Geospatial-Bigdata-Enabled Automation of Agricultural Decision-Making

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Content

- Agriculture and its sustainability
- Decision-making automation
- Approach for decision-making automation-the roles of geospatial bigdata
- WaterSmart: Automation of irrigation decision making
- Conclusions

Agriculture

- The English word "Agriculture" comes from Latin "agricultura"
  - ager, "a field"
  - cultura, "cultivation" in the strict sense of "tillage of the soil". Thus, a literal reading of the word yields "tillage of a field"
- Agriculture was developed at least 10,000 years ago
  - Play a key role in the development of human civilization
  - Provide stable and more abundant supplies of nutrient and fiber than hunting and gathering
    - Improve living condition and health
    - Support more people within unit area
  - Although now agriculture is a small percentage of overall economy, it is the foundation of the society on which other industries are built

Agricultural Industry in the USA

- Agriculture, food, and related industries contributed
  - $992 billion to U.S. gross domestic product (GDP) in 2015
  - a 5.5-percent share.
- The output of America's farms contributed $136.7 billion of the $992 billion
  - **about 1 percent** of GDP
  - About 1% of U.S. labor works on farming

Agricultural Sustainability

- Importance of agricultural sustainability
  - Agriculture consumes majority of nature resources
    - Fresh water
    - Land resources
    - Nutrients
  - One of major sources unsustainability
    - Water pollutions
    - Land degradation
    - GHG emission
- It is challenge to meet the increasing demands on agricultural products while
  - Reducing the environmental footprints
  - Sustaining the environment and ecosystems that supports agricultural production
- One of the keys is to realize the science-based automated agricultural decision making

Automated Agricultural Decision Making in Crop Farming

- For crop farming, decision making for an action (e.g., irrigation, application of fertilizers requires to know
  - Current conditions of the crop and its environment
  - Predicted future conditions of the crop and its environment, with and without the action
  - Optimizing the future conditions (decision goal) through trade-off (data driven knowledge based reasoning)
- Methods
  - Current conditions
    - Remote sensing, sensor web, IOT, modeling
  - Future conditions
    - Modeling
      - Physical-based, statistics, machine learning
  - Decision making
    - Data (current and future conditions) driven, knowledge-based
    - Ontological reasoning, machine-learning

The Roles of Geospatial Bigdata

- Timely and accurate geospatial bigdata is foundation for
  - Current condition monitoring
  - Future condition prediction
  - Form the database for the AI-based decision making
- Timely and accurate are two fundamental requirements for geospatial bigdata to support the unmanned farming
- Next several slides will introduce an on-going project for supporting the fully automation of data-driven automated agricultural decision making
  - WaterSmart project

WaterSmart Project

- A key NSF project funded by NSF INFEWS program
- INFEWS stands for Innovation for Innovations at the Nexus of Food, Energy and Water Systems
  - A large inter-disciplinary research program
- WaterSmart: A cyberinfrastructure-based integrated agro-geoinformatic decision-support web service system to facilitate informed irrigation decision-making

WaterSmart

- What it does
  - tell farmer when and how much water should be irrigated for each field
- Objective
  - Fully automate the irrigation decision making for large area
  - save 10% of irrigation water and energy
- How
  - Data-driven automated irrigation decision making
- Where
  - The whole state of Nebraska as the test site

Nebraska Facts

- Population: 1.92 million (2017)
- Area: 77,358 mi² (200356.3 km2)
- Nebraska had 47,400 farms and ranches during 2017
  - the average operation consisted of 954 acres (386 ha)
- Nebraska's farms and ranches utilize 45.2 million acres
  - 91% of the state's total land area
- The state has 96,547 registered, active irrigation wells
  - supplying water to over 8.3 million acres of harvested cropland and pasture.
  - 44% of cropland was irrigated
- The average age of a Nebraska principal operator was 55.7 in 2012

Irrigation

- Irrigation enables intensified agriculture
  - Currently, the total irrigated cropland in the U.S. is over 22 million hectares and is expanding
- Irrigation can significantly increase crop yields, a increase farmer's income and enhance food security. However, it
  - consumes approximately 80% of the U.S.'s consumptive water use and over 90% in many western states, and 40% of all energy used in farming
  - affects water, nutrient, and energy cycles of the land.
- With urban expansion and climate change, freshwater has become a scarce resource in many parts of the U.S.
  - the water-use conflicts between agriculture and other sectors are intensifying.
- Excessive irrigation often happens, which not only wastes precious water resources but also increases agriculture run-off, pollutes surface and ground waters, depletes water sources and soil nutrition, and salinizes soils

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Central Pivot Irrigation System (CPIS)

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A field view of CPIS in Nebraska

Landsat image of CPIS

optimal irrigation and problems in traditional irrigation decision making

- Optimal irrigation management, which applies the right amount of water at the right time and place, is vital to agriculture sustainability and the national economy.
- Traditionally, irrigation decisions are most often made by individual farmers based on their judgment or experience or by using a pre-determined calendar schedule of irrigation events based on previous seasons' water requirements
  - subjective, ad hoc, and far from optimal, and often results in water waste or yield loss

