Decision Support Systems Useful for Agricultural Decision Makers

Larry Brazil
Riverside Technology, inc.
Throughout the World we face an increasing threat from drought – and the social, economic, and environmental impacts that come with it.

The combination of diminished water supplies and increasing demand for urban and other uses is gradually depleting surface and ground water reserves traditionally allocated for agriculture.
Making Decisions with Today’s Environmental Data

Global Information

Data Collection
- Hydropower
- Climate Change
- Natural Hazards Monitoring
- Satellite Development
- Information Technology

Data Management
- Energy
- Land Use
- Streamflow Forecasting
- Water Management
- Agriculture

Data Analysis

Dissemination

Customer Decisions
- Water Use
- Conservation
- Planning
- Policies
- Operations
- Trading
- Production
- Development
- Management

Building Customer Solutions
Agricultural Decisions

- How to manage seasonal and multi-year farm production given uncertainty in
  - the availability of water
  - planting and harvest dates
  - the application of pesticide and fertilizer
  - the variability of markets
  - communication technology
  - …
A DSS (Decision Support System) helps you make decisions by presenting information relevant to your critical questions in a configuration that’s easy to understand.

- Integrated data
- Consistent methodology
- Better, faster, more efficient
- Helps answer “what if” questions
- Increasingly relies on communications, Internet, and databases
Specific Agricultural Problem

- Needs assessment
  - What problem are we’re trying to solve?
- In this case, issues related to “Early Warning System for Agricultural Weather Management”
  - Forecasting availability of water supply
  - Managing use of water for agriculture
  - Providing useful information to agricultural producers
DSS Framework

Problem
- Forecast availability of water supply
- Manage use of water for agriculture
- Provide useful information to agricultural producers

Decisions
- Planning for new reservoirs
- Developing irrigation
- Enhancing water supply operations
Specific Agricultural Decisions

- A farmer’s decisions range from tactical day-to-day decisions, to mid-term planning/crop selection decisions, to long-term strategic investment decisions that affect the farm for several years, such as the purchase of machinery or infrastructure improvements.

- Specific decisions to address “Early Warning System for Agricultural Weather Management”
  - Pre-season: crop type selection, parcel-crop assignment, planting dates
  - In-season: irrigation timing and amount, weed and pest control, fertilizer application
  - End-of-season: harvest dates and methods, target markets
  - Post harvest: crop residue removal methods, choice of tillage
DSS Framework

Influences
- Triple bottom line
  - Social
  - Economic
  - Environmental

Decisions
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Problem
- Forecast availability of water supply
- Manage use of water for agriculture
- Provide useful information to agricultural producers
Specific Influences

- Availability and prices of inputs
- Markets for and prices of products
- Climate change
- Government policies and regulations (e.g., taxes)
- Donor organizations preferences
- Labor (political and other events that affect the availability of off-farm labor)
- Access to credit and availability of loans and grants
DSS Framework

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Decision Constraints
- Government policies
- Public perception/reaction
- International agreements
- Market access or regulation
Specific Decision Constraints

- Farmer goals and objectives, e.g., self food supply
- Farmer technical and management skills, e.g., level of expertise with specific crops and technologies
- Availability of information and knowledge (how to) sources, extension services, consultants, and training.
- Market access (e.g., distance, transportation, storage)
- Weather: level and distribution of precipitation, temperature, and humidity, events of hail, frost, wind, and flood
- Community organization, irrigation/ditch company
DSS Framework

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**Tools**
- Data analysis
- Stochastic data generation
- Hydraulic simulation
- Population growth projection
Specific Agricultural Tools

- River basin modeling
- Irrigation simulation
- Consumptive use modeling
- ET estimation
- Crop modeling
- Hydrologic simulation
- Data analysis
- Risk assessment

...
DSS Framework

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Tool Constraints
- Licensing arrangements
- Access to code
- Support and maintenance
- Public domain versus private sources
- Applicability
- Robustness

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- ...

