Universitatea Transilvania din Brașov

Interdisciplinary Doctoral School

ADMISSION TO DOCTORAL STUDIES Session September 2023

Field of doctoral studies:
Doctoral supervisor:

TOPICS FOR THE ADMISSION TO DOCTORAL STUDIES

TOPIC 1: ***Integrated Assessment of Vegetation Dynamics and Land Cover Changes using Satellite Imagery, Terrestrial Laser Scanning, and Hemispheric Images in Romanian forests***

Introduction:

The study aims to integrate satellite imagery, terrestrial laser scanning (TLS), and hemispheric images for the assessment of vegetation dynamics and land cover changes, with a specific focus on detecting and validating Leaf Area Index (LAI). The research objectives include investigating the suitability of satellite imagery for LAI estimation, assessing the accuracy of TLS in capturing LAI variations, evaluating the potential of hemispheric images for LAI estimation, analyzing the spatial-temporal dynamics of LAI, and providing recommendations for integrating these techniques in LAI monitoring and its implications for ecosystem functioning and land management.

Methods:
The study will be conducted in Brasov, Romania, with 200 plots selected using a systematic sampling approach. Data collection will involve satellite imagery acquisition, TLS scanning in each plot for 3D vegetation structure and LAI information, and capturing hemispheric images within the plots to estimate gap fraction and indirectly estimate LAI. Ground-based measurements will be conducted for LAI validation. Satellite data from sensors like Sentinel2, MODIS, AVHRR, or VIIRS will be used for LAI estimation, employing vegetation indices such as NDVI, EVI, or SAVI. Preprocessing steps will involve atmospheric correction to remove atmospheric effects. Ground truth data collected from TLS and hemispheric photography will establish relationships between LAI and vegetation indices.

TLS data will be processed to remove noise and outliers, segment vegetation points, estimate leaf area density, and convert it to LAI using suitable conversion equations or models. Software tools like Cloud Compare, Las-tools, or ENVI LiDAR can be used for TLS data processing.

Hemispheric images will be processed using software tools like Gap Light Analyzer (GLA), Canopy Openness Analyzer (COA), or Hemisfer to estimate LAI based on gap fraction analysis. The Beer-Lambert law can be employed to establish the relationship between LAI and gap fraction, with the extinction coefficient (k) obtained through calibration or field measurements.

A machine learning approach, such as random forest or support vector regression, will be used to develop a model for improving LAI estimation from satellite data. The model will be trained using TLS and hemispheric data as target variables and satellite data as predictors. The model's accuracy will be evaluated using statistical measures.

Expected outcomes:

Expected outcomes of the study include an assessment of satellite imagery accuracy for LAI estimation, validation of satellite-derived LAI using TLS and hemispheric images, investigation of spatial-temporal LAI variability, and the development of a model to enhance LAI estimation from satellite data.

Main Aspects to be Considered:

- Select appropriate satellite imagery with suitable spatial and temporal resolutions for capturing vegetation patterns and LAI changes.
- Collect ground truth data through fieldwork to provide reference values for validating remote sensing-derived LAI estimates.
- Preprocess and segment TLS data to estimate leaf area density within the point cloud accurately.
- Process hemispheric images using specialized software to calculate the gap fraction and assess canopy openness for LAI estimation.
- Develop a model integrating satellite data, TLS, and hemispheric images, using machine learning techniques, to improve LAI estimation accuracy and understand vegetation dynamics and land cover changes.

Recommended bibliography:

1. Baldocchi, Dennis D., Detlef R. Matt, Boyd A. Hutchison, and Robert T. McMillen. "Solar radiation within an oak—Hickory Forest: An evaluation of the extinction coefficients for several radiation components during fully-leafed and leafless periods." Agricultural and forest meteorology 32, no. 3-4 (1984): 307-322.
2. Becker, P., D. W. Erhart, and A. P. Smith. "Analysis of forest light environments Part I. Computerized estimation of solar radiation from hemispherical canopy photographs." Agricultural and Forest Meteorology 44, no. 3-4 (1989): 217-232.
3. Chen, Jim M., Thomas Andrew Black, and R. S. Adams. "Evaluation of hemispherical photography for determining plant area index and geometry of a forest stand." Agricultural and forest meteorology 56, no. 1-2 (1991): 129-143.
4. Pierce, Lars L., and Steven W. Running. "Rapid estimation of coniferous forest leaf area index using a portable integrating radiometer." Ecology 69, no. 6 (1988): 1762-1767.
5. Cleugh, Helen A., Ray Leuning, Qiaozhen Mu, and Steven W. Running. "Regional evaporation estimates from flux tower and MODIS satellite data." Remote Sensing of Environment 106, no. 3 (2007): 285-304.

TOPIC 2: ***Nationwide Native Forest Structure Maps for Romania based on Field 3D Laser Scanning and Remotely Sensed Metrics***

Introduction:

Accurate, large-area, and fine-resolution forest structure maps are essential for management agencies to support sustainable forest management and conservation planning. Mobile 3D lidar scanners have the potential to significantly enhance field inventories of forest sampling plots. Moreover, radar and optical satellite data offer the capability to provide comprehensive metrics for predicting forest structure over vast areas. This research aims to develop a methodology that combines field-based 3D laser scanning with metrics from Sentinel-1 and 2, along with topography and climate variables, to predict forest attributes and generate nationwide native forest structure maps for Romania.

