Improving and Sustaining the NEWA System

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Background & Justification

The Network for Environment & Weather Applications (NEWA) system has a proven track record for saving grower's money, reducing pesticide use, improving IPM and crop production, and documenting crop insurance and risk management needs (Carroll et al 2011). NEWA provides a reliable flow of weather data that supports the implementation of pest, disease and crop forecasts (Agnello and Reissig, 2010). Growers using NEWA state that they reduced spray costs, on average, by $19,500 dollars per year and that they prevented crop losses, on average, of $256,000 dollars per year as a direct result of using NEWA pest forecast models (Carroll, 2007).

In a NEWA survey of NY growers (Carroll, 2007), we found the greatest impact of the system is making pest, disease and crop forecasts available online. This project, researching improvements to sustain NEWA, will result in increased use of forecast models which, in turn, help reduce the number of sprays applied, improve the timing of sprays, and thereby reduce risk to the environment and human health. NEWA pest forecasts have a positive impact on IPM practice: 99.2% of farmers using NEWA would recommend NEWA to other farmers.

These agricultural forecasts have the potential to save agricultural interests, especially apple farms, substantial money in crop production costs and eliminate unneeded, ineffectual pesticide use. A significant amount of research has been devoted to the development of forecast models; 27 are implemented on NEWA and, of these, 10 are for apple, including apple scab infection events, apple scab ascospore maturity, fire blight Cougar Blight, sooty blotch & flyspeck, obliquebanded leafroller, spotted tentiform leafminer, codling moth, plum curculio, oriental fruit moth, and apple maggot.

NEWA provides historical records of weather data, current data, and forecasts. Growers can access growing degree day accumulations and track cold temperatures, such as the frosts and freezes that occurred in May 2010. In addition, NEWA data supports research and development of new models like the highly successful apple carbohydrate utilization model to inform apple thinning sprays.

Extension educators will benefit from reliable weather data and forecast model outputs on NEWA that they can utilize in their extension newsletters, crop updates, and pest alerts. Crop consultants also benefit by improving their knowledge of when pests and diseases may be active, when to deploy traps, scout for primary infections, etc. Researchers benefit by having a source of weather data from agroecosystems that is available for use in their research programs.

Providing more accurate leaf wetness duration information in NEWA and utilizing this information in the models will improve the precision of the model results. Placing the daily "I need to know" information in the hands of apple growers with e-NEWA alerts will eliminate the need to dig several clicks down a website for the information and the subscriptions will help sustain the system and all its benefits. This project will lay the groundwork for full development of e-NEWA.

Objectives

1. Leaf wetness duration. We will investigate implementation of the fuzzy logic model (Kim et al, 2004) for estimating leaf wetness duration and correlate the results from this mathematical formula with those obtained from the plastic grid sensors on the weather stations in the NEWA system. Comparing NEWA leaf wetness sensor data against that generated by mathematical formulas that use more reliable weather parameters collected at the same NEWA site will pave the way for better prediction of leaf wetting events that drive fungal and bacterial diseases of apples.

2. e-NEWA alerts. We will research the feasibility of a customizable, subscription-based e-NEWA daily email alert, test a prototype with apple growers, and investigate pricing guidelines for e-NEWA subscription.

Procedures

Objective 1. Leaf wetness duration - Our hypothesis is that the fuzzy logic model will provide better estimates of leaf wetness duration than the plastic grid sensors used on weather stations.

We (Carroll and DeGaetano) will hire a programmer to implement the fuzzy logic model for leaf wetness duration using the NEWA weather database. The fuzzy logic model uses RH, temperature, and wind speed to estimate leaf wetness duration following a precipitation event; use of solar radiation data can further improve model estimates. Results of estimated leaf wetness will be displayed on the NEWA website, newa.cornell.edu, in a column next to the leaf wetness sensor data in the weather tables of hourly and monthly data.

These leaf wetness estimates will be compared to leaf wetness plastic grid sensor data collected from the same location through correlation analysis. Errors in leaf wetness plastic grid sensor data (i.e. no leaf wetness minutes per hour during a rain event) will be taken into account in the comparison. Because the current NEWA system utilizes "data query" programming to display model results, the leaf wetness duration comparisons can be done across all years and locations having appropriate sensors for the fuzzy logic model estimate. This large data set will improve the correlation analysis.

If estimated leaf wetness duration is found to provide good and consistent results, the fuzzy logic model will be deployed at NEWA locations that do not have leaf wetness sensors (i.e. NWS airport stations) and estimated leaf wetness duration will be used in pest and disease forecast models that require leaf wetness duration information (i.e. apple scab Mills Tables).

