TECHNISCHE UNIVERSITÄT DRESDEN
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Analyzing and Visualizing the Relationships between Vegeta-tion Traits and Soil Moisture in Wetland Environment from Remote Sensing Data

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2019

Master Thesis
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Background and Research Goals

Despite its small volume, soil moisture is a critical component of the hydrological cycle. It is defined as the amount of water contained in the root zone that can be utilized by plants [1], thus, it strongly links to vegetation conditions. Understanding soil moisture could provide farmers, scientists, and policymakers a better chance to make wiser land management decisions and prevent disasters, such as flooding. However, measuring soil moisture has been a challenging topic. On the one hand, soil moisture measurements with microwave remote sensing technology excelled field measurements in obtaining more continuous and frequent monitoring; well-known missions include the Soil Moisture Active Passive (SMAP), Soil Moisture Ocean Salinity (SMOS) and Advanced Scatterometer-Soil Water Index (ASCAT-SWI) [1][6]. On the other hand, coarse spatial resolution and complex interactions of microwave radiation with surface roughness and vegetation structure [2] present limitations within these products to monitor soil moisture variations on landscapes with a high precision that is relevant to land management. This thesis seeks to understand the relationships between vegetation traits [4] and soil moisture conditions in wetland environment as observed from satellite data, and to visualize the relationships from the remote sensing analysis with modern cartographic techniques to make the results accessible and understandable to a broader audience.

Methodology

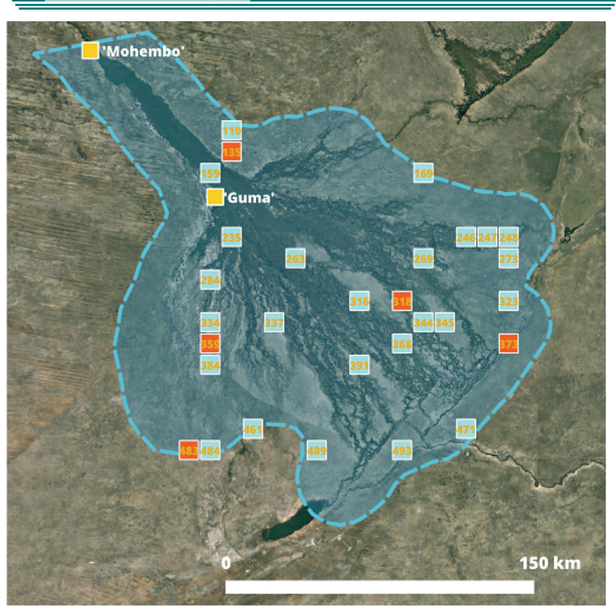

Figure 1: Study area and sample sites. Yellow is in-situ water level stations; red is the experimental sample sites; blue is the 25 extended sample sites.

This research seeks to answer the soil-vegetation relationships from two aspects: temporal/-seasonal and spatial. Dates for wet and dry seasons are selected based on the in-situ water level records. 5 sites are first selected to experiment with the workflow; 25 sites are then selected to increase spatial coverage. 2 sites are excluded due to high seasonal inland water extent. Land cover conditions in the sites are examined to identify the dominant vegetation type for each site. Vegetation indices (VIs), are calculated from the Sentinel-2 optical data in SNAP. Characteristic statistics (mean, standard deviation, coefficient of variation) and second-orde texture information (Grey Level Coccurence Matrix-Entropy & Homogeneity) are calculated from the VIs using RStudio. VI statistics are correlated to SWI to analyze the correlation direction and strength, and multiple regression is used to model the relationship between the selected VI statistics and SWI in RStudio.The interactive cartographic visualization is implemented with Leaflet JavaScript library, HTML/CSS and D3.js.

