Global Crop Pest and Disease Monitoring & Forecasting (PEST&DISEASE)

1. Executive Summary
Title: Global Crop Pest and Disease Monitoring & Forecasting
Short Name: PEST&DISEASE
Category: Community Activity
Overview and planned activities

Pests and diseases are major threats to food security in the world, especially for wheat, rice, and soybeans, the world's dominant food crops. More than 10 percent yield loss is caused by pests and disease every year, while in some regions the loss may be higher than 30 percent.

Crop pests and diseases habitat monitoring and risk forecasting at continental and global scale are important to assess the effect of global change on agriculture production. Earth observation is very important for global crop monitoring and pest & disease forecasting due to its capability of collecting large scale data quickly and efficiently. In 2018 and 2019, we integrated with satellite images, meteorological data (temperature, humidity, wind, radiation, etc.), and plant protection datasets to monitor global wheat, rice, and soybeans growth, habitat of main pests and diseases, and then released the first global crop pest and disease monitoring and forecasting products and reports.

In this project, we will focus on the dominant food crops, such as wheat, rice, soybeans etc., aiming to map main pests and diseases for these crops. For wheat, we select wheat aphid (*Sitobion avenae & Rhopalosiphum padi*) and rust (*Puccinia striiformis*), for rice is planthopper *(Nilaparvata lugens*) and blast (*Magnaporthe oryzae*), for soybeans is aphid (*Aphis glycines Natsumura*), rust (*Phakopsora pachyrhizi*) and mosaic virus.

We focus on retrieving global crop planting areas, growth conditions, pests and diseases habitat, and risk forecasting based on several high spatial and temporal resolution satellites, including GF series and ZY series in China, Sentinel series in EU, MODIS and Landsat in NASA. First, we will combine land surface products and remote sensing indices to ascertain the soil temperature and moisture, which provides information about crop habitat. This, in turn, allows us to ascertain which habitat types are attractive to pests and diseases and provide information on where they may migrate to. Second, climate and climate forecast data are analysed to give a probability of immigration or dispersal of pests and diseases. Finally, crop growth condition, crop pests and diseases habitat monitoring, and pests and diseases biological dispersal models are integrated to mapping crop pest and disease spatial distribution and damage levels.

Three main work packages are included in the project. In WP1, higher-level remote sensing satellite datasets and Earth observation (EO) products (such as re-analyses and weather forecasts) are used to perform a classification of crop land, and then to ascertain the habitat of crop pests and diseases. For WP2, habitat monitoring results, geographic and plant protection information, are assimilated with pests and diseases immigration and dispersal models to forecast the risk of target pests and diseases outbreak. Then, in WP3, we develop an application and dissemination platform to deliver our products and reports to end users, which could provide references for cropland plant protection. The achievements of this project could promote agri-food improvement and reduce poverty. Meanwhile, the tools and methods that developed could create stable, higher-paying jobs for skilled laborers.

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2. Purpose

Our project focuses on global crop pest and disease habitat monitoring and risk forecasting. The objects to be addressed are aphid and rust for wheat, planthopper and blast for rice, aphid, rust and mosaic virus for soybeans. Wheat aphid and rust are the most

important pest and disease for wheat, causing significant crop losses in about 76 countries all over the world; for rice, planthopper and blast are the most common pest and disease in over 20 countries, especially in southeast Asia; for soybean, aphid, rust and mosaic virus are the dominant pest and disease in North America, South America, and Asia.

Currently, in the research field of pests and diseases monitoring and forecasting, on the one hand, field surveys, agrometeorology records in field, and laboratory tests are rarely integrated into crop pests and diseases monitoring and forecasting models, because they are often operated by different organizations; on the other hand, such information normally supports mid-term or long-term forecasting, which may unable to meet the demand of effective field management. A key issue in crop pest and diseases management is prediction of the occurrence areas, together with the damage levels. For this, habitat monitoring and early risk forecasting of crop pest and disease in major crop production regions globally are especially important. This Community Activity also able to construct maps of the severity to facilitate insect pests and diseases management in a timely manner and ultimately efficiently reduce the use of chemical pesticides and reduce yield losses.

This project aims to bring together cutting edge research to provide global pest and disease monitoring and forecast information on wheat, rice, and soybeans by integrating multi-source information, which includes EO, meteorological, biological and plant protection datasets to support decision making in sustainable management of insect pests and diseases. The main objective of this project is to improve the utilization of EO data for monitoring and forecasting of pests and diseases through development of new algorithms and fusion of new and existing data products using multi-source EO data to produce full cover and dynamic land surface information. The project will comprehensively consider the capability of high spatial and temporal land surface information provided by moderate- to high- resolution satellite data in crop pests and diseases monitoring, forecasting and mapping at the global scale. Approaches for better estimation of surface temperature statistics, diurnal surface temperature patterns, leaf area index (LAI) and vegetation dynamics will be investigated. In addition, we will validate and prove the relevance of these data products to existing pest and disease development models, and to forecast the potential distribution of pest and disease, as well as damage levels. To ensure the project outcomes will have the greatest impact, an investigation into the best practice for routes of dissemination of these information products will be conducted during the project.

