**Preproposal Guidelines for WSARE**

**1.** **Project Basic Information**

This section prompts for general information about the project including:

* ***Main* subject matter**

1. Development of late blight forecasting models for Washington State.

* **Proposed starting and ending date**

1. Start date: April 1, 2021

2. End date: October 1, 2023

* **State(s) where the work of the project will be conducted**

1. Washington State

* **Cooperating institutions**

1. Washington State University (WSU)

2. AgriNorthwest

3. Schneider farms

4. Warden Hutterian Brethren

5. Knutzen Farms

* **Commodities and practices that will be involved in the project**

1. The potato industry will be involved in this project.

2. Practices involved in the project include agricultural production of potatoes, pesticide applications, and disease forecasting.

* **Budget amount to be requested**

1. $350,000

* **Whether this submission is a long-term project.**

1. No

* **Whether this submission is a re-submission.**

1. No

* **How did you learn about WSARE.**

1. Flyers

***Please choose a start date that corresponds with the first-of-the-month. Start dates must be no earlier than April 1, 2021 and no later than October 1, 2021.***

**2.** **Project Team (10% of review criteria)**

**The project team *must* be a minimum of five (5) people and must include: A principal investigator (PI), an Extension/outreach representative, and at least three (3) producers. You may also identify Co-Principal Investigator(s) (Co-PIs), if applicable. (See “Other members” below). *At the time of full proposal submission, you should include signed letters of each producer cooperator*.**

**Principal Investigator (PI): This person serves as the principal researcher. The PI (applicant) is responsible for coordinating the project and carrying out its contractual provisions.**

* PI: David Linnard Wheeler, Assistant Professor, WSU

**Extension/outreach representative, educator, or equivalent: The outreach representative may be an Extension agent, specialist, educator, or equivalent. This person is responsible for all education and outreach activities, and might serve as Co-PI.**

* Co-PI: Mark Pavek, Professor, WSU

**Producers: Producer involvement means that each producer is meaningfully involved in some aspect of the research or education activities of the project. One of the producers will be designated as the Advisor Representative. The Advisor Representative must be involved in all aspects of the project from idea inception through project completion. Each producer must be associated to independent operations. Nonprofit farm operations may participate in the project as an optional team member, but do not count as one of the three required producers. A person qualifies as a producer (farmer/rancher) if they have a *for-profit operation and*:**

**Their primary occupation is farming or ranching and have a farm/ranch taxpayer identification number (TIN); *or***

**They are a part-time producer with at least $1,000 documented annual income from farming or ranching activities.**

* Marvin Wollman (Advisor representative), Warden Hutterian Brethren
* Grant Morris, Schneider farms
* Mike Madsen, AgriNorthwest
* Jack Jensen, Simplot
  + - Kraig Knutzen, Knutzen Farms

**Other members**: Besides the aforementioned project team of five people, the team may include additional producers, researchers, educators, Co-PIs, and others with appropriate expertise for the project scope.

* Co-PI: Joe Zagrodnik, Postdoctoral Research Associate, AgWeatherNet, WSU

**C. Project Summary** (Limited to 300 words)

The summary must include a brief description of the problem or need and the creative approach to solve it. Identify the research question(s). Describe the research methods and outreach activities and explain how your project will address the identified problems. Explain the potential significance of the project and its expected outcomes. A clear and concise description of your pre- proposal is important for the review process.

Late blight of potato has caused socioeconomic damages worldwide since the 1840s. Management of the causal pathogen, *Phytophthora infestans*, is dependent on fungicides. These fungicides are costly, toxic, and select for fungicide-resistant pathogens. Alternative management strategies are needed to mitigate crop losses and reduce fungicide applications. The goal of this research is to develop and deploy site-specific late blight forecasting models for producers in Washington state. We propose to develop forecasts and outreach with late blight incidence data from producers (**Figure 1A**), severity data from field surveillance and satellite imagery (**Figure 1A** & **C**), phenology data (**Figure 1B**), and weather data from AgWeatherNet (**Figure 1D**). To accomplish this goal, late blight intensity (incidence and severity) data will be collected from cooperating producers and ground-truthed by the PIs during the growing seasons. Late blight intensity data will then be modeled as a function of satellite imagery, phenology, and weather data with machine learning models (**Figure 1E**). Models that generate accurate predictions will be used for future forecasts (**Figure 1F**). Expected outcomes of this research include (i) site-specific forecasts that integrate data on late blight intensity, phenology, and weather, (ii) weekly management recommendations during the growing season (**Figure 1G**), and (iii) control of late blight with fewer fungicide applications. The effectiveness of the outcomes will be measured with surveys. Site-specific forecasts will be distributed to producers and researchers via listservs, field days, conferences, extension bulletins (**Figure 1I**), and peer-reviewed journal articles (**Figure 1H**). Late blight forecasts and digital outreach will help minimize fungicide applications without compromising yields by providing weekly site-specific disease management recommendations. Thus, this project will directly contribute to the sustainability of potato production and natural resource conservation in Washington. Ultimately, accurate late blight forecasting systems will enable producers to apply less fungicides without increasing the risk of crop failure.