Objective 2. e-NEWA alerts - Our hypothesis is that a subscription-based alert system for insect, disease, crop production, and weather conditions will provide significant funding resources to sustain the NEWA system and will provide apple growers with convenient, daily access to highly relevant NEWA information.

A web portal will be outlined by Carroll and estimated costs for the portal will be investigated with ITX, Inc., the web hosting service for NEWA. In the portal users will select the NEWA model(s), the type(s) of weather information, and the location(s) alerts are requested for. There will also be a subscription page. A statement of work with estimated costs will be generated to guide future development.

Alerts will contain results for the two days prior and the five days in the forecast. Carroll, Breth and Fargione will survey and confer with apple growers regarding the types of results and messages that will prove most useful. Current research has shown that growers access NEWA typically once per week. The e-NEWA emails will place NEWA results directly in the hands of growers (i.e. email access via smart phone) on a daily basis.

The programmer hired under objective 1 will develop a prototype e-NEWA alert email message with NEWA results for one apple disease, one apple insect, and one weather parameter (i.e. growing degree days). This prototype will be delivered to 4 to 6 apple growers, recruited by Breth and Fargione to collaborate on the project, half in the Lake Ontario region and half in the Hudson Valley region, respectively. Comments and suggestions on the prototype will be collected from the growers.

Rickard will work with Carroll to develop pricing guidelines for e-NEWA subscription fees and offer guidance on conducting appropriate market research.

Results and Outcomes

Objective 1: Leaf wetness duration.

Investigations of the Fuzzy Logic leaf wetness model caused us to compare its leaf wetness estimates with those of four other models.

1. Fuzzy Logic Decision Tree (temperature, RH, wind speed, time of day)
2. CART (Classification and Regression Tree) model (temperature, RH, wind speed, time of day)
3. Relative Humidity threshold (≥ 90%)
4. Dew Point Depression threshold (wet if ≤ 1.8C; dry-off if ≥ 2.2C)
5. Extended Relative Humidity threshold (wet if RH ≥ 87%; dry-off if ≤ 70%; dry-off if RH decreases more than 4% in an hour.)

Comparisons of the above models were done as described in Sentelhas et al (2008).

		Estimated leaf wetness	
		Yes	**No**
Observed leaf wetness	**Yes**	Hit (H)	Miss (M)
	No	False Alarm (FA)	Correct Negative (CN)

Where best estimates are defined when the "fraction of correct estimates" is closest to one; the "correct success index" is closest to one; and the "false alarm ratio" is closest to zero. There is also a "bias" measure, < 1 is an underestimate and > 1 is an overestimate.

Equations for the Estimate Scores

Fraction of Correct Estimates = (H + CN) / (H + M + FA + CN); = 1 is best

Correct Success Index = H / (H + M+ FA); = 1 is best

False Alarm Ratio = FA / (H + FA); = 0 is best
Bias = (H + FA) / (H + M); < 1 = underestimate, > 1 = overestimate

The comparisons were made for the periods May through October of years 2010 and 2011. Each model's leaf wetness estimate was compared to the observed leaf wetness sensor measurements for NEWA weather instruments located primarily in the apple growing regions of NY, including: Albion, Appleton (North), Appleton (South), Ashwood, Chazy (grower), Clifton Park, Clintondale, Clintondale (Minard), Crown Point, Geneva, Granville, Guilderland, Highland HVL, Hudson, Ithaca Cornell Orchards, Knowlesville, Lafayette, Lansing, Lyndonville, Marlboro, Peru, Portland, Redhook, Somerset, Watermill, Waterport, Watkins Glen, Williamson (DeMarree), Williamson (Mason), and Williamson (Motts).

Estimate Scores for the Leaf Wetness Models vs. Observed Leaf Wetness ≥ 1 min/hr*.

Leaf Wetness Model	Fraction of Correct Estimates	Correct Success Index	False Alarm Ratio	Bias
Fuzzy Logic	0.730	0.247	0.533	0.736
CART	0.711	0.388	0.540	1.550
Dew Point Depression	0.746	0.417	0.506	1.469
Extended RH	0.656	0.355	0.600	1.894
RH ≥ 90%	0.756	0.420	0.491	1.385

* This is the leaf wetness threshold used in the apple disease models.

Highlighted in yellow are the best estimate scores, highlighted in red are the worst estimate scores. The RH ≥ 90% model gave the best estimate scores for all the comparison indices. Relative Humidity ≥ 90% performed well for all leaf wetness duration thresholds (≥ 12 min/hr and ≥ 30 min/hr data not shown) and among all four statistical scoring methods. Relative Humidity thresholds set at 97%, 98%, or 99% generally work best according to the four statistical scoring methods used, however, these RH measurements fall within a range where the RH sensor is more prone to error. For this group of stations in the 2010-2011 growing seasons, leaf wetness appeared to be more heavily influenced by rain and fog than dew (given the better scores for ≈99% RH).

