The Value of Using Irrigation Water in South Florida Agriculture

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Basic Framework

1. Introduction
2. Economic Analysis of Water Use – Model Assumptions and Production Function
3. Water Penalty Function – Analysis and Results
4. Water Penalty Function – Spatial Analysis
5. Summary

National Science Foundation — WHERE DISCOVERIES BEGIN

USDA — United States Department of Agriculture — National Institute of Food and Agriculture

Project Director: Julie Harrington, Ph.D.
Center for Economic Forecasting and Analysis, The Florida State University

Water, Sustainability and Climate for South Florida – Category 2 Collaborative: Robust decision-making for south Florida water resources by ecosystem service valuation, hydro-economic optimization, and conflict resolution modeling

Objective:	Approach:
• To develop adaptive water management schemes that are capable of sustaining important social-ecological interactions, while accounting for uncertainty in larger-scale stressors associated with climate change, sea level rise, and economic settings.	• The South Florida Water Sustainability Project comprises about 7 task or working group areas. The value of water will be analyzed in its direct use (e.g., sector outputs), in socio-ecologic use (e.g., water storage and flood control), and in non-use (e.g., sustainability).
• To develop a regional-scale hydro-economic model that is capable of optimizing the resilience of water supplies for the built & natural systems while also accounting for the broad-sector value of water use and water quality improvements.	• The first task involves the economic analysis of urban and agricultural water use. In addition, the project team will examine the potential risks and economic impacts of salt water intrusion from SLR.

Impact: Participating local, state, and federal agencies responsible for managing the region's water resources, among other stakeholders, will benefit from these broad-sector analyses of adaptive schemes that explicitly incorporate uncertainty estimates of potential outcomes.

FIU Florida International University · Miami Abess Center for Ecosystem Science & Policy · UCF · Michigan Tech · South Florida Water Management District sfwmd.gov · Geodesign Technologies

UF University of Florida · USF University of South Florida · Wharton University of Pennsylvania · University of Hawai'i Mānoa · PennState

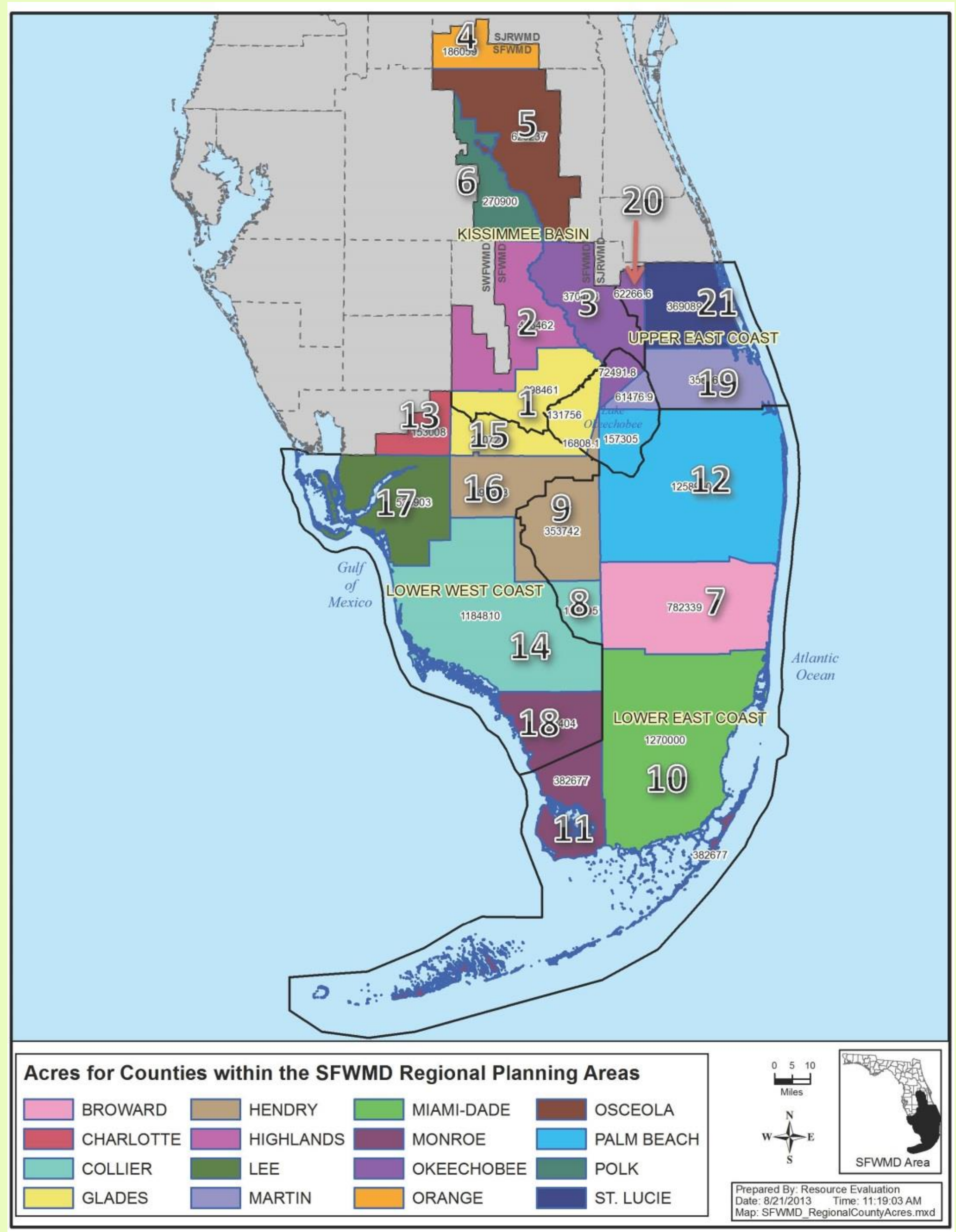
Introduction

The Florida Department of Environmental Protection (FDEP) and South Florida Water Management District (SFWMD) conveyed that traditional sources of fresh groundwater would have difficulty meeting all of the additional demands by 2030 (FLDEP, 2013 and SFWMD, 2012).

