Crop Stage-Based Yield Modeling Using Wx & VHI

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This all started in 2015, when we were trying to quantify the impacts of late-summer heat and dryness in Ukraine and Russia on Corn.
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Using our in-house software for selecting, plotting, and analyzing the weather, I exported the data (CSV) and worked with it in Excel to try and come up with a yield relationship.
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The data was manually imported into Excel.
Regression analyses were run manually on the data.
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Final Ukraine Corn Yield (PSD): 5.71

While the skill scores were promising, the results for Ukraine were disappointing.
In contrast, the results for Russia suggested this utility offered a great deal of promise!
Concurrently, I began to import this same data (manually) into Excel to estimate stage of development based on GDDs.
Within Excel, I could quantify the key stage-specific weather parameters to help guide yield-forecast estimates. But it was a slow, labor-intensive process.
The first big breakthrough came when Brian Morris provided a dynamic link to our in-house WMO database I could use in Excel; I could now work with the updated data within Excel versus having to [SAVE AS] from our data plotter.
Using the built-in database link, macros, VBA, and Excel’s plotting capabilities, the ability to select and plot weather data increased by an order of magnitude.
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The next addition was a direct link to our online PSD country-level yield data; the natural progression was to use this weather analysis tool in conjunction with the yield data as a template for yield modeling.

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The next breakthrough:
In June of 2017, I noticed the VHI ascii data was now available to download. I began to work with the data that summer; this would become a game changer.
While working on the data, year to year variations in crop stage of development jumped out, such as Russia corn 2017 → 2018.
The differences were often significant. For example, winter wheat is now *flowering much earlier* in **Turkey**:

Flowering week # has gone from ~ 22 in the early 90’s (*late-May/early June*) to as early as week 16 in 2018 (*mid-April*), a 6-week swing. Accounting for this change is key for yield modeling in my AOR...

**Crop stages are a moving target, so I am using year-specific GDD-based crop stage in the yield-modeling effort.**
Moisture Yield Response Factors (FAO) show the key stages for yield impacts from drought; extracting when these stages occur would be the driving force behind the yield modeling.
Pairing the VHI and WMO databases into Excel and using GDD-based crop stages, 

**Stage-specific VHI, Weather “Start”, & Weather “End”**

are analyzed.

This ensures year-to-year consistency allows easy testing of different scenarios.
A quick note about the VHI data acquisition methodology....
We are downloading the ascii data using **WGET**. The WGET code is automatically produced for a specific country by using an Excel “assembler”; the user selects the country and then the Excel sheet puts together the code based on the STAR website addresses and structure.
The Excel code is copied into a batch file, which can subsequently be run manually or scheduled. We can ramp up new areas quickly this way.
For VHI ascii, we rely on a country, admin, or a weighted average of multiple admins (shown here, a 5-admin weighted average)
Stage-specific VHI has been ported to different regions and crops for yield modeling.
Yield regression are also driven by stage-specific rainfall...
... and of course, **temperature**.
The Net Result:
A suite of yield-modeling guidance (streamlined with macros) which include:

- Last Year: 4.70
- 5-Year Avg: 4.18
- Last Month: 5.63
- VHI*: 4.94
- Wx*: 5.88
- VHI+Wx*: 5.80
- VHI+Wx/Intcpt*: 5.78

*Includes Trend

Regression: 2005-2017
Median Regression Yield: 5.79

Record: 5.63 (2018)
Trend: 4.4 (R²=0.29)
A suite of yield-modeling guidance (streamlined with macros) which include:

- Trend
- VHI
- VHI + Trend
- Wx + Trend
- VHI + Wx + Trend
- VHI + Wx + Trend + Intercept*
- VHI + Wx(2) + Trend + Intercept*

* Dummy variable to account for yield change from technology, seed improvements, etc.

These two “combo” regression (VHI + Wx) are almost always the best performers.

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<tr>
<th>Last Year</th>
<th>5-Year Avg</th>
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<tr>
<td>Last Month</td>
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<tr>
<td>Last Year</td>
<td>5.63</td>
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<td>5-Year Avg</td>
<td>4.70</td>
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<td>+/- 0.45</td>
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*Includes Trend
A quick look at some 2018 results...
Wheat: Key stages are Flower and early Grain Fill. Regression are “set” as soon as the crop reaches mid-stage filling.
Corn: The key stages are Tassel, Silk, & Blister. Once past Blister, the regression are set.
In 2018, the Wx & VHI stage-based regression provided good--to at-times excellent--yield guidance for grains and oilseeds (winter and summer crops).
During this 2018 trial run, USDA coordinated with NOAA (Kogan, et al) for a croplands masked VHI.
We agreed to use the NASA/Columbia global croplands mask. The masked VHI data came online in November, 2018, and I am using this product moving forward.
In areas with concentrated, well-defined croplands, the new masked VHI product improved the regression considerably.
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Not all areas saw this type of improvement, but in some it made a notable difference.
In the most recent WASDE (May, 2019), VHI & Weather data were featured prominently in my analysis, my presentation to the WAOB, and the subsequent slides used by the WAOB Chairman in the Secretary’s Briefing the following morning.
For this month’s WASDE, WAOB and FAS staff directly referred to the regression results to help determine the latest yield forecasts.
In fact, the **Chairman of the Oilseeds Committee** and his assistant used this “**Summary Table**” to calculate the range of rapeseed production possibilities within the EU.
Wx- & VHI-driven regression are being run operationally for nearly 70 different country-crop pairs in my AOR alone! Many of these were specific requests from WAOB Economists or FAS personnel.

EU Wheat:
- Spain
- Italy
- France
- UK
- Denmark
- Germany
- Poland
- Lithuania
- Czech Republic
- Slovakia
- Hungary
- Romania
- Bulgaria

EU Rapeseed:
- Spain
- France
- Germany
- Poland
- Italy
- Hungary
- Serbia
- Romania
- Bulgaria

EU Corn:
- Spain
- France
- Italy
- Germany
- Hungary
- Serbia
- Romania
- Bulgaria

EU Sunflowers:
- Spain
- France
- Italy
- Germany
- Hungary
- Serbia
- Romania
- Bulgaria

FSU:
- Russia Winter Wheat
- Ukraine Winter Wheat
- Russia Spring Wheat
- Kazakhstan Spring Wheat
- Ukraine Corn
- Russia Corn
- Moldova Corn
- Ukraine Sunflowers
- Russia Sunflowers
- Moldova Sunflowers
- Ukraine Soybeans
- Uzbekistan Cotton
- Kazakhstan Cotton

MIDEAST:
- Turkey Wheat
- Syria Wheat
- Iran Wheat
- Turkey Barley
- Iran Barley
- Turkey Corn
- Turkey Sunflowers
- Turkey Cotton

NW Africa:
- Morocco Wheat
- Algeria Wheat
- Tunisia Wheat
- Morocco Barley
- Algeria Barley
- Tunisia Barley
Final VHI Thought: “ROPE”

Reliable (Established, Peer Reviewed, Quality Controlled, Updated) ✓

Operational (Timely, Routine, What Ifs, Back Ups (data & personnel)) ?

Portable (Global, Admin 00 & Admin 01, Universal Cropland, Uniform Format, Compatible) ✓

Expedient (Openly Available, Easily Acquired, Simple, “Schedule-able”) ✓ & ?

Thank you!