Solutions Network Formulation Report

Using NASA Sensors to Perform Crop Type Assessment for Monitoring Insect Resistance in Corn

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1. Candidate Solution Constituents

a. Title: Using NASA Sensors to Perform Crop Type Assessment for Monitoring Insect Resistance in Corn

b. Authors: David Lewis, Ken Copenhaver, Daniel Anderson, Kent Hilbert

c. Identified Partners: U.S. Environmental Protection Agency

d. Specific DST/DSS: Pest Infestation and Resistance Decision Support System

e. Alignment with National Application: Agricultural Efficiency

f. NASA Research Results – Table 1:

Missions	Sensors/Models	Data Product
NPOESS (National Polar-orbiting Operational Environmental Satellite System) and NPP (NPOESS Preparatory Project)	VIIRS (Visible/Infrared Imager/Radiometer Suite)	NDVI (Normalized Difference Vegetation Index)

g. Benefit to Society: The benefit of this candidate solution is a more efficient crop production system and minimal impact of spray insecticides on the environment.

2. Abstract

The EPA (U.S. Environmental Protection Agency) is tasked to monitor for insect pest resistance to transgenic crops. Several models have been developed to understand the resistance properties of insects. The Population Genetics Simulator model is used in the EPA PIRDSS (Pest Infestation and Resistance Decision Support System). The EPA Office of Pesticide Programs uses the DSS to help understand the potential for insect pest resistance development and the likelihood that insect pest resistance will negatively affect transgenic corn. Once the DSS identifies areas of concern, crews are deployed to collect insect pest samples, which are tested to identify whether they have developed resistance to the toxins in transgenic corn pesticides. In this candidate solution, VIIRS (Visible/Infrared Imager/Radiometer Suite) vegetation index products will be used to build hypertemporal layerstacks for crop type and phenology assessment. The current phenology attribute is determined by using the current time of year to index the expected growth stage of the crop. VIIRS might provide more accurate crop type assessment and also might give a better estimate on the crop growth stage.

3. Detailed Description of Candidate Solution

a. Purpose/Scope

This candidate solution will benefit sustainable agriculture by assisting the EPA in monitoring insect pest populations' resistance to the toxic proteins produced by transgenic crops. Sustainable agriculture combines efficient production with wise stewardship of the Earth's resources. Development of environmentally benign production techniques is one focus of sustainable agriculture. New transgenic crops producing toxic proteins that target specific crop pests are one example of these developments (Glaser and Matten, 2003). The amount of broad spectrum pesticides used to manage pest populations has been significantly reduced by using this new technology. A significant threat to the continued use of this technology is the evolution of resistance in pest populations to the toxins incorporated to control these pests. The management of the new crops has a strong focus on the conservation of controlling the toxicity of Bt proteins in field populations of insect pests and is important to the future of sustainable agriculture (Williams et al., 1992).

The high benefits and low risks associated with varieties of transgenic crops have pushed transgenic-insecticidal plants into the limelight for debates about insecticide-resistance management. The EPA considers preservation of susceptibility to transgenic toxins to be in the "public good," and proteins such as those produced by Bt are therefore worthy of conservation (Carrière et al., 2001). Insect resistance management (IRM) describes practices aimed at reducing the potential for insect pests to become resistant to a pesticide or transgenic plant. IRM is important for transgenic crops expressing Bt insecticidal proteins because insect resistance poses a threat to the future use of the microbial Bt formulations in organic farming and to Bt technology as a whole (Tabashnik et al., 2003). Academic and government scientists, public interest groups, and organic and other farmers have expressed concern that the widespread planting of these genetically modified plants will hasten insect resistance to Bt endotoxins.

Under the Federal Insecticide, Fungicide, and Rodenticide Act (U.S. Government, 1996), the IRM is "a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks." The EPA has to consider what management decisions are environmentally acceptable in the event that Bt can no longer control insect pests, including the possibility that more toxic insecticides may have to be sprayed onto crops. Traditional blanket broadcast of insecticide has detrimental economic and environmental effects and should be minimized. Sound IRM will prolong the life of Bt insecticides and adherence to IRM plans benefits growers, producers, researchers, and consumers.

The PIRDSS provides information that helps the EPA to determine where to deploy field personnel to sample for development of insect pest resistance to transgenic pesticides within crops. Without such locational information, the search for resistance development by targeted insect pest populations would be random. Identification of crop type is the first step in isolating locations to be sampled for insect pest outbreaks. MODIS (Moderate Resolution Imaging Spectroradiometer) data products have been successfully used for crop type assessment projects in Argentina. Replacing PIRDISS current crop type assessment and crop phenology layers with products derived from simulated VIIRS data may increase the capability for identification of insect pests that develop resistance to transgenic crops.

b. Identified Partner(s)

The EPA is tasked to evaluate environmental threats from a variety of sources. The agency has developed methods for evaluating and addressing risk and management options within a variety of environmental settings, such as agricultural land used to grow transgenic crops. Without proper monitoring, the usefulness of these crops to the grower could be reduced. The EPA is interested in these crops since they represent a significant improvement to human health and ecological considerations by replacing broad spectrum pesticide applications with transgenically placed toxins.

