**NASA DEVELOP National Program**

**2018 Summer Project Proposal**

**Maryland – Goddard**

**New England Agriculture & Food Security**

Incorporating NASA Earth Observations into an Assessment Tool to Identify Correlations Between Factors Associated with Bee Health

**Project Overview**

***Project Synopsis*:** Globally, bees are the most important pollinator of food crops, as bees pollinate more than 70 of the fruits and vegetables that make up American diets. However, honey bee (*Apis mellifera*) populations in the United States are declining in many agricultural regions leading to concerns about food security and ecosystem health. The Urban Beekeeping Laboratory and Bee Sanctuary (UBL) and The Bee Informed Partnership (BIP) focus on identifying ecological and environmental factors associated with healthy honey bee colonies in order to improve overall honey bee health. The UBL and BIP will partner with NASA DEVELOP to develop a correlation assessment tool that will integrate environmental parameters from NASA Earth observations into current efforts to identify where and why honey bees are thriving in New England. The model will guide the UBL and the BIP’s future efforts to measure and understand the risks and hazards faced by honey bee populations.

***Community Concern:*** More than one-third of food crops depend on bees for pollination. However, over the last ten years, beekeepers in the United States have reported annual hive losses of over 30 percent. It is believed that the health of bee populations in the United States is declining as a result of multiple stressors, including Colony Collapse Disorder, mite infestations, pathogens, pesticides, fungal infections, and poor nutrition due to decreasing plant diversity. Because of the importance of bees as pollinators for both agricultural crops and wild plants, continued decline of bee populations will have a negative impact on plant biodiversity, agriculture, and the nation’s food security.

***Source of Project Idea:*** The idea for this project originated when DEVELOP participant Sara Lubkin heard Dr. Noah Wilson-Rich, the founder of UBL, speak about his work with bee diversity at the X-STEM Symposium in Washington, DC. Sara introduced herself to Dr. Wilson-Rich and told him about DEVELOP. The idea for the project was then refined over multiple conversations involving GSFC node leadership, NPO, and UBL.

***National Application Area Addressed:*** Agriculture & Food Security

***Study Location:*** New England, including CT, MA, NH, RI

***Study Period:*** January 2015 – May 2018

***Advisor:*** Sean McCartney (Science Systems & Applications, Inc., NASA Goddard Space Flight Center)

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Urban Beekeeping Laboratory and Bee Sanctuary, Inc.** | Dr. Noah Wilson-Rich, Chief Scientific Officer | End User | Yes |
| **The Bee Informed Partnership, Inc.** | Dr. Dennis vanEngelsdorp, Project Director | End User | Yes |
| **University of Maryland, vanEngelsdorp Honey Bee Research Lab** | Dr. Nathalie Steinhauer, Post-doctoral researcher  Kelly Kulhanek, Researcher | Collaborators | No |

***End User Overview***

***End User’s Current Decision-Making Process:***

*Urban Beekeeping Lab and Bee Sanctuary, Inc.* – UBL staff (PI, post-doctoral researcher, analyst, manager, and students) work directly with 65 beekeepers at The Best Bees Company to evaluate both best practices for beekeeping (applied science), as well as ecological variables that impact bee health (basic science). Data are collected using the FileMaker Pro database platform, for which code is written in-house. Results are reported across a variety of platforms, including scientific publications, general media, and subsequent studies.

*The Bee Informed Partnership, Inc.* – Bee Informed studies honey bee health on an epidemiological scale. The partnership relies heavily on national survey results to determine the current leading factors affecting bee health, especially the factors which beekeepers have difficulty combating. Based on both surveys and direct communication with beekeepers, Bee Informed is able to discern the bee health issues which need attention from scientists. This helps direct decision-making about studies to perform, variables to measure, and solutions to test. All of these processes are aimed at creating solutions that can be communicated to and adopted by beekeepers to improve overall colony health.

***End User’s Capacity to Use NASA Earth Observations:***

*Urban Beekeeping Lab and Bee Sanctuary, Inc.* – UBL currently uses GIS software to identify where and why honey bee hives are thriving, and compare these data with other known ecological and environmental factors, including population density, height off the ground, and proximity to protected lands. UBL has not incorporated NASA Earth observations into their research, but would benefit from adding satellite-derived environmental parameters associated with bee health to their bee health studies, including: phenology, photosynthesis, vegetation water content, evapotranspiration, surface temperature, soil moisture, humidity and precipitation.

