Design of Crop Progress Monitoring System Based on Spatial WOFOST Model Simulation

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Outline

- Background
- Input Data
- Study Site
- Architecture
- Prototype Simulation Results
- Conclusion

Rational

- Crop development and progress information is critical for agricultural production and food prices.
- NASS provides crop progress and condition reports in growing season by casual field observations and assessments.
  - These assessments are subjective, unreliable and not covered all counties nor systematically stratified by geographic location.
- Remote sensing based vegetation indices such as NDVI cannot accurately detect all crop development stages.
- Therefore, it is necessary to develop alternative methods to better monitor the crop progress.

WOFST Model

- One-dimensional (time scale only), mechanistic, with no geographic scale reference though could be site-specific.
  - Regional application relies on the selection of representative points, followed by spatial aggregation or interpolation (e.g., linked to a GIS).
- Growth driving processes: light interception and CO2 assimilation;
- Growth controlling process: Crop phenological development;
- Considers only ecological factors (Assume optimum management practices)
- Can be used to estimate crop production, indicate yield variability, evaluate effects of climate changes or soil fertility changes, and determine limiting biophysical factors.
- Crop models available: wheat, grain maize, barley, rice, sugar beet, potato, field bean, soybean, oilseed rape, and sunflower.

Phenology - Phenological Development and Model Stage (DVS)

- sowing
- Emergence DVS=0
- tiller formation
- floral initiation or double ridge appearance
- spikelet formation
- stem elongation
- anthesis (flowering) DVS = 1
- grain set
- grain dehydratation (ripening)
- dead-ripe (maturity) DVS=2
- The DVS and the phenological stage can be calibrated statistically.

Why is Spatial WOFOST Model Simulation?

- Crop growth model is abstract of real world crop growth dynamics;
- Crop phenological development reflects crop growth process;
- There many crop growth models, such as EPIC, DSSAT, YIELD, LINTUL, SUCROS, ALAMANC, CROPSYST, ADEL, CENTURY, DNDC, and WOFOST. Each one has its own focus and limitations.
- WOFOST has open source code and has been successfully used for wheat, grain maize, barley, rice, sugar beet, potato, field bean, soybean, oilseed rape, and sunflower, etc. crop simulation;
- However, it is one-dimensional, mechanistic, and site-specific. Selecting representative points, followed by spatial aggregation or interpolation (e.g., linked to a GIS) for large scale regional or national application is difficult.
- Therefore, a spatial WOFOST model simulation based on GIS is necessary!