What is the economic loss (water penalty) if water is under shortage?

SFWMD

REGION NO	AREA NO	County	% County Area
Kissimmee Basin (KB)			
1	1	Glades	0.60
1	2	Highlands	0.75
1	3	Okeechobee	0.75
1	4	Orange	0.32
1	5	Osceola	0.73
1	6	Polk	0.24
Lower East Coast (LEC)			
2	7	Broward	1.00
2	8	Collier	0.09
2	9	Hendry	0.48
2	10	Miami-Dade	1.00
2	11	Monroe	0.56
2	12	Palm Beach	1.00
Lower West Coast (LWC)			
3	13	Charlotte	0.35
3	14	Collier	0.91
3	15	Glades	0.40
3	16	Hendry	0.52
3	17	Lee	1.00
3	18	Monroe	0.44
Upper East Coast (UEC)			
4	19	Martin	1.00
4	20	Okeechobee	0.13
4	21	St Lucie	1.00



Economic Variables and Input Data Used in the Water Penalty in SFWMD

YEAR	CV ($ millions)	EMPC	SWC (acre-ft)	GWC (acre-ft)	SWC/ (SWC+GWC)	RICL	FR	CL
2000	$ 4,406	27,176	1,860,824	805,354	0.70	0.84	0.94	1,169,025
2005	$ 4,471	25,180	1,445,617	596,459	0.71	0.83	0.88	1,056,914
2010	$ 3,234	20,698	1,072,932	548,780	0.66	0.79	0.73	973,252

CV = the value of farm cropland products sold in million dollars, which his adjusted according to the inflation rate based on the producer price index cropland in 2010 (PPI 2010=100).

EMPC= employment in cropland

SWC = surface water usage in cropland in acre-foot per year (acre-ft)

GWC= ground water usage in cropland in acre-foot per year (acre-ft)

RICL=the ratio of irrigated cropland out of the cultivated cropland

FR=the ratio of fertilized cropland out of the cultivated cropland

CL= the size of cropland (acres)

SFWMD and Associated Subdistricts

REGION NO	REGION	YEAR	CV ($ millions)	EMPC	SWC (acre-ft)	GWC (acre-ft)	SWC/(SWC+GWC)	RICL	RF	CL
1	**KB**	2000	$ 617	3,045	57,231	159,615	0.26	0.77	0.92	186,968
		2005	$ 649	2,724	66,124	133,319	0.33	0.77	0.83	175,570
		2010	$ 446	2,917	93,818	101,124	0.48	0.75	0.70	157,693
2	**LEC**	2000	$ 2,441	15,837	1,209,633	261,927	0.82	0.88	0.97	603,375
		2005	$ 2,533	14,321	973,746	195,076	0.83	0.86	0.90	564,272
		2010	$ 1,864	12,014	598,084	161,094	0.79	0.77	0.72	544,306
3	**LWC**	2000	$ 929	6,937	237,193	311,545	0.43	0.90	0.96	206,981
		2005	$ 886	6,953	186,026	220,900	0.46	0.88	0.88	190,902
		2010	$ 650	4,915	273,623	271,108	0.50	0.85	0.71	174,264
4	**UEC**	2000	$ 419	1,357	356,767	72,266	0.83	0.80	0.92	171,701
		2005	$ 402	1,182	219,721	47,164	0.82	0.80	0.90	126,170
		2010	$ 274	852	107,407	15,454	0.87	0.78	0.81	96,990

Assumptions Used in Cobb-Douglas Production Function

The level of surface water use changes from SWCo (the current/original level) to SWCn (the new or future level).

If all other variables are held constant, then the production (value of crop sold) level would change from CVo to CVn.

The difference of the production level (d CV) is:

$d\ CV_{i,t} = CVn_{i,t} - CVo_{i,t}$

Empirical Framework: Cobb-Douglas Production Function and Results

$$CV_{i,t} = a\ EMPC_{i,t}^{c}\ SWC_{i,t}^{d}\ GWC_{i,t}^{e}\ RICL_{i,t}^{f}\ FR_{i,t}^{g}\ YEAR_{i,t}^{h}.$$

which can be rewritten as

$$\ln CV_{i,t} = \ln a + c \ln EMPC_{i,t} + d \ln SWC_{i,t} + e \ln GWC_{i,t} + f \ln RICL_{i,t} + g \ln FR_{i,t} + h \ln YEAR_{i,t}.$$

	Coefficients		*Standard Error*	*t Stat*	*P-value*
ln a	-0.497		0.395	-1.26	0.22
ln EMPC	0.550	**	0.040	13.65	0.00
ln SWC	0.078	**	0.032	2.42	0.02
ln GWC	0.136	**	0.044	3.07	0.00
ln RICL	0.692	**	0.325	2.13	0.04
ln FR	1.440	**	0.593	2.43	0.02
ln YEAR	0.290	**	0.133	2.18	0.04
R Square	0.928				
Adjusted R Square	0.917				
P-value	0.000				
Observations	45				