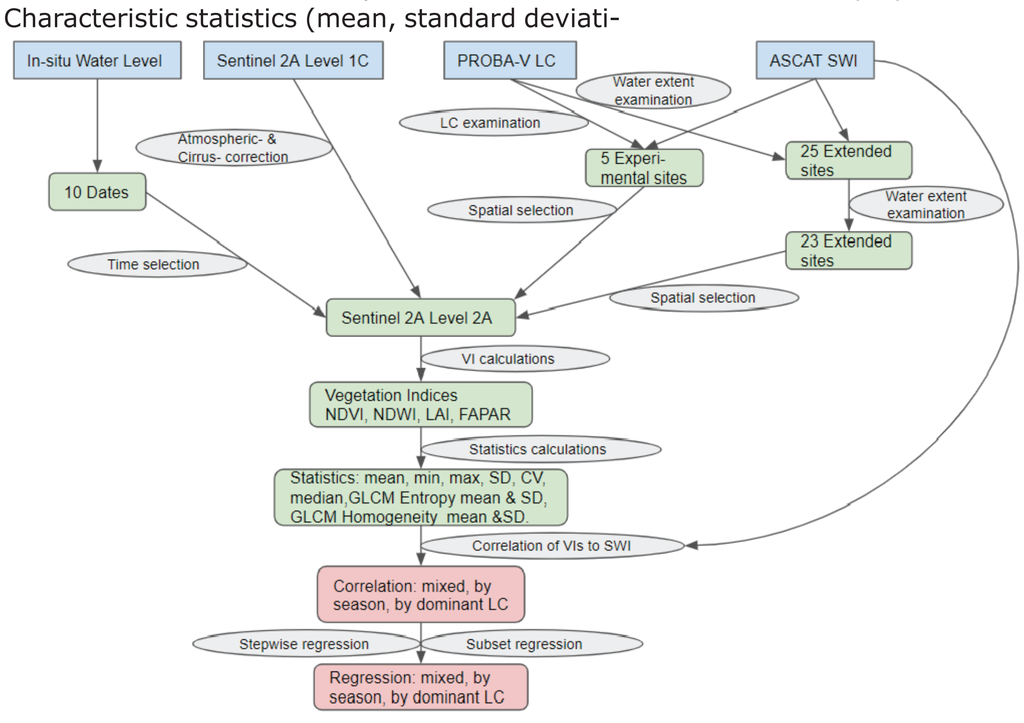

Figure 2: Research workflow.

Remote Sensing Analytical Results

Correlations and regression methods demonstrated the possibility of using VIs to estimate soil water conditions in the wetland environment. The analysis indicates that optical data can uncover information about soil moisture in a finer spatial resolution. Seasonal differences in using vegetation proxies for soil moisture are obvious—in the wet season, vegetation information has a strong linkage to soil moisture while very scattered results are observed in the dry season. Differences in using remote sensing VIs to understand soil moisture also exist for areas with different dominant vegetation but not drastic—in sites with shrubs as dominant vegetation, vegetation proxies performed generally well in estimating soil moisture; in sites with Deciduous Broadleaf Open Forest (DBOF), a moderately strong correlation can also be found.In the subset regression, the mean FAPAR explained the most variance observed in SWI (around 45%), indicating the vegetation's average evapotranspiration and photosynthetic primary production capacity are well linked to soil moisture. In the regression model for wet season observation, LAI alone explained 48% of the variance. Vegetation's vitality and greenness conveyed through the NDVI also help to explain the variance in SWI but NDWI measuring the liquid water content in vegetation does not contribute greatly in understanding soil moisture variance.

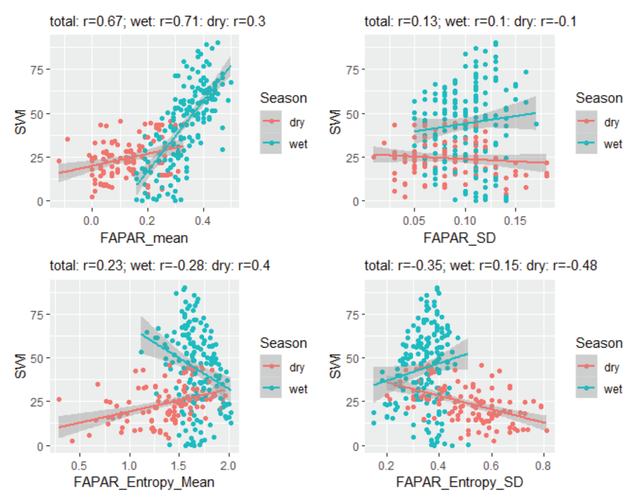

Figure 3: Scatterplots display the correlation strength and significance between the mean and standard deviation of FAPAR to SWI grouped by seasons. Grey lines display a confidence interval of 0.95.