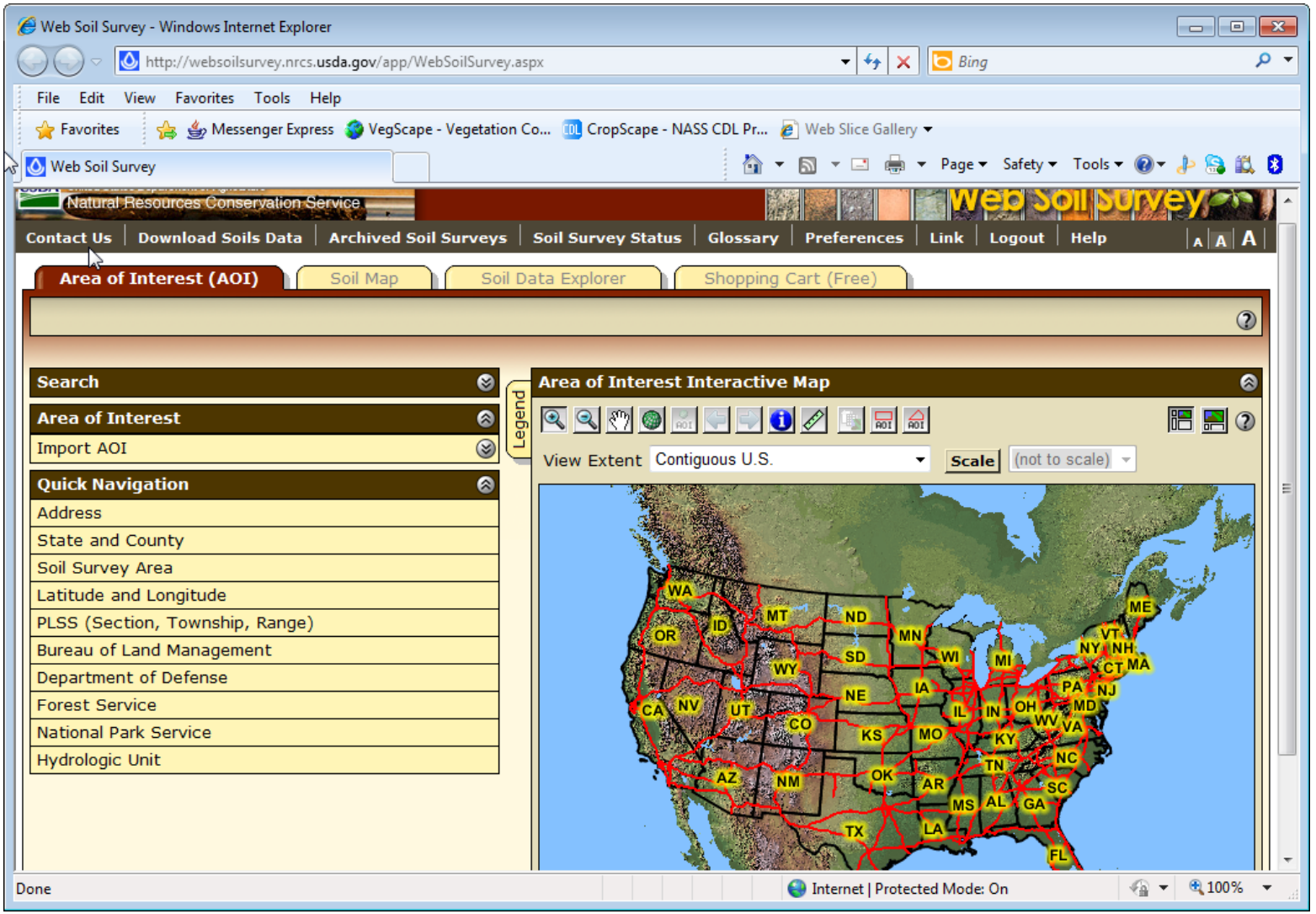
Objectives

- Investigate the feasibility of using WOFST crop model simulation results combined in-situ observation data for crop progress monitoring;
- Generalize point WOFST model spatially based on GIS framework.
- Design a web service based geospatial crop progress monitoring system.

Input Data

- ***Model Inputs***
  - ***Crop Parameters – Crop management;***
  - ***Weather Data - rainfall, temperature, wind speed, global radiation, air humidity;***
  - ***Soil Data - soil moisture content at various suction levels, data on saturated and unsaturated water flow, and data on site-specific soil.***
- ***Cropland Data Layer(CDL)***
- ***Crop Mask - Cultivated land cover data Layer***

Soil Data- USDA NRCS' Soil Survey Data – Web map access



USDA NRCS Soil Survey Data

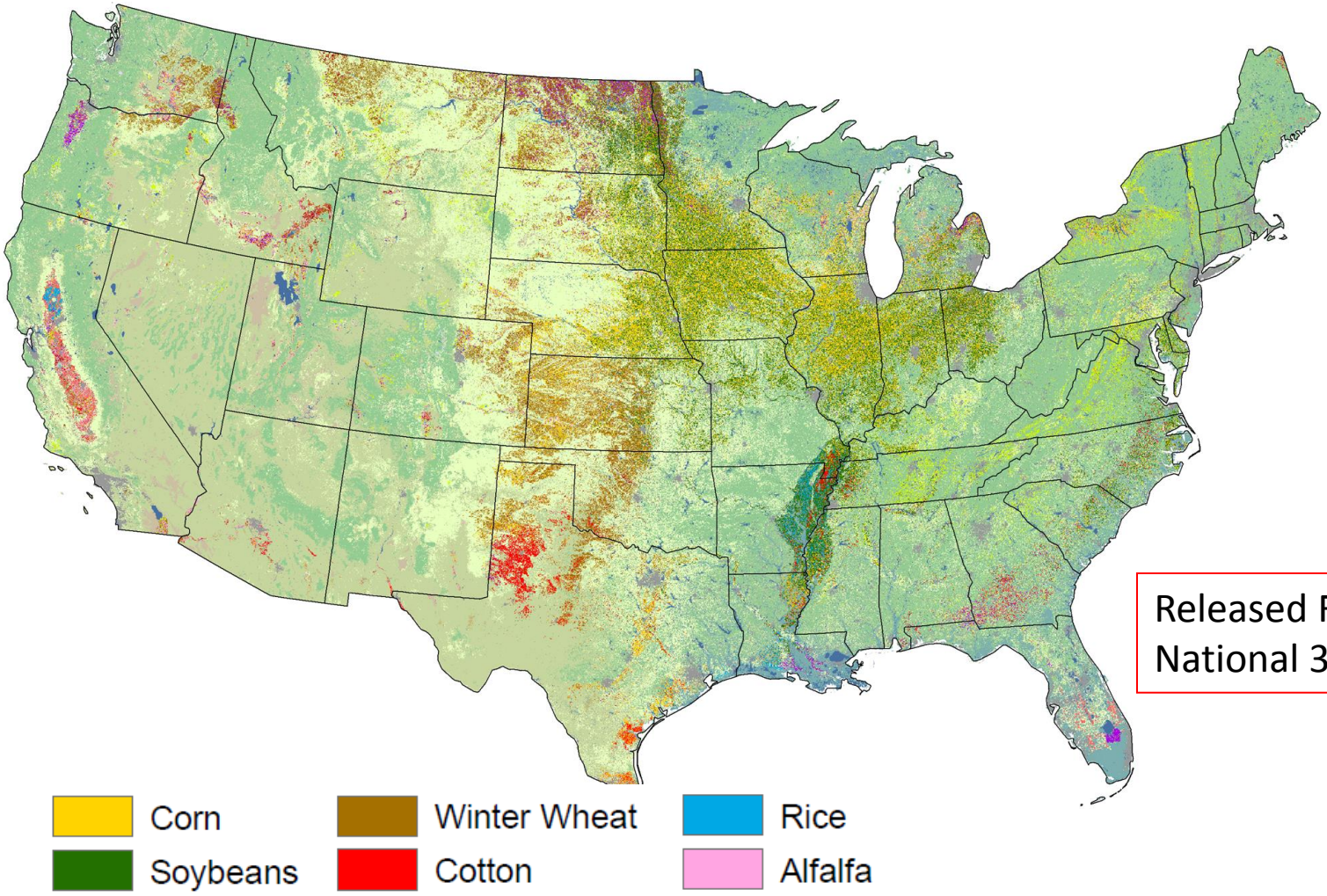
- Soil survey data archived and distributed in Soil Survey Geographic (SSURGO) Database
- Only file downloads were available.
- Extra Soil productivity data map (100m)
- Publically available from USDA web site

