

Straw Utilization for Fiber Based Materials

Submitted to:

Agricultural Burning Task Force

RFP ECY 0420

Kristi Lewis

President

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Bill McKean University of Washington
Mark Lewis University of Washington

Appendix A

CERTIFICATIONS AND ASSURANCES

I/we make the following certifications and assurances as a required element of the bid or proposal to which it is attached. I/we understand that the truthfulness of the facts affirmed here and the continuing compliance with these requirements are conditions precedent to the award or continuation of the related contract(s):

1. The prices and/or cost data have been determined independently, without consultation, communication or agreement with others for the purpose of restricting competition. However, I/we may freely join with other persons or organizations for the purpose of presenting a single proposal or bid.
2. The attached proposal or bid is a firm offer for a period of 60 days following receipt, and it may be accepted by the Department of Ecology without further negotiation (except where obviously required by lack of certainty in key terms) at any time within the 60-day period.
3. In preparing this proposal or bid, I/we have not been assisted by any current or former employee of the State of Washington whose duties relate (or did relate) to this proposal, bid or prospective contract, and who was assisting in other than his or her official, public capacity. Neither does such a person nor any member of his or her immediate family have any financial interest in the outcome of this proposal or bid. (Any exceptions to these assurances are described in full detail on a separate page and attached to this document.)
4. I/we understand that the Department of Ecology will not reimburse me/us for any costs incurred in the preparation of this proposal or bid. All proposals or bids become the property of the Department, and I/we claim no proprietary right to the ideas, writings, items, or samples.
5. I/we understand that any contracts awarded as a result of this RFP will contain terms and conditions substantially similar to those attached as Appendix B. I/we certify that I/we will comply with these or substantially similar Terms and Conditions if selected as a contractor.

Krist Lewis

Signature

3/30/05, 2005

President

Title

Straw Utilization for Fiber Based Materials

The proposed work in this Grant Application will develop further utilization of wheat, seed alfalfa, and blue grass straw as an alternative fiber source in the pulp, paper, and molded products industry. Research funded by the Washington State Department of Ecology has led to never-before opportunities both by the farmer and by a variety of pulp fiber based producers. The 2003-2005 research led to the first ever commercial papermachine runs (2), first ever commercial molded pulp runs using Washington wheat and seed alfalfa straws.

This biennium's project will continue to advance much of the progress that has been made. It will also review and address hurdles that have been brought to light in past research. This project will also show the viability of agricultural-fiber cooperatives coupling raw material suppliers with users to create a relationship whereby both parties could utilize each other's assets and equipment.

The United States pulp and paper industry is under pressure from offshore competition utilizing low cost manpower and fiber sources. The industry will need available economically viable sources of raw material. Over a million tons of cereal straw is burned every year in Washington State. Research has continued to show the opportunities that exist for manufacturing pulp and paper from this bioresource.

The overall areas of focus for this integrated project are:

1. Pulping and Papermaking
Bleached wheat straw for copy paper, alfalfa and wheat for molded pulp products, wheat and alfalfa for paperboard product trials
2. Liquor Utilization
Dust control on roads; grass straw pulping for hydroseeding
3. On Farm Economics
4. Dissemination of Information

Anticipated Outcomes from the Project:

1. Create a demand for copier paper containing wheat and or seed alfalfa straw.
2. Two successful trials at the Sonoco mill in Sumner which will provide the support needed for the mill to start partial substitution of OCC with cereal straw pulp.
3. Complete a large scale trial at a molded pulp operation in Eastern Washington to make apple trays and replace old newspapers (ONP) as the fiber source.
4. Determine the effectiveness and possible business opportunities around utilization of straw black liquor in dust abatement programs on roads
5. Develop a process whereby grass seed straw can be pulped on the back of a flatbed, then mixed with seed to hydroseed.
6. Complete a definitive analysis of on farm cost to remove straw to make available for further utilization.
7. Research will be presented locally and internationally on the benefits of straw pulping and papermaking.

The reports will be completed after every task, and also a final report will be available in print and in electronic format.