** siginificant at the 0.05 level

Marginal Benefit of Water Using Cobb-Douglas Production Function

$$\mathbf{CV_{i,t} = a_{i,t}\ EMPC_{i,t}^{0.550}\ SWC_{i,t}^{0.078}\ GWC_{i,t}^{0.136}\ RICL_{i,t}^{0.692}\ FR_{i,t}^{1.440}\ YEAR_{i,t}^{0.290}}.$$

The difference of the production level (d CV) is:

$d\ CV_{i,t} = CVn_{i,t} - CVo_{i,t}$

$$= (a_{i,t} EMPC_{i,t}^{0.550}\ \mathbf{SWCn},_{i,t}^{0.078}\ GWC_{i,t}^{0.136}\ RICL_{i,t}^{0.692} FR_{i,t}^{1.440} YEAR_{i,t}^{0.290}) -$$

$$(a_{i,t}\ EMPC_{i,t}^{0.550}\ \mathbf{SWCo}_{i,t}^{0.078}\ GWC_{i,t}^{0.136}\ RICL_{i,t}^{0.692}\ FR_{i,t}^{1.440}\ YEAR_{i,t}^{0.290})$$

Marginal Benefit of Water Using Cobb-Douglas Production Function

$$CV_{i,t} = a_{i,t}\ EMPC_{i,t}^{0.550}\ SWC_{i,t}^{0.078}\ GWC_{i,t}^{0.136}\ RICL_{i,t}^{0.692}\ FR_{i,t}^{1.440}\ YEAR_{i,t}^{0.290}.$$

The marginal benefit (MB) of water?

Producer's value marginal product (VMP) for surface water

$$VMPS_{i,t} = \partial CV_{i,t} / \partial SWC_{i,t}$$

$$= a_{i,t}\ (0.0078)\ EMPC_{i,t}^{0.550}\ SWC_{i,t}^{(0.078-1)}\ GWC_{i,t}^{0.136}\ RICL_{i,t}^{0.692}\ FR_{i,t}^{1.440}\ YEAR_{i,t}^{0.290}$$

Marginal Benefit (MB) of Water in SFWMD Regions

	Surface Water			Ground Water		
	2000	2005	2010	2000	2005	2010
KB	$ 845	$ 770	$ 372	$ 527	$ 665	$ 601
LEC	$ 158	$ 204	$ 244	$ 1,272	$ 1,772	$ 1,579
LWC	$ 307	$ 373	$ 186	$ 407	$ 547	$ 327
UEC	$ 92	$ 144	$ 200	$ 791	$ 1,164	$ 2,423
SFWMD	$ 186	$ 243	$ 236	$ 747	$ 1,023	$ 804

($ / acre-ft per year)

Water Penalty Function (1) : Cost

When farmers decide upon the irrigation water level, we assume that their objective is to maximize their profits by adjusting the amount of water use. Thus, water can be optimally used and efficiently allocated in cropland when farmers choose the amount of irrigation. Under this condition, producer's profit is maximized, which interprets that the marginal benefit (MB) of the use of irrigation water is equal to the marginal cost (MC) of supply of irrigation water (Young, 2005 and Dudu and Chumi, 2008).

$$MC_{i,t} = MB_{i,t}$$
$$= VMPS_{i,t} .$$

If the surface water levels are changed from the current level (SWCo) to the new level (SWCn), then the cost difference (d COST) associated by the change in water use (SWn-SWo) can be calculated by the following:

$$d\ COST_{i,t} = (MC_{i,t})\ (\mathbf{SWCn_{i,t} - SWCo_{i,t}}).$$

Water Penalty Function (2)

Water penalty is profit loss when the amount of irrigation water is changed:

$$\text{Profit} = CV_{i,t} - COST_{i,t}$$

$$PENALTY_{i,t} = d\,CV_{i,t} - d\,COST_{i,t}$$

$$PENALTY_{i,t} = (CVn_{i,t} - CVo_{i,t}) - (MC_{i,t})\,(\mathbf{SWCn_{i,t} - SWCo_{i,t}})$$

Water Penalty Function (3)

Water penalty is profit loss when the amount of irrigation water is changed:

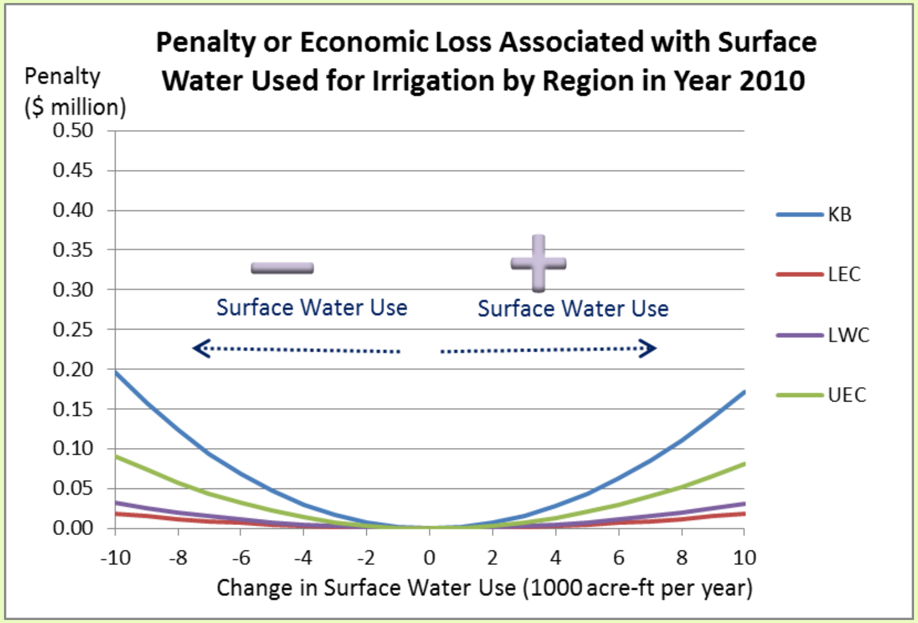
$$PENALTY_{i,t} = d\,CV_{i,t} - d\,COST_{i,t}$$
$$= (CVn_{i,t} - CVo_{i,t}) - (MC_{i,t})\,(\mathbf{SWCn_{i,t}} - \mathbf{SWCo_{i,t}})$$

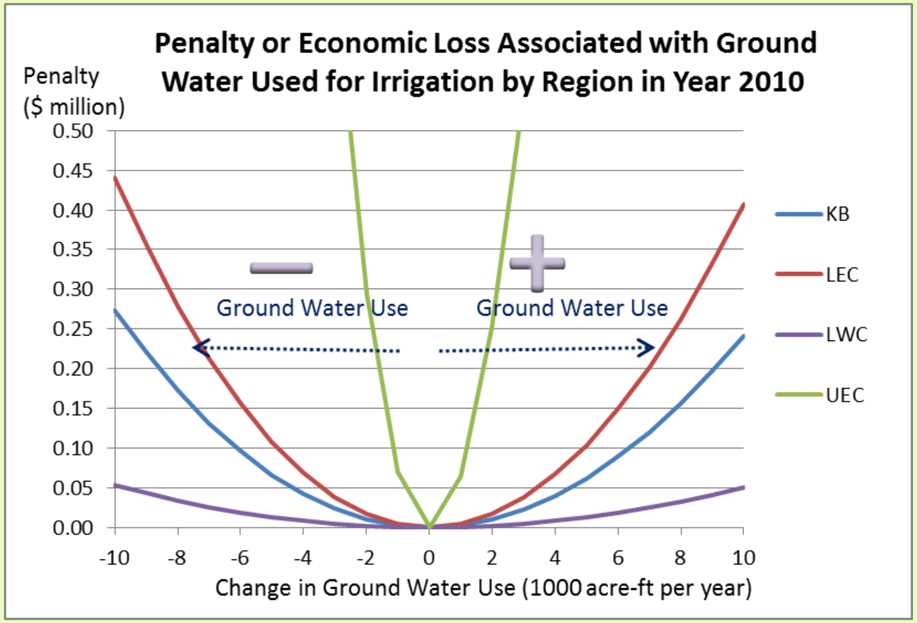
$$PENALTY_{i,t} = b1_{i,t}\,\mathbf{SWCn_{i,t}}^{0.078} - (0.078\,b1_{i,t})\,\mathbf{SWCo_{i,t}}^{(0.078-1)}\,(d\,SWC_{i,t}) - CVo_{i,t},$$

where $b1_{i,t} = a_{i,t}\,EMPC_{i,t}^{0.550}\,GWC_{i,t}^{0.136}\,RICL_{i,t}^{0.692}\,FR_{i,t}^{1.440}\,YEAR_{i,t}^{0.290}$, and