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**D. Narrative**

***Relevance to Sustainable Agriculture:*** (20% of review criteria, limited to 500 words)

Explain why this project is needed, and how it addresses sustainable agriculture in the Western region. Describe the potential benefits and impacts for producers and agriculture in general. Clearly articulate how the project and its measurable outcomes are relevant to the goals of Western SARE (see page 2). Projects should address how they:

* Sustain and improve the environmental quality and natural resource base on which agriculture depends;
* Improve the profitability of farmers/ranchers and associated agricultural businesses; ***and***
* Enhance the quality of life for farmers/ranchers, communities, and society as a whole.

Washington state produces almost a quarter of potatoes grown in the US (NASS, 2020). The collective efforts of approximately 300 producers and 36,000 employees generate the highest potato yields on the planet and $7.4 billion annually for Washington (Capital Press, 2016).

Unfortunately, the potato industry is often threatened by diseases like late blight. For example, in 1998 the cost of potato losses, fungicide applications, and other management activities in Washington was $22.3 million (Johnson et al. 2000). These losses translate to $35.3 million in 2020. Successful management of late blight is therefore of paramount importance to enable sustainable potato production.

Management of late blight typically includes sanitation, cultural practices, and fungicides. Sanitation and cultural practices are used to minimize disease pressure and maximize fungicide efficacy. Fungicides can provide acceptable control when applied at the appropriate time and in the absence of fungicide-resistant strains of the causal organism, *Phytophthora infestans*. Unfortunately, optimization of fungicide applications is limited by the availability of accurate and site-specific disease forecasts. Without these forecasts, producers are forced to either apply potentially excessive amounts of fungicides or risk severe crop loss and disdain from community members for enabling disease spread. Site-specific forecasts need to be developed to satisfy the needs of producers, minimize needless fungicide applications, and maximize profits for long-term and sustainable potato production.

The goal of this project is to develop and deploy site-specific late blight forecasts and outreach for Washington state. The current forecasting system for late blight in Washington was created in the late 1990s (Johnson et al. 1998) and is maintained by the PI. Forecasts developed by Johnson et al. 1998 continue to be a valuable source of information for producers in Washington. These forecasts, however, rely on human detection of late blight and sparse weather data from a few weather stations. The former limitation introduces bias because most humans can not accurately scout hundreds or thousands of acres of potatoes. The latter limitation also introduces bias because weather conditions are variable on local scales and not all farms are proximal to weather stations.

To generate site-specific late blight forecasts, we propose to integrate local weather forecasts with satellite imagery and phenological data into machine learning models. Forecasts will then be deployed with recommendations via listservs, field days, social media, conferences, extension bulletins, and peer-reviewed journal articles. Thus, the expected outcomes of this research include (i) site-specific forecasts (ii) weekly management recommendations, and (iii) promotion of fungicide stewardship. These outcomes will be measured with surveys before and after forecasts are deployed.

The outcomes of this research are aligned with the goals of Western Sustainable Research & Education. Ultimately, this research will help (i) sustain and conserve natural resources by promoting fungicide stewardship and thereby minimize off-target exposures, (ii) improve profitability of producers by reducing losses due to late blight and fungicide applications, and (iii) enhance the quality of life for producers, community members, and consumers by stabilizing the food supply without excessive use of fungicides.

