FORESTRY FUTURES TRUST ONTARIO

Enhanced Forest Resource Inventory

Knowledge Transfer & Tool Development Program

Application Form "A"

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FOR OFFICE USE ONLY: PROJECT NUMBER

GENERAL INFORMATION

PROJECT NAME:

Disturbance Monitoring Platform to Enhance Forest Inventory using historical LiDAR datasets.

APPLICANT INFORMATION

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PROJECT SUMMARY:

Human activity in the forests has resulted in a reduction in their ability to act as "carbon sinks" and has been attributed to speed up climate breakdown. In the past few decades the amount of carbon absorbed by the world's intact forest ecosystem has fallen and the forests now take up a third less carbon than they did in the last'90s, owing to the effects of higher temperatures, droughts, deforestation, forest fires and biotic disturbances. The human activity and biotic disturbances (including abiotic, biotic, fire, pests) cause significant damage and subsequently alter the forest structure and its underlying ecosystem. LiDAR technology has been widely used to get accurate data to estimate land cover and ecological changes over time. This research aims to investigate multiple factors related to disturbance caused either due to human activity, biotic disturbances or due to forest fires and the complex interactions that occur on a spatiotemporal frame for the region of Ontario. The spatio-temporal analysis of these aforementioned parameters over a period of 10 years would help us build reliable models to simulate their impact at large spatial scales. By using multi-modal data acquisition technique, we aim to derive forest biodiversity metrics, vegetation structure density and spatio-temporal foraging patterns of various species. This would in turn help us derive spatio-temporal foraging patterns of their habitats and movement corridors to assess their impact over time.

PROJECT DURATION:

FROM: March 2021 **To: March 2023**

PROJECT THEME

Theme 5: Advanced Remote Sensing B. Disturbance Monitoring (abiotic, biotic, and fire for disturbance types and pests in Ontario)

EXTERNAL REVIEWERS:

1.

2.

Section1: PROJECT DESCRIPTION

Human activity has caused irreversible alterations to the Earth's geological, biological and ecological systems. Among the many systems, forest ecosystems play a significant role as "carbon sinks" with their ability to absorb CO_2 emissions. These emissions contributed to alter climate cycles to the extreme; causing flooding, droughts and fire creating fluctuations in the biodiversity of their underlying ecosystem. It is of interest to us, to assess the spatio-temporal impact of different disturbances (abiotic,biotic and fire) which cannot be studied in isolation. There is growing need to address this by considering coupling effect by combining these disturbances on the underlying ecosystem. This study considers 10-year high resolution historical LiDAR and Hyperspectral imaging data at 1m resolution for the region of Ontario to derive spatio-temporal patterns using agent-based modeling of the aforementioned disturbances. The use of hyperspectral imaging for enhanced forest inventories can help us derive meaningful reflectance attributes of the vegetation, while LiDAR data offer alternative for analyzing structural properties of the canopy. The fusion of these two data sources can help us better model various disturbances. One of the key limitations to fuse data at pixel level is the intraclass variations. This can be improved with the aid of high resolution images. The fusion of spatial, temporal and spectral properties cannot be achieved by using a single algorithm and would require us to investigate new algorithms that present high application value with high accuracy (Chang and Bai, 2018). The objective of this research is on providing more detailed, finer resolution, accurate, integrating historical data with near-real time data on a) forest tree species identification, b) historical change detection of vegetation and assessing the damage using optical air and space-borne hyperspectral and multi-spectral data. This information would help us draw significant insights to assess and forecasting biotic, abiotic, fire and human induced disturbance through agent based simulation models. Finally, would help us draw data-driven policy guidelines for ecologically sensitive infrastructure development.

SECTION2: PROJECT TEAM

TEAM MEMBERS

ROLES & RESPONSIBILITIES

PARTNERSHIPS (IF APPLICABLE)