$d\,SWC_{i,t} = SWCn_{i,t} - SWCo_{i,t}$

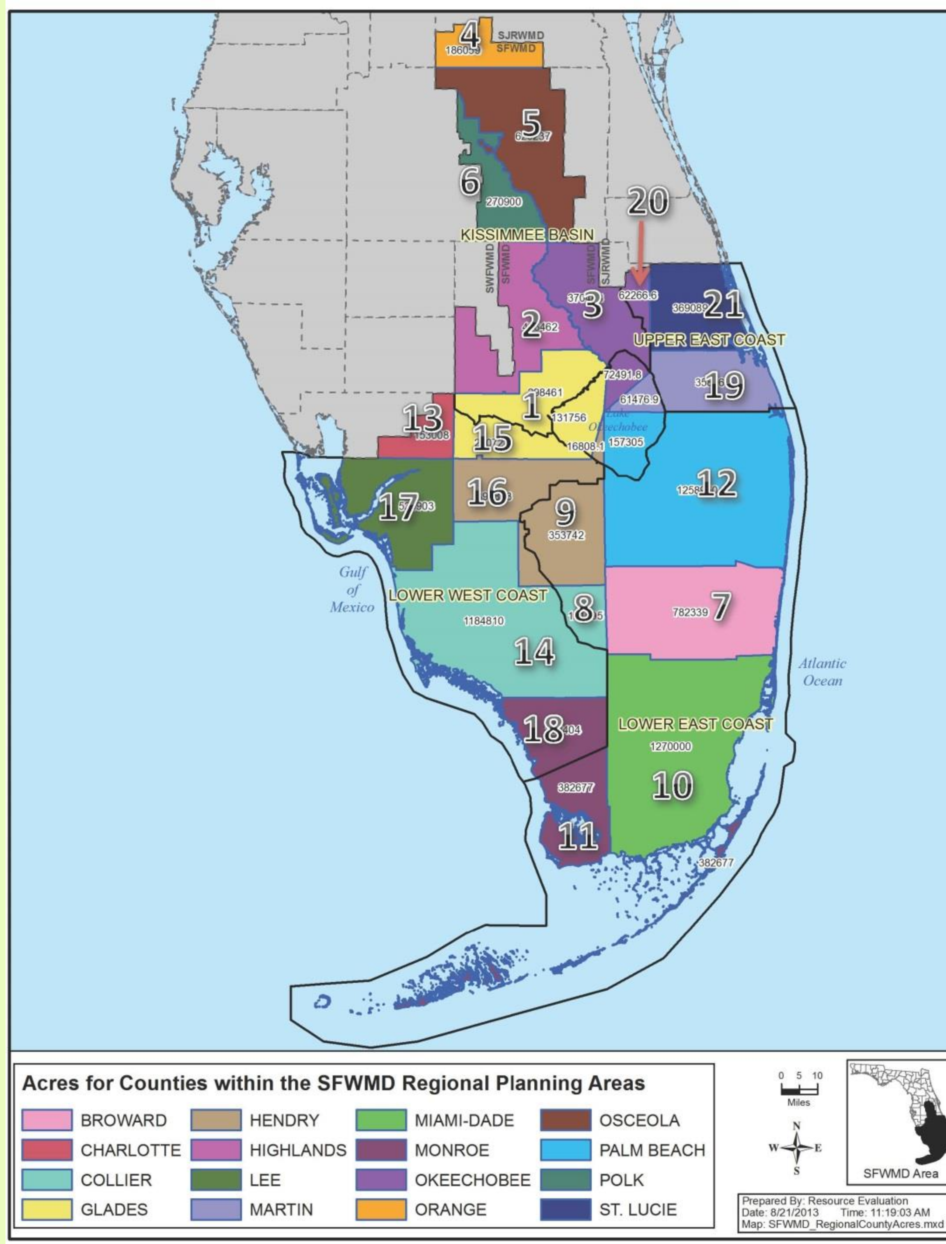
Water Penalty Results for SFWMD Regions



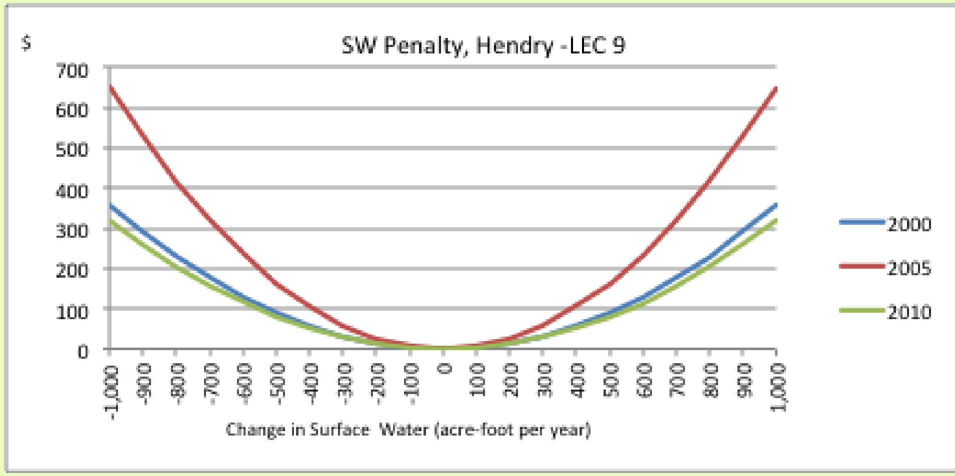


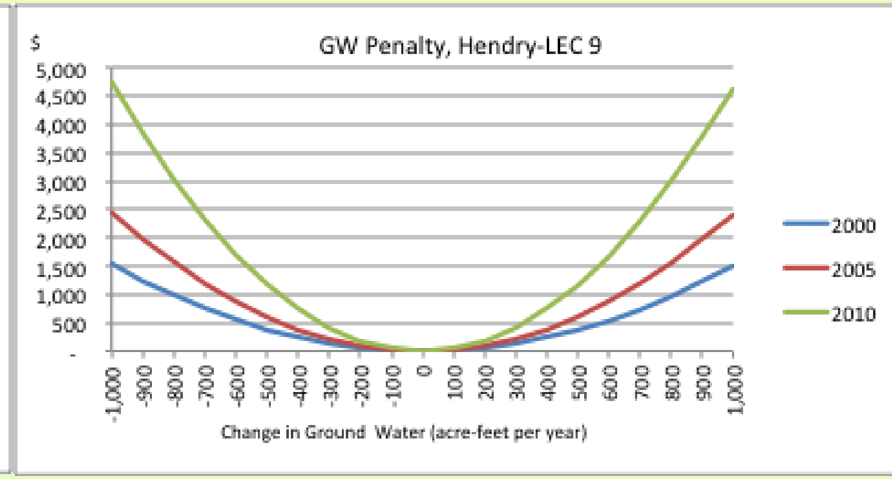
SFWMD

REGION NO	AREA NO	County	% County Area
Kissimmee Basin (KB)			
1	1	Glades	0.60
1	2	Highlands	0.75
1	3	Okeechobee	0.75
1	4	Orange	0.32
1	5	Osceola	0.73
1	6	Polk	0.24
Lower East Coast (LEC)			
2	7	Broward	1.00
2	8	Collier	0.09
2	**9**	**Hendry**	0.48
2	10	Miami-Dade	1.00
2	11	Monroe	0.56
2	12	Palm Beach	1.00
Lower West Coast (LWC)			
3	13	Charlotte	0.35
3	14	Collier	0.91
3	15	Glades	0.40
3	16	Hendry	0.52
3	17	Lee	1.00
3	18	Monroe	0.44
Upper East Coast (UEC)			
4	19	Martin	1.00
4	20	Okeechobee	0.13
4	21	St Lucie	1.00