BACKGROUND AND RATIONALE

Continued burning of agricultural straw residuals has an economic, environmental and health effect on the farmer and the surrounding communities. Burning is slowly being reduced, but previous efforts into straw utilization have not been particularly successful for a variety of reasons. Burning is coming under increasing scrutiny due to health and environmental concerns. Approximately 2000 fires are set every year burning approximately 250,000 acres. An estimated 40,000 tons of pollution are put into the atmosphere every year in the form of particulate matter, carbon monoxide and VOC's. (Washington DOE Ag Burning web site) These have been proven to create a wide range of health problems from residents downwind of the fires.

The northwest pulp and paper industry is coming under increasing pressures from domestic and international concerns. The increasing development of the pulp and paper infrastructure in China and Southeast Asia has put economic and raw material pressure on northwest paper mills. As more mills start up in China the demand for a fiber source is focusing on the Pacific Northwest. The demand for old corrugated containers (OCC) has increased dramatically in the last 4 years putting direct pressures on the fiber supply for many Washington Pulp and Paper mills. As the demand for all secondary fiber increases small molded pulp operations are seriously concerned that they will have a constant flow of raw materials to manufacture a consistent economically viable product.

RELATED AND CURRENT WORK

Recent research funded by the Washington State Department of Ecology has led to tremendous developments in the past two years. Commercial trials have been completed on a molded pulp machine in eastern Washington utilizing wheat straw and seed alfalfa straw. Both of these have been deemed a success by the manufacturer. The first ever papermachine run using wheat straw pulp from Eastern Washington was completed in August 2004. The manufacturer then processed the paperboard into a final product. A second larger trial using two tons of wheat straw produced five tons of paper was completed in December 2004. All of these trials were viewed as partial successes. They were successful enough for the paper manufacturers to want to pursue future longer trials.

This related and current work has moved along commercial paper and pulp milestones. This proposed research will involve an integrated system which encapsulates pulping, papermaking, liquor utilization, and on farm economics.

PROPOSED WORK

The pulp and paper industry recognizes the viable fiber supply that exists with cereal straw residues. Previous efforts to pulp cereal straws have led to technical and economic issues, which have caused the industry to stay with wood and secondary fiber as a raw material. In the past there has been enough of this raw material available to not need to look at non-wood fibers. Asian pulp and paper mills utilizing North American secondary fiber has put economic and logistical pressures on the northwest pulp and paper industry. Forecasts are that the increasing production in China will continue to apply pressure to the secondary fiber market in the United States.

There are two molded pulp operations in Eastern Washington, and two paperboard mills in Western Washington whose total fiber supply is secondary fiber. The molded pulp operations use

A blend of newsprint and OCC to manufacture, apple trays, berry trays, egg cartons, and specifically designed containers. The two one hundred percent secondary fiber paperboard mills use a blend of papers as their raw materials. Their primary source is OCC; this is also the most in demand recycled fiber source for the Asian pulp and paper market.

An integral portion of this project is the complete cradle to cradle aspect. The straw needs to be harvested, handled processed for transportation to the mill. It then needs to be preprocessed, pulped and the fiber separated from the liquor. The drawback to previous work in the area of straw pulping has been what to do with the spent liquor. The utilization of this liquor is a necessary element of the whole project.

The seven integrated objectives for this project are:

PULPING AND PAPERMAKING (UW)

1. Produce a high brightness (80+) pulp from wheat straw.
2. Two additional commercial papermachine runs using wheat and seed alfalfa on a cylinder machine partially replacing OCC (old corrugated containers)
3. Produce enough pulp for a one ton commercial run on a molded pulp machine

LIQUOR UTILIZATION (UW/WSU)

- 4 Evaluate spent black liquor from the pulping process for dust control on dirt roads.
- 5 Produce a grass straw pulp that could be used by the hydroseed industry.

ECONOMICS (WSU)

6. Complete an economic study to determine exact costs to harvest and bale wheat, seed alfalfa and blue grass straw.
7. Results will be presented at International Pulp and Paper conference as well as to Eastern Washington high schools and community colleges.

