Research Proposal for the Strategic International Partnership Initiative: Chile

Title: **Using Acoustic Sensors and Mobile Terrestrial LiDAR for Market-Driven Harvest Planning and Forest Management**

Principal and Co-principal Drs. Temesgen Hailemariam (Forest Engineering, Resources, and Management Department), Sean Garber, Olympic Resource Management, Poulsbo, Washington

Co-principal: Dr. Guillermo Trincado, Instituto de Bosques y Sociedad, Facultad de Ciencias Forestales y Recursos Naturales, Universidad Austral de Chile, Box 567, Valdivia, Chile

Introduction:

The amount of wood volume and wood quality vary with both tree and stand attributes. At tree level, crown development, stem shape and taper, branch size and branch location, knot size, type and placement influence wood properties. At stand level, stand density, moisture and nutrient availability, competition, disturbance, and stand age are key determinants of wood volume and wood quality. Light Detection and Ranging (LiDAR) measures the three-dimensional distribution of branches directly and other vegetation attributes in a stand. As a result, LiDAR is well suited to quantify wood volume and wood quality at tree- and stand-levels.

Market-driven planning requires reliable and spatially-explicit estimates of forest attributes including log product volumes, rather than broader based estimates at the stand level. Optimally matching wood quality to markets should lead, not only to improved product uniformity, profitability and sector competitiveness, but also contribute to reduced wastage, energy consumption and environmental impacts along the seedling to customer supply chain. To accomplish this from traditional inventory techniques would imply prohibitive costs due to the required sampling intensity.

In previous research, we have demonstrated the use of airborne and terrestrial LiDAR to quantify biomass and vegetation structure. Using case studies, we demonstrate the to use acoustic sensors and mobile terrestrial LiDAR to better address information needs for *market-driven* harvest planning and forest management across Oregon and Chile.

Objectives:

1. Evaluate the use of acoustic measurements and mobile terrestrial LiDAR to provide reliable and cost effective estimates of wood volume and wood quality.

2. Examine a combination of model-assisted and non-parametric methods to quantify wood volume and wood quality under varying stand density and structure.

3. Determine how variables-derived from acoustic sensors and mobile terrestrial LiDAR could be integrated with traditional forest inventory techniques to predict wood volume and wood quality (e.g., wood density and stiffness).

Rationale:

Sustainability and a globally competitive forest product supply market are two of the pressures that forest managers face today. Both require that managers have good metrics of the quantity, quality and location of timber resources within the forest. New technologies and approaches to obtain key variables are required with the goals of increasing their accuracy and reducing their data gathering costs. As a result, acoustic sensors and mobile terrestrial LiDAR have recently emerged as prominent tools for market-driven harvest planning and forest management.

Past research has demonstrated that LiDAR can be used to estimate tree- and stand-level attributes including above ground biomass, volume, and stand density. Rapid advances in data capture technology have allowed for the collection and storage of acoustic sensors and mobile terrestrial LiDAR data. However, the use of these data to quantify wood volume and wood quality (e.g., wood density, stiffness, and microfiber angle) are lacking. The next frontier in LiDAR research is to relate LiDAR metrics with selected branch and wood quality attributes. Further research is needed, particularly on how these technologies can be integrated into an existing or new inventory system.

Dean's Investment Funds would facilitate collaboration between Drs. Temesgen (FERM), Guillermo Trincado, and Sean Garber (Forest biometrician at Olympic Resource Management) on acoustic measurements and mobile terrestrial LiDAR to quantify standing wood biomass and wood quality. Our work directly supports the internationalization efforts of the CoF and seeks to increase the competitiveness of Oregon's forestry businesses by improving the quality of wood volume and wood quality prediction. Cooperation among the team members will improve research excellence both at OSU and Universidad Austral de Chile.

Methods:

Field data on standing and felled trees and metrics derived from acoustic sensors and mobile terrestrial LiDAR will be used to examine their relationships to standing wood volume and wood quality. A conceptual framework for predictive modeling of these relationships will be developed based on existing literature and empirical observations.