Water Penalty Results for –Hendry County (LEC 9)





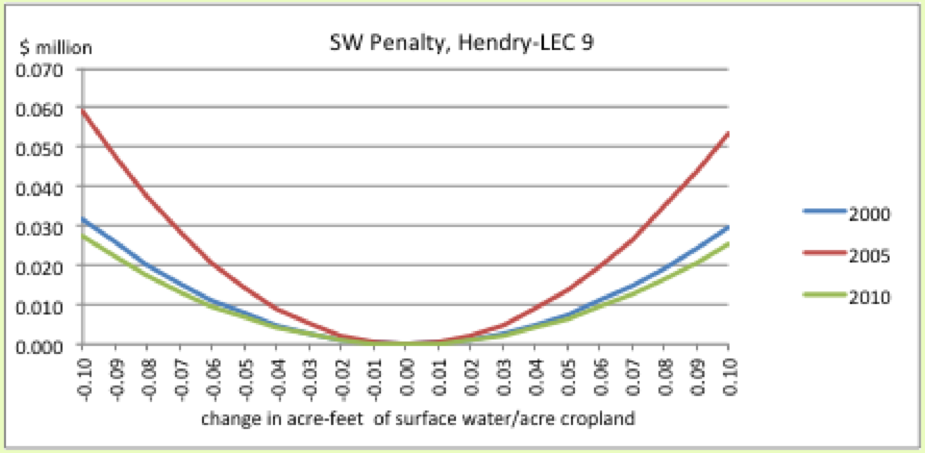
Penalty ($ million) of 1,000 acre-ft per year (in 2010)

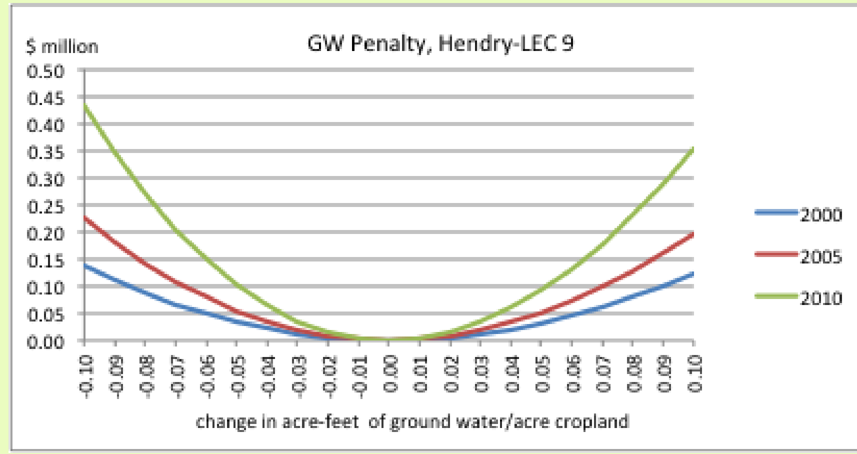
		When SW changes		When GW changes		When either SW or GW changes		
		d SW=-1,000 acre-foot/year	d SW=+1,000 acre-foot/year	d GW=-1,000 acre-foot/year	d GW=+1,000 acre-foot/year	d IW=-1,000 acre-foot/year	d IW=+1,000 acre-foot/year	Lower penalty
LEC 9	Hendry	0.0003	0.0003	0.0047	0.0046	0.0003	0.0003	SW

Water Penalty Per Acre Cropland- Hendry (LEC 9)

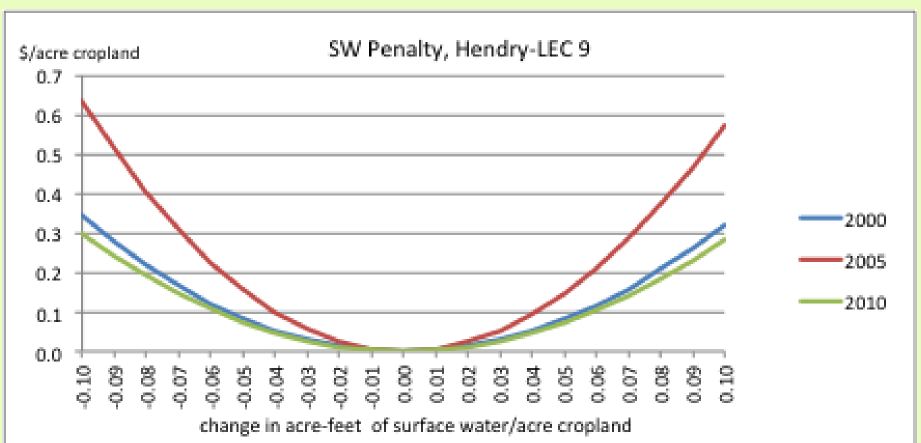
Cropland 91,083 acres (in 2010)…if the amount of water changes by 9,108.3 acre-ft in Hendry, it means that amount of water changes by 0.1acre-ft/ acre or by 0.1 feet.