APPROACH: MATERIALS AND METHODS

PHASE 1: High Brightness Wheat Straw Pulp for Copy Paper Production (UW)

Copy paper is traditionally made of a blend of hardwood and softwood fibers with a certain percentage of recycled fiber content. Hardwood fiber is becoming a raw material which is in high demand and short supply. Minimum brightness for commercial copy paper is 83. An 80 brightness straw pulp blended with a higher brightness softwood pulp could make a copy paper surpassing 80 brightness. Wheat straw fiber is of similar length to that of hardwood fibers. Previous research at the University of Washington has shown that wheat straw pulp is difficult to bleach using non-chlorine containing compounds. Ferrulic acid chromophores in the straw pulp give it a residual yellow color. Yellow is extremely detrimental to brightness.

Task 1.1 Pulping and Bleaching of Wheat Straw

Preprocessed wheat will be pulped to achieve a maximum unbleached brightness. Chlorine-free pretreatment and or additional bleaching chemicals will be evaluated to help remove the ferrulic acid compounds. The second step will be a systematic research study into bleaching of the optimum unbleached brightness pulp will be completed using a range of non-chlorine containing compounds. Brightness and strength properties will be evaluated. A minimum of 80 brightness will be acceptable.

Task 1.2 Papermaking with 80 Brightness Wheat Straw pulp

A series of pilot papermachine runs will be completed on the University of Washington pilot machine. A blend of bleached softwood and a minimum of 30% recycled content will be blended with 10, 20, and 30 percent bleached wheat straw. Optical, strength and printing properties will be evaluated and compared with a furnish without wheat straw pulp.

PHASE 2: Pulp Manufacture for Commercial Paperboard Production (UW/Industry)

Two successful trials have been completed on the papermachine located at Sumner Washington. The two trials had 25 and then 35 percent straw pulp substitution. The following tasks are the next steps needed prior to a full-scale trial at the mill.

Task 2.1 Pulp manufacture for 35% Substitution in Higher Strength Grades

The first two trials were targeting lower strength grades that the mill manufactures. The second trial with 35% straw substitution showed increased strength properties over the normal production of the grade that was manufactured. Three tons of straw will be procured, preprocessed in a tub grinder at the WSU facility at Pullman. This straw will then be transported to the Paper Science Lab at the University of Washington for pulping and refining for the papermachine run. Strength and bulk properties will be evaluated at the University of Washington lab. End products will be manufactured and tested by the paper mill.

Task 2.2 Straw cooking for refining at the Paper mill

The final step before a full scale pulping trial at the mill is to cook 3 tons of preprocessed straw at the University of Washington lab. This cooked straw will be transported to Sumner where it will be added into their system before the refiners. The straw will be blended with the repulped OCC then passed through their refiner system. The straw will be refined in one pass through the existing mill refiner system. Accepts and rejects will be measured by University of Washington personnel on site for the trial. Paperboard will then be manufactured and tested at the mill site.

Phase 3 Pulp Manufacture for Large Scale Molded Pulp Production (UW/Industry)

Two trials with wheat straw and seed alfalfa were run at a molded pulp facility in eastern Washington. The trials were both successful from the point of view of reduced water drainage time and increased strength. Cases of berry trays were produced on a Mahlstrom pilot former. This mill cannot get an adequate fiber supply to operate the mill full time at present production rates. Furthermore, this mill would like to increase production and the utilization of local cereal straw on a consistent basis could make that a reality.

Task 3.1 Manufacture one ton of pulp for large scale trial

1000 pounds of wheat straw pulp and 1000 pounds of seed alfalfa straw pulp will be produced to run at the Keyes Fibre facility in Wenatchee to manufacture apple trays. The mill currently runs a blend of newsprint and OCC at the facility. 100% straw and a 50/50 blend of straw and normal fiber furnish will be evaluated. Key properties are drainage rate and strength. Mill personnel will measure drainage characteristics and strength will be tested at the University of Washington Lab.