The CART, Dew Point Depression, and Extended RH Threshold models consistently overestimated leaf wetness. The Fuzzy Logic performed satisfactorily for this group of stations, but generally underestimated leaf wetness, possibly due to assumptions made regarding the handling of net radiation and wind speed during the overnight hours. The Fuzzy Logic model obtained high Correct Estimate scores because it does a good job of predicting "Correct Negative" events.

The recommendations from this work are to use the Relative Humidity ≥ 90% to estimate hours of leaf wetness. We will implement this for all NEWA stations beginning in April 2012. The "estimated leaf wetness" hour value will appear in a column in the Hourly Data and Daily Summary tables under the heading Estimated Leaf Wetness. The model will return either a "yes" or a "no" value for a wet hour or a dry hour, respectively. The occurrence of precipitation will be taken into account such that if there is measurable precipitation, the leaf wetness hour would be considered wet. Estimated leaf wetness will be used in the disease models for those NEWA station locations where there is no leaf wetness sensor.

Over time we will continue to improve on this leaf wetness estimation. One approach that shows promise is to calibrate each station location for the best RH threshold for estimating leaf wetness.

Objective 2: e-NEWA alerts.

The e-NEWA daily email alert for weather, plum curculio and apple scab forecasts will be implemented in April 2012 and run through September 1. Weather data will include High, Low, and Avg Temp (F); Rainfall (in); Wind Speed (mph); RH (%); and Solar Radiation (ly). Growing degree days (GDD) will be tallied. Appls scab model results will be summarized for ascospre maturity and infection events. Plum curculio status and management messages will be summarized. Messages will include two past days, the current day, and the 5-day forecast, as available.

Carroll met with apple growers in the Hudson Valley and Lake Ontario regions to describe the e-NEWA prototype. Sixteen growers volunteered to test the prototype e-NEWA email alerts. Growers signed up to receive alerts from one to four station locations, one to five times per day. In addition, Breth, Fargione, and Carroll will be receiving the e-NEWA emails. Interest from Massachusetts and New Jersey was expressed and Jon Clements, Univ Massachusetts Extension and MA-NEWA Administrator will also test the prototype.

During the meetings with growers, additional comments were received for formatting the emails as well as the idea for a frost alarm. Although it is unlikely that we will be able to implement the frost alarm this season, all but three growers would want to receive a frost alarm text message. The frost alarm is designed so growers would select the NEWA location(s) and set the temperature threshold at which the alarm text message would be sent. Most set the alarm for 32 F, 33 F, or 34 F.

Carroll met with ITX, NEWA's web hosting and design company, to discuss cost estimates for developing a website within NEWA through which users would subscribe to the daily email alerts. This cost estimate will provide a basis for grants to develop the e-NEWA subscription registration system. Within this project it has become clear that there are three components to this, the Registration gateway, the pricing and billing gateway, and the NEWA email gateway. Development of the billing gateway may be the greatest challenge.

	Number of Farms*				
Crop	**NY**	**NJ**	**VT**	**MA**	**Total**
Apple	1350	471	264	369	2454
Grape	1438	192	45	76	1751
Onion	234	19	72	48	373
Potato	530	103	93	103	829
Total	**3552**	**785**	**474**	**596**	**5407**

* NASS 2007

We started developing the audience parameters for the market research analysis to determine the pricing guidelines for the subscription e-NEWA alerts. The number of growers in the states where NEWA is operational is tabulated for the four major crops for which we have pest forecast models in NEWA. If 5% of farms subscribed to e-NEWA for $5 per month this would generate $16,221 per year gross to support NEWA.

References

Agnello, A.M. and Reissig, W.H. 2010. Development and validation of a "real-time" apple IPM website for New York. NY Fruit Quarterly 18:25-28.

Carroll, J.E. 2008. Impact of NYS IPM Program's Network for Environment and Weather Awareness (NEWA) on agricultural production. NYS IPM Program Project Reports 2007-2008, NYS IPM Pub 506: 261-267.

Carroll, J., Weigle, T. and Petzoldt, C. 2011. The Network for Environment and Weather Applications (NEWA). NY Fruit Quarterly 19(1):4-9.

Kim, K.S., Taylor, S.E., and Gleason, M.L. 2004. Development and validation of a leaf wetness duration model using a fuzzy logic system. Agric. Forest Meteorol. 127:53-64.

Sentelhas P.C., Dalla Marta A., Orlandini S., Santos E.A., Gillespie T.J., and Gleason M.L. 2008. Suitability of relative humidity as an estimator of leaf wetness duration. Agricultural and Forest Meteorology. 148 (3): 392-400