A Crop Loss Assessment Service System Using Remote Sensing

Liping Di[1], Eugene Genong Yu[1], Zhengwei Yang[2], James Hipple[3], G. Robert Brakenridge[4], Li Lin[1] , Ranjay Shrestha[1] , Lingjun Kang[1] , Md. Shahino Rahman[1] , Junmei Tang[1]

1. Center for Spatial Information Science and Systems, George Mason University, 4400 University Drive MSN 6E1, Fairfax, VA 22030
2. USDA-NASS 1400 Independence Ave. SW, Washington, DC 20250
3. USDA-RMS 1400 Independence Ave. SW, Washington, DC 20250
4. INSTAAR, University of Colorado, Campus Box 450, Boulder, CO 80309

ABSTRACT

Flood causes crop damages on a large scale. Correct decisions to mitigate flood-induced crop loss need extended information (time series and different spatial resolution and extend). A survey of user requirements reveals that the USDA National Agricultural Statistics Services (NASS) and the USDA Risk Management Agency (RMA) have been identified as two of the largest users on the flood-induced crop loss information. The former requires statistics of crop loss assessment after all flood events in the United States of America. The latter needs time series of flood assessment to make correct decisions in crop insurance management. To meet the requirements of both agencies, a system of service-oriented services has been designed and developed for better disseminating and providing much needed decision-support information. Geospatial Web services are adopted as the fundamental components. Standard and specifications are the glue to support interactions and integrations among loose-coupled components to form a unified system. Standard geospatial Web services include those following OGC specifications: Web Coverage Service (WCS) for data/product servicing, Web Map Service (WMS) for data presentation, Web Feature Service (WFS) for geographic features, and Web Processing Services (WPS) for data processing and analysis. The system consists of four functional modules to provide monthly and annually flood statistics, crop condition profiles, flood duration/frequency, and crop loss. The latency of information production is reduced by establishing live workflows from Earth Observations (EO) to flood duration and frequency and crop condition profiles.

FLOODING AND DECISION ACTIVITIES

Flooding, although infrequent events, causes loss of agricultural production over large scale. Agricultural land is often in relatively flat and lowland due to soil fertility and water availability, while those lowland areas are often subject to flooding risks. The damage caused by flooding can be significant – one incomplete statistic reports that more than $56 billion direct loss and damage were due to flooding in United States between 1900 and 2013. This accounts for more than 8% of total natural disaster damage.

Proper decision activities and mitigation measures rely on accurate and prompt information surrounding flooding and their extent for those decision makers involved in flood and its loss assessment in agricultural sectors in response to flooding disaster. In the agricultural sectors of United States, two agencies of the US Department of Agriculture, National Agricultural Statistics Service (NASS) and Risk Management Agency (RMA), have played important roles in monitoring and dealing with flood-induced damages on crops. Once a flood happens, the decision activities related to post-flood appraisal and response in agricultural sectors are as follows.

- Monitor and archive statistics of flood acreage and flood duration with national coverage
- Evaluate and record annual crop loss due to flood
- Survey and assess flood-related crop insurance rating areas
- Investigate and verify crop policy compliance
- Valid and check on spot the crop loss claim due to flood

There exist gaps with the current practices to satisfy these requirements in timeliness, accurateness, and completeness. The major reason is rooted in the current practice relying on sampling surveys or incomplete coverage from limited field investigations. The limitations of current practices can be summarized as follows.

- Uncertainty due to limited number of field investigators and uneven knowledge of field investigators
- Long latency of time due to the length sample data collection and analysis process
- Incomplete coverage due to limitation of resources

GOAL AND OBJECTIVES

The remote-sensing-based flood crop loss assessment service system (RFCLASS) aiming at meeting the requirements with improved timeliness, accuracy, and completeness by leveraging two maturing technologies – remote sensing and open geospatial standards. Remote sensing provides the source of observations for analysis at different scales. In this project, two scales for flood information and crop assessment have been identified: 1) *coarse results on flooded acreage and degree of damages for the early assessment* and 2) *high-resolution detailed results for in-depth assessment*. Remote Sensing data at different spatial resolutions, specifically MODIS and Landsat ETM+ data for historical assessment and VIIRS and Landsat OLI data for continuation of current and future assessment, are considered and used as the pivot input data to obtain relatively objective, accurate, responsive and intelligent crop loss information. Another technology is the geospatial Web technology with open standards. The advancement of geospatial web service technologies in the Web environment facilitates the data access, processing, integration, visualization, and result dissemination and the development agility through reusability and interoperability.