Phase 4: Black Liquor as a Dust Suppressant (UW/WSU)

Management of black liquor will be an integral part of any system producing fiber from agricultural residues. Black liquor contains the spent pulping chemicals and organic materials dissolved from the straw during pulping. This liquor is rich in potassium and degraded lignin and carbohydrates derived from the straw. Potential uses include soil supplement, nutrient source, and erosion control (Pan WSU 2005) Lignin and lignosulfonates from wood based pulping have been widely and effectively used for road dust control on unpaved roads. They provide an economical and environmentally friendly alternative to oil or salt based materials for road surface stabilization. Lignin and lignosulfonates are natural adhesives that bind soil particles together, packing them together to create a cohesive surface that is more traffic and erosion resistant. As a result, the roads are more stable, require less grading and emit less dust to the atmosphere. To our knowledge, crop based lignin and lignosulfonates have yet to be evaluated for this potential application. Verification of this potential use could provide a local source of road stabilization material that could be used on unpaved county and farm roads in rural areas. Development of on site, low cost pulping methods could further reduce costs of transportation of straw and straw byproducts.

Task 4.1 Generate 500 gallons of 15% solids black liquor

Straw will be pulped and utilized for the Paperboard production. The spent liquor will be separated and recycled. After every third recycle the liquor will be separated and stored. Two separate trials with liquor applications on dirt roads will be completed. Monitoring will be done by Washington State University Crop and Soils Science. Dust agglomeration will be monitored over time. A seed alfalfa farm will be utilized to possibly determine the effectiveness on dust reduction and control of mite transportation into the fields.

Task 4.2 Increased solids with straw dust.

The second trial will blend wheat straw dust from a tub grinding operation in with 250 gallons of spent liquor to produce a 30% solids system, which will be applied to a controlled road substance. Effectiveness will be measured against a commercially available lignosulfonate product.

Phase 5 Hydroseeding with grass straw pulp (WSU)

Hydroseeding is used in the landscaping industry to prevent soil erosion while providing an optimal environment for grass seed germination. Wood and recycled paper fibers are commonly used for this application because of their propensity for absorbing and retaining water in the seed bed and for its porosity in allowing new seedlings to emerge. Straw mulches have also been used in grass establishment, but it is more labor intensive and includes weed seeds not present in hydromulches. Furthermore, straw must be raked as grass is established. Blown straw does not interconnect effectively, which is required to stabilize the seed environment. Pulped crop straw could potentially provide an alternative to wood fiber in hydromulching and black liquor from the pulping could provide a supplemental source of nutrients and organics.

Task 5.1 Pulping of Blue Grass Straw

Blue grass straw will be pulped under a wide range of conditions to determine the optimum straw pulp characteristics for pumping and spray of pulp with grass seeds. A series of sites at WSU Pullman will be used to determine which of the pulping and chopping conditions will produce a

mat which will have the necessary integrity to hold seeds and produce successful seed germination. The chemistry will be varied to determine possible improved growth of seeds.

Phase 6. Economic Evaluation of Straw Removal (WSU)

Task 6.1

Economic data will be collected on straw harvest, baling, transportation and storage costs to compare with raw material values at the mill gate to define the economics of straw harvest and use for these purposes. Data will be gathered on seed alfalfa, wheat straw and grass straw.

Phase 7. Dissemination of Information

Washington State University and the University of Washington offer a wide range of opportunities to disseminate the information gathered from this and previous research. One of the collaborators on this and previous proposals has presented technical information at international pulping and papermaking conferences. Presentations on this research have also been presented at the Northwest Paper Forum, where there were representatives from the State of Washington, the State of Oregon, cities of Portland and Seattle. Also in attendance were representatives from the Governor’s office, the State Department of Ecology, and the Environmental Protection Agency.

The University of Washington Paper Science and Engineering program has a recruitment program across the state of Washington where current and past research into cereal straw pulping and papermaking is presented. It is also presented in high schools across the state where the program is presented.

