Minnesota Department of Agriculture
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Agricultural Marketing and Development Division

Minnesota Crop Research Grant Program Proposal *(p. 1 of 13)*

Project Title: *The project title should be clear, concise, and describe the project's intent.*

Digital Imagery - Precision Agriculture

Name of Principal Investigator: Dr. Dave Grafstrom | Organization Name: Northland Comm. & Tech. College

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Is the individual authorized to sign a contract with the State different from applicant? Yes ☑ No ☐

If yes, please provide this individual's name, organization, address, phone number and email address.

Name of Authorized Signatory: Curtis Zoller | Organization Name: Northland Comm. & Tech College

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Eligibility

I (and my organization or institution) am in good standing with the State of Minnesota Yes ☑ No ☐
(no back taxes or current noncompliance actions).

I am a current Minnesota resident or entity authorized to conduct business in Minnesota. Yes ☑ No ☐

Signature:  Date: 11-20-2014

Project Start Date: January 1st, 2015 | Project End Date: December 31st, 2017

Amount of Grant Request	Applicant's Match (Not required)	=	Total Project Cost
$249,480	35,000	=	284,480

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Abstract *(2,500 characters, including spaces)*

This is a summary of the contents of the proposal. Include a succinct account of the project's goals and objectives, a description of the approach and methodology, and the anticipated outcomes, or products.

Northland Community & Technical College (NCTC) realizes the goal of precision agriculture is to improve production efficiency by adjusting crop inputs based on specific field conditions and target yield goals. However, the relationship between production-inhibiting factors and yield must be correctly identified, in a timely manner, so growers can make efficient use of crop inputs and be good environmental stewards.

NCTC will seek cooperation from growers, students enrolled in NCTC's Farm Business Management (FBM) and Imagery Analysis (IA) programs, MSU Moorhead and U of MN's Magnusson Research farm to collect digital agricultural data from satellites, unmanned aerial vehicles (UAV), and combine yield monitors. This will be augmented with LiDAR, inherent soils data, and crop sensor data such as NDVI.

NCTC will streamline the process of data collection, analysis, dissemination, and outputs to create a digital product that producers can use to increase their ROI and implement the precision agriculture practices in a real-time scenario. Working with Precision Agriculture technicians from John Deere and Case IH and students in NCTC's IA program, the digital data will be processed into an application map that communicates with commercial application equipment to apply crop nutrients and crop protection products in a true prescription agriculture format. Research fields will be in-field laboratories in which data and information will be a source for education and training in addition to providing information to the farmer to better manage crop inputs.

NCTC will develop a comprehensive weed-mapping project in Roseau County. Using the data gathered from UAV's and satellites, application maps will be generated based on light signatures that can discern wild oats from other crops. Application maps will be made that can be downloaded into sprayers to apply herbicides targeted only to affected areas. Early identification through NextGen technologies allows farmers to combat herbicide resistant wild oats within ryegrass fields. Northland has already achieved initial success with this in 2014 and seeks to extend the ability to create weed maps using the NextGen technologies. This research will open the door to future weed mapping for other crops grown in Minnesota.

This will be a three-year project with three phases explained in the approach section. The real power of this project is when we can use year over year information from specific fields to average this information to make management decisions.

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Rationale and Beneficiaries *(2,500 characters, including spaces)*

Provide the background and need for the proposed work. Explain why the research you are proposing is important and timely. Include references to relevant supporting literature. Say who stands to benefit, directly or indirectly, from your project.

Precision agriculture has been a topic of discussion and of interest to agricultural producers for several decades. In reality, precision agriculture and the associated technology was ahead of its time. Crop producers did not recognize the value and felt the cost/return ratio was not favorable. As with most technologies, the cost of this technology declines over time. This is very true with precision agriculture and this project will provide direct evidence of this. For example, in a few short years, guidance systems (tractors, sprayers, combines) went from an expensive add on to a standard issue on new equipment. The network of GPS satellites now makes it possible for sub-inch accuracy at the field level. Finally, the ability of computers to process various layers of data now makes it possible for farm managers to utilize GIS information to make better management decisions in many facets of the agricultural production system. Students at NCTC and MSU Moorhead stand to benefit from real-world experience as they help to analyze and disseminate the data. A minimum of 100 Imagery Analysis students within the life of the grant and 10 FBM students annually will benefit from the real world applications of this project. 25-30 students will benefit per semester at MSU Moorhead within their work with satellite imagery research.

Participant growers stand to see significant benefit from the research project. In year one, 8-10 growers will be utilized with fields of 80 to 160 acres to develop the process. Half of these fields can be wheat and the other half ryegrass. In year two 16 and year three 24 growers stand to benefit.

This project will create not only real-time maps to help the identified growers but will create a process to streamline this type of precision agriculture for widespread adaptation in multiple implement brands.

Much has been done in the field of precision agriculture but creating a usable format for data collection has been a consistent obstacle. By working directly with our project partners that are precision agriculture specialists from John Deere and Case IH dealerships in northwestern MN, the project will work to create functional maps for farmers across both platforms. With the help of partners, Farm Intelligence and Sentera, they will provide in-kind contributions of $10,000 in Subject Matter Expertise and $25,000 of equipment to develop the functionality for cross-platform use, a continual problem for this segment of precision agriculture.