*The Bee Informed Partnership, Inc.* – Bee Informed has not used NASA Earth observations before. Their honey bee health and mortality studies would benefit from correlations with landscape and climate parameters from NASA Earth observations such as evapotranspiration, surface temperature, soil moisture, humidity and precipitation.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*University of Maryland, vanEngelsdorp Honey Bee Research Lab* – Dr. Nathalie Steinhauer is a post-doctoral researcher who leads the management and loss survey program at the vanEngelsdorp Honey Bee Research Lab. Kelly Kulhanek is a graduate student who leads the Sentinel Apiary Program. They will provide and help interpret data sets describing colony health, pest and parasite loads, beekeeping management practices, and other information related to bee health. These data points can be used as parameters to compare bee health across regions. For example, weather affects floral bloom, which may affect honey production and overall colony health. Kelly and Nathalie will assist in conceptualizing the best ways to use these data to make meaningful comparisons, and how to translate outcomes into actionable recommendations for beekeepers.

***Dissemination by Boundary Organizations*:**

*Urban Beekeeping Laboratory & Bee Sanctuary, Inc.* – UBL analyzes and reports results from data collected through The Best Bees Company. Both UBL and The Best Bees Company conduct outreach to beekeeping clubs nationwide, in addition to employing local beekeepers to spread ideas and practices within 16 states throughout the United States. The organizations also work with students to reach out to local beekeepers and student organizations to communicate results and findings related to bee health and beekeeping practices.

*The Bee Informed Partnership, Inc.* – The Bee Informed Partnership is a collaboration of leading research labs and universities in agriculture and science to better understand honey bee decline in the United States. Their goal is to bridge the gap between science and stakeholders, providing useful management recommendations to beekeepers in real time. Overall, they aim to compile a comprehensive honey bee health database, and to reduce honey bee colony mortality. The results collected from collaborations within the partnership are disseminated through multiple programs, such as the USDA’s National Honey Bee Disease Survey. The Partnership also disseminates research results to thousands of daily visitors through the BeeInformed.org website.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The team lead will serve as the primary point of contact for communication with the project partner. The team will communicate with project partners through tri-weekly teleconferences, and the team lead will email weekly updates.

***Transition Plan*:** During week 10, end products will be transitioned remotely during a virtual and in-person handoff, during which the team will discuss results and answer any questions regarding the products. Tools and scripts will be handed off after they have gone through the NASA software release process. A tutorial for the tools will be provided.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 8 OLI** | Multispectral imagery | Environmental factors, vegetation data, and phenological information derived from this dataset will be correlated with bee health data. |
| **Sentinel-2 MSI** | Multispectral imagery | Environmental factors, vegetation data, and phenological information derived from this dataset will be correlated with bee health data. |
| **SMAP** | Soil Moisture | Environmental factors derived from this dataset will be correlated with bee health data. |
| **SRTM** | Elevation | Environmental factors derived from this dataset will be correlated with bee health data. |
| **Terra MODIS** | Vegetation indices | Environmental factors and phenological information derived from this dataset will be correlated with bee health data. |
| **GPM IMERG** | Precipitation | Environmental factors derived from this dataset will be correlated with bee health data. |

***Ancillary Datasets:***

Urban Beekeeping Laboratory and Bee Sanctuary bee health data – Overwintering survival rate and bee health data for hives in New England

Urban Beekeeping Laboratory and Bee Sanctuary SmartHive – Environmental data collected from bee hive

sensors

Urban Beekeeping Laboratory and Bee Sanctuary Honey DNA data – Pollen biodiversity

Bee Informed Sentinel Apiary Program – Longitudinal colony health and management data

Bee Informed honey bee health database – Colony health data for hives throughout the United States

Bee Informed Loss and Management Survey Data – Beekeeper reported colony losses and management techniques

USDA Animal Plant Health Inspection Service (APHIS) National Honey Bee Survey – National apiary health data

USDA National Agricultural Statistics Service Cropland Data Layer (CDL) – Agricultural land use information, including crop types, pesticide use, honey production measures, distance to cropland

USGS National Land Cover Database (NLCD) – Land cover at 30 meter resolution

NASA Global Land Cover Facility Landsat Global Inland Water – Distance to bodies of water

PRISM Daily Spatial Climate Dataset – Minimum and maximum daily temperature, precipitation

NASA North American Land Data Assimilation System (NLDAS) – Humidity

NASA Global Land Data Assimilation System (GLDAS) – Modeled data for evapotranspiration, soil

temperature, soil moisture, air temperature, transpiration

Federal Communications Commission (FCC), Antenna Structure Registrations Shapefile – Location of cell

phone towers

WorldPop Project Population Data – Estimated residential population

***Software & Scripting:***

Google Earth Engine API – Image processing and delivery platform

Google App Engine – Platform to create and host Earth Engine dashboard

Esri ArcGIS – Image enhancement and map creation

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Honey Bee Health Correlation Tool using Google Earth Engine Repositories** | There is no confirmed single cause of declining honey bee populations throughout the world. This product will allow the partners to directly input different variables believed to affect honey bee health in combination with their own data collections in order to assist in recognizing correlations between potential factors. The tool will provide a basis for future studies as more bee health data is collected. | Environmental factors, landscape characteristics (humidity, LST, precipitation, soil moisture, elevation, habitat fragmentation) and vegetation data (phenology, vegetation diversity, leaf water content, leaf area index, vegetation health) obtained from GPM (IMERG), Landsat 8 OLI, Sentinel-2 MSI, SMAP, SRTM, Terra MODIS, and ancillary datasets will be combined with bee health and hive monitoring data. | IV |
| **Honey Bee Health Correlation Tool Tutorial** | The tutorial will provide partners with instructions for the use of the Honey Bee Health Correlation Tool | N/A | I |

