Trends in U.S. Irrigated Agriculture and Effects of Improved Irrigation Efficiencies

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Presentation for the
International Workshop
GOING BEYOND AGRICULTURAL WATER PRODUCTIVITY
World Bank
December 8-9, 2014
Washington, DC

Thoughts and opinions presented today are those of the author and do not represent those of USDA or the Natural Resources Conservation Service.
Outline of presentation

• Provide a U.S. National perspective on water and irrigated agriculture
  ▪ Acres
  ▪ Location
• The scale challenge of improving irrigation water management
  ▪ Field view
  ▪ Basin view
• Conclusions
Total and agricultural water withdrawals (1960-2010) and consumptive use estimates (1960-1995)

Source: USDA, NRCS, based on Kenny, et al, 2009

* Data limitations do not allow estimation of consumptive use in 2000.
U.S. Irrigated acres 1900-2012 and location in 2012

Source: USDA, NRCS, based Census of Agriculture Data
How was reduction in applied water accomplished?

• Location,
  ▪ Reduced acres in higher application areas (Southwest and west)
  ▪ Increased acres in lower application areas (Southeast & Northern Plains)

• Improved, more efficient management and technology
  ▪ Environmental Externalities
  ▪ Irrigation Externalities
Change in U.S. Irrigated Acres location, 1978-2012

Map: Change in Irrigated Acres by County, 1978 to 2012 - Density Map

Source: NRCS based on 1969 and 2007 Census of Agriculture data

United States Net Increase: 10,990,040

Changes in Irrigated Acres
1 Red Dot = 1,000 Acres Decrease
1 Blue Dot = 1,000 Acres Increase

Data Source:
1978 & 2012 Census of Agriculture
U.S. Department of Agriculture, National Agricultural Statistics Service

Map Source:
U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS)
Soil Science and Resource Assessment (SSRA)
Resource Assessment Division (RAD) - Beltville, MD - December 2014
Changing Irrigation Application Technology

In 2013, all technologies total 111%.

Source: USDA based on Farm and Ranch Irrigation Survey Data
Farm Production: Applying water to crops with a profit motive
Impact of Improved Efficiency

Base Irrigation System

Cumulative Frequency Distribution

Infiltrated Depth

Percent of Field Area
Impact of Improved Efficiency

Base Irrigation System

Infiltrated Depth

Percent of Field Area

Targeted Irrigation Level

Cumulative Frequency Distribution
Impact of Improved Efficiency

![Graph showing the impact of improved irrigation efficiency on infiltrated depth and percent of field area.](image)
# Irrigation Efficiency (IE)

## Beneficial Uses
- Crop Evapotranspiration ($ET_c$)
- Water Harvested with Crop
- Salt Removal
- Soil Preparation
- Seed/Weed Germination
- Climate Control (frost protection, cooling)

## Non-Beneficial Uses (*: unrecoverable)
- Evaporation* (sprinklers, wet soil)
- Deep Percolation (non-uniformity, management)
- Excess Tailwater/Runoff
- Filter Flushing
- Water required for WQ in Drains/Wetlands

$$IE = \frac{\text{Water Beneficially Used}}{\text{Water Applied}}$$
Acres impacted with improved water management and application technology practices from USDA’s Environmental Quality Incentives Program (EQIP)

From 2006 to 2014

Source: USDA, NRCS, based EQIP data
Improved Efficiency: Field View

• Improved accomplishment of target irrigation
  ▪ The infiltration depth for a low-pressure, under-canopy, center pivot (or subsurface drip) approaches the target irrigation level

• Decline in the area of field with over & under irrigation
  ▪ Increase in yield
  ▪ Increase in water consumed by crop ET because improved uniformity decreases water stress from over/under irrigation
  ▪ Reduction in runoff & deep percolation with impact on return flows and groundwater recharge

• Increased water use and reduced deep percolation can create environmental & irrigation externalities because
  ▪ Institutions operate on water withdrawals (also termed diversions or water duty or allocation)
  ▪ Hydrologic system operates on consumptive use
The scale challenge and irrigation: Basin View
Base system
IE = 50%

Flow Amount
110
8
Diversion

102
4
Beneficial Use

106
4
Return Flow

0
Escape

Flow Direction
Forces in Ag Water Management

Legal/Institutional Considerations
- Water rights allocation and protection
- Transfer limits and cost
- Crop Insurance and other subsidies
Institutional: Water Rights are Administered through State Doctrines

Forces in Ag Water Management

Hydrologic (physical) Considerations
- Water availability & demands
- Runoff & return flows
- Surface and ground water linkages
- Environmental flows

Legal/Institutional Considerations
- Water rights allocation and protection
- Transfer limits and cost
- Crop Insurance and other subsidies
Generalized basin water budget with irrigation

Source: Bales, Gollehon and Bernacchi, 2010
Forces in Ag Water Management

Farm Production Considerations
- Water as a relatively low cost input
- Yield increasing
- Minimize total input cost (water, labor & energy)
- Risk reduction
- Use, not waste

Hydrologic (physical) Considerations
- Water availability & demands
- Runoff & return flows
- Surface and ground water linkages
- Environmental flows

Legal/Institutional Considerations
- Water rights allocation and protection
- Transfer limits and cost
- Crop Insurance and other subsidies
Forces in Ag Water Management