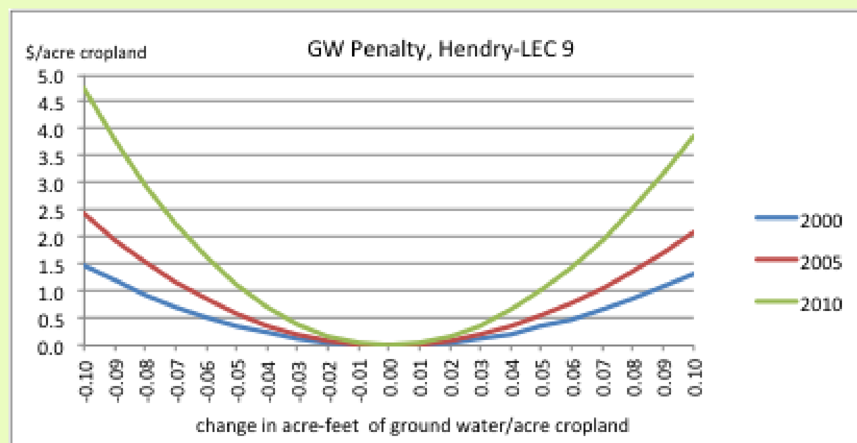
1. **Total Penalty when the irrigation water changes in acre-ft/acre (= feet)**





2. **Penalty/acre when irrigation water changes in acre-ft/ acre (=feet)**





Water Penalty of 0.1 Acre-Ft per Year/ Acre- Hendry (LEC 9)

Cropland is 91,083 acres (in 2010)…if the amount of water changes by 9,108.3 acre-ft in Hendry, it means that amount of water changes by 0.1acre-ft/ acre or by 0.1 feet.

1. **Total Penalty when the irrigation water changes by 0.1 acre-ft/acre (= 0.1 feet)**

When SW changes		When GW changes		When either SW or GW changes		
d SW=-0.1 acre-foot/year	d SW=+0.1 acre-foot/year	d GW=-0.1 acre-foot/year	d GW=+0.1 acre-foot/year	d IW=-0.1 acre-foot/year	d IW=+0.1 acre-foot/year	Lower penalty
0.03	0.03	0.43	0.35	0.03	0.03	SW

($ millions)

2. **Penalty/acre when irrigation water changes by 0.1acre-ft/ acre (=0.1 feet)**

When SW changes		When GW changes		When either SW or GW changes		
d SW=-0.1 acre-foot/year	d SW=+0.1 acre-foot/year	d GW=-0.1 acre-foot/year	d GW=+0.1 acre-foot/year	d IW=-0.1 acre-foot/year	d IW=+0.1 acre-foot/year	Lower penalty
0.30	0.28	4.75	3.87	0.30	0.28	SW

($)

Water Penalty in $ of 0.1 Acre-ft per Year per Acre Cropland

		When either SW or GW changes			
		d W=-0.1 acre-foot/year	d W=+0.1 acre-foot/year	Lower penalty	SFWMD Rank (Lowest to highest penalty)
KB					
KB 1	Glades	0.07	0.07	SW	1
KB 2	Highland	6.48	5.16	**GW**	16
KB 3	Okeechobee	1.04	0.91	GW	13
KB 4	Orange	86.18	62.34	**GW**	**18**
KB 5	Osceola	1.44	1.28	GW	14
KB 6	Polk	n/a	206.17	GW	**19**
LEC					
LEC 7	Broward	21.91	18.30	**GW**	**17**
LEC 8	Collier	0.19	0.19	GW	4
LEC 9	Hendry	0.30	0.28	SW	5
LEC 10	Miami-Dade	4.95	4.45	**GW**	15
LEC 12	Palm Beach	0.78	0.69	SW	8
LWC					
LWC 13	Charlotte	0.59	0.55	SW	7
LWC 14	Collier	0.19	0.19	GW	3
LWC 15	Glades	0.07	0.07	SW	1
LWC 16	Hendry	0.30	0.28	SW	5
LWC 17	Lee	1.00	1.00	GW	11
UEC					
UEC 19	Martin	0.79	0.71	SW	9
UEC 20	Okeechobee	1.04	0.91	GW	12
UEC 21	St Lucie	0.91	0.80	SW	10

Water Penalty in $ Millions of 1,000 Acre-Ft per Year, by SFWMD Subdistrict or Area