Data driven irrigation decision making

- The data-driven irrigation decision making relies on timely and accurate data of crop, soil, and weather conditions to make optimal irrigation decisions
  - demonstrated significant water-saving and economic benefits.
  - 10-20% water savings
- But nationwide popular adoption of the approaches has not happened
  - farmers and water managers lack either the data or the knowledge to make the data-driven irrigation decision.
- The WaterSmart project intends to build a large cyberinfrastructure to provide the timely and accurate irrigation decision information to the stakeholders for enabling the data-driven irrigation decision making

Significance

- Direct economic benefit
- If 10% saving in the irrigation water can be realized, in Nebraska alone
  - **1 billion cubic meters of water**
  - **~34 million gallons of diesel fuel** equivalent energy
    - Most of irrigation uses electricity
- If promoted to cover nationwide. It can save
  - 8.85 million acre-feet (10,916.3 million cubic meter) of water per year
  - $270 million irrigation energy cost per year
- Indirect benefits
  - Ecological
  - Sustainability
  - Pollution reduction
  - Healthier waterways

Methodology

- Current condition monitoring
- Future condition prediction
- Based on current and predicted future condition
  - Ontological reasoning to make decision

Current Condition Monitoring

- At field scale (~30 meters)
- Crop type identification
  - Remote sensing, citizen scientists
- Crop condition and progress stage (phenology)
  - Remote sensing, field photo, modeling
- Root-zone soil moisture and ET
  - Remote sensing, modeling, data assimilation

Future Condition Forecasting

- At field scale (e.g., 30 meters)
- Future in here is next 3-7 days
- Weather conditions- modeling approach
  - Precipitation at field scale
  - ET
  - Wind speed and relative humidity
- Root-zone soil moisture
  - Modeling
    - Land processing model
    - Surface energy balance model
    - Regression model
    - Water-balance model

Data-driven ontological reasoning for irrigation decision-making

- Multiple irrigation goals
  - Maximization of yield
  - maximization of economic returns
  - minimization of water usage with a reduced yield
- Irrigation scheduling ontologies
  - Converted from human readable data-driven irrigation guides to machine-readable irrigation ontologies
- With available current and predicted conditions as the input, perform the ontological reasoning to determine when and how much water should be applied.

Implementation into WaterSmart system

- WaterSmart
  - Implemented as operational automated decision making system
  - Users will subscribe the services
- The methods, algorithms, and models will be tested and validated before implementing them into WaterSmart as web services
- Open standards will be followed when implementing WaterSmart

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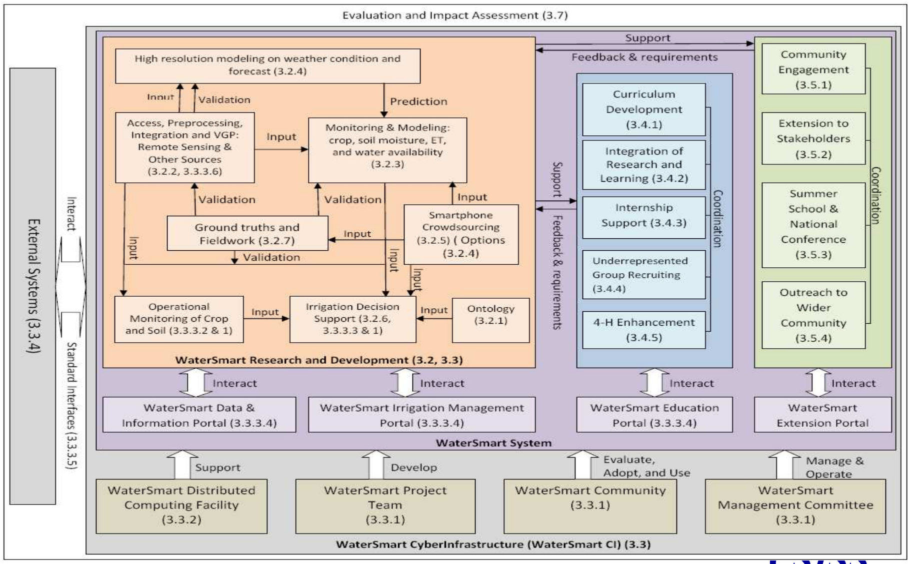
WaterSmart irrigation decision cyberinfrastructure



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Conclusion

- Digital information technologies will revolutionize the large scale agriculture
  - Make data-driven science-based automatic decision making possible
- WaterSmart is a first attempt to automate the agriculture decision making
  - Large direct and indirect benefit can be expected
- Other agriculture decision making can be automated with the same approach.
- These automated decision makings, combining with digital-controlled unmanned agricultural machinery will push agriculture into a fully-automated unmanned practices
  - Significantly increase the agricultural productivity
  - Make Agriculture more sustainable.

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