Farm Production Considerations

Hydrologic (physical) Considerations

Legal/Institutional Considerations

Intersection of the three forces is what makes producer’s decision regarding irrigation.
Basin Hydrologic View of Improved Irrigation Efficiency

Base system
IE = 50%

Flow Amount

Flow Direction

Legal water right diversion
8

On-Farm Beneficial Use
4

Return Flow
4

Water lost to non-beneficial consumption
0

Farm Production Considerations

Hydrologic (physical) Considerations

Legal/Institutional Considerations
Basin Hydrologic View of Improved Irrigation Efficiency: One Outcome

**Base system**
IE = 50%

- **Flow Amount**
  - 110
  - 102

- **Legal water right diversion**
  - 8

- **On-Farm Beneficial Use**
  - 4

- **Return Flow**
  - 106

**Improved system**
IE = 60%
Reduce stream flow

- **Flow Amount**
  - 110
  - 102

- **Legal water right diversion**
  - 8

- **On-Farm Beneficial Use**
  - 4.8

- **Return Flow**
  - 105.2

**BEFORE**

**AFTER**
Irrigation Efficiency depends on how you define the area of the calculation.

Look at the ‘Irrigation Efficiency’ calculation at alternative scales:
1. The “Field” Scale ~ 50-200 ac
2. The “Main Canal” Scale ~ 500-1,000 ac
3. The “Basin” Scale ~ more than 10,000 ac

Irrigation efficiency will increase as the scale increases because water lost to one farm is reapplied on another. IE can be 50% in the field and 90% in the basin at the same time.

Note: this naming convention and these acreage figures are for this example only
Improved efficiency: Basin View

• Improved irrigation efficiency does not assure an increase in downstream flow
  ▪ Carefully define the goal

• Motivation to reduce withdrawals depends on the water source and institutional circumstance

• Reducing hydrologic water use (ET) usually reduces production

• Without institutional or water supply constraints or monetary reward for reducing water applications, improving technology generally increases private benefits (more acres irrigated or higher yield) while increasing “hydrologic” water consumption.
The wrap-up
Conclusions – Part 1

• Irrigation “water conservation” is complex because water used for irrigation is
  ▪ Mostly renewable,
  ▪ Mobile,
  ▪ Supplied from alternative sources,
  ▪ Includes return flow linkages, and
  ▪ Governed by alternative laws and institutions.

• “Water conservation” is a broad term that represents a range of actions to use less water:
  ▪ In absolute terms (water use reduction);
  ▪ To achieve the goal (water efficiency); and
  ▪ Per unit of output (water productivity).
Conclusions – Part 2

- Reducing consumptive water use on irrigated agricultural land (water use reduction) usually involves a decline in irrigated area or production.
  - Can be expensive

- Improving “water productivity” through better irrigation management and technology:
  - Increases output with the same or reduced levels of water application.
  - Rarely increases downstream water availability.
  - Is a significant accomplishment, given the domestic and international demand for the products from irrigated agriculture.
Conclusions – Part 3

• Continued and increasing pressure on irrigation water supplies:
  ▪ to meet growing demands for other water uses (municipal and industrial supplies, environmental flows, and increasingly, energy production);
  ▪ from climate induced pressures on water quantities and runoff timing, faster spring runoff, shift from snow to rain, or reduced precipitation;
  ▪ increased pressure on crop production and stable crop yields to meet food, fiber, feed, and fuel demands, both domestically and internationally.

• More areas will face limited water supplied for irrigation.
  ▪ How will these needs be met….?????
Balance the Objectives

- There are **many reasons to support improved irrigation management & technology**, water “conserved” for increased basin streamflow is not one of them.
  - Save Energy!!
  - Improved water quality (runoff & drainage water often carries nutrients or chemicals)
  - Increase yield
    - Potentially increases profits for producer
    - Potentially decreases pressure to convert land to production in other areas (indirect land effect) to supply world markets
  - Reduce yield variability
    - Stable production leading to more stable markets
Thank you!

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Indicators of water availability and the location of irrigated land

Source: RCA, USDA, NRCS, 2011
Western Water Market Activity 1990-2003

Annualized average “new” exchange volume
1.7 million acre-feet

Source: NRCS based on Brown, Water Resources Research, 2006
Examples of “improved” irrigation activities
Furrow Irrigation – Poorly managed advance
Furrow Irrigation – Poorly managed tailwater
Laser leveled fields – Improved water management
Improving onfarm conveyance
Subsurface Drip Irrigation Conveyance
Subsurface Drip Irrigation on annual crop
Drip Irrigation in Perennial Crops
Precision Spray Irrigation
Early Valley center pivot irrigation system. The pipes are 9½ feet above the ground, so the towers are over 20 feet tall.

http://www.livinghistoryfarm.org/farminginthe50s/water_01.html
Modern High-Pressure Center Pivot Sprinkler
Low-Pressure Center Pivot Irrigation Sprinkler
Sprinkler on a Low-Pressure Center Pivot
Low-Energy Precision Application Sprinkler
Precision Application requires Precision Management
References

- 2007 Census of Agriculture, National Agricultural Statistics Service, USDA
- 2008 Farm and Ranch Irrigation Survey, National Agricultural Statistics Service, USDA