...
Specific Tool Constraints

- Licensing issues
- Data requirements
- Human capacity
- Internet access
- ...
**DSS Framework**

**Data**
- Availability
- Quality
- Frequency
- Resolution

**Tools**
- River basin modeling
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Specific Agricultural Data

- Historical observations of streamflow, soil moisture, meteorological conditions
- Satellite observations with appropriate resolution and spectral bands
DSS Framework

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**Influences**
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- Markets for and prices of products
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- ...

**Data Constraints**
- Availability
- Cost
- Coverage

**Tool Constraints**
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- Data requirements
- Human capacity
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[Diagram showing the flow of information and decision-making process]
Specific Data Constraints

- Availability of data with appropriate coverage, resolution, frequency, and accuracy for land and vegetation, climate, water availability, soil, crop and market conditions.
Agricultural DSS Framework

- **Influences**
  - Availability and prices of inputs
  - Markets for and prices of products
  - Climate change
  - ...

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Agro-Climate Decision Support Project Diagram

**Data Products**
Satellite Remote Sensing Data

**Decision Support System**
GMU, USDA & UFI Crop Modeling & DSS Tools for Data Management

**Decision-Making**

- **Policy Making**
- **Extension & Training**
  - Drought/Flood/Heat
  - Weather, Climate & Farmers Seminars

**User Community**

- **National Drought Policy**
- **Kenya & Other African Nations**
- **Agricultural Extension**
- **Rain Gauge On Site Data**

**Integrated Agromet Data Products**

- Satellite Remote Sensing Data
- Soil & Crop Moisture

**WAMI**
SNU/NCAM IBIMET

**Policy Making**

- **Farm Decisions**
  - Drought/Flood/Heat

**Extension & Training**

- **Farm Decisions**
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**User Community**

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  - Rain Gauge On Site Data

**Decision-Making**

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**Data Products**

- Satellite Remote Sensing Data
- Soil & Crop Moisture
Experience with other DSSs
Synopsis: The World Bank needed assistance in design and implementing a project that would help the Nile riparian countries develop and manage the waters of the Nile River in a rational and equitable manner.

- Project Preparation & Design
- Decision Support System (DSS) for River Basin Planning & Management
- Institutional Analysis & Design
- System Integration
The Nile Basin Decision Support System

Development Process and Key Features
Nile Basin Initiative

Shared Vision for the Nile

-To achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin water resources.-
The Nile Basin

- Longest River, 6700km
- Basin Area: 3.2 million sq.km, 10% of Africa
- Basin covers ten Basin countries: Burundi, DR Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, Uganda
- Population of over 400 million; 190 mill. in the basin
- Rich natural and environmental assets
- Rich historical heritage
Why a Nile Basin Decision Support System?

• The Nile Riparians are in the process of **developing/managing the shared water resources**
• To support this process, need identified for **accurate information and common analytical tools**
• Accurate information and the shared tools provide a sound technical basis for joint decision making
• Such tools and information basis provide the means for tradeoff analysis and identification of mutually beneficial development/management interventions
• Due to the complexity of the Nile Basin and the issues to be addressed, a suite of modeling and analytical tools are required
• The suite of models/analytical tools, data/information and data management tools need to be provided in an integrated manner

• → the Nile Basin DSS as a common analytical platform for the Nile Basin
The Nile Basin Decision Support System:

• Policy and Strategy Level
  • Provide the Knowledgebase
  • Serve as informed basis for policy and strategic analyses and dialogues
  • A platform for communication to facilitate the joint identification of development strategies
  • Rational support for decision making

Planning and Management Level: to support
- Identification of cooperative projects that provide mutual benefits
- Evaluation of impacts/benefits of alternative plans
- Assessments of trade-offs and investment sequencing
- Trend analysis and forecasts of the development of hot-spots,
- Provide Baseline data and support for environmental management.
DSS Needs Assessment – key questions

• What are the key thematic focus areas for the Nile Basin DSS?
• What are the decisions to be supported in these thematic areas?
• What outputs should the system produce to support these decisions?
• Who are the main users and clients?
• How do the users interact with the system?
• What data are available to support the development and use of the DSS?
• What are existing systems that need to be taken into account?
• How to develop and deploy the system?
• How should future users be involved during development?
• ...