Methods:

The proposed methodology will employ machine learning (RF,GTB and CART alglorithms) regression to predict forest attributes by integrating data from different sources. Field-based 3D laser scanning will be utilized to measure key forest attributes such as diameter at breast height (DBH), basal area, height, and volume. Mobile 3D lidar scanners will be employed to capture high-resolution data within forest sampling plots. The random forest regression algorithm will be trained using this field data, in combination with metrics derived from Sentinel-1 and 2 satellite data, topography data, and climate variables.

Expected outcomes:

To select the most informative predictors for the random forest regression model, feature selection techniques such as variable importance measures, recursive feature elimination, or stepwise regression can be employed. The performance of the model will be evaluated using various statistical measures, including the coefficient of determination (R2) and the root mean square error (RMSE). Cross-validation techniques, such as k-fold cross-validation, will be applied to assess the model's robustness and generalizability.

Main Aspects to be Considered:

- Integration of field-based 3D laser scanning, Sentinel-1 and 2 satellite data, topography, and climate variables for accurate forest attribute predictions.
- Development of a machine learning random forest regression model to capture complex relationships between predictor variables and forest attributes.
- Selection of informative predictors using feature selection techniques to improve model performance and interpretability.
- Evaluation of the model's accuracy using statistical measures and cross-validation techniques.
- Consideration of scalability and transferability of the developed methodology for nationwide forest structure mapping in Romania.

Recommended bibliography:

1. Wulder, M. A., White, J. C., Loveland, T. R., Woodcock, C. E., Belward, A. S., Cohen, W. B., Fosnight, E. A., Shaw, J., Masek, J. G., & Roy, D. P. (2018). The global Landsat archive: Status, consolidation, and direction. Remote Sensing of Environment, 205, 186-197.
2. Cote, J. F., Fournier, R. A., Egli, R., & Wulder, M. A. (2021). Individual tree detection from airborne lidar and imagery data using a deep convolutional neural network. Remote Sensing of Environment, 256, 112353.

3. Frazer, G. W., Magnussen, S., & Wulder, M. A. (2019). Continuous change in Canada's forests detected using operational satellite remote sensing data. Remote Sensing of Environment, 221, 613-628.
4. Hudak, A. T., Crookston, N. L., Evans, J. S., & Hall, D. E. (2008). A new estimator for 3D tree canopy volume using a combination of fixed and variable radius plots and lidar. Remote Sensing of Environment, 112(2),

TOPIC 3: ***Mapping Forest Resources in Guyana: Providing reliable data for Sustainable Strategic Development***

Introduction:

The tropical forests of Guyana are not only rich in biodiversity but also hold immense economic and environmental significance for the country. These forests provide essential ecosystem services, such as carbon sequestration, water regulation, and habitat preservation. Moreover, they contribute significantly to Guyana's economy through sustainable timber extraction, ecotourism, and the potential for carbon credits.

However, the effective management and development of Guyana's forest resources require accurate mapping and a comprehensive understanding of their distribution, composition, and dynamics. This research plan aims to bridge this knowledge gap by employing advanced remote sensing and GIS techniques to map forest resources in Guyana. The primary objective is to provide reliable data and insights that will support the sustainable development of these valuable resources.

By leveraging remote sensing technologies, such as satellite imagery, LiDAR data, and aerial photography, it is possible to acquire detailed spatial information on forest cover, vegetation types, and ecological features. These data can be processed and analyzed using specialized software and GIS tools, allowing for the identification and classification of different forest types and their associated attributes. Integrating field data collection, including ground truthing and socio-economic surveys, will further validate and complement the remote sensing information, providing a more accurate and comprehensive understanding of Guyana's forest resources.

The outcomes of this research plan will be far-reaching. A comprehensive forest resource map, incorporating various forest types, including primary forests, secondary forests, and disturbed areas, will be generated. This spatial representation will serve as a crucial tool for informed decision-making and land-use planning. Additionally, through the analysis of historical satellite imagery, the research will shed light on forest cover changes, deforestation hotspots, and areas of regeneration, enabling a better understanding of the dynamics of forest ecosystems over time.

Based on the research findings, the plan will provide policy recommendations for sustainable forest management practices. These recommendations will encompass strategies for balancing economic development and environmental conservation, including land-use planning, conservation measures, sustainable logging practices, and the establishment of protected areas. By integrating socio-economic data, the research will also address the socio-economic dimensions of forest resource use, considering factors such as land tenure, livelihoods, and resource utilization patterns.

To ensure the long-term success of sustainable forest management, the research plan will emphasize capacity building initiatives. Training programs and workshops will be developed to enhance the knowledge and skills of local stakeholders, empowering them to actively participate in decision-making processes and contribute to the sustainable development of Guyana's forests.

