Vulnerability of Giant Sequoia to Moisture Stress in A Changing Climate using Remotely-Sensed Canopy Moisture

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Introduction

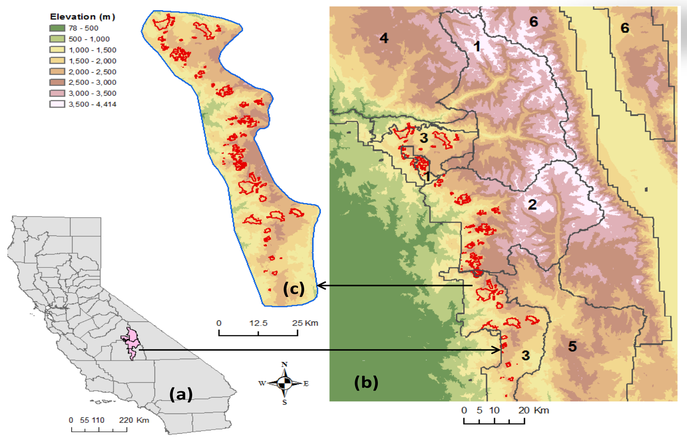
Giant sequoia trees and their ecosystems are unique to the Sierra Nevada, where most groves are federally managed. Increasing temperatures over the next several decades may create conditions unfavorable to giant sequoia. In order to effectively and efficiently allocate management efforts to conserve this tree species, the vulnerability of giant sequoia groves to drought/water stress must be evaluated.

This study took **normalized difference water index** *(*NDWI) and **topographic wetness index** (TWI) as the indicators of moisture conditions to evaluate the vulnerability of giant sequoia groves to moisture stress under a changing climate. The temporal changing trend in NDWI, spatial change in TWI, the correlation among NDWI , TWI, precipitation and temperature, and the relationship between the vulnerability of giant sequoia groves to moisture stress and their moisture conditions were analyzed.

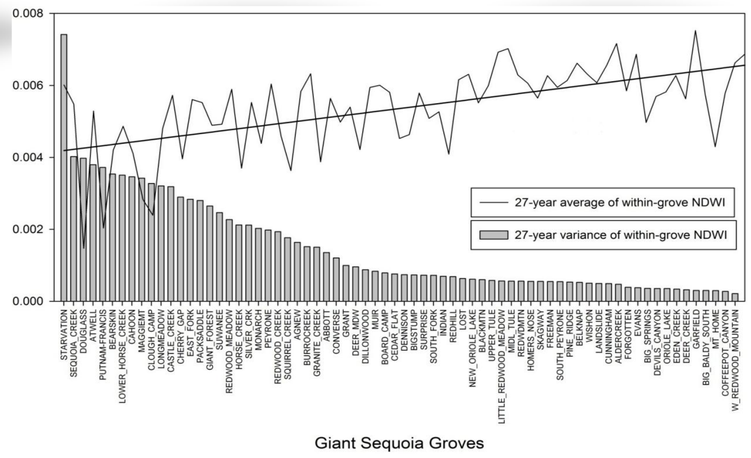
Normalized difference water index: NDWI is defined as the ratio of the difference between reflected short-wave infrared (SWIR) and reflected near infrared (NIR) and the sum of the two bands; it gives a measurement of the vegetation moisture .

$$NDWI = \frac{\rho_{NIR} - \rho_{SWIR}}{\rho_{NIR} + \rho_{SWIR}}$$

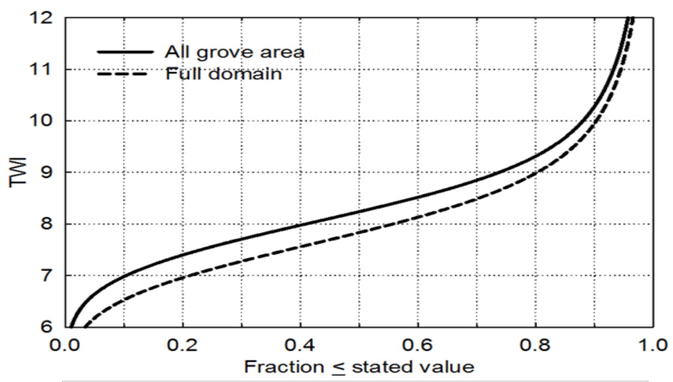
where ρ_{NIR} is the reflectance value of the NIR band (TM band 4) and ρ_{SWIR} is the reflectance of SWIR band (TM band 7) .