Outputs

1) Monitoring and forecasting indexes will be constructed for target crop pest/disease, which include spectral features, crop growth condition, soil characteristics, rain fall, temperature, wind, and their variation characteristics.
2) Methods and algorithms for crop pest and disease monitoring and forecasting will be developed to extract global habitat area of target crop pest/disease, outbreak risk, damaged areas and levels.
3) An intelligent automatic system will be constructed to provide crop pest and disease services, which include data collection and processing, model calculation, products service (periodic thematic maps and scientific reports).
4) Our crop pest and disease monitoring and forecasting services will provide insight into the development of individual pests and diseases, providing a deeper understanding of pests and diseases for global plant protection practitioners. We will send our outputs to governments, institutions, business companies, and landlords to support field management and agricultural trade policy making, through web site, Wechat, E-mail, and interactive voice response messaging.

3. Background and previous achievements

RADI aims to optimize crop pest and disease control and management, and further to improve the efficiency (and therefore cost of) resource use, protect environmental and human health by reducing release of chemical pesticides into ecosystems. RADI's researches provide a comprehensive approach to dealing with major agricultural pests and diseases by combining cutting edge technologies, modelling and biological mechanism. We have developed crop

pest and disease monitoring, forecasting and management services on global, national and regional levels including dynamic crop pest and disease warning and risk assessment maps, damaged areas and levels spatial distribution maps, and scientific analysis report.

During the 2017-2019 period, we integrated multi-source EO data, meteorological data, and plant protection data, with self-developed models and algorithms for wheat, rice, and soybeans pests and diseases monitoring and forecasting, to analyze the spatial distribution and damage levels of pest and disease, and then to release thematic maps and reports in global, national, and regional levels. For example, during April to May 2019, our results illustrated that, pests occurred heavier than diseases in eleven main winter wheat production countries, including Russia, China, United States, Pakistan, Iran, France, Turkey, Germany, Canada, Uzbekistan and United Kingdom. The total affected area by wheat rust (Puccinia striiformis) and aphid (Sitobion avenae & Rhopalosiphum padi) has reached 27 million hectares.

These achievements have been released in the official crop pests and diseases website (http://www.rscropmap.com/, Chinese version is online, English version is under development) and Wechat official account (rscrop_english). Worldwide users could check and download our products for global, national and regional crop pest and disease monitoring and forecasting. From 2015 to now, our services have been cited 83 times by General offices of the CPC central committee and the state council, MOA, Cropwatch, National Aviation Plant Protection Science Technology Innovation Alliance.

4. Key Activities

WP1: Global crop growth and pest & disease habitat monitoring

In this WP, the crop growth information and habitat conditions will be first collected, and then crop growth conditions, soil characteristics, temperature, and their variation characteristics will be derived based on high spatial and temporal resolution satellite data, such as Sentinel-2, Landsat OLI, GF-6, etc. Data from the COSMOS sensors, and ground meteorological measurements will be involved to improve the EO retrieval models, and moderate to high resolution satellites, such as MODIS, would be used to calibrate and validate the retrieved EO products with full consideration of sensing and pathological mechanisms of individual pest or disease. Assimilating the land use investigation, meteorological data, field investigation, and epidemic mechanisms of crop pests and diseases with EO data, the remote estimates of land surface parameters and crop growth status for crop pests and diseases habitat condition mapping would be produced to identify host habitats of crop pests and diseases hotspots. Based on previous work of this Community Activity, the different pests and diseases on different crop types have evident differences in spectral and landscape patterns, which provide the evidence for monitoring and assessing their habitat conditions.

WP2: Crop pest and disease risk forecasting and warning

The aim of this WP is to integrate information from different sources (remote sensing, biological indicators and meteorological data) to forecasting and mapping risks of pests and diseases on wheat, rice, and soybeans worldwide. First, the retrieved parameters in WP1 will be inputted into individual pest or disease habitat monitoring models that are specific to different areas worldwide to assess the suitability of the habitat area for pest and disease live and infection. Secondly, novel methods and technologies are constructed to integrate multi-source and multi-temporal EO observations, environmental parameters, biological models to characterize the evolution and risk probability of crop pests and diseases outbreak in wheat, rice and soybeans. In addition, for early prediction, we will build a risk index using locally recorded weather data at daily intervals. Finally, based on the proposed models, remote sensing data, and meteorological data for the typical phenological stage of crop, thematic maps will be created to describe the relative risks in the typical crop planting countries and areas.