***End User Benefit*:** The UBL and Bee Informed Partnership study bee health using different approaches. UBL staff monitors hives across 16 states and collects information using a standardized beekeeping technique across beehives, with data sensors for temperature and humidity, for highly-controlled bee health studies. The Bee Informed Partnership collects information about bee health directly from beekeepers and from Sentinel hives monitored with scales. The Honey Bee Health Correlation Tool will be used by both the UBL and the Bee Informed Partnership to supplement their current studies with environmental data from NASA Earth observations and to standardize methods to measure colony health. The methods produced from this project will be used by both groups to guide future studies of honey bee health.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 1 Term: 2018 Summer

***Related DEVELOP Work:***

2017 Summer (GSFC) – Niger Water Resources: Implementing a Global Tool Based on Spatially Continuous

Precipitation Analysis for Resiliency Monitoring and Measuring at the Community Scale

2016 Summer (GSFC) – Puerto Rico Agriculture: Utilizing NASA Earth Observations to Map the Spread of

the Red Palm Mite, *Raoiella indica* Hirst, in Puerto Rico, for Detection, Management, and Conservation

2015 Summer (LaRC) – Northwest United States Agriculture: Analyzing Impacts of Potential Temperature

and Precipitation Changes on Apple Crop Production and Insect Pest Development

**References:**

***References:***

Cresswell, J. E., Desneux N., & vanEngelsdorp, D. (2012).Dietary traces of neonicotinoid pesticides as a

cause of population declines in honey bees: an evaluation by Hill’s epidemiological criteria. *Pest Management Science*, *68*. Retrieved from <http://onlinelibrary.wiley.com/doi/10.1002/ps.3290/abstract>

Kulhanek, K.,Steinhauer, N., Rennich, K., Caron, D.M., Sagili, R.R.., Pettis, J.S., . . . vanEngelsdorp, D. (in

review). A national survey of managed honey bee 2015-2016 annual colony losses in the USA. *Journal of Apicultural Research*.

Pettis J. S., Lichtenberg, E. M., Andree, M.. Stitzinger, J., Rose,R., & vanEngelsdorp, D. (2013). Crop

pollination exposes honey bees to pesticides which alters their susceptibility to the gut pathogen *Nosema ceranae*. *PloS ONE, 8*, e70182. Retrieved from <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0070182>

Spleen, A. M., Lengerich, E.J., Rennich, K., Caron, D., Rose, R., Pettis, J. S., . . . vanEngelsdorp, D. (2013). A

national survey of managed honey bee 2011-12 winter colony losses in the United States: results from the Bee Informed Partnership[.](http://www.ibra.org.uk/articles/US-honey-bee-winter-colony-losses-2011-12) *Journal of Apicultural Research, 52*. Retrieved from <http://www.tandfonline.com/doi/abs/10.3896/IBRA.1.52.2.07>

Tarpy, D. R., vanEngelsdorp, D., & Pettis, J. S. (2013). Genetic diversity affects colony survivorship in

commercial honey bee colonies. *Naturwissenschaften, 100*. Retrieved from <https://link.springer.com/article/10.1007%2Fs00114-013-1065-y>

vanEngelsdorp, D., Tarpy, D. R., Baylis, K., Spivak, M. Caron, D. M., Connell, J., . . . Wilkes, J. (2012). The

Bee Informed Partnership: Using Beekeeper’s Real-World Experience to Solve Beekeepers’ Real-World Problems. *American Entomologist, 58*, 116-118.

vanEngelsdorp, D., Lengerich, E., Spleen, A., Dainat, B., Cresswell, J. Baylis, K., . . . Saegerman, C. (2013).

Standard epidemiological methods to understand and improve Apis mellifera health. *Journal of Apicultural Research, 52.* Retrieved from <http://www.coloss.org/beebook/II/epidemiology>

vanEngelsdorp, D. (2008, July). A plea for bees [Video file]. Retrieved from

<https://www.ted.com/talks/dennis_vanengelsdorp_a_plea_for_bees>

Wilson-Rich, N., Dres, S. T., Starks, P. T. (2008). The ontogeny of immunity: Development of innate

immune strength in the honey bee (*Apis mellifera*). *Journal of Insect Physiology, 54*(10-11), 1392-1399. <https://www.sciencedirect.com/science/article/pii>

Wilson-Rich, N. (2012, June). Every city needs healthy honey bees [Video file]. Retrieved from

<https://www.ted.com/talks/noah_wilson_rich_every_city_needs_healthy_honey_bees>