SECTION 3: DESIGN & METHODOLOGY

DESIGN

The study is designed to collate and integrate 10-year historical SAR, LiDAR, Hyperspectral image data, when combined with optical imagery provides us the ability to identify disturbance and quantify its ecological effect more precisely than using a single data set. The study area is the province of Ontario which covers large areas of uplands, particularly within the Canadian shield which traverses the province from northwest to the southeast and also above the Niagara Escarpment which crosses the south. This study intends to combine field-collected forest structural metrics and disturbance parameters with remotely sensed imagery to design and evaluate a base line image for analysis. Prior to the multi-phase design strategy, image restoration and rectification to correct for sensor and platform-specific radiometric and geometric distortions of data are performed. In the subsequent phase, we use airborne profiling LIDAR instruments to seek the characteristics of the forest area to record various (spatial, spectral and structural) attributes over spatio-temporal frame of 10 years. In the third phase, forest inventory plots are identified for the study area using a stratified statistical sampling protocol by combining elevation and solar insolation. The elevation and solar insolation influence forest productivity, species composition, and leaf area index that describes the forest canopy conditions. Our specific objective are: a) to plan and evaluate a feasible method for multi-scale, multi-sensor detection and mapping of forest disturbance, b) to undertake field campaign to collect, calibrate data from disturbance-impact forest areas, c) to assess the impact of disturbance events on forest attributes, d) to assess our ability to use alternate remote sensing technology to characterize wide-ranging disruption incidents, e) to develop standard image processing techniques that can be widely used in real-time by using API calls, f) to design a seamless integration API that enables us to collate, process and analyze the data sets to generate regional maps based on disturbance parameters. g) create a continuously ground validated application system using the probability maps.

METHODOLOGY

To quantify disturbance and regeneration dynamics of forest ecosystem for a wide range of parameters, the fusion of multi-temporal 10-year data from SAR, LIDAR and Hyperspectral sensors is used. The characterization of the vegetation structure, species and the underlying micro-climatic conditions remains very coarse and sometimes imprecise; using multi-sensor fusion data we capture highly accurate data to identify, extract and classify features with high precision. Post rectification and correction operations, the integration process combines various contextual aspects of image, information and survey data to draw high application value for assessing disturbance and regression dynamics of the forest ecosystem. Dechesne (2017) outlines the various schemes of fusion at *observation level, feature level and decision-level,* with machine learning at play, ”*data fusion approaches not only enhance spatial, temporal and spectral resolution of the input remotely sensed imagery, but also improve prediction accuracy and optimize the data quality and spatial coverage simultaneously, which would in-turn help us explore the coupling effects among the biosphere, atmosphere, hydrosphere etc…”* (Chang and Bai, 2018). Using statistical fusion methods such as regression-based techniques, Geostatistical approach and spatio-temporal modeling algorithms, multi-temporal and multi-spectral data sets are integrated to build a base line image as input for disturbance analysis. Post data fusion process, stratified statistical sampling techniques are applied for identifying forest inventory plots and species-abundance plots for the study area. A variety of approaches and the number of readily available predictor variables are available for the modeler for forest inventory analysis. Brosofske *et al* (2014) states that decisions are governed by the degree to which the modeler attempts to describe or interpret the system versus generating accurate predictions. It is of interest for us to model and evaluate the performance of various methods that help us quantify the disturbance and regeneration dynamics on a spatio-temporal frame. Hence, we intend to evaluate the performance of various methods such as *linear multiple regression equations resolved using ordinary least squares, Classification and Regression Tree (CART), Multivariate Adaptive Regression Splines(MARS), Random Forest Ensemble* to analyse, estimate and predict the impact on the forest ecosystem due to disturbance parameters. Subsequent to this analysis, classical image to image change detection technique are applied from the start of the monitoring period to the end using time series analysis-based change detection. We intend to apply the extensional methods to time-series analysis they being: *threshold-based change detection, curve fitting, trajectory fitting and trajectory segmentation* for mapping forest disturbance and degradation (Hirschmugl *et al.* 2017). This would help us draw predictive insights that will enable both near real-time disturbance mapping to support operative curative insights for defining and evaluating the policy to amplify forest regeneration dynamics.

SECTION 4: SCHEDULE
PROJECT DATES
March 2021- March 2024

DELIVERABLES/Milestones

1. User requirements study to create enhance forest inventory repository to collate multi-temporal , multi-resolution, multi-sensor data set
2. Collection of Datasets from the period of 2010 to 2021 for the study area of Ontario
3. Investigate data fusion strategies to integrate multi-sensor data to create a baseline application data
4. Design, implement and test a multi-modal application programming interface to collate, process and analyze data
5. Develop thematic spatio-temporal perspective based on disturbance parameters.

SECTION 5: PROJECT BUDGET

SECTION 6: KNOWLEDGE & TECHNOLOGY TRANSFER

SECTION 7: REFERENCES

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Hirschmugl, M., Gallaun, H., Dees, M. et al. 2017 Methods for Mapping Forest Disturbance and Degradation from Optical Earth Observation Data: a Review. Curr Forestry Rep 3, 32–45 https://doi.org/10.1007/s40725-017-0047-2

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