Weather Data

- IOWA weather data obtained from 13 Iowa weather stations via a website (http://mesonet.agron.iastate.edu/agclimate/hist/dailyRequest.php).
- Parameters include:
  - High Temperature, Low Temperature, Average Wind speed, Daily Precipitation, Solar Radiation, and Evapotranspiration;
  - “vapour pressure” can be calculated from the parameter “Evapotranspiration”.
- These weather data are scattered. They are to be interpolated to all pixels in State. The method first implemented is called the inverse weighted interpolation.
- Kriging method is considered to replace this method.

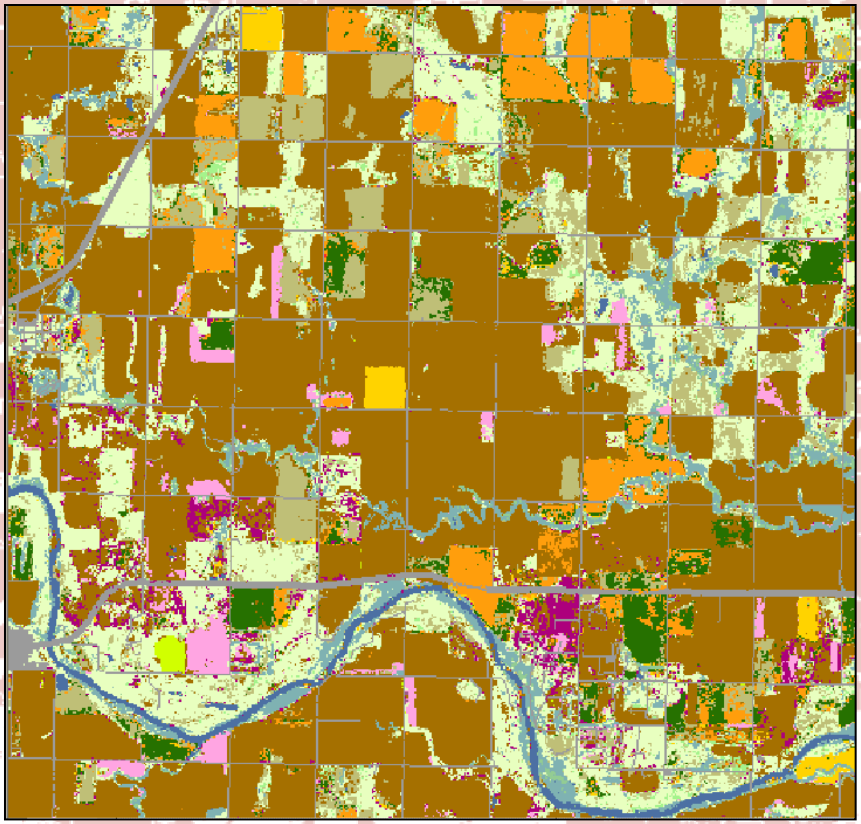
Cropland Data Layer (CDL)

- The Cropland Data Layer product is a raster-formatted, geo-referenced, crop specific, land cover product.