ANTICIPATED SCHEDULE

	Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	Q-7
Phase 1 High Brightness Wheat Straw Pulp							
Task 1.1	X	X	X	X	X	X	
Task 1.2				X	X	X	
Phase 2 Pulp Production for Paperboard Trial							
Task 2.1	X	X					
Task 2.2			X	X	X		
Phase 3 Pulp for Molded Pulp Operations							
Task 3.1	X	X					
Phase 4 Black Liquor as a Dust Suppressant							
Task 4.1	X	X	X	X	X	X	
Task 4.2			X	X	X	X	
Phase 5 Hydroseeding with Grass Straw							

Task 5.1				X	X	X	X
Phase 6 Economic Evaluation of Straw Removal							
Task 6.1		X	X			X	X
Phase 7 Dissemination of Information	X	X	X	X	X	X	X

EVALUATION CRITERIA

Phase 1. Success in Phase 1 will be determined by technical, professional and social acceptance. Technically achievement of an 80+ brightness wheat straw pulp using non-chlorinated compounds will be a technical success. The paper that will be manufactured if it can beat or meet paper made on the pilot papermachine with wood pulp and recycled pulp that will be considered a technical success. If this group working on this project can move forward in social acceptance of the paper, or by having a commitment from Gray's Harbor Paper or another local copy paper manufacturer to run a trial that, would be both a professional and social success.

Phase 2. Success in Phase 2.1 will be determined by the company personnel running the trials. Criteria for success will be to meet or beat strength properties for the grades manufactured. Phase 2.2 will be much tougher to measure. Runnability of the cooked straw through the system to the papermachine with minimal issues will be the first criteria for success. Meeting or beating strength properties while maintaining bulk will be the second criteria.

Phase 3 Success for Phase 3 will be to manufacture one ton of pulp and have it be made into 1.5 tons of apple trays. The technical success will be measured by improved drain time, improved drying efficiency, stronger trays and overall acceptance by the end user.

Phase 4 The success of using spent black liquor as a dust suppressant on roads will be more of a subjective measure. Production of the black liquor and the application will be the first success measured. The effectiveness of the trial compared with no treatment and a commercially existing treatment will be determined by the farmer and by other monitoring devices.

Phase 5 Hydroseeding with straw pulp will also be a subjective trial with pictures used to determine the success of the project. Knowledgeable professionals in the industry will be consulted to determine the effectiveness of the mat. The fertilizer effect of the pulping process will take into consideration root and stem length, as well as water holding capabilities of the mat structure.

Phase 6 A comprehensive economic report that will evaluate all aspects of straw removal.

Phase 7 The University of Washington is a world recognized leader in non-wood fiber pulping and papermaking. Their continued efforts to publish and profess the benefits of cereal straw utilization will be measured through papers given at technical conferences, mentions in high school recruiting visits, and with working with state and local government agencies.

Budget Page

Phase 1	High Brightness Wheat Straw Pulp (UW)	\$20,000
Phase 2	Pulp Production for Paperboard Trial (UW)	\$15,000
Phase 3	Pulp Production for Molded Pulp Trial (UW)	\$ 5,000
Phase 4	Black Liquor as a Dust Suppressant (WSU/UW)	\$20,000
Phase 5	Hydroseeding with Blue Grass Straw (WSU)	\$10,000
Phase 6	Economic Evaluation of Straw Removal (WSU)	\$ 5,000
Phase 7	Dissemination of Information	\$ 0
	Administration and Final Report	\$ 5,000
Total		\$80,000

ACCOMPLISHMENTS, CAPABILITIES AND QUALIFICATIONS OF APPLICANTS

1. LEWIS ENGINEERING CONSULTANTS

Lewis Engineering Consultants is an engineering firm concentrating on structural, mechanical engineering and providing project management and technical assistance to the pulp and paper industry.

2. PULP AND PAPER CENTER, UNIVERSITY OF WASHINGTON

The Pulp and Paper Center is part of the Paper Science and Engineering Group at the University of Washington and is the only facility of its kind in the western U. S. The Center contains equipment and test facilities to process most fiber raw materials into pulp, to bleach by conventional and chlorine free sequences, to manufacture small quantities of paper (less than about 50 pounds) on small paper machines. In addition, the facilities are present for full chemical and physical testing of raw materials and products. This group has been active in undergraduate and graduate education related to pulp and paper, nonwoven and composite materials for about 50 years. It is recognized throughout the world as a leader in education and research in those areas.