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Approach, Methodology, and Timeline *(10,000 characters, including spaces)*

Describe your approach; scientific methodology (proposed treatments and reason for selection); plot/sample size; lab procedures or protocols; and data to be collected); experimental design; and measurements that will be used to evaluate the project. Explain how these methods are appropriate for the research project. Include a timeline for the research. Charts, graphs, or pictures should be included on a separate page if applicable.

This research project aims to collect a variety of geospatial and digital imagery to develop and implement a usable precision product within the grower's machinery for real-time crop management solutions. NCTC identifies three separate goals in three phases all convening to support the overall project goal of creating a functional product to be utilized by thegrower. With this said, it is crucial to see the creation of the process to do this as just as monumental of an achievement. The continual disconnect in this process has evolved from creating an efficient process. Many have tried with limited success to map and implement, but with different equipment companies using different software, the process to date has been inefficient and largely ignored within the farming community due to its costly and cumbersome nature. We aim to streamline this process and make the exploding quantities of digital data accessible to the average grower in three phases.

Phase one of the project will be to collect the data from all the modalities digital imagery permits us. These digital avenues include: satellite imagery, combine yield maps, UAS sensor imagery, NDVI, inherent soils data, LiDAR, and crop sensor data. . Important derivatives such as NDVI, NDRE, CCCI, and hydrological networks will be calculated from the data. All data collection and processing will be targeted to predetermined plots of land that include cooperator grower land and the U of M Magnuson Research farm. Through MSUM's gathering of satellite imagery we will be able to create an overall picture of the field as it relates to growing conditions. By augmenting this with real time data from the UAS flights, we can further determine problem areas in real time.

Phase two will utilize Northland's Imagery Analysis, and Geospatial Intelligence Analysis students, MSU Moorhead's Geoscience program, and partners Sentera and Farm Intelligence. With the help from these stakeholders, all of the digital data collected will be analyzed and prepared in a format that our Precision Agriculture specialist partners can begin tobuild into the commercial application equipment.

Phase three will be the implementation of the data collected, analyzed, and disseminated in a user-friendly format. With help from Precision Agriculture specialists, the process we have aimed to create will be tested through a real-world analysis as we put the process and deliverables to work in the commercial application equipment.

Within phase three, Northland's farm business management students will prepare a case study that investigates the cost/benefit of utilizing these precision agriculture technologies versus a control group of similar farms not utilizing the same precision agriculture technologies. Measures will include fertilization costs, herbicide usage, yield/acre, financial gain or loss/acre.

Methodology: NCTC will work directly with the MN Turf Council, MN Wheat Growers, commodity groups, and the FBM instructors to create a network of willing grower participants. Each participant will allow research to be done on one of his or her fields (minimum of 80 acres) to include yields and all digital data. Each producer will use extensive and best management practices to achieve above average yield goals. Growers will agree to collect a combine yield map during year one on each parcel. NCTC will provide all digital imaging and NCTC, MSUM, and project partners will create a layered map on top of the yield map to provide real-time grower solutions for problem areas. This method will repeat for three years to create an overall picture of the research field and avoid a one-year picture that could be swayed by unfavorable growing conditions. At the end of the research period, the digital data gathered and analyzed, and disseminated will better guide grower decisions. The entire field will be used to determine how yield varies with respect to different factors. Using the digital imagery, we can identify those factors. We plan to use the combine yield map as an annual report card. The process and data will be leveraged to make real-time decisions that provide the farmer with the opportunity for in-season realignment.

A three-year crop rotation for farmers in the Roseau area is overwhelmingly wheat-ryegrass-soybeans. We propose to collect the digital information acknowledging this rotation. During the non-growing season students within NCTC and MSUM's programs will continue to analyze the imagery to create additional layers from sensor data.

You may continue your Approach, Methodology and Timeline in the space on p. 5.

Approach, Methodology, and Timeline CONTINUED *(10,000 characters, including spaces)*

Timeline: The proposed project is designed as a three-year project. With funding, the project would start with phase one in the winter of 2015. During this phase, the main objectives include establishing a network of growers that will partner in the project by sharing field level data. Phase one will continue into spring of 2015, when we will utilize our digital data collection tools on cooperator fields and on the Magnuson Research Farm to collect the necessary data and to demonstrate these precision agriculture practices for production agriculture. The collection of data will continue throughout the growing season through the use of UAV systems. Utilizing theleveraged sensor systems onboard the UAV, we will be able to collect a widevariety of digital imagery for comparison with other sensor data collected as well as satellite imagery and data collected from the commercial application equipment.

Phase two will begin in fall 2015/winter 2016 once the data is collected from the participant growers. This phase will be an analysis phase and will utilize our partnerships and students from Northland and MSU Moorhead. MSU Moorhead will prepare satellite imagery and Northland students will work to analyze combine yield maps that growers provide. After the historical data is analyzed and a baseline created, the digital data collected during phase one will be delivered for comprehensive analysis.