Methods:

- Remote sensing and GIS techniques: Utilize high-resolution satellite imagery, LiDAR data, and aerial photography to acquire spatial data on forest cover, vegetation types, and ecological features. Process and analyze these data using remote sensing software and GIS tools such as ArcGIS or QGIS.
- Field data collection: Conduct ground truthing to validate and complement the remote sensing data. This involves collecting field measurements, such as tree inventories, species identification, and biomass estimation. Additionally, socio-economic data can be collected

through surveys and interviews with local communities to understand their dependence on forest resources.

- Mapping and classification: Develop a methodology for mapping and classifying forest types, incorporating factors such as tree density, canopy height, and spectral characteristics derived from remote sensing data. This can be achieved through supervised or unsupervised classification techniques, including Maximum Likelihood Classification or Random Forests.
- Socio-economic assessment: Integrate socio-economic data with the spatial data to assess the human impact on forests and identify opportunities for sustainable development. Analyze variables such as land tenure, livelihoods, and resource utilization patterns to understand the socio-economic dynamics related to forest resources.

Expected Outcomes:

- Comprehensive forest resource map: Generate a detailed map of forest types, including primary forests, secondary forests, and disturbed areas, to provide a spatial representation of Guyana's forest resources.
- Forest dynamics analysis: Assess historical forest cover changes using time-series satellite imagery and change detection techniques. Identify deforestation hotspots and areas of regeneration to understand the dynamics of forest ecosystems over time.
- Sustainable management recommendations: Based on the research findings, propose policy recommendations for sustainable forest management. This includes strategies for land-use planning, conservation measures, sustainable logging practices, and the establishment of protected areas to balance economic development and environmental preservation.
- Capacity building initiatives: Develop training programs and workshops for local stakeholders, including forest managers, policymakers, and local communities, to enhance their understanding of sustainable forest resource management practices. This will empower them to actively participate in decision-making processes and contribute to the long-term development of Guyana's forests.

Main Aspects to be considered:

- Remote sensing data acquisition and analysis techniques: Consider the appropriate satellite sensors, image resolutions, and data processing methods to obtain accurate and up-to-date information on forest resources.
- Field data collection methods for validation and complementation: Design efficient field sampling protocols to collect data on forest structure, species composition, and socio-economic variables. Ensure the integration of local knowledge and community participation in the data collection process.
- Mapping and classification methodology for forest resources: Develop robust algorithms and workflows for classifying forest types and identifying key ecological features using remote sensing data and ground truthing information.
- Integration of socio-economic data for comprehensive assessment: Establish mechanisms to collect and analyze socio-economic data in conjunction with spatial data to understand the human dimensions of forest resource use and develop sustainable management strategies.
- Policy recommendations for sustainable forest management: Consider national and international policies, legal frameworks, and stakeholder engagement to formulate practical and context-specific recommendations for sustainable forest management in Guyana.
- 6. Capacity building initiatives for local stakeholders: Design and implement targeted training programs, workshops, and knowledge-sharing platforms to enhance the capacity of local stakeholders in sustainable forest resource management practices and

Recommended bibliography:

1. Achard, F., et al. (2014). Determination of tropical deforestation rates and related carbon losses from 1990 to 2010. Global Change Biology, 20(8), 2540-2554.

2. Asner, G. P., et al. (2013). Mapping Brazil's forested landscapes using remote sensing, satellite imagery, and GIS. Remote Sensing, 5(6), 3061-3080.
3. Food and Agriculture Organization (FAO). (2010). Global Forest Resources Assessment 2010: Main Report. Rome: FAO.
4. Grinand, C., et al. (2016). Mapping tropical forest biomass with radar and spaceborne LiDAR in Lopé National Park, Gabon: overcoming problems of high biomass and persistent cloud. Biogeosciences, 13(5), 5447-5462.
5. Guyana Forestry Commission. (2016). State of Guyana’s Forests Report. Georgetown: Guyana Forestry Commission.
6. Hansen, M. C., et al. (2013). High-resolution global maps of 21st-century forest cover change. Science, 342(6160), 850-853.
7. Mather, A. S. (2017). Guyana's forests under global change. The Geographical Journal, 183(1), 16-30.
8. Ramdass, K. (2016). The economic value of forests in Guyana. Natural Resource Economics Review, 20, 1-26.
9. Reitsma, F., et al. (2019). Mapping social-ecological systems: The power of bridging different social and environmental data sources. Sustainability Science, 14(6), 1577-1593.
10. Southworth, J., et al. (2015). Forests, people, and pixels: Linking remote sensing, ground-based measurements, and socioeconomic data to understand forest change. Environment and Society: Advances in Research, 6(1), 111-128.
11. United Nations Development Programme (UNDP). (2020). Human Development Report 2020: The Next Frontier - Human Development and the Anthropocene. New York: UNDP.
12. Wijedasa, L. S., et al. (2016). Denial of long-term issues with agriculture on tropical peatlands will have devastating consequences. Global Change Biology, 22(6), 2328-2341.

Prerequisites / Remarks: *to be adapted/ completed/ deleted*

Doctoral supervisor,

Prof. Dr. Nita Mihai Daniel

Signature

Coordinator of the field of doctoral studies,

Prof. Dr. Ionescu Ovidiu

Signature