***Stakeholder Involvement and Support:*** (10% of review criteria, limited to 250 words)

Western SARE is committed to addressing the needs of agricultural stakeholders. Pre-proposals must include evidence that stakeholders’ identified needs are being addressed, as well as support for the project beyond the project team. Describing and documenting stakeholders’ needs and support demonstrates (a) that the proposed project is relevant and timely and (b) that the applicants are engaged with agricultural stakeholders. Evidence of stakeholder identified needs and support may include, but are not limited to:

* Recommendations from stakeholder groups such as grower organizations or commodity commissions. Please identify stakeholder group(s) or organization(s).
* References and citations to previous studies/reports.
* Community support letters from neighboring farmers or local co-op.
* Needs assessments.

Stakeholders are both involved with and supportive of this project. Since late blight became an annual issue in the Columbia Basin of Washington state in the 1990s, stakeholders have expressed their needs to manage this disease. Current evidence of stakeholder involvement is presented below as Letters of Producer Cooperation. Similarly, evidence of stakeholder support is presented below as Letters of Stakeholder Support from the Northwest Potato Research Consortium and the Washington State Potato Commission. Additional evidence of stakeholder support can be found in the Integrated Pest Management Strategic Plan for Potatoes (<https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9275.pdf>). This group of scientists, producers, industry representatives, and other stakeholders identified a list of top-priority critical needs for 2019 (page 8 in the document linked above). Among the research topics identified as a top-priority critical need was “Refine decision support tools for potato diseases, including mapping and forecasting”. The project described herein satisfies this goal.

***Producer Involvement and Collaboration:*** (10% of review criteria, limited to 250 words) WSARE requires the involvement of producers throughout the project by actively collaborating in the project. Identify the level of involvement of each producer at all stages – from inception to completion of the project. Signed and dated producer collaboration letters stating their role in the project ***are expected*** for each producer. However, if letters are not available at the pre-proposal submission time, producers’ e-mail confirmation of collaboration is acceptable. Attach the producer collaboration letters or e-mail in the Supporting Documents section.

Each of the five cooperating producers will participate in this project from inception to completion. More specifically, each cooperating producer will:

* report weekly late blight intensity estimates (e.g. 1 field is ~10% infected)
* report weekly phenology updates (e.g. fields are at row-closure)
* host an AgWeatherNet weather station(s).

If and when late blight is detected in fields, the cooperating producers will guide the PI to the field(s) for confirmation. The producers will be free to manage their fields as they would normally.

***Objectives:*** (10% of review criteria, limited to 250 words)

Provide a list of the project objectives. Each objective should be a statement describing an intended achievement. Objectives must be specific, measurable, achievable, and time bound. For more details see *Successful Objectives* .

The objectives of this project include:

* Develop site-specific late blight forecasts for potato producers in Washington state. This objective can be measured qualitatively after the completion of each field season. Completion of this objective will be constituted by identification of model(s) that accurately predict late blight intensity.
* Issue weekly late blight disease management recommendations to producers in Washington. Starting in 2023, these recommendations will be deployed weekly with stakeholder listservs and less frequently with field days, extension bulletins, conferences, and peer-reviewed articles. Measurement of this objective can be completed by counting (i) weekly management recommendations and (ii) the number of producers who use the recommendations. If the machine learning models used for the forecasts are more accurate than existing models before 2023, then the weekly management recommendations can be issued earlier.

After completion of this project, subsequent proposals will be submitted to generate a website for producers to interface with the data and recommendations.

* Control late blight with fewer fungicide applications than used without the forecasts. This objective will be difficult to accurately measure, however; the number of fungicide applications used before and after the site-specific forecasts can be estimated with surveys, as described below.

***Materials and Methods:*** (30% of review criteria, limited to 1000 words)

For each objective -including research and education objectives- describe the experimental design (including a survey study if applicable), site (experimental station research plots, private farm/ranch, demonstration farms, greenhouse, etc.) data collection and analysis methods, and materials. Include sufficient information so that reviewers can determine if the approaches are suitable to achieve your objectives. Avoid the use of jargon that may be unfamiliar outside your specialty area and define all acronyms.

1. **Develop site-specific forecasts for producers in Washington.**

**Late blight intensity data collection.** From spring 2021 to 2023, late blight intensity data will be obtained from cooperating producers and confirmed by the PI. Cooperating producers and their teams will scout their fields weekly for late blight symptoms. If and when late blight symptoms are detected, the producer will inform the PI. The PI will confirm the diagnosis with laboratory assays. Late blight incidence will be estimated as the proportion of symptomatic fields. Late blight severity will be estimated as the symptomatic proportion of each field.  GPS coordinates for symptoms within fields will be recorded to inform collection of satellite imagery and weather data.

