

**Image composite**
- Max / min / median / latest / mean value composite
Algorithm—Image difference

Time series big data

How long?

Traditional bi-temporal way

Before

After

How to?

Satellite Imagery

Image Composite

Before

After

Difference

Satellite Imagery

Image Composite

Difference

Disaster hit date

Disaster assessment map

Assessment relies heavily on large scale cloud free image
3. Results and discussion
Cloud-free image coverage assessment

(a) Image statistics before tornado hit

(b) Image statistics after tornado hit

- 10 days step
- 10 days step

Tornado hit date, 2019/08/29

- 30 days almost full coverage, average pixel coverage is three times
- 60 days average pixel coverage is six times
- 90 days average pixel coverage > 8 times
Indicators and composite methods before tornado

Absolute change

\[ \text{Absolute change} = \text{After} - \text{before} \]

Percent change

\[ \text{Percent change} = \frac{\text{After} - \text{before}}{\text{Before}} \times 100\% \]
Indicators and composite methods before tornado

- SWIR1 and SWIR2 increased after tornado
- NIR, NDVI, EVI, LSWI, and NBR decreased
Indicators and composite methods before tornado

• EVI value and percent of LSWI drop the most
• Max value composite perform best, followed by latest value composite
Indicators and composite methods before tornado

Tornado hit in growing season, the max value composite method can capture the latest growing state of rubber plantation.
Composite methods after tornado

Absolute change = After - before

Percent change = \( \frac{\text{After} - \text{before}}{\text{Before}} \times 100\% \)
Composite methods after tornado

- EVI value and LSWI percent drop the most, much better than NDVI widely used in previous studies.
- Min value composite shows largest difference, followed by median value composite.
Time window test based on best indicators

- Indicators become stable about 40 days
- Recommend 60 days window, Max-Min best, then is Max-Med by ground reference.
Spatial change of EVI/LSWI values

- All maps clear show tornado route except $\text{EVI}_{\text{MaxMin}}$;
- Lots of noise in difference image come from Max-Min composite images;
- Max-Med composite show better performance;
- $\text{EVI}_{\text{MaxMed}}$ is slightly better than $\text{LSWI}_{\text{MaxMed}}$. 
Spatial change of EVI/LSWI percent value

- All maps clearly show tornado routes except EVI\textsubscript{MaxMin};
- Lots of noise in difference images come from Max-Min composite images;
- Max-Med composite show better performance;
- LSWI\textsubscript{MaxMed} is slightly better than EVI\textsubscript{MaxMed}.
Recommend ways for tornado damage assessment

- All maps clear show tornado route except EVI_{MaxMin};
- Lots of noise in difference image come from Max-Min composite images;
- Max-Med composite show better performance;
- LSWI_{MaxMed} is slightly better than EVI_{MaxMed}.

Why EVI_{MaxMin} has more noise?
Recommend ways for tornado damage assessment

- All maps clear show tornado route except \( \text{EVI}_{\text{MaxMin}} \);
- Lots of noise in difference image come from Max-Min composite images
- Max-Med composite show better performance
- \( \text{LSWI}_{\text{MaxMed}} \) is slightly better than \( \text{EVI}_{\text{MaxMed}} \);

- Using Landsat 7/8 and Sentinel-2A/B images of about 60 days;
- Max (Before)-Median (After) composite method;
- Using EVI or LSWI percent value as indicator;
Damage area statistics

- Two algorithms agree well with most towns;
- Qifang town rank the top, loss about 300 ha of rubber plantation;
- Total damage area ranges from 576 to 712 ha;
- Manual adjustment is necessary if need very high accuracy damage data.
4. Conclusion
Take home message

Increasingly extreme weather and natural disasters under climate change pose huge challenges to rubber industry.

Remote sensing big data brings lots of opportunities for disaster assessment

For tornado/typhoon disaster of rubber plantation, we recommend:

• Using Landsat 7/8 and Sentinel-2A/B images of about 60 days;
• Max (Before)-Median (After) composite method;
• Using EVI or LSWI percent value as indicator;
Thank you!

Question and suggestion?