	Using Monte Carlo experiments, we will evaluate the adequacy and sufficiency of selected metrics derived from acoustic sensors and mobile terrestrial LiDAR for estimating wood volume and wood quality, and also assess selected linear and nonlinear models to expand tree-level estimates to a larger landscape level estimates. Sources of error will be identified and potential procedures for integrating these new types of inventory data will be evaluated.
Leveraged funding	Our proposed effort will leverage existing acoustic sensors and 3-dimensional laser scanning, and takes advantage of a terrestrial LiDAR dataset that has been collected across Oregon by the Forest Biometrics and Measurements Lab. This study leverages the additional funding ($200K) of Dr. Temesgen to provide spatially explicit biomass data for western Oregon forests.
Partner linkages:	This project will directly complement a project that Dr. Temesgen recently initiated to estimate and map biomass: An Improved Biomass and Carbon Database for West Coast Tree Species (JV-11242305-110). Olympic Resources will plan to provide trees and other materials for the project. Throughout this project, the team will remain in close contact to relevant stakeholders to ensure a maximum benefit for all parties.
Conveying Results:	A peer-reviewed journal paper, and conference presentations at the annual Western Mensurationist Meeting, professional meetings (i.e. the annual SAF and OSAF meetings), and an international meeting in Europe will be used to convey results of this project.
Duration:	September 2015 to December 2017.
Budget:	**Total amount requested is $18,800**. The grant will be used to support a graduate student and associated cost to acquire field data, travel to Chile, materials and supplies, and conveying results through publications and regional and international conference presentations. Please attached budget for details.
External Funding	Dr. Guillermo Trincado, at Instituto de Bosques y Sociedad, will contribute $2000 USD to support a graduate student to collect data in Chile and $2000 USD to travel to OSU and promote student and faculty exchange. Forestal Mininco Company has agreed to contribute $10,000 towards this Project. Please see attached support letters for additional information.
Anticipated Outcomes	Two-peer reviewed manuscript and an algorithm will be anticipated as a results of this project. The algorithm for mobile terrestrial lidar and acoustic measurements will improve inventory techniques by optimally matching wood volume and quality to

markets. Using two case studies in Oregon and Chile, we seek to demonstrate the use of acoustic sensors and mobile terrestrial LiDAR to better address information needs for *market-driven* harvest planning and forest management across.

Universidad Austral de Chile
Instituto de Bosques y Sociedad

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To whom it may concern,

I am writing to you in support of the research proposal titled "**Using Acoustic Sensors and Mobile Terrestrial LIDAR for Market-Driven Harvest Planning and Forest Management**". This proposal is presented by Dr Temesgen Hailemariam at the College of Forestry in the framework of the Strategic International Partnership Initiative: Chile.

In my view the proposed research is innovative and relevant to advance the application and linkage of acoustic sensors and mobile terrestrial Lidar to forest inventory and assessments. This proposal expands the use of new methodologies to intensive-managed radiata pine plantations in Chile. Furthermore, it will plant seeds for long-term collaborative research in forest biometrics between Universidad Austral de Chile and OSU.

If this proposal is successful I commit myself during the progress of this research project to:

- Design a comparative study in Chile in conjunction with the research team to test the application of acoustic sensor and particularly mobile terrestrial LiDAR to increase accuracy in tree volume and wood quality estimate.

- Collaborate with the selection of study sites, organization of logistic required for data gathering and measurements in radiata pine plantations owned by Forestal Mininco. In order to support field measurements a Chilean graduate student will be hired part-time for three months (2,000 USD).

- Promote student and faculty exchange from OSU related to this research project and contribute funding from my own projects and cover stay costs for one week in Valdivia (1,500 USD). Flight costs need to be provided by OSU.