**Phenology data collection**. Phenology data will be collected by cooperating producers at each location. During weekly field scouting, the producers will determine potato phenology using a scale: 0: pre-emergence, 1: post-emergence but pre-row closure, 2: row closure, 3: post-row closure and pre-harvest. Like the satellite imagery and weather data, the phenology data will be used as an explanatory variable in the forecasting models.

**Satellite imagery data collection.** Satellite imagery will be collected when and where late blight is detected. Both low- and high-resolution satellite data will be collected from public and commercial sources. Satellite imagery data will be used for two purposes. First, satellite imagery data will be used as explanatory variables in the forecasting models. Second, satellite imagery data will be used to identify features (e.g. spectral bands) that are correlated with late blight intensity. Both applications will be discussed in turn.

Upon confirmation of late blight detection, low-resolution satellite imagery data will be collected from Google Earth Engine. High-resolution satellite imagery data will be collected from commercial providers, like LandViewer. After the end of each potato growing season, these data will be combined with the phenology and weather. Model selection and validation will be described below.

Satellite data will also be used to identify features like specific spectral bands that are correlated with late blight intensity. This is an achievable goal under controlled (Fernández *et al* 2020; Gold et al. 2020) and, we imagine, observational settings. The impetus for this effort is to enhance late blight detection. For example, if we identify a feature(s) of the imagery data that is sufficient for late blight detection, then we can supplement the late blight intensity data with that feature(s) as our response variable in the future. Ultimately, this could enable remote detection of late blight in large fields where thorough scouting is resource-intensive.

**Weather data collection.** Historical quality-controlled weather observations and future site-specific daily weather forecasts will be produced by AgWeatherNet. Historical weather data including soil and air temperature, relative humidity, total precipitation, wind, and solar irradiance will be collected weekly from AgWeatherNet (<https://weather.wsu.edu/>). AgWeatherNet will generate historical datasets from the 111 of 193 AgWeatherNet stations located in potato producing counties (red dots in **Figure 1D**)**.** To enhance the spatial resolution at which weather data can be obtained and interpolated, 10 new AgWeatherNet stations will be installed and maintained. AgWeatherNet will generate 7-day site-specific daily forecasts for these stations. Both historical weather data and 7-day forecasts will be curated and used for model selection and validation.

**Model selection and validation.** Towards the end of 2023 model selection and validation will begin. Data will be processed to ensure that values of variables are coded correctly and within the expected ranges. Exploratory data analysis will be performed to further confirm that the data satisfy statistical expectations and assumptions. A binary response variable will be created from late blight incidence data to enable the use of both classification and regression. Several machine learning models will subsequently be used to fit the data. Candidate models include multiple logistic and linear regression, support-vector machines, random forest, and neural networks. These models will be fit to the data, tuned to maximize performance, and validation. Model performance will then be compared across models and the model with the best performance will be selected to produce future forecasts. Exploratory data analysis and modeling will be completed in R and python with JupyterLab to enable reproducibility. Relevant code will be publicly available upon project completion.

1. **Issue weekly late blight management recommendations to producers in Washington.** During the funding period, weekly late blight management recommendations will be issued, as they are now, with the forecasting models developed by Johnson *et al.* 1998. For 2023 and beyond, new site-specific forecasts and outreach will be generated and disseminated.

Site-specific forecasts and outreach will be deployed via listservs, field days, conferences, extension bulletins, and peer-reviewed journal articles (**Figure 1**). More specifically, the site-specific forecasts will be shared with producers with the *WSU Potato Pest Alerts* listserv, maintained by Dr. Carrie Wohleb at WSU. Field days, including the Washington Potato Field Days, organized by Co-PI Dr. Mark Pavek, will be used to share information about the forecasts with producers and other stakeholders. During field days, extension bulletins will be provided to remind producers of the services provided by the site-specific forecasts. Conferences and peer-reviewed journal articles will be used to share the scientific contribution of the research.

1. **Control late blight with fewer fungicide applications than used without the forecasts.** To complete this objective potato producers will be surveyed before and after deployment of the site-specific forecasts. Surveys will be designed with Qualtrics to capture data about: the producer; acres, varieties, and yields of potatoes grown; types, rates, and frequency of fungicide applications; late blight incidence; compliance with forecast recommendations. This information will enable us to compare fungicide applications for individual producers while holding agronomically important factors, like late blight incidence, constant.