The first major commercial non-wood pulp run was recently completed at the Samoa Pacific mill in northern California. All of the research leading up to that run was completed at the University of Washington Pulp and Paper Center. The raw material used was *Arundo donax*, and plant, which can be grown in plantations in many states, including Washington.

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Education:

BS Colorado St University 1977 Wood Science and Technology
University of Washington 1980-86 Paper Science and Engineering Graduate
Studies worked on Ph.D. Research area: Pressure/Temperature Diffusion in Hot
Nip Presses
Master's Thesis: The Effects of Load Cycling in Tension on Young's Modulus

Work Experience:

University of Washington Paper Science and Engineering Dept.
Manager of Program Operations – Responsible for managing the laboratories and
all contracts service work. Currently doing research in utilizing existing deinking
technology to process agfibers. Developing new bleaching techniques for
agfibers. Instructor for Paper Physics, Paper Properties, and Papermaking Unit
Operations, Pulping and Bleaching Laboratory classes

Penford Products- Regional manager- responsible for sales and service to West
Coast paper mills. Provided on machine technical support in the area of wet end
chemistry and coating

Vinings Industries- Territory Manager- providing technical support to both pulp
and paper mills. Areas of concentration: ECF and TCF bleaching in mechanical
mills and kraft mills, and wet end chemistry and biocide usage on paper machines

GK Carbonate- Paper Making Research Manager- Responsible for managing the
wet end and physical testing labs. Developed a state-of-the-art papermaking
laboratory for doing research into Alkaline Paper Making and Coatings with
Precipitated Calcium Carbonate

Weyerhaeuser Co. Scientist- managed the testing facilities in the central research
building.

Worked in the Papermaking Research Group on press section developments.
Worked as Technical Asst. to Papermachine Supt. at Rothschild, WI fine paper
mill.

Current Research Activities

Development of Arundo donax as a viable non-wood fiber raw material.

“Distributed Physical and Molecular Separations for Selective Harvest of Higher Value Wheat Straw Components”

Universal Pulping research with cereal straws

Optimization of TCF and ECF bleaching chemistry

Utilization of Atmospherically pulped wheat straw in brown stock papermachines

Professional Development Activities

First Chair, Pacific Section TAPPI

Past Chairman of TAPPI’s Physical Methods Committee, and Paper Testing Committee. Member of TAPPI’s Pulp Testing Committee and Optical Properties Committee.

Member of TAPPI’s Pressing and Drying Committee

Member of TAPPI’s Non-Wood Pulping Committee

Member of Paptac’s Non-Wood Pulping Committee

Professional Services: Consulting and Advising

Nile Fiber Pulp and Paper

Western Pulp Products

Fort James

Weyerhaeuser

US Gov’t.

Raitt Industries

Environmental Technologies

Ponderosa Fibers of America

Recent Publications:

Jackson M, Lewis M. S., Arundo Donax: A Non-Wood Fiber Source Suitable for Use in Existing US Pulp Mills 2001 TAPPI Pulping Conference, Seattle, WA 2001

Thompson D. N., Foust T. D., Grant D. R., Hess J. R., Hoskinson R. L., Houghton T. P., Lacey J. A. Lewis M. S., McKean W. T., Shaw P. G., Selective Harvest of Higher Value Wheat Straw Components. Fifth Biomass Conference of the Americas September 2001

Jackson M, Lewis M. S., Arundo Donax: A Non-Wood Fiber Source Suitable For Existing Pulp Mills Cost Effectively Manufacturing Paper and Paperboard From Non-Wood Fibres and Crop Residues, PIRA October 2001

Lewis M. S. A Non-Wood Fiber Source for Existing US Pulp Mills, Fifth National Symposium New Crops and New Uses Atlanta, GA Nov. 2001

Jackson M., Lewis M. S., Evaluation of Arundo Donax as a Papermaking Fiber Replacement 2002 TAPPI Pulping and Engineering Conference Sept. 2002 San Diego, CA

