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Cover Page Footnote

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Research in Brief

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Weather Information and Decision-Support Tool Needs Assessment

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Abstract. University of Maine researchers developed three commodity-specific grower focus groups (lowbush blueberry, apple, mixed vegetable) to discuss and survey 1) current access to weather information, and 2) interest in weather-based decision support tools. NOAA National Weather Service (30%) (n=47) was most commonly cited as a weather information source. Growers ranked greater forecast accuracy (31%) and localization (19%) (n=48) as highest priorities. Only 34% of growers reported current use of weather-based decision support tools, but 86% expressed interest in future use (n=134). The project team is using grower input to improve weather data access and decision-support tools for Maine farmers.

INTRODUCTION

Agriculture is inherently sensitive to weather, and it is well documented that weather conditions have changed in Maine over the past century in association with a warming climate (Fernandez et al., 2020; Wolfe et al., 2018; USGCRP, 2019; Easterling et al., 2017; Birkel and Mayewski, 2018; Jacobson et al., 2009). The changes of particular importance to agriculture include warmer winter overnight low temperatures, increased daily high and low summer temperatures and increased humidity, delayed fall frosts, greater frequency of high intensity rain events (Spierre and Wake, 2010), and decreased snow cover (Notaro et al., 2014). Higher temperatures tend to increase evapotranspiration and decrease soil moisture (Anderson et al., 2009). More frequent high intensity rain events can lead to increased soil erosion, disease pressure, pesticide residue depletion, water lost to runoff, and restricted or delayed timing of essential management practices (Wolfe et al., 2018).

Climate warming and the resultant changes in weather threaten to reduce agricultural productivity and efficiency at many levels (Liang et al., 2017). The co-CEO of Johnny's Selected Seeds, based in Winslow Maine, recently noted that "We are hearing a lot about [farmer] customers who have had to deal with more significant weather changes" (Valigra, 2019). To this end, Wolfe et al. (2018) stated, "Farming success in the Northeast will require technologies that integrate site-specific monitoring with decision tools to adapt to rapid changes in environmental conditions." In a 2019 survey of Maine commercial tree fruit growers, 100% of respondents reported that the AgRadar weather-based models were useful to them during the previous growing season. Their responses indicated a $436 per acre savings in pesticide and growth regulator purchase and application costs and a 31% reduction in crop pest damage (Koehler et al., 2019). Maine lowbush blueberry growers use the AgriNET disease forecasting tool (Annis, 2020) which has been adopted by approximately 83% of growers who use fungicides to manage mummy berry disease (*Monilinia vaccinii-corymbosi*). A 2018 survey of these growers indicated that the number of fungicide applications has decreased from an average of three per year to one since the tool's introduction in 2009.

AgRadar and AgriNET are web-based decision tools operated by UMaine Cooperative Extension for apples and lowbush blueberry, respectively. AgRadar combines hourly observed and forecast weather data with model logic to translate weather into management guidance for apple growers. The resulting output is communicated to growers by automated publication of tables and charts as web pages. AgRadar can run with any compatible data source. It has used data purchased from a private vendor but is switching to a UMaine data source (WeatherGrid2U) in 2021.

AgriNET downloads weather data from 15 weather stations located in fields across the Maine lowbush blueberry growing regions to inform growers when to apply fungicide for mummy berry and botrytis. While this program cannot forecast future conditions, the indication that an infection period occurred at a specific time improves the accuracy of fungicide applications allowing growers to reduce the number of pesticide applications.

WeatherGrid2U, developed by co-authors Birkel and Koehler, is an emerging framework for delivering high-resolution site-specific hourly weather forecasts and observations for agriculture by utilizing publicly available output from National Oceanic and Atmospheric Administration/National Weather Service (NOAA/NWS) forecast models and gridded observation data products. In addition to providing common variables such as temperature, precipitation, and wind speed, WeatherGrid2U also provides soil moisture, soil temperature, solar radiation, evapotranspiration, and growing degree-days. Reports with hourly 10-day forecasts and 7-day observations are sent to users via e-mail or fax twice daily. CSV-formatted spreadsheet files are also generated with each forecast and stored on a publicly accessible website. The forecast models utilized include the NOAA Global Forecast System, North American Mesoscale, High Resolution Rapid Refresh, and NWS National Digital Forecast Database. Observation data are from the NOAA Unrestricted Mesoscale Analysis and Global Daily Assimilation System.