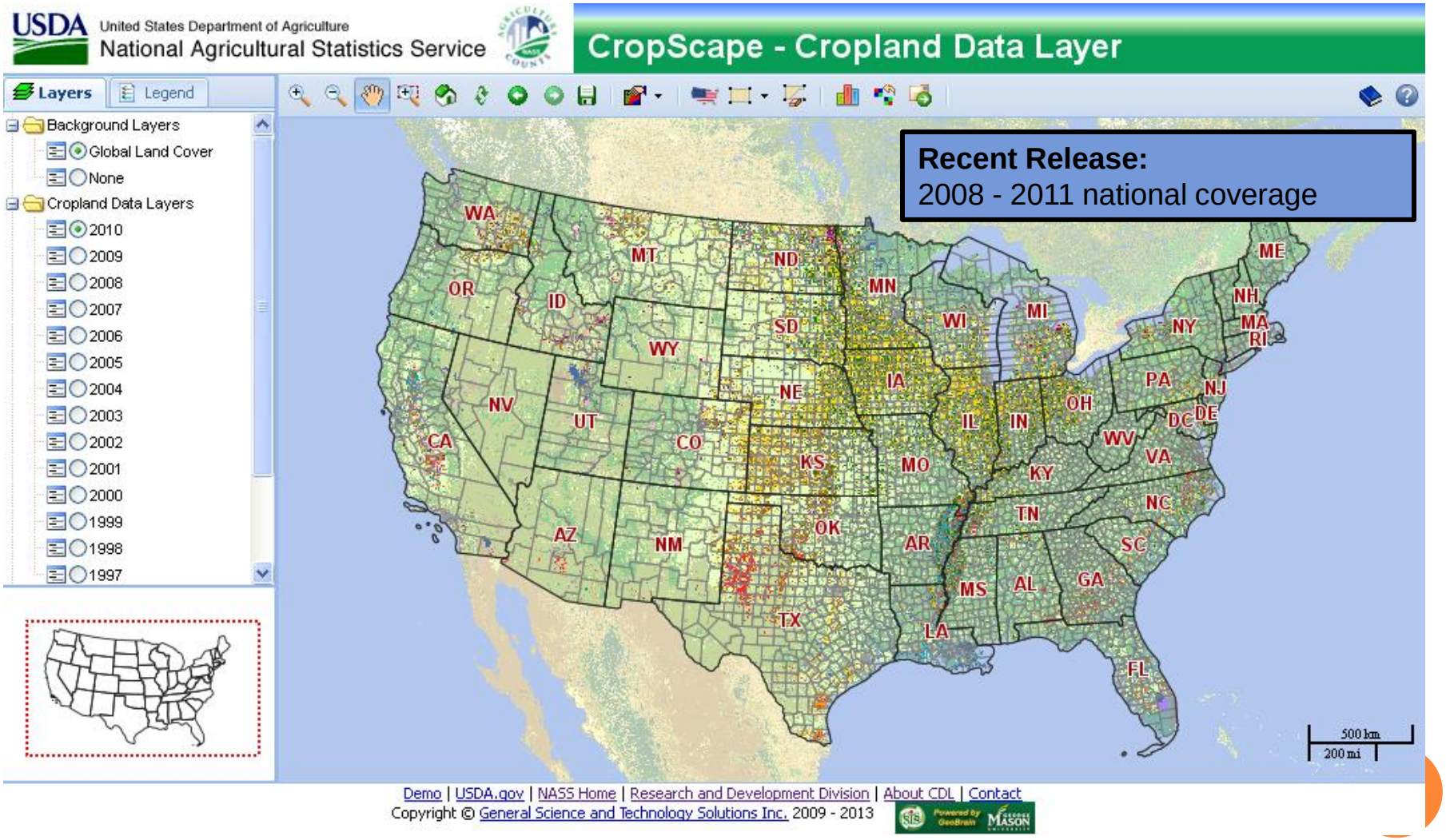


Released Feb. 3, 2012
National 30m Product

Total crop mapping accuracies for historic CDLs range from 85% to 95% for the major crops