WP3: Application and dissemination

The aim of this WP is to integrate the outputs of WP1 and WP2, and to study and improve the two-way flow of information in prediction/advisory services to end users. End users include governments, institutions, landlords, extension workers, and suppliers. RADI will work closely with CABI and NATESC, the main information customer for project outputs

and the body with responsibility for public messaging both globally and nationally. WP3 will focus on disseminate our output to end users to support their decision-making on field management, and biological and ecological control scheme design for pest and disease protection. Worldwide users could benefit from our services through channels including web site, Wechat, E-mail, and interactive voice response messaging.

Milestones.

NO.	Title	Responsibility	Due date
1	Sensing mechanism of crop pests and diseases infestations	RADI/CABI	M1-M9
2	Global crop and phenology growth monitoring and habitat conditions retrieval	RADI/MMU	M10-M18
3	Crop pests and diseases risk prediction for dominant global wheat, rice and soybean planting areas	RADI/CABI	M19-M30
4	Outputs dissemination	NATESC/RADI/CABI	M31-M36

5. Relationship to GEO Engagement Priorities and to other Work Programme Activities

1) Global wheat, rice, and soybean pests and diseases habitat monitoring is expected to inform the achievement of SDG goal 2: *End hunger, achieve food security and improved nutrition and promote sustainable agriculture.* Timely understanding of pests and disease habitat conditions could help maintain ecosystems, improve the quality of agriculture resources, and ensure sustainable food production systems.
2) The global crop pest and disease risk forecasting products will support the Paris Agreement pillar of *Loss and Damage*. The global crop pests and diseases risk forecasting products are able to assess the potential loss and damage associated with the adverse effects of infestation of pests and diseases on agriculture and promote the role of sustainable development in reducing the risk of loss and damage. We could support pests and diseases early warning, emergency preparedness, comprehensive risk assessment and management.
3) The global crop pest and disease risk assessments support achievement of the targets of the Sendai Framework: *Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020.* It will develop pest and disease monitoring, forecasting and management service products on global, national and regional levels including dynamic crop pest and disease warning and risk assessment maps that will enable governments and business companies to determine strategies to spray pesticides.

6. Governance

Leaders: China--RADI, UK--CABI

Contributors: China--NATESC, UK--MMU

1) Remote Sensing and Digital Earth Institute, Chinese Academy of Sciences (RADI) will be the lead organization in China and responsible for the coordination of Chinese team and UK team. Prof. Huang Wenjiang (PI), the team leader, is focused on quantitative and hyperspectral remote sensing (RS) for vegetation especially on crops, data fusion (multi-scale, multi-sensor, multi-temporal) for agricultural applications, monitoring crop pests and diseases using hyperspectral airborne and spaceborne images. Prof. Dong Yingying and Dr. Ye Huichun are RADI experts who have conducted interdisciplinary work combining RS, agricultural, biological and field survey to identify, monitor and forecast crop pests and diseases, and published numerous research articles. Ma Huiqin, Liu Linyi, Geng Yun, and Guo Anting are PhD candidates in RADI, majoring in Cartography and GIS. RADI will focus on the whole project to provide researches applications of crop pests and diseases habitat monitoring and risk forecasting with remote sensing technologies.

2) CAB International (CABI) will lead and coordinate work across UK partners and in close collaboration with RADI. Belinda Luke is a CABI expert in identify, control and management of crop pests and diseases, and published numerous research articles. CABI will focus on WPs 2 and 3 to provide biological models for pest and disease immigration and dispersal.
3) Manchester Metropolitan University (MMU) will focus on WPs 1 and 3 to provide land surface temperature and humidity mapping algorithms. Prof. Han Liangxiu will build new database and explore the integration of image pattern recognition with reflectance models for pest and disease forecasting.
4) Ministry of Agriculture's National Agro-Tech Extension and Service Centre, China (NATESC) will focus on WP3 to assess measurement and evaluation of agricultural technological innovation. Dr. Zhu Jingquan has been working in NATESC for more than 13 years related to plant protection. He is familiar with plant quarantine and protection laws, regulations, and standards in China.

7. Data Policy

1) To cater to the developmental needs of this project, RADI is vested with the authority to acquire and disseminate all satellite remote sensing data from Chinese satellites.
2) The crop pest and disease monitoring and forecasting thematic maps and scientific reports are open to public for free download and use.
3) RADI reserves the right to impose restrictions over imaging tasks and distribution of RS data in any country when it is of the opinion that national security and/or international obligations and/or foreign policies of the Government so require.