- Collaborate in data analysis and preparation of research papers resulting of this research study. Funds for covering flight costs (2.000 USD) will be secured for making a research visit at OSU on 2016 in order to complete work in conjunction with the research team. Stay costs are expected to be provided by OSU.

Finally, I would like to express my gratitude to the College of Forestry for developing in a very short time this financial initiative to promote concrete research collaboration between OSU and Chilean Institutions. I also thank Dr Temesgen by making efforts to develop this proposal and share part of his advanced research with us at the Universidad Austral de Chile.

Sincerely,

Guillermo Trincado, PhD

INSTITUTO DE BOSQUES Y SOCIEDAD
FACULTAD DE CIENCIAS FORESTALES
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FORESTAL MININCO

02 June 2015

To whom it may concern,

In behalf of Forestal Mininco Company, I am writing in support of the research project titled **"Using Acoustic Sensors and Mobile Terrestrial LIDAR for Market-Driven Harvest Planning and Forest Management".** This proposal is presented by Dr Temesgen Hailemariam at the College of Forestry in the framework of the Strategic International Partnership Initiative: Chile.

The proposed study is of interest to Forestal Mininco because it could be useful for obtaining information that can be used to improve the estimation of the amount and quality of the forest products. Such results could be used by managers to get a better characterization of the forest and finally to optimise desired product outturn and value.

The contribution of Forestal Mininco to the project will be: the participation of experts and professionals, trees and plots for testing, measuring costs associated with them, costs associated with logistics activities of experts from UACh and OSU . The estimated total contribution will be US$5,000 in materials and field operations, and US$5,000 in costs associated with logistics (accommodation, travel, food, etc.)

We look forward that this project will be allocated to improve the exchange and interaction between our company and the prestigious Oregon State and Austral Universities.

Yours sincerely,

Jean-Pierre Lasserre

EB-2-JVA Form rev 11/19/14

Forest Research Laboratory, Oregon State University
ESTIMATED BUDGET FOR DURATION OF RESEARCH PROJECT

Agency: University of
Principal Investigator: Temesgen Hailemariam,
Start Date: 09/01/15
End Date: 12/30/2017
Salary Escal 0%

Proposal Title: Using Acoustic Sensors and Mobile Terrestrial LiDAR for Market-Driven Harvest Planning and Forest Management