As described, there are different approaches to crop and pest decision-support tools in Maine. Barriers and requirements for providing farm management decision-support that once existed (e.g. Bingham et al. 1990) have been surpassed by advancements in computer capacity and internet communication. Local farmer-specified guidance on what information is most useful and how to deliver it efficiently is still needed. The goal of this effort was to identify specific needs and priorities around access to weather information and farm management decision-support tools. We engaged farmers in a survey and a series of commodity-group focus groups with lowbush blueberry, apple, and mixed vegetable growers. The input provided by growers has enabled our team to move forward with improvements to the existing and emerging weather-based agricultural decision support tools in Maine.

METHODS

This needs assessment was conducted between June 2019 and May 2020. We began by conducting an in-person and online survey that was completed by 90 producers. Surveys were distributed at six in-person events and online through Extension newsletters (Table 1).

Extension has shown that focus groups are a proven methodology to assess the needs and constraints of a target group (Gamon, 1992). The survey population was narrowed to 8 15-member commodity-specific focus groups, with the goal of gathering more detailed information about weather information and decision support tool needs from each commodity group. Growers were informed about this opportunity at field day events where the survey was distributed and through Extension email list serves. Participants were compensated $350.00 for their focus group time. The project team used the responses from the survey to structure focus group discussions. At the focus group meetings, the project team described weather and decision support resources available in Maine for farmers. Farmers explained their growing season operations in detail to highlight specific weather-related decision-support tool needs. Meetings finished with a discussion of how the content, access, and delivery of weather information and decision-support tools could improve. The last step in the project was to use grower feedback to make improvements to AgRadar, AgriNET, and WeatherGrid2U.

RESULTS

The greatest percentage of growers are currently getting their weather information directly from NOAA (21%), followed by various television channels (14%) (n=55) (Figure 1). The next most frequently cited sources were AgRadar, AgriNet, Weather Underground and smartphone weather applications (12%, each). Of all growers surveyed, 34% currently use weather-based crop or pest management tools, while 66% do not. However, 86% of growers indicated they would be interested in using such tools.

GROWER-SPECIFIED PRIORITIES & NEEDS

Survey results revealed large gaps between the weather information growers currently receive and what they would find useful. Growers indicated that weather sources and decision support tools should include alerts, have improved accuracy and accessibility, be pest and crop specific, and include both historical and long-range forecasts. The main desire was for alert or warning capabilities to better forecast major agricultural meteorological stress events such as frost, extreme heat, intense precipitation, and drought.

Many growers mentioned the lack of internet connectivity in their region or found existing weather-based platforms difficult to operate. As a result, 13% of growers surveyed implied they would like an accessible, user-friendly platform that did not require high speed internet connection. Survey respondents would like to see observed and forecast measures (e.g., temperature, precipitation, etc.) presented in continuity as close to real time as possible. This would require continuity showing yesterday's weather in addition to the forecast.

Growers were also asked about how weather affected on-farm decisions. The top three weather-based factors that impacted important or difficult farm management decisions were frost, rain, and wind. A majority of responses revolved around how observed or forecast weather conditions determined the timing of management decisions, and how environmental factors affected operational needs or capability (Figure 2). In terms of timing, 41% of surveyed growers identified "when to spray" as the most important/difficult decision to make. This was followed by "when to plant" and "when to harvest" (17% and 14%, respectively). It is important to keep in mind that two of the three focus groups

Table 1. Number of Responses and Survey Questions Used in the Survey

Question	# Responses
What types of weather information and sources are most important to you for making farm management decisions?	86
What are the most important unmet needs for access to useful, relevant weather information to help with farm management?	59
Do you currently use any weather-based crop or pest management models or other tools?	83
If you answered "yes" to the above question, please list the tools that you currently use.	29
What is/are your most economically significant pest(s)?	77
What are your most important or difficult farm management decisions affected by short-term or long-range weather?	83
How can UMaine help growers with weather-related farming challenges?	52
Are you interested in using web-based weather tools?	82