Key elements of the conceptual design

- **Ease of use**: interactive, easy to learn, intuitive understanding for infrequent users

- **Flexibility**: expandable as requirements evolve, technology changes and more data becomes available

- **Modularity**: multiple, alternative, complementary tools/models

- **Openness, transparency**: inspection (source code); backtracking, logs of interaction, modifications

- **Advanced technology**: client-server architecture; single as well as corporate use

- **Cost efficiency**: long term commitment for maintenance and support
Key functionalities of the DSS – overview

- **Query/filter tool**
- **Data explorer (TS)**
- **Data view**
- **Toolset(TS)**
- **Metadata (TS)**
# Decision making tools

- Economic analysis of scenarios (CBA)
- Tradeoff analysis
- Multi-Criteria analysis

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$X_{ij} = \begin{cases} 
\text{Good} & \text{if} \quad x_{ij} > \text{threshold} \\
\text{Bad} & \text{otherwise}
\end{cases}$

Abdulkarim H. Seid, DSS - Lead Specialist
Overall features

• Generic system that can be applied at different scales
• Wide range of functionalities: from data management to choice making (MCA)
• Configurable interface for web publishing of results (linkage with Nile-IS)
• All data (spatial & non-spatial) shall be stored in the RDBMS: PostgreSQL with PostGIS
• Flexible/ Expandable architecture: new model tools, new modules can be added by users
• Scripting through which users can extend available functionality or automate repetitive tasks
• Support for multiple simultaneous uses (corporate edition)
Key lessons

• *Expectation management* is key; what a DSS can do and what it can’t do
• Maintain the stakeholder interest on the DSS - show early results
• Clear understanding of future *users* and *uses* vital
• Involve future users at *appropriate* levels
• Capacity building efforts should consider key *cross section of future users (not only modelers)*
• Requirements gathering/analysis, design, development and testing require *iterative process* ⇒ plan ahead with adequate slack
• DSS development is for the future -- future is ‘uncertain’ ⇒ Keep system *flexible* (requirements evolve, technology improves)
• Software systems are like organisms … if we don’t ‘feed’ them, they die ….. *Sustainability*
Synopsis: State agencies, water providers, and water users needed a means to make informed decisions regarding major water issues and policies.

- Systems Integrations
- Software Development
- DSS for the Colorado River, South Platte River and Rio Grande
- Water Resources Management
- Data Collection/Data Analysis
- Graphical User Interface (GUI)
Colorado’s Decision Support Systems (CDSS) are data and tools that help users make more informed decisions about Colorado’s water resources.

http://cdss.state.co.us
Main CDSS Activities/Areas

- Data collection
- Data management
- Software tools
- Baseline model data sets
- Access/distribution
- Management, coordination, application, extension
CDSS Data Collection – Irrigated Lands

- New evaluation approximately every 5 years
- Crop type
- Irrigation method
- Supply sources
  - Ditches
  - Wells
- Input to consumptive use analysis
CDSS Data Collection – Observations

- New gages
- New observation wells
- Well tests
- GPS locates
- Additional data facilitates model calibration and water resource administration
CDSS Data Management – Geographic Information System (GIS)

- Irrigated lands
- Point layers extracted from HydroBase
- Imagery and background layers
- Other useful layers

http://cdss.state.co.us
CDSS Software – TSTool

- Processes time series
- Reads model files, HydroBase, other inputs
- Filling, analysis, quality control, etc.
- Product generation
- Can be automated
CDSS Software – StateCU Model

- Consumptive use model
- Compatible with StateMod and groundwater model
- Calculates agricultural, municipal, and industrial demands
CDSS Software – StateMod Model

- Water allocation model
- Distributes water supply to meet demand based on system definition, water rights, and operations
- Shares files with StateCU and MODFLOW
CDSS - Access to Data and Tools

- CDSS website: cdss.state.co.us
- HydroBase DVD
- Email: ray.alvarado@state.co.us
- See also presentations for specific tools
Bonneville Power Administration
Decision Support Tools

Synopsis: Bonneville Power Administration required models including graphical displays to examine meteorologic and hydrologic conditions, simulate predictions, and analyze the results.