Pan W. L. McKean W. T., Lewis M. S. Evaluation of Blue Grass Pulping and Black Liquor for Fertilizer Application. Annual Conference of Northwest Grass Seed Growers December 2002 Portland, OR

Lewis M. S. "Nalgrass: A Viable Non-Wood for Use in a US Pulp Mill", "Trends in New Crops and New Uses" Edited by Jules Janick and Anna Whipkey ASHS Press Alexandria, VA 2001

William L. Pan, Department Chair, Professor

revised

1/05

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FACULTY APPOINTMENT

Professor and Soil Scientist, Department of Crop and Soil Sciences; 70% research/30% teaching; appointed 12/84; Adjunct Professor, Program in Environmental Science; appointed 5/94.

AREA OF SPECIALIZATION

Soil Fertility, Plant Nutrition, Nutrient Cycling and Rhizosphere Ecology of Agricultural Systems, Site-specific Nutrient Management; Computer Imaging of Plant Root Systems

EDUCATION

1983 Ph.D. Soil Science, North Carolina State University, Raleigh, NC
1979 M.S. Soil Science, University of Missouri, Columbia, MO
1976 B.S. Biochemistry, University of Wisconsin, Madison, WI

PROFESSIONAL EXPERIENCE

2002-present Chair/Soil Scientist/Professor of Soil Science, Dept. of Crop and Soil Sciences, Washington State University
1996 - 2002 Soil Scientist/Professor of Soil Science
Dept. of Crop and Soil Sciences, Washington State University
1991 -1996 Associate Soil Scientist/Associate Professor of Soil Science,
Dept. of Crop and Soil Sciences, Washington State University;
Adjunct faculty in the Environmental Science Program (5/94-present)
1984 - 1991 Assistant Soil Scientist/Assistant Professor of Soil Science,
Dept. of Crop and Soil Sciences, Washington State University
1983 -1984 Post-doctoral Research Associate, Department of Soil Science,
North Carolina State University, Raleigh, NC
1979-1983 Graduate Research/Teaching Assistant; Department of Soil Science, North Carolina State University, Raleigh, NC
1977-1979 Graduate Research/Teaching Assistant in Soils; Department of Agronomy, University of Missouri, Columbia, MO

PROFESSIONAL AND HONORARY SOCIETIES

American Society of Agronomy Sigma Xi
Soil Science Society of America Gamma Sigma Delta
American Society of Plant Physiologists
Far West Fertilizer and Agrichemical Association

ACADEMIC TEACHING

Soils 441 (Soil Fertility)
Soils 541 (Soil-Plant-Microbial Relationships)
Soils 442 (Soil Analysis)
Soils 412 (Undergraduate seminar)
Graduate student major adviser: 11 M.S. and 8 Ph.D.

PUBLICATIONS

Book Chapters

Pan, W.L., R.G. Stevens, and K.L. Labno. 2004. Cadmium accumulation in wheat and potato from P and waste-derived Zn fertilizers. *In* W.L. Hall and W.P. Robarge, Environmental Impacts of Fertilizers on Soil, Air, and Water, American Chemical Society, Washington, D.C.

Huggins, D.R. and W.L. Pan. 2003. Key indicators for assessing nitrogen use efficiency in cereal-

based agroecosystems. In *Cropping Systems: Trends and Advances Part I & II*, A. Shrestha (ed.), Haworth Press, Binghamton, NY.

Camberato, J. J. and W. L. Pan. 1999. Bioavailability of calcium, magnesium, and sulfur. In M. E. Sumner (ed.), *Handbook of Soil Science*, CRC Press, Boca Raton, FL.

Pan, W. L., D. R. Huggins, G. L. Malzer, and J. L. Smith. 1997. Variable soil-plant relationships: implications for site-specific nitrogen management. p. 81-100. In, F. J. Pierce and E. J. Sadler (ed.) *The state of site-specific management for agriculture*. ASA, CSSA, SSSA, Madison, WI.