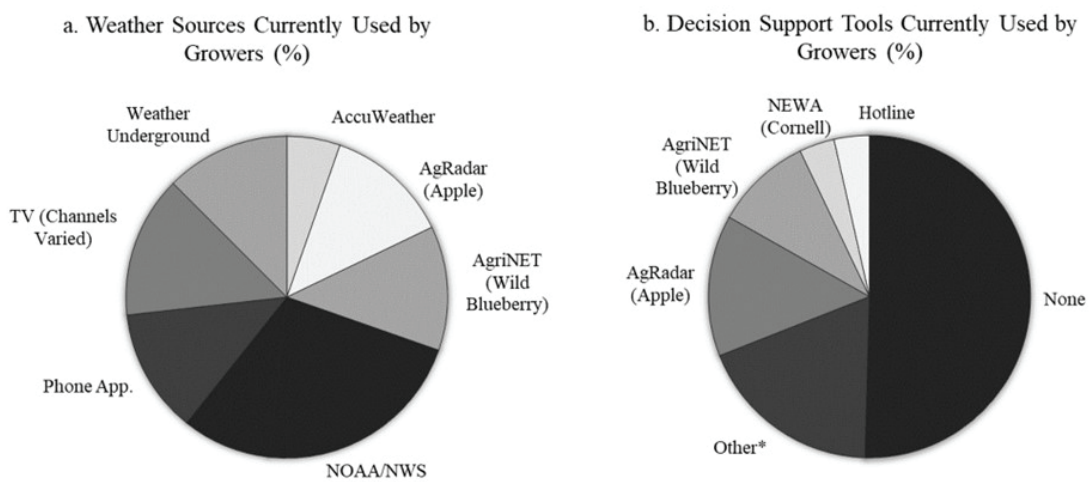

Figure 1. Weather sources (1a) and decision support tools (1b) currently used by growers. In 1b., 'Other' included growing degree day models, personal weather stations, newsletters, and personal communications with Extension specialists.

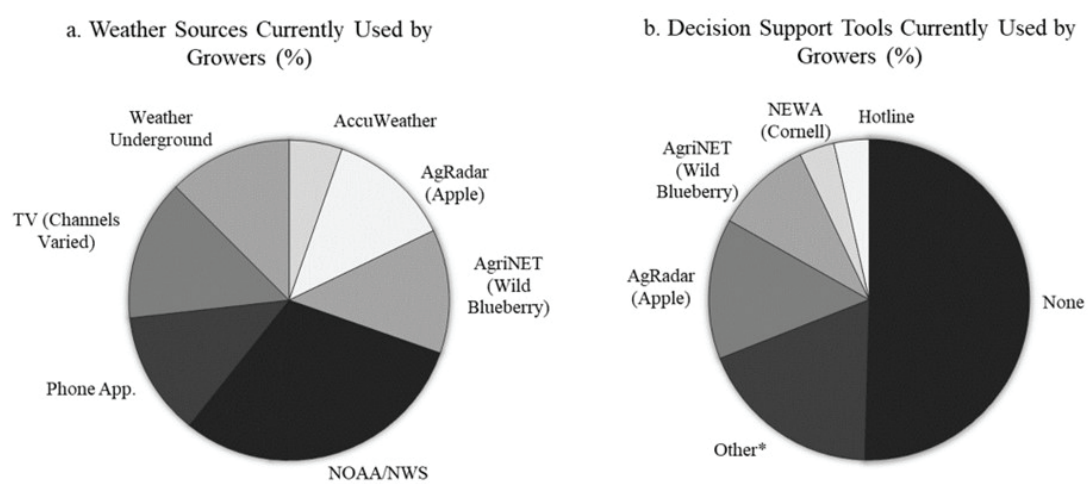

Figure 2. Survey results of the most important or difficult farm management decisions affected by short-term or long-term weather across three crops (apple, lowbush blueberry, and mixed vegetables). 4a shows the priorities (%) for aid in the timing of management decisions; 4b. shows weather factors (%) that affect these decisions.

were for perennial crops (apples and lowbush blueberry) for which planting timing is not a major concern. Many growers wanted to know when to irrigate or cover their crops to protect against frost. Predicting disease infection, when to thin or prune, and field workability (i.e., soil saturation) were also mentioned. Growers expressed interest in long-range seasonal forecasts to help predict costs relative to predicted yield for a given season.

Pests with the greatest economic impact by crop group were surveyed to help discern the need for IPM (integrated pest management) decision support tools (Figure 3). While disease and wildlife also pose major economic threats to these crops, insect pests received the highest ratings for economic significance for all three crops.

Surveyed growers reported that they currently use website, television, and smartphone apps to access weather information. For future platforms, in addition to website and phone app access, they would like to receive updates or alerts via email or text message. Growers living in more remote locations require use of a telephone hotline (Figure 4).

IN-PERSON FOCUS GROUPS

Focus group discussions reinforced the survey results. Growers emphasized a need for more accurate localized weather with prediction (notification) capabilities that is mobile friendly, customizable, easy to read, and shared across multiple crop commodities. Discussion ranged from on-farm weather station hardware to the reality that farmers are looking for “windows of weather” to accomplish a task. The effects of weather on work crew scheduling and tasks beyond crop and pest management were also discussed.