The EPA has partnered with several government agencies to develop DSSs to assist in the management of these lands. These systems contribute to scientific information for managing insect resistance to transgenic crops by providing improvements to crop monitoring technology. The research has focused on "proof of concept" studies to detect pest infestation in transgenic corn crop plants. This research established initial methods for distinguishing "conventional" corn isolines or "near" relatives from "bioengineered" corn crop lines. The development of these systems has provided tools to assist the resistance monitoring program that is part of the EPA registration requirements for these crops. Additionally, this information can provide enhanced support to the concerned public in its deliberations about the use of transgenic plants.

Dr. John Glaser, who works at the EPA National Risk Management Research Laboratory in Cincinnati, Ohio, has been instrumental in the development of DSSs for the EPA to use in the identification of *Bacillus thuringiensis* (Bt) pest resistance in a variety of crops. One tool, the Pest Infestation and Resistance Decision Support System, uses a variety of inputs, including in situ field data collection and airborne remote sensing sensors. PIRDISS uses various detection devices to identify potential outbreaks of pest resistance, enabling the EPA to deploy field data collection teams for insect sampling to determine the extent of resistance that the pest has developed. Understanding the neighboring crop types and phenology is important to understanding potential refuge areas for pests.

c. NASA Earth-science Research Results

Vegetation index products provide significant insight into vegetation growth (Myneni et al., 1995). The NDVI (Normalized Difference Vegetation Index) has been developed to compare vegetation characteristics between different dates. The NDVI consists of a ratio between the infrared and red bands of radiometric sensors to provide indications of crop health. The NDVI has been a key analysis tool for vegetation research using data from a variety of NASA/NOAA (National Oceanic and Atmospheric Administration) sensor missions, including the Advanced Very High Resolution Radiometer (AVHRR), Landsat, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and MODIS (NASA, 2006). These and other NASA sensors have been used to develop NDVI products. The NDVI generated from these sensors provides a legacy of data products for the analysis of vegetation (Los, 1998).

The heritage of using these NASA/NOAA sensors has led to a large collection of vegetation research that affects agriculture. In addition to NDVI, MODIS also provides other vegetation products, such as the Enhanced Vegetation Index, the Leaf Area Index, and the Fraction of Absorbed Photosynthetically Active Radiation. Future NASA missions will continue to enhance this body of research with additional data products, including the Gridded Weekly Vegetation Index and the Advanced Vegetation Index products to be generated from data collected by the VIIRS sensor onboard the future NPOESS (National Polar-orbiting Operational Environmental Satellite System) and the NPP (NPOESS Preparatory Project).

MODIS data can be used to simulate VIIRS vegetation products. This concept proposes the use of these MODIS and simulated VIIRS vegetation products for crop type and phenology identification. MODIS and simulated VIIRS vegetation products collected periodically over crop regions can be stacked together to create hypertemporal datasets. Growth curves of crop fields can be generated from these hypertemporal datasets by graphing values of the vegetation products over time. Variations in the NDVI values may indicate phenology stages. These growth curves could be used to uniquely identify crop type and to help estimate phenology stages for the PIRDSS.

d. Proposed Configuration’s Measurements and Models

The regional crop type and phenology component of PIRDSS is not currently estimated using NASA sensors or other remotely sensed data. However, MODIS data has been used in crop type assessment projects. MODIS NDVI products were used to estimate crop type for the USDA Foreign Agriculture Service. The project generated 8-day composite layerstacks of MODIS NDVI data over the Argentine growing season. Field data was collected to identify crop types and other information for specific fields near Cordoba, Argentina. The hypertemporal layerstacks were used to track the growth of different fields over time. Classification tools used the hypertemporal layerstacks to identify crop types. Corn and soybean were the two main crop types in the region. Accuracy assessments were able to show some promise in separating corn from soybeans (ITD, 2007). Similar methods may be used to develop crop type assessments and phenology estimates for the EPA. The spatial resolution of VIIRS data is roughly 400 meters, which lends itself well to regional studies. Since PIRDSS deals with crop types on a regional basis, VIIRS vegetation products seem to respond to the requirements of the PIRDSS. Should the simulated VIIRS vegetation products be effective in crop type assessment, the life-cycle of its use in the PIRDSS would extend for many years, with MODIS products providing solutions in the near-term and NPP and NPOESS providing solutions into the next decade.

4. Programmatic and Societal Benefits

Estimating crop type and phenology provides benefits to the EPA through enhancing and refining the current regional crop type map for the PIRDSS, which would provide better understanding of the refuge areas for insect pests. In addition, it would complement other localized crop condition measuring systems with a coarser resolution but broader mapping of the layout of crop field geometry. Enhancing the PIRDSS will provide better understanding of pest resistance to transgenic corn varieties, allowing for remediation and mitigation activities to extend the efficacy of the transgenic insecticide treatments and to maintain a viable alternative to broadcast spray applications of pesticide. Therefore, maintaining efficacy of transgenic crops will reduce cost to agricultural producers while also reducing the amount of environmental degradation caused by excessive insecticide spray techniques.

5. References

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