- Model calibration/validation
- Database design & implementation
- GUI development
- Data analysis
- QA/QC
- Training, documentation, & maintenance

Hydrometeorological Data Display System
Web-based Climate Change Drought Decision Support System

Synopsis: The effects climate change has on water supply are an increasing concern for water managers. As a result, a means to rapidly assess the impact of predicted climate change on natural flows at critical nodes along a river network is needed.

- Decision Support System (DSS)
- Data Analysis
- Hydrologic Modeling
- Streamflow Forecasting
- Climate Change
- Time Series Study
Synopsis: Denver Water required decision support tools to improve the operations and management of local reservoirs.

- Streamflow Forecast Modeling
- Data Analysis
- Decision Support System
- Forecasting
- Hydrologic Analysis
- Software Development
- System Integration

- Data Dissemination
- Information Management
- Data Acquisition & Analysis
- Geographic Information Technology
Synopsis: The Northern Colorado Water Conservancy District required improved information including streamflow forecasts and snowpack data to help improve daily operations.

- Data Management & Storage
- Hydrologic Forecast System
- Snow & Soil Moisture Accounting Models
- Extended Streamflow Prediction Analysis & Display Program (ESPADP)
Synopsis: Under a NASA Research Opportunities in Space and Earth Science (ROSES) Grant, Riverside is leading an effort to utilize remote sensing data to capture actual evapotranspiration over irrigated areas.

- Decision Support System
- Evapotranspiration
- Remote Sensing
- Water Management
Real-time Decision Support for Reservoir Operations

Synopsis: New Hampshire Department of Environmental Services required a flood forecasting/reservoir operations model that allowed them to respond more effectively to hydrologic events.

- Flood Forecasting
- Reservoir Operations Model
- RiverTrak® System
- Web-based Information Display System
- Interactive Data Review
Central Asia Republics - Decision Support System for the Syr Darya River Basin

Synopsis: The Syr Darya River’s water resources are over-extended throughout the Central Asian region, and water allocation systems among the four riparian states needed modernization and a more robust information management system.

- Decision Support System (DSS)
- GIS
- Information Management
- Systems Integration
- Water Resources Management
China - Feasibility Study for the National Flood Control Decision Support System

Synopsis: China’s Ministry of Water Resources needed to know the feasibility of a national flood control system, including a pilot model to help Chinese officials make key operational decisions during devastating seasonal floods.

- Flood Management
- Hydraulic Modeling
- Decision Support System
- Technical Analysis
- U.S. Army Corps of Engineers (USACE) Water Management System (CWMS)

Inundation Map and Model Interface
Panama Canal – Decision Support for Real-time System Operations

Synopsis: The Autoridad del Canal de Panamá required forecast information on a more timely basis to insure better decisions are made regarding reservoir operations in the Panama Canal.

- River Forecasting
- Data Collection & Analysis
- Reservoir Simulation Model Development
- Technology Transfer
- Training & Support
**Synopsis:** Assist river basin agencies to design and develop an IMS for water and irrigation to help them establish a good governance of water at the regional scale.

- Existing Data and modeling Assessment
- Needs assessment
- Hydrologic, Groundwater and hydraulic modeling
- Design and develop Information Management System
- Training and capacity building
Synopsis: Bangladesh required a flood warning system specific to the local hydrology with actionable information and messages that Bangladeshi villagers could understand.

- Community Flood Disaster Preparedness
- GIS
- Flood Forecasting
- Flood Warning Systems
- Operational System Development
Concluding thoughts …

- Well designed and constructed Decision Support Systems can provide invaluable information to decision makers.
- A plan for system support and maintenance with regular updates is a critical part of the overall approach to a successful project.
Thank You!