Growers reiterated the survey results by indicating that they would like a customizable, accessible tool that “is here to stay”, with improved weather accuracy, various options for decision support tools (models) and the ability to request alerts or notifications for extreme weather, disease infection periods, or insect activity periods that could lead to potential crop loss.

The frequency and intensity at which growers use weather information was a prominent theme in animated discussions with all three focus groups. Growers reported checking the weather multiple times per day and using multiple sources to make their own interpretation of what the different reports meant for their operations. Access to weather information while away from the office through a smartphone was another frequently identified priority, as was weather data tuned for specific agricultural needs not often represented in typical generic forecasts (Table 2).

ONGOING EXPANSION OF EXISTING TOOLS BASED ON FEEDBACK

As a result of the feedback we received from growers, the project team made changes to the existing AgRadar and AgriNET web interfaces. AgriNET added growing degree day (GDD) calculation and improved website readability. WeatherGrid2U and AgRadar already had GDD information and are expanding the platforms to include frost, extreme heat, precipitation intensity, drought, and seasonal forecasting. AgRadar developed a website with interactive charts for viewing site-specific forecasts and increased frequency of available forecast updates to four times per day.

DISCUSSION

From this in-depth look at Maine farm weather needs, we learned that growers make intensive and frequent use of weather information every day during the growing season and would like to consolidate their weather access to one website or application. Many growers prefer to access weather information through a smart phone. This project

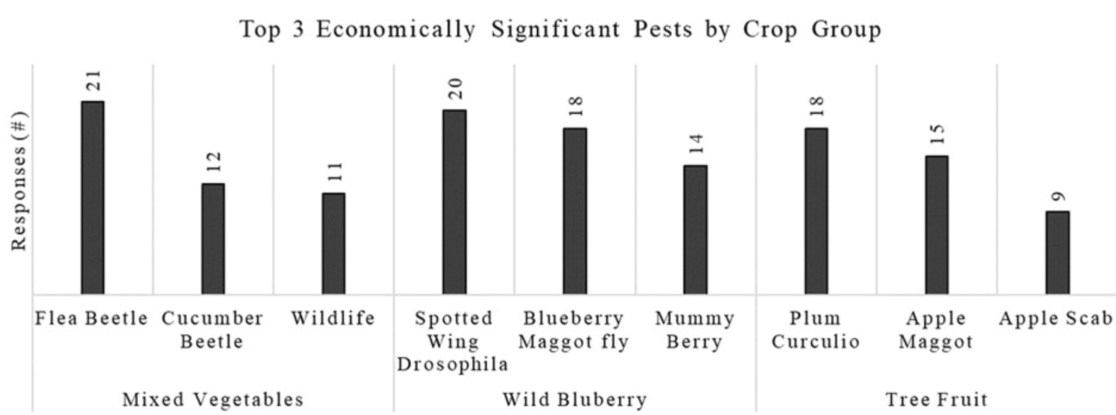

Figure 3. The top three most economically significant insect pests by crop identified by grower surveys.

Table 2. Specific Weather Data Needs Identified in Focus Group Discussions

Weather Element(s)	Examples of Farm Operations and Decisions Affected
Wind speed, wind direction.	Specific tasks sensitive to wind such as spray application for good coverage and drift prevention. Spread potential for field burning. Frost protection.
Rainfall amount.	Irrigation, crop development for non-irrigated crops. Field drivability for planting, spraying and other operations. Pesticide residue depletion.
Precise timing of rainfall.	Timing spray application. Worker scheduling for hand-weeding, harvesting, or keeping home etc.
Drying conditions. Leaf wetness duration.	Spray application timing for growth regulators, herbicides and other materials affected by absorption time on plant tissue. Spray material selection. Fungal crop disease prediction. Potential for spread of bacterial crop disease.
Soil moisture.	Timing, amount, and optimal use of irrigation water and pump energy.
Temperature.	Crop, insect pest, disease, weed development, critical life stages for crop and pest management.
Minimum temperature and timing. Integration of min. temp. with wet-bulb temp. or wind.	Timing for frost protection measures. Spray timing and material selection. Low temperature effects on crop maturation (e.g., apple color development and scald susceptibility).
Maximum temperature. Integration of max. temp. with relative humidity.	Worker protection. Potential for crop phytotoxicity, pesticide deactivation, or excessive growth regulator effect. Pollinator activity. Livestock stress (need for cooling, feed ration adjustment).
Near-surface and sub-surface soil temperature.	Frost, heat stress, development/maturation for low canopy crops. Seed germination temperature. Addition or removal of row covers.
Solar radiation and cloud cover.	Pollinator activity and protection. Irrigation scheduling. Growth regulator spray timing and dosage (e.g. apple thinners).
Long range temperature and precipitation forecasts.	Crop or crop variety selection. Sequential planting/harvest dates. Harvest and sales planning (e.g. availability date of produce).