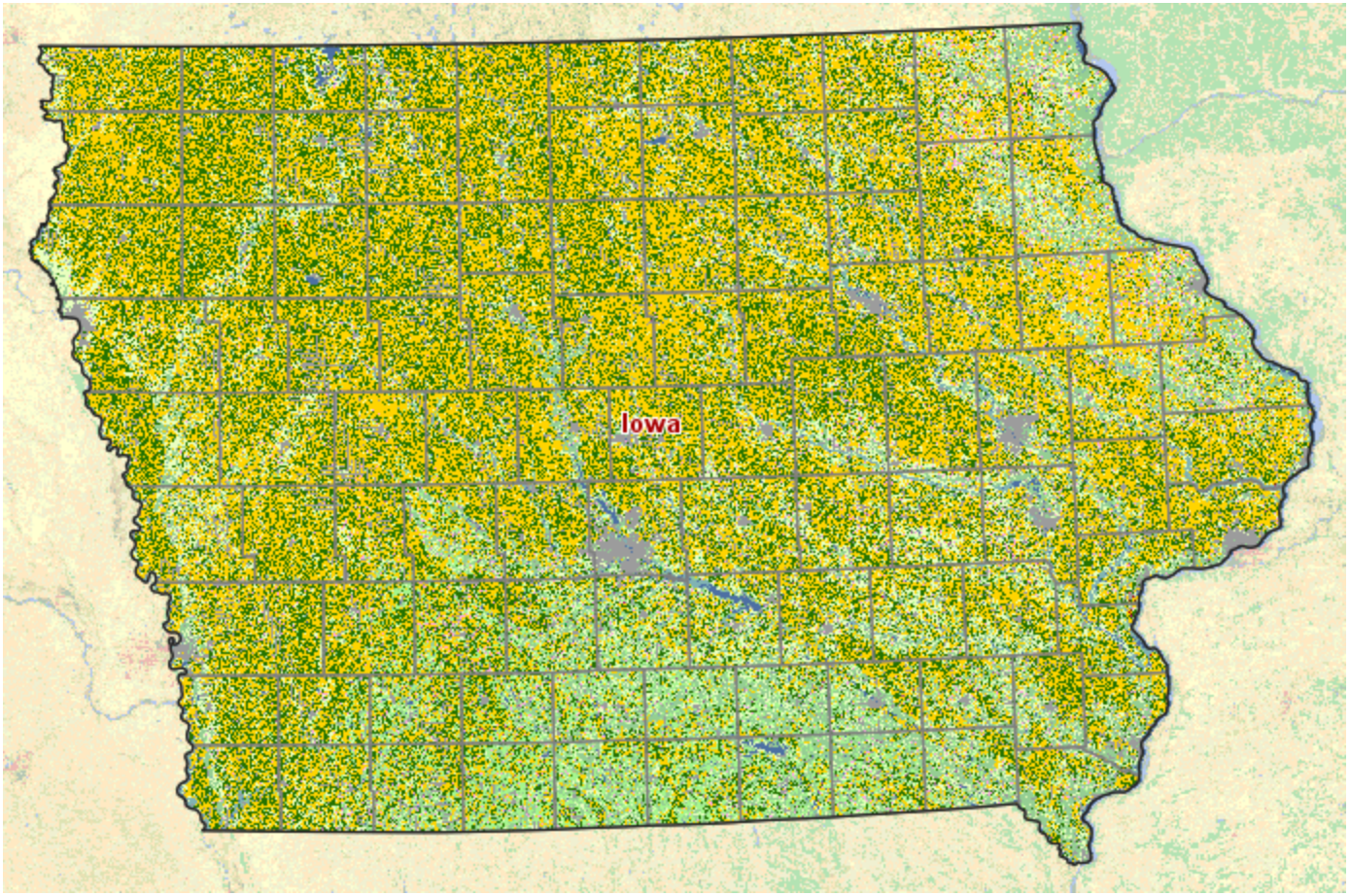


Data Source: CropScape Portal



nassgeodata.gmu.edu/CropScape

Study Area –Iowa State



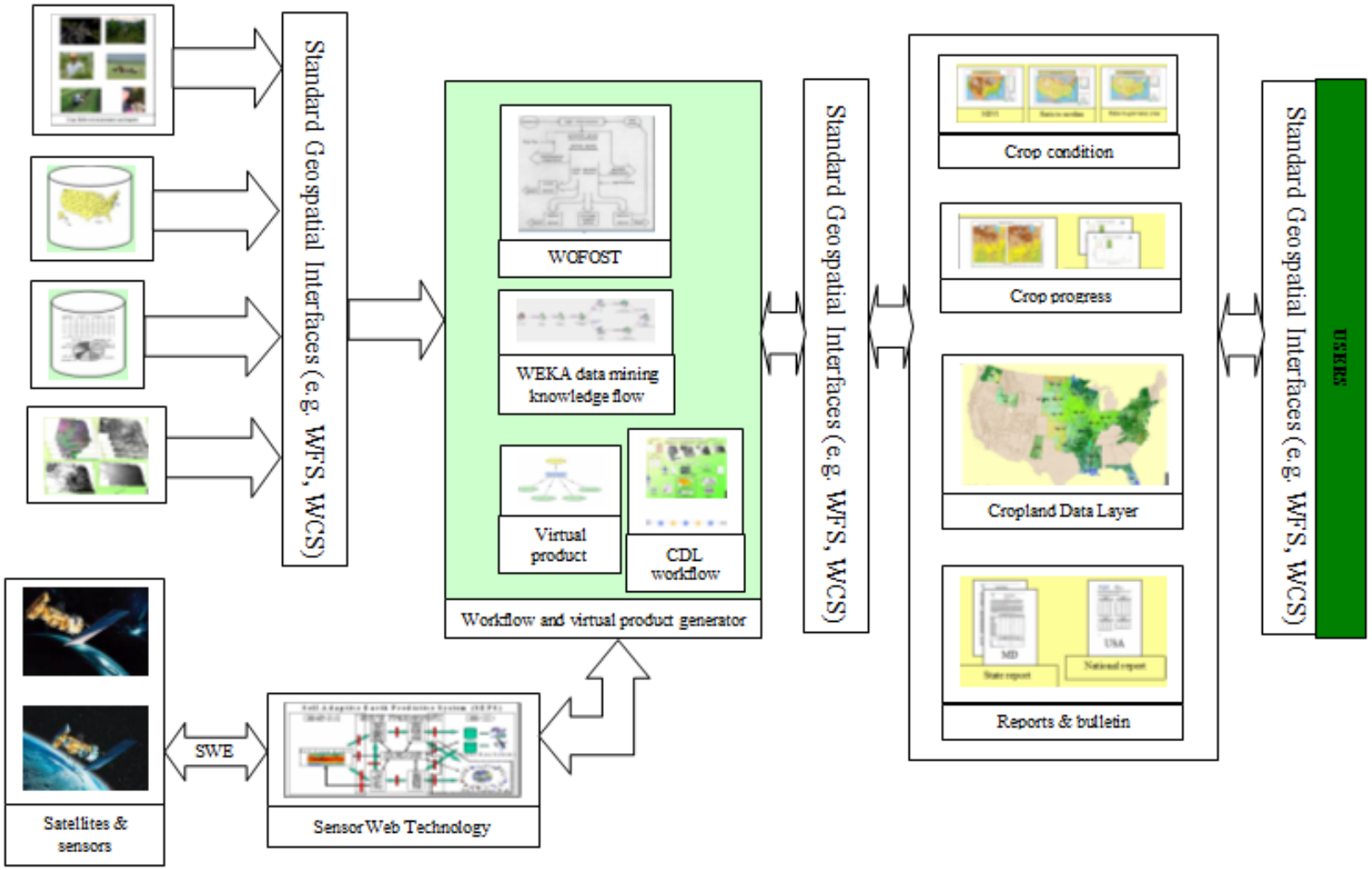
Requirements

- Automate the process of data acquisition, retrieving, processing and database update.
- Provide full geo-spatially covered crop progress monitoring based on crop growth model and simulation;
- Provide new capabilities of on-line geospatial crop progress information access, geospatial query and on-line analytics via interactive maps;
- Disseminate all data to the decision makers and users via near-real time retrieval, processing and publishing over the web through standards-based geospatial web services
- Leave no burden to users
  - No client software development &installation
  - No special software tools needed for data visualization, geospatial query and online analytics
- Use industry standard compliant GIS technology.

Spatial WOFST Model simulation Design Considerations

- Using Geospatial Information Technology
  - OGC standard compliant web services are to be used;
  - Web geo-processing services and Web Process Service are to be used for data processing and manipulating;
  - The crop simulation results are to be presented and published with Web Map Service (WMS) for the purpose of sharing and interoperation over Web.
  - The final model simulation results is a visualized image accessed by an online portal with Web service technology.
- Using crop growth model for simulation
  - Considering: model inputs, components, simulation and result dissemination.
- Using a crop mask to focus on crop only.
- Designing data structure of the model inputs to be easy to manage and easy to use;
- Crop simulation will be pixel-based:
  - Each pixel represents a specific crop or other land cover type;
  - Model inputs are different for every pixel.
- Model input data:
  - Crop, weather, and soil data, model output data such as crop development stage, biomass, and crop yield;