The expected improvements are expected on:

- Completeness of information (complete coverage across space and time)
- Satisfied levels of details and accuracy (two different scales resulted from two different spatial resolution satellite remote sensors)
- Promptness of information production and availability (through using advanced geospatial Web service technology)

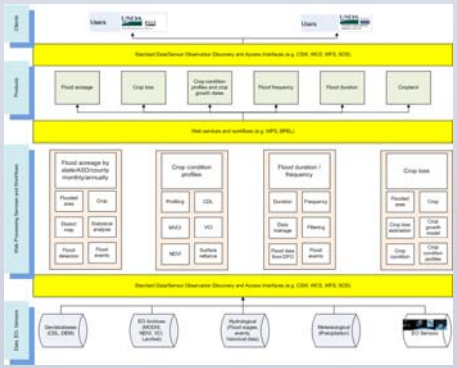
TECHNOLOGIES AND ARCHITECTURE

Combinations of remote sensing, geographical information systems, and open geospatial Web services provide the technology backbone for developing the RF-CLASS to be operational in the Web environment with live link to Earth Observations and their products, geospatial Web processing workflows, and interactive online information disseminate and on-demand customization and analysis. Functionally, the system has the following the modules:

(1) Suites of geospatial processing modules

(2) Interactive presentation and dissemination of products

(3) Live access to satellite observations and their products



RESULTS

The System

Prototype URL: https://dss.csiss.gmu.edu/RFCLASS/

OGC-compliant Web services to support delivery and presentation of results

- Web Coverage Service (WCS) for data/product servicing
- Web Map Service (WMS) for data presentation
- Web Feature Service (WFS) for geographic features
- Web Processing Services (WPS) for data processing and analysis

Flood frequency (2011-2016)

Crop Loss Map (2014)

Functional capabilities of RF-CLASS

The Products

- Flood, flood duration, and frequency
- Cropland and cropland fraction
- Crop conditions and profiles
- Crop loss assessment
- DVDI flood impact maps
- Flood extent maps from SMAP

Corn fraction(2014)

Annual flood (2014)

Monthly flood (July 2014)

NDVI (3rd week in Feb. 2014)

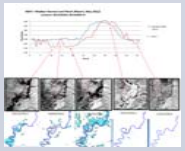
DVDI (August 22-September 15, 2017)

Flood extent map from SMAP (August 22-September 15, 2017)

The Analytics

Capabilities

- Crop condition profile comparison
- Crop loss estimate due to flood
- Statistic summaries



CONCLUSIONS

A prototype RFCLASS based on geospatial Web services was developed, implemented, deployed, and operated at https://dss.csiss.gmu.edu/RFCLASS. Flood and crop condition are lively fed into the system in near-real-time from MODIS observations in combination with NASS CropLand Data Layer (CDL) and the Flood Observatory. The system demonstrates the agility of development with reusability and interoperability under open geospatial specifications. The current system provides the following functions: (1) Visualization of crop condition, (2) Historical NDVI, VCI, MVCI, RVCI, (3) Generation of condition profiles, (4) Visualization of flood area, and (5) Statistics for flood assessment.

The system fulfills the following functions operationally in the Web environment.

- Statistics of flooded acreages and crop loss on-demand with sub-setting spatially and temporally
- Crop loss assessment and estimation using different models – including regression models and crop-growth-model-based approach
- Event-based flood extent mapping from SMAP
- Event-based flood impact mapping from DVDI

REFERENCES

Di, L., E.G. Yu, L. Kang, R. Shrestha, Y. Bai (2017). RF-CLASS: A remote-sensing-based flood crop loss assessment cyber-service system for supporting crop statistics and insurance decision-making . *Journal of Integrative Agriculture*, *16*(2), 408-423. [doi: 10.1016/S2095-3119(16)61499-5]

Shrestha, R., Di, L., Eugene, G. Y., Kang, L., SHAO, Y. Z., & BAI, Y. Q. (2017). Regression model to estimate flood impact on corn yield using MODIS NDVI and USDA cropland data layer. *Journal of Integrative Agriculture*, *16*(2), 398-407. [doi: 10.1016/S2095-3119(16)61502-2]

MS Rahman, L Di (2017). The state of the art of spaceborne remote sensing in flood management. *Natural Hazards 85 (2)*, 1223-1248. [doi: 10.1007/s11069-016-2601-9]

R. Brakenridge and E. Anderson, "MODIS-based flood detection, mapping and measurement: the potential for operational hydrological applications," in *Transboundary floods: reducing risks through flood management*, Springer, 2006, pp. 1–12.

R. Brakenridge and E. Anderson, "MODIS-based flood detection, mapping and measurement: the potential for operational hydrological applications," in *Transboundary floods: reducing risks through flood management*, Springer, 2006, pp. 1–12.

R. Shrestha, L. Di, G. Yu, Y. Shao, L. Kang, and B. Zhang, "Detection Of Flood And Its Impact On Crops Using NDVI - Corn Case," in *Proceedings of the Second International Conference on Agro-Geoinformatics, August 12-16, 2013, Fairfax, VA USA*, Fairfax, VA, USA, 2013.

G. Yu, L. Di, Z. Yang, Z. Chen, and B. Zhang, "Crop condition assessment using high temporal resolution satellite images," in *2012 First International Conference on Agro-Geoinformatics (Agro-Geoinformatics)*, 2012, pp. 1–6.

Z. Yang, L. Di, G. Yu, and Z. Chen, "Vegetation condition indices for crop vegetation condition monitoring," in *Geoscience and Remote Sensing Symposium (IGARSS), 2011 IEEE International*, 2011, pp. 3534–3537.

Acknowledgements

This project was funded by NASA Earth Science Applications Program. Project number is NNX12AQ31G. Principle Investigator is Professor Liping Di.

www.PosterPresentations.com