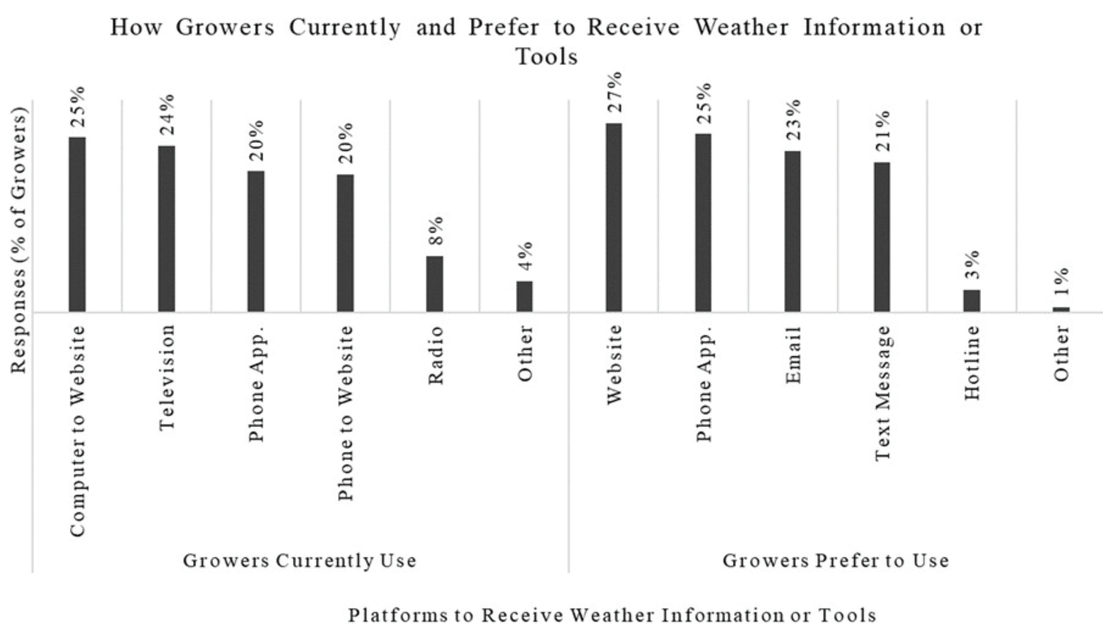

Figure 4. Survey results of how growers currently access weather information or tools (4a) and how they would prefer to access this information (4b).

highlighted the fact that each commodity group has specific weather needs, and obtaining feedback on these details by commodity and farm size from growers is particularly useful for designing products to meet those needs. For example, the lowbush blueberry growers indicated that they need wind speed and relative humidity for prescribed burn pruning. Diversified vegetable growers highlighted the need for weather information to manage farm worker time while attending to a myriad of insect and disease pests for multiple crops grown simultaneously. Grower feedback highlighted the importance of direct physical threats posed by high and low temperature extremes in addition to too much and too little precipitation. The expertise and knowledge contributed by growers brought complex links between weather and the agricultural system forward, showing the importance of consulting with these expert weather consumers when designing weather-based decision-support tools to meet their needs.

These results illustrate that a large majority of growers are interested in using weather-based crop, pest, and farm management tools. Our results clearly demonstrate that Maine growers require accurate and local weather to make their daily farm management decisions. The project team believes that accuracy and localization can be improved by pairing station data with NOAA gridded data. Numerous pest and crop forecasting models exist in the literature but are not actively available for farmers to use. Some of these models need to be validated for use in Maine. Tools should be easy to use, adaptable to various grower needs, and available through a system built on a solid operational foundation to provide long-term service. Membership fees or commodity group funding to build and maintain long-term tools for farmers is thought to be a more sustainable funding option than short-term grant-driven project funding.

Weather determines how these stakeholders start their day, get work done, plan for tomorrow, and end their day. While project staff already knew the importance of weather in farming, the degree to which farmer livelihoods rely on weather was impressive, inspiring, and an unexpected highlight from our discussions. With the increasing availability of advanced computer and communication technologies, we now have the ability to combine data sources and analytic platforms with field-based science and communication tools to enhance farm viability in Maine.

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