BUDGET CATEGORIES	annual base salary	YEAR 1	Non-cash Contribution - Chilean	Agency to OSU	OSU	YEAR 2	Non-cash Contribution - Chilean	Agency to OSU	OSU	TOTAL	Non-cash Contribution - Chilean	Agency to OSU	OSU
ACADEMIC WAGES													
ON CAMPUS		FTE				FTE				FTE			
PI- Hailemariam													
Name -				-	-			-	-		-	-	-
Grad Res Assistant - MS	43788	0.25		10,947	10,947			-	-		-	10,947	10,947
Grad Res Assistant - PhD	44220												
OFF CAMPUS - CHILE											-	-	-
Co-PI - Guillermo Ticando			5,000	-	-	5000		-	-		10,000	-	-
Name -				-	-			-	-		-	-	-
Grad Res Assistant - MS	43788			-	-			-	-		-	-	-
Grad Res Assistant - PhD	44220			-	-			-	-		-	-	-
TOTAL SAL & WAGES			**5,000**	**10,947**	**10,947**		**-**	**-**	**-**		**10,000**	**10,947**	**10,947**
FRINGE BENEFITS (OPE)		Rate				Rate							
ON CAMPUS													
PI- Hailemariam			-	-	-		-	-	-		-	-	-
Name -			-	-	-		-	-	-		-	-	-
Grad Res Assistant - MS			-	-	-		-	-	-		-	-	-
Grad Res Assistant - PhD			-	-	-		-	-	-		-	-	-
OFF CAMPUS											-	-	-
Name -			-	-	-		-	-	-		-	-	-
Grad Res Assistant - MS			-	-	-		-	-	-		-	-	-
Grad Res Assistant - PhD			-	-	-		-	-	-		-	-	-
TOTAL OPE			**-**	**-**	**-**		**-**	**-**	**-**		**-**	**-**	**-**
TOTAL PERSONNEL COSTS			**5,000**	**10,947**	**10,947**		**-**	**-**	**-**		**10,000**	**10,947**	**10,947**
ON CAMPUS TRAVEL, SUPP, SVC													
Travel / Domestic				400				1,253			-	1,653	-
Travel / Foreign - Chile								4,600			-	4,600	-
Materials & Supplies				400				400			-	800	-
Minor Equipment											-	-	-
Maintenance & Repair											-	-	-
Other Fees & Services											-	-	-
Publication Costs				200				200			-	400	-
Computer Services				200				200			-	400	-
Other											-	-	-
SUBTOT			**-**	**1,200**	**-**		**-**	**6,653**	**-**		**-**	**7,853**	**-**
OFF CAMPUS TRAVEL, SUPP, SVC													
Travel / Domestic											-	-	-
Travel / Foreign											-	-	-
Materials & Supplies											-	-	-
Minor Equipment											-	-	-
Maintenance & Repair											-	-	-
Other Fees & Services											-	-	-
Publication Costs											-	-	-
Computer Services											-	-	-
Other											-	-	-
SUBTOT			**-**	**-**	**-**		**-**	**-**	**-**		**-**	**-**	**-**
BASE - DIRECT COSTS (eligible for indirects)			**5,000**	**12,147**	**10,947**		**-**	**6,653**	**-**		**10,000**	**18,800**	**10,947**
OTHER DIRECT COSTS (exempt)													
Equipment											-	-	-
Tuition					13,380						-	-	13,380
Other											-	-	-
SUBTOT (exempt from indirects)			**-**	**-**	**13,380**		**-**	**-**	**-**		**-**	**-**	**13,380**
TOTAL DIRECT COSTS			**5,000**	**12,147**	**24,327**		**-**	**6,653**	**-**		**10,000**	**18,800**	**24,327**
F&A INDIRECTS													
FS INDIRECTS		**14.0%**	**700**			**14.0%**	**-**				**700**		
F&A INDIRECTS ON CAMPUS		**46.0%**		**5,588**	**5,036**	**46.5%**		**3,094**	**-**			**8,682**	**5,036**
F&A INDIRECTS OFF CAMPUS		**26.0%**		**-**	**-**	**26.0%**		**-**	**-**			**-**	**-**
TOTAL PROJECT COSTS			**5,700**	**17,735**	**29,363**		**-**	**9,747**	**-**		**10,700**	**27,482**	**29,363**
Cost share F&A INDIRECTS				**(5,588)**	**5,588**			**(3,094)**	**3,094**			**(8,682)**	**8,682**
ADJUSTED TOTAL PROJECT COSTS			**5,700**	**12,147**	**34,951**		**-**	**6,653**	**3,094**		**10,700**	**18,800**	**38,045**

AGENCY PLUS OSU	**47,098**	**9,747**	**56,845**
TOTAL PROJECT COSTS	**52,798**	**9,747**	**67,545**
OSU TOTAL CONTRIBUTION	**34,951**	**3,094**	**38,045**

OSU SHARE %	**66.2%**	**31.7%**	**56.3%**	

Table 1. Schedule of activities for proposed 2-year project (J=January-April, M=May-August, S=September--December).

Activity	2015/16		2016/17		
	S	J	M	S	J
Oregon Select stands and measure tree attributes, azimuth, and distance.					
Chile Select stands and measure tree attributes, azimuth, and distance.					
Assess the relationship between acoustic sensors and mobile terrestrial LiDAR, using Oregon's and Chile data					
Simulation and analysis					
Analysis of the predictive abilities of acoustic sensors and mobile terrestrial LiDAR Conduct Monte Carlo Simulation					
Prepare and write manuscripts Technology and algorithm transfer					