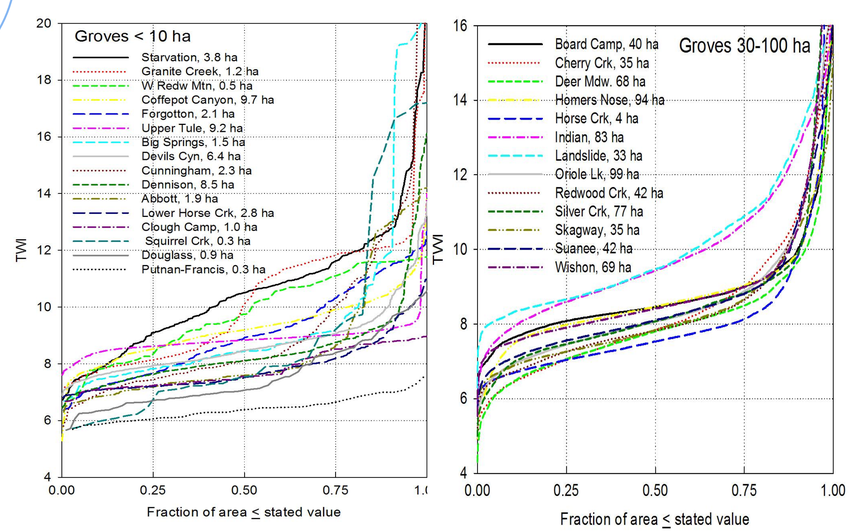
Locations of the 70 Sequoia Groves (polygons in red): a) California; b) DEM for larger region with national parks and forests; c) and selected region for analysis. *1. Kings Canyon Nat. Park, 2. Sequoia Nat. Park, 3. Giant Sequoia Nat. Monument, 4. Sierra Nat. Forest, 5. Sequoia Nat. Forest.*



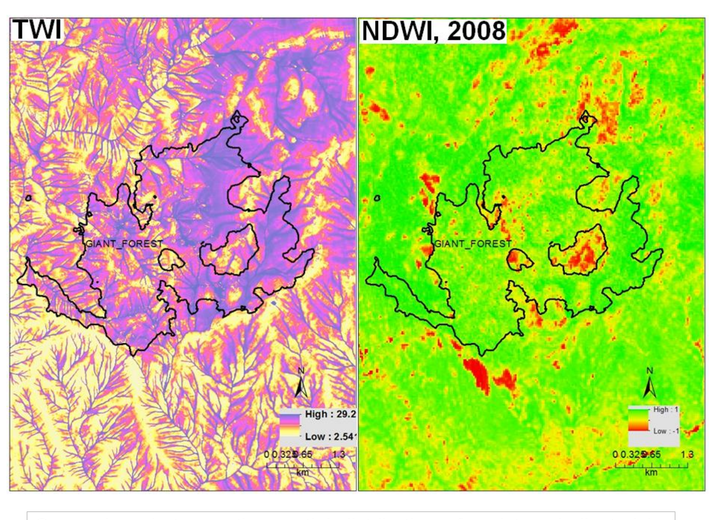
Ranking of giant sequoia groves based on the within-grove variance of NDWI over 27 years (1984–2010), and variation of 27-year average NDWIs over all groves. However, NDWI shows similar moisture distribution year to year.