Hergert, G. W., W. L. Pan, D. R. Huggins, J. H. Grove, T. R. Peck, and G. L. Malzer. 1997. The adequacy of current fertilizer recommendations for soil specific management. p. 283-300. In, F. J. Pierce and E. J. Sadler (ed.) *The state of site-specific management for agriculture*. ASA, CSSA, SSSA, Madison, WI.

Selected recent publications, refereed (42 total)

J J Camberato, B Gagnon, D A Angers, W L Pan. 2004. Pulp and Paper Mill Byproducts as Plant Nutrient Sources and Soil Amendments. presented at American Society of Agronomy Annual Meetings, Seattle, WA. Nov 1, 2004. Refereed journal article is in progress

C. Xiao, M. Fauci, D.F. Bezdicek, W.T. McKean, and W.L. Pan*. 2005. Soil Microbial Responses to Potassium-Based Black Liquor From Straw Pulping. *Soil Sci. Soc. Am. J.* (Accepted with minor revisions)

Mohammad, M.J., W.L. Pan, and A.C. Kennedy. 2005. Chemical alteration of the rhizosphere of mycorrhizal-colonized wheat roots. *Mycorrhiza* (in press; currently available on line at http://springerlink.metapress.com/media/MM8XD75NXM6VYGBOED4T/Contributions/B/N/R/3/BNR3E UH4A5Y7NEQ4_html/fulltext.html)

Baker, D.A., D.L. Young*, D.R. Huggins, and William L. Pan. 2004. Economically optimal nitrogen fertilizer for yield and protein in hard red spring wheat. *Agron. J.* 96: 116-123.

M.E. Thorne, F.L. Young, W.L. Pan, R. Bafus, J.R. Alldredge. 2003. No-till spring cereal cropping systems reduce wind erosion potential in the wheat/fallow region of the PNW. *Journal of Soil and Water Conservation.* 58: 250-257.

Weinert, T., W.L. Pan, M.R. Moneymaker, G.S. Santo, and R.G. Stevens. 2002. Nitrogen recycling by non-leguminous winter cover crops to reduce leaching in potato rotations. *Agron. J.* 94: 365-372.

Pan, W.L., F.L. Young, and R.P. Bolton. 2001. A scanner-based, portable rhizotron system for monitoring field-grown Russian Thistle (*Salsola iberica*) roots. *Weed Tech.* 15: 762-766.

Kunch, T., B.E. Frazier, W.L. Pan and A.M. Smith. 2001. Satellite radar assessment of winter cover types. *Can. J. Rem. Sens.* 27: 603-615.

Johnston, W.J., C.T. Golob, C.M. Kleene, W.L. Pan and E.D. Miltner. 2001. Nitrogen leaching through a floating sand-based golf green under golf course play and management. *Int. Turf Soc. Res. J.* 9: 3-8.

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CURRICULUM VITAE

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B.S. 1960 University of Colorado (Chemical Engineering)

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PROFESSIONAL EXPERIENCE:

1961-1962 Hydraulics Engineer, Sverdrup and Parcell Engineers, Titan I Program

1967-1970 Senior Development Engineer, Battelle Northwest, Richland, Washington

1970-1976 Associate Professor, Wood and Paper Science, N.C. State University, Raleigh, N.C.

1974-1975 Visiting Scientist, Weyerhaeuser Company, Everett, Washington

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PROFESSIONAL ACTIVITIES:

Technical Committee, Water Resources Research Institute, North Carolina Member, Board of Directors, Triangle Universities Consortium on Air Pollution Director (1978), Forest Products Division, American Institute of Chemical Engineers Chairman, Forest Products Division, American Institute of Chemical Engineers, 1979 Tasman Fellow, 1985, Christchurch and Rotorua, New Zealand.

Invited lectures: 1985, FRI, Rotorua, New Zealand and CSIRO, Melbourne, Australia.

Numerous seminars, lectures and short courses on pulping, bleaching recovery and papermaking topics
Member, TAPPI Board of Directors, 1993 to 1996

TEACHING SUBJECTS:

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PARTIAL LIST OF CONSULTING CLIENTS:

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ABRIDGED PUBLICATION LIST:

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