Phase three will be an implementation phase and will start in spring 2016. After the data has been analyzed and developed into a usable format, it will be manipulated with the assistance of Precision Agriculture partners into a format that is functional in Variable Rate Technology (VRT) equipment. Phase three will also include the case study conducted by Northland FBM students as they investigate the cost/benefit ofutilizing precision agriculture.

Each phase will repeat in the 2016 and 2017 growing seasons to streamline the process and deliverables.

Within the project, NCTC will provide a working example of the technology within a weed mapping study in Roseau County, Minn. Northland received a Certificate of Authorization (COA) from the Federal Aviation Administration (FAA), the first of it's kind in Minnesota, to fly unmanned aerial vehicles in Roseau County in 2014. We propose to fly UAV's with remote sensing capabilities to identify wild oats in perennial ryegrass. In the summer of 2014, NCTC began the identification project and had initial success. In 2015 and with MDA funding, we can extend the reach of our initial research to grower participant fields to identify and diagnose problem wild oats in perennial ryegrass fields. With the imagery that shows the infestation, we can createlayered application maps that communicate with VRT equipment to spray only in problem areas. This research will create efficiencies, both financial and environmental. A perennial ryegrass field may be 40 acres but infestation has only happened in eight acres. With the digital imagery maps, we can correlate the application map to the technology to only spray infested acres to save on overall cost and promote more efficient spray practices. Each year we will replicate this process on different growers fields to extend project research and best practices as we strive to create the overall streamlined process for weed map generation to automated sprayer response.

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Results or Products *(2,500 characters, including spaces)*

Describe the near-term (3 to 7 years) results or products you expect from the proposed research. If project results will not be realized during the grant period, describe anticipated outcomes and timelines. Results should be specific, clear, and measurable.

The overall goal of this precision agriculture project is the integration of digital images from agricultural fields into a format that can be utilized by commercial application equipment. Combine yield data will be the backbone of this project. The combine yield data of specific fields will be the base line information for future management decisions. For example, crop inputs for the next year's crop will be adjusted based on the previous yields. Further, satellite, UAV or other crop sensor data will be processed into real-time application maps that can be used by commercial application and be applied in-season.

This on-farm project will use field scale equipment to incorporate precision agriculture techniques, processes and procedures. Precision agriculture data and information collected annually will make it possible for variable rate technology (VRT) maps to be developed using real-time information. VRT in commercial fertilizer and crop protection application equipment is now a reality. In year two and three of this project, VRT technology will allow application maps to apply products in a variable manner based on combine yield maps and crop sensor information. The NCTC Imagery Analysis program will work with project partners to generate these field yield maps, allowing farmers and farm advisors to employ GIS information and make better management decisions in nitrogen use efficiencies and other facets of the crop management production system.

NCTC Farm Business Management students will prepare a case study of cost/benefit ratios to farmers utilizing these precision agriculture technologies versus farms not currently utilizing the technology. This individual farm analysis will be merged with other farms to strengthen the precision agriculture data base. This financial analysis will help determine the cost/return ratios based on actual crop yields and inputs required to produce a crop based on realistic yield goals. This analysis will provide direct evidence of the actual costs and returns, at the farm level, to farms that use agriculture technology compared to farms that use traditional management practices.

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Outreach Plan *(2,500 characters, including spaces)*

Research results must be widely and publicly disseminated. Explain how you will inform others about your results and findings. Be specific about the audience you will target and the methods you will use.

Summer Field Day
The MN Wheat Growers, MN Turf Council and the U of MN host summer field tours for farmers, support businesses and interested stakeholders. Field days are held in northern MN. Precision agriculture will be a part of these summer day activities and will strive to have an on-farm location within close proximity to preplanned summer field days. Projected summer field days will be near Roseau, Hallock, Strathcona, Warren and Thief River Falls.

Winter Grower Meetings
Project results will be presented at the MN Turf Council, MN Wheat Growers and U of MN sponsored winter meetings. The MN Turf Council sponsors a December and March meeting for area growers. The MN Wheat Growers sponsor a large regional meeting at the Alerus Center in Grand Forks in December and host a series of producer meetings in January.

Peer Group Meetings
Project partners include the MN Turf Council, MN Wheat Growers, U of MN, MSU Moorhead, Titan, Evergreen, and NCTC. Peer group meetings will be held at several locations in northern MN during the winter months to review data collected on farmer cooperator fields.

Publications
Project results will be distributed in an annual report available to growers and interested stakeholders at the winter meetings. These annual reports are also archived at the MN Turf Council website: Mnturfseed.org and the MN Wheat Growers site Smallgrains.org. Selected research results will be summarized for potential publication in regional publications, (Prairie Grains, MN Turf & Grounds Foundation) scientific journals, and web-based outlets.

Electronic and Social Media Exposure
Updates, pictures, video, and results will be posted through Electronic and Social Media channels. This allows a real-time participation experience that encourages open-ended communication to motivate interest and participation within the 21st century farming community.

MSUM Public Forums:
MSUM will show findings and products at two public forums associated with MSUM and the Geospatial Research Center. Annually, one will occur in the fall and another in the spring and will target rural community outreach opportunities and leverage the Research Center's connections throughout their service area.