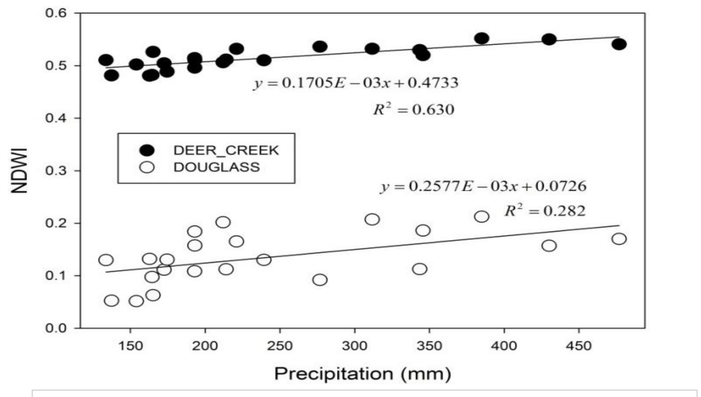
Comparison of aggregate TWI distribution for area within the 70 groves and the full study domain.



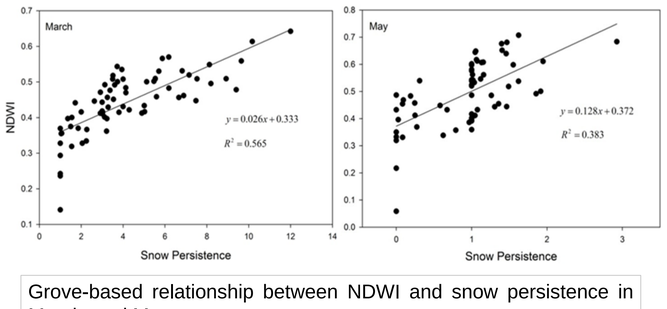
Inter comparison of TWI in smaller and larger groves. Analysis shows that the Smaller groves have wider spread of TWI.



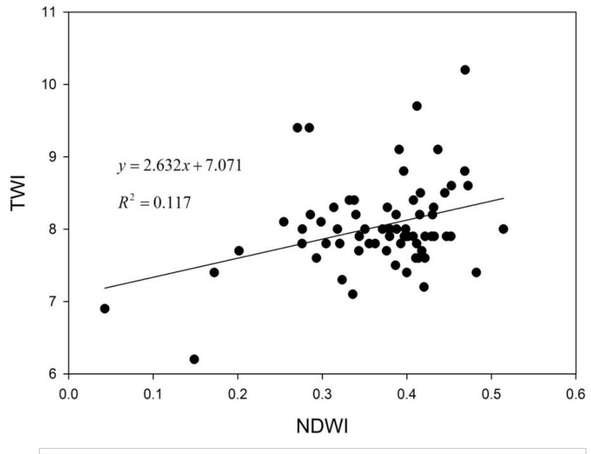
Comparison between the spatial distribution of moisture indicated by NDWI and TWI at Giant Forest grove. Both TWI and NDWI have identified same dry and wet region in Giant Forest grove.



Relationship between NDWI and annual total precipitation for the driest (DOUGLASS) and the wettest (DEER_CREEK) giant sequoia grove.



Grove-based relationship between NDWI and snow persistence in March and May.



Grove-based relationship between NDWI and TWI.

Findings

Results showed that in the period from 1984 to 2010:

1) NDWI is an effective indicator of climate change which shows a slightly negative response to temperature and a strongly positive response to precipitation;

2) TWI can contribute to identify potential sequoia groves that are more or less vulnerable to soil moisture.

3) There are both smaller groves and smaller areas within larger groves that have low TWI, and thus are potentially vulnerable by this index;

3) In addition to climatic factors, fire event and snow cover can also affect NDWI: the former one matches well with obvious decreases in NDWI (and NDVI) time-series, the latter one have a positive correlation with NDWI in March, April, May, and June;

4) NDWI has a positive but very weak correlation with Topography Wetness Index (TWI) implying that variations in local soil water content might have a little contribution to changes in tree moisture;

5) In general, a lower NDWI grove has a higher moisture stress and a higher NDWI grove one has a lower. Also, a comparison between within-grove NDWI variances over the 27 years and 27-year average NDWIs over all groves indicates a similar result. Moreover, combined TWI and 27-year average NDWI can function as an indicator of the vulnerability to moisture stress.

Acknowledgements

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