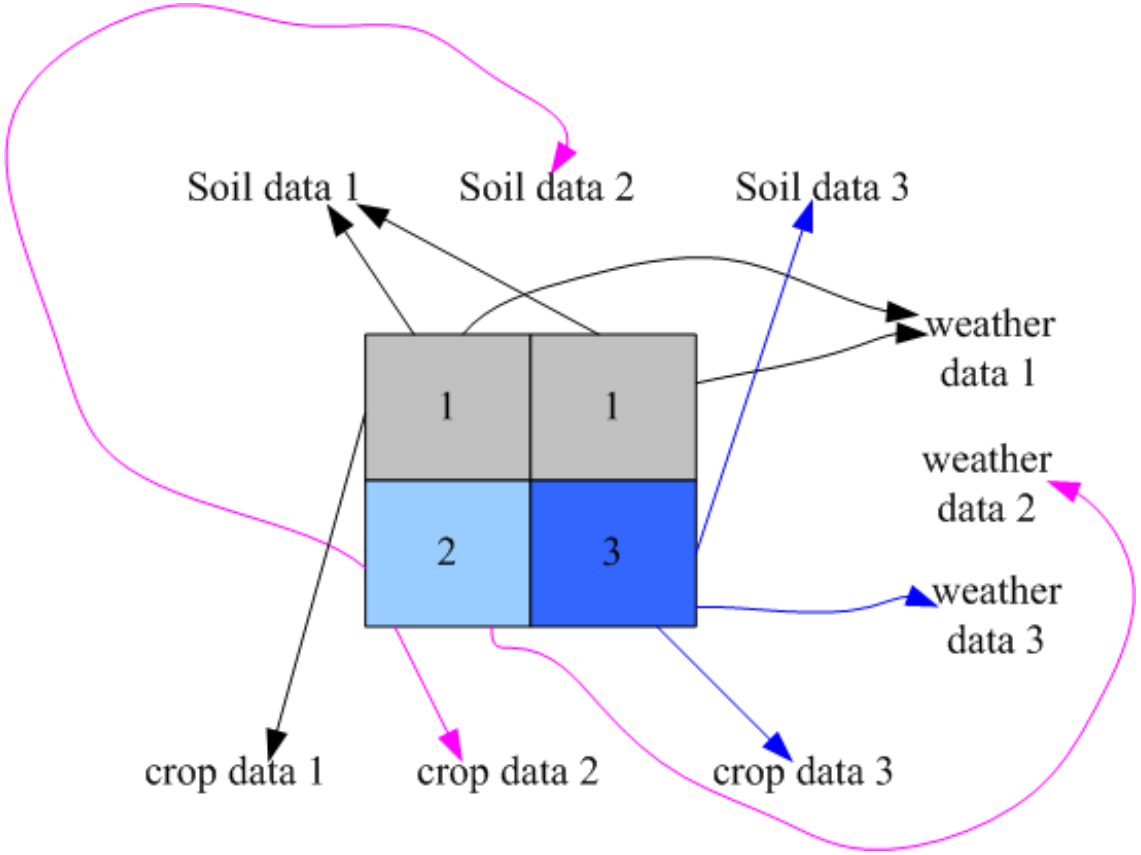
ARCHITECTURE



Spatial WOFOST Model Implementation

- Input data are organized into different soil, weather, and crop management three groups.
- Soil data are extracted and reprocessed from NRCS SSURGO) Database. They are reformated into grid and resampled to the appropriate resolution.
- Weather data are interpolated into grid of the appropriate resolution.
- Optimal crop management practice is assumed; the cropland cover and crop type are extracted from CropMask and CDL.
- All data are organized in either GIS database or files;
- An original WOFOST model with its associated parameters is valid only a given pixel (grid).