The first survey will be issued before the site-specific forecasts are deployed. Similarly, the second survey will be issued at the end of the growing season in 2023. Differences in fungicide applications before and after deployment of site-specific forecasts will be estimated. This objective will be achieved if fungicide applications decline in response to adherence to site-specific disease management recommendations while other related agronomic factors remain constant.

***Innovations and Benefits to Sustainable Agriculture:*** (10% of review criteria, limited to 250 words) Explain how this project is novel and creative. Describe the potential benefits and impacts of your project and its findings to other producers (local, state, and regional) or agriculture in general. For example, provide an economic analysis or address how the outcomes of the project would affect: overall farm/ranch productivity levels, operational profits, soil or water quality or quantity, rural communities, society as a whole. Where possible, use specific estimates of benefits – for example, dollars saved per acre, tons of soil protected from erosion, pounds of chemical reduced, number of acres or people affected, markets expanded, jobs created, etc.

This project is novel and creative because it synthesizes data from disparate sources to solve a pernicious problem- late blight management. While other projects have developed decision support systems, this project aims to integrate the relevant data needed to help control late blight of potato **and** reduce fungicide applications. Moreover, this approach is not specific to late blight. Researchers and stakeholders interested in the development of similar solutions for other pathosytems can easily apply this approach to solve similar problems. More specifically, producers who raise hundreds to thousands of acres of crops that demand substantial time investments for scouting could benefit from this approach, since it includes remote sensing data that could supplement or replace human scouting efforts. Thus, this approach is applicable to various agricultural settings and is scalable over large acreage. As a result, it follows that this approach could (i) enhance farm productivity and profits by reducing the costs of fungicide applications, improving disease control, and reducing time spent scouting fields, (ii) improve soil and water quality by limiting fungicide applications and the risk of runoff, (iii) help society by catalyzing the development of sustainable, large-scale, and commercial food production. More concretely, if this project results in one less fungicide application for all producers in the Columbia Basin of Washington, then producers should collectively save approximately $3.1 million. Thus, even if this project only reduces the number of fungicide applications by one, substantial capital will be saved and the negative impacts of fungicides will be reduced.

**E. Supporting Documents**

All supporting documents should be attached in the online grant application. PDF documents are preferred, but images in jpg and png formats are accepted.

***Current Vita:*** Attach a current 2-page vita for the Principal Investigator and each project team member, ***except producers***.

***Letters of Producer Cooperation***: ***Each producer who is part of the project team must submit a signed letter of cooperation***. The letter verifies the producer’s willingness to participate in the project and outlines their commitment to (resources and/or time) and role in it. If letters are not available at the pre-proposal submission time, producer e-mail confirmation of collaboration is acceptable.

***Letters of Stakeholder Support (Optional)***: Attach letter(s) of support from stakeholder individuals and/or organizations that support the proposed research and education activities.

***Citations***: Attach a list of cited sources.

1. Capital Press 2016. <https://www.capitalpress.com/state/washington/study-washington-potatoes-net-state-7-42b-annually/article_2c828ccf-69ce-5c30-abd4-ce91457d6d69.html>

2. Fernández CI. Leblon, B Haddadi A. Wang K; Wang J. 2020. Potato Late Blight Detection at the Leaf and Canopy Levels Based in the Red and Red-Edge Spectral Regions. *Remote Sens.12*, 1292.

3. Gold KM. Townsend PA. Chlus A. Herrmann I. Couture JJ. Larson ER. Gevens A.J. 2020. Hyperspectral Measurements Enable Pre-Symptomatic Detection and Differentiation of Contrasting Physiological Effects of Late Blight and Early Blight in Potato. *Remote Sens.* *12*, 286.

4. Johnson DA, Alldredge JR, and Hamm PB. 1998. Expansion of potato late blight forecasting models for the Columbia Basin of Washington and Oregon. Plant Dis. 82:642-645.

5. Johnson DA., Cummings TF, and Hamm PB. 2000. Cost of fungicides used to manage potato late blight in the Columbia Basin: 1996 to 1998. Plant Dis. 84:399-402.

6. NASS,2020. <https://www.nass.usda.gov/Statistics_by_State/Washington/Publications/Potatoes/2020/PTSTK04.pdf>