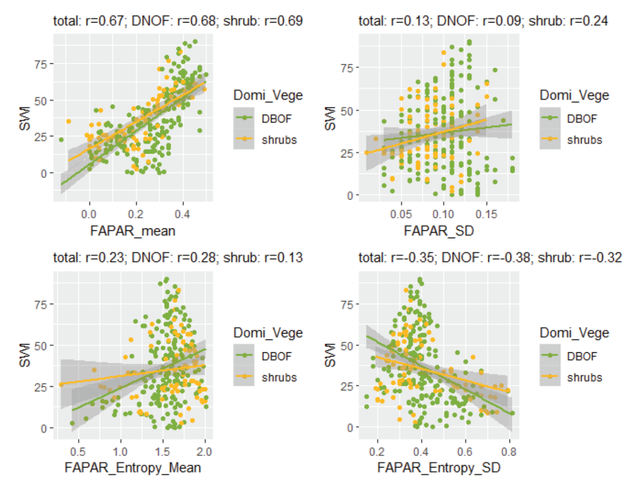

Figure 4: Scatterplots show correlation strength and significance between FAPAR mean and SD to SWI grouped by dominant vegetation type in the sample site. Grey lines display a confidence interval of 0.95.

Cartographic Visualiation Results

The user groups for the project are targeted at students in remote sensing classrooms and decision-makers who need insights for building in-situ sensor networks. This visualization can be introduced to remote sensing students as a case study and can demonstrate a workflow of remote sensing analysis as well as the multidimensional nature of remote sensing data and natural phenomena. People who develop in-situ sensor networks for water or soil can use this platform to get an overview of the patterns in the soil and vegetation and identify interesting locations for further investigation. In the visualization product development, several key interactive strategies for visualizing multidimensional spatial-temporal data are adopted allowing the targeted users to explore the data used in this research and to develop visual thinking about the research workflow. Simple User Interfaces (UIs) like the slider bars can add important information about the temporal dimension of the data and will provide additional initiatives for users to perceive the complexities of the topic through visual thinking [5]. Using Leaflet to provide the main UI has the advantages of easy implementation and simple interaction for exploring various thematic datasets. Additionally, this product demonstrates the value-adding role of cartographic visualization in remote sensing analysis by allowing users to interact with the data/results and generate their own insights (scan the QR code in the left corner to access the map).

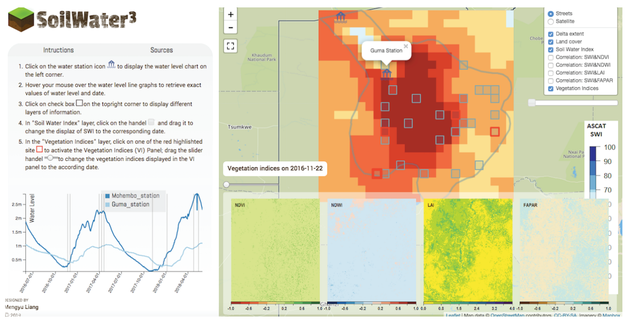

Figure 5: One view of the SoilWater³ product.

Conclusion and Outlook

This project aligns with ongoing scientific efforts to explore the relationships between remote sensing vegetation traits and soil moisture and seeks to use vegetation as sensors for soil monitoring. The implementation of the interactive web map demonstrates cartographic visualization's potential in adding values to remote sensing analysis and appeal to a border audience. Limitations exist in this research and indicate the need for further scientific efforts. The vegetation indicator method can reflect soil moisture conditions as VI changes [3], but VI cannot immediately reflect when the vegetation is stressed. Time lagged analysis is not implemented because of the limitation in Sentinel-2 data due to cloud coverage and general temporal resolution. Therefore, long term and high temporal resolution series providing information on the vegetation traits should be developed and analyzed to better uncover the time-lag between vegetation dynamics and soil water content. Improvement of the visualization product could be to add more case studies in the other focal areas, to implement advanced computation capacities with spatial data accessed from other data hubs via WMS, and to conduct user tests for feedback on usability.

References

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