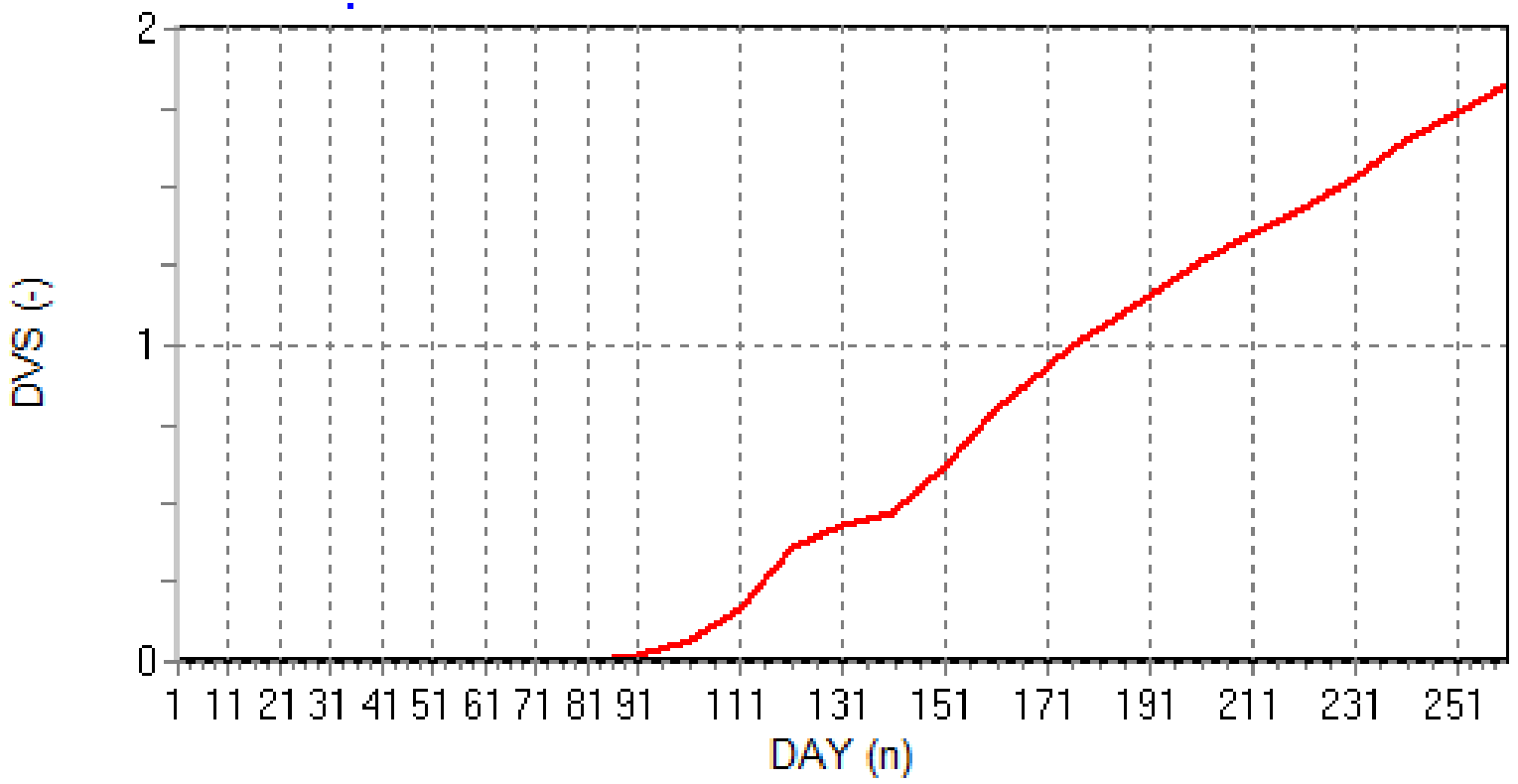
Model Pixel (Grid) for simulation



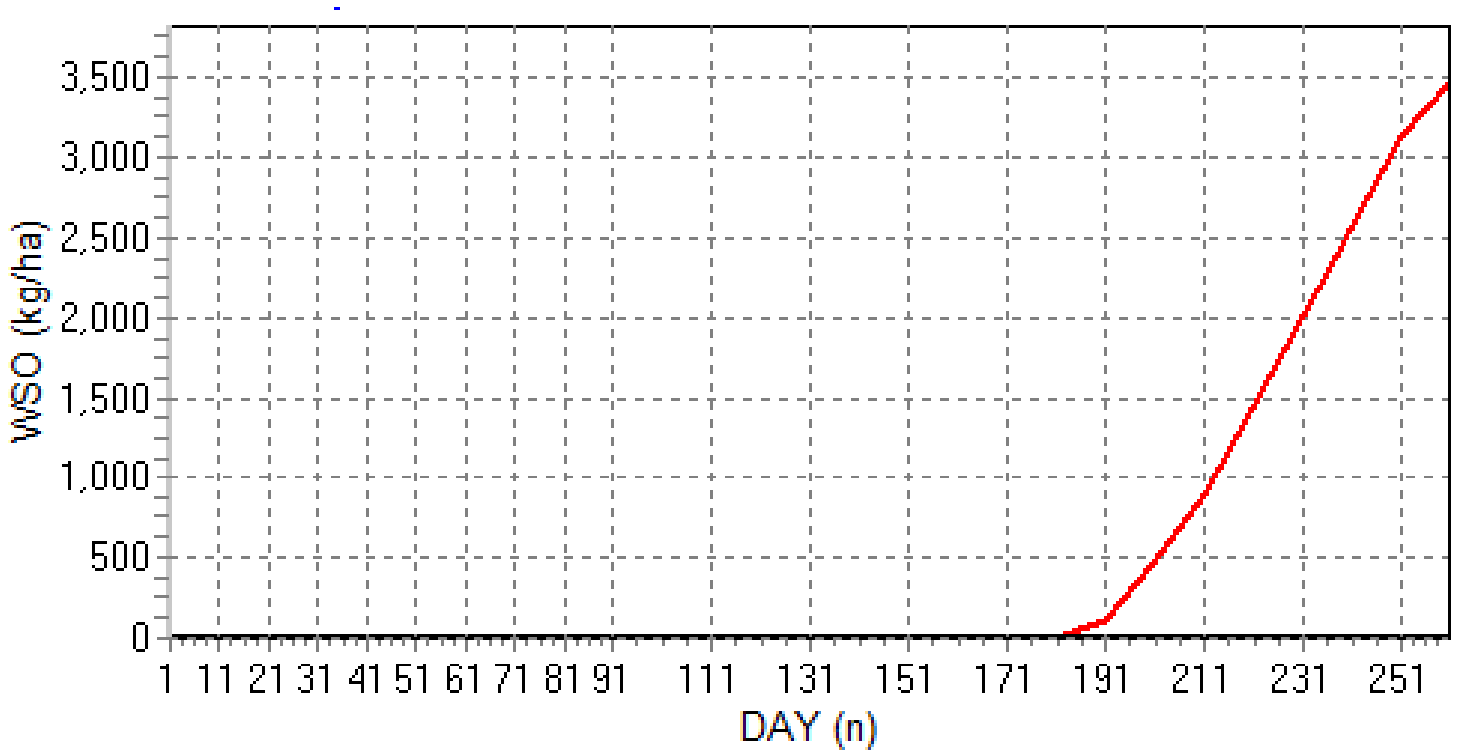
Simulation Test

- The simulation of prototype spatial WOFOST model implementation was successfully tested.
- The simulation interval is day; the simulation runs for whole soybean growing season.
- The input soil data are static while the weather data are dynamic. Weather data change every day. The crop management parameters are assumed optimal, which maximize the crop production.
- Soybean crop development stage and yield are selected as outputs.

Simulation Results - Soybean development stage



Simulation Results - Soybean Yield



Conclusion

- This paper proposed using a crop growth model, World Food Study (WOFOST) model to simulate the crop growth and generalize it spatially for a gridded crop progress monitoring.
- A design framework of the spatial WOFOST model simulation system is presented.
- Initial implementation has been prototyped with successful simulation results.
- The simulated weekly crop development stage (DVS) needs to be calibrated with ground truth data observed from the field

Question?

Thank you!

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