When irrigation water is decreased by 1,000 acre-ft per year or 1 MGD

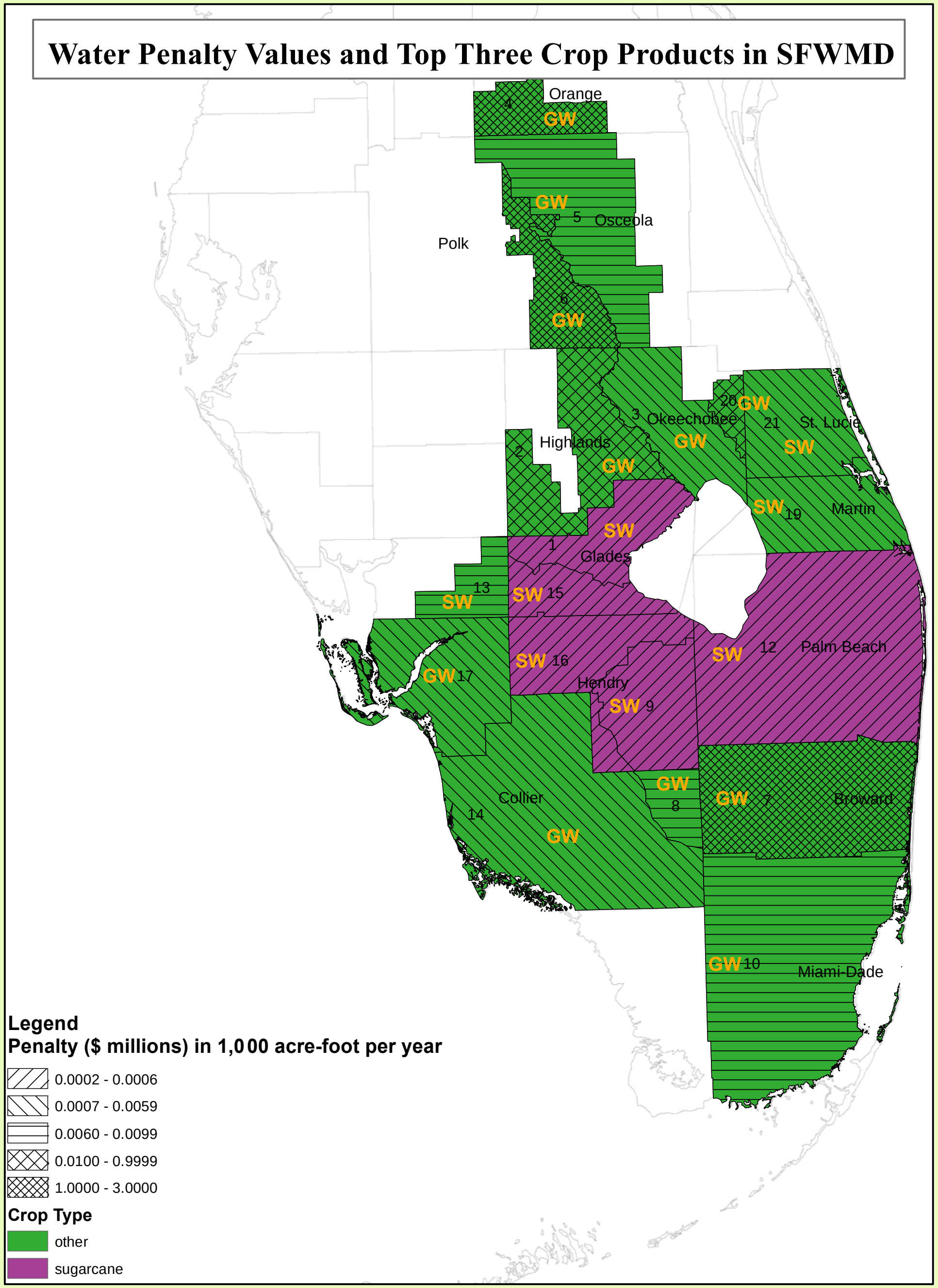
		Penalties (in $ million)				Top crop (by acre)		
		Change in IW=-1,000 acre-ft/year	Change in IW=-1 MGD (1121 acre-ft/year)	Lower penalty	SFWMD Rank (Lowest to highest penalty)	1	2	3
KB								
KB 1	Glades	$0.0002	$0.0003	SW	2	sugarcane	oranges	other oranges
KB 2	Highland	$0.0104	$0.0130	GW	15	oranges	valencia oranges	forage-land
KB 3	Okeechobee	$0.0042	$0.0052	GW	10	forage-land	oranges	vegetables harvested
KB 4	Orange	$2.8970	$4.0357	GW	19	oranges	sod harvested	other oranges
KB 5	Osceola	$0.0076	$0.0096	GW	12	sod harvested	oranges	forage-land
KB 6	Polk	$2.1942	$2.9821	GW	18	oranges	valencia oranges	forage-land
LEC								
LEC 7	Broward	$1.0339	$1.3913	GW	17	nursery stock crops	forage-land	vegetables harvested
LEC 8	Collier	$0.0066	$0.0083	GW	11	oranges	vegetables harvested	valencia oranges
LEC 9	Hendry	$0.0003	$0.0004	SW	4	oranges	sugarcane	valencia oranges
LEC 10	Miami-Dade	$0.0084	$0.0105	GW	13	vegetables harvested	Avocado	nursery stock crops
LEC 12	Palm Beach	$0.0002	$0.0002	SW	1	sugarcane	vegetables harvested	sweet corn
LWC								
LWC 13	Charlotte	$0.0097	$0.2109	SW	14	oranges		
LWC 14	Collier	$0.0006	$0.0006	GW	6	oranges	vegetables harvested	valencia oranges
LWC 15	Glades	$0.0004	$0.0005	SW	5	sugarcane	oranges	other oranges
LWC 16	Hendry	$0.0003	$0.0004	SW	3	oranges	sugarcane	valencia oranges
LWC 17	Lee	$0.0028	$0.0036	GW	9	oranges	valencia oranges	vegetables harvested
UEC								
UEC 19	Martin	$0.0021	$0.0026	SW	8	oranges	valencia oranges	other oranges
UEC 20	Okeechobee	$0.0290	$0.0375	GW	16	forage-land	oranges	vegetables harvested
UEC 21	St Lucie	$0.0015	$0.0019	SW	7	grapefruit	oranges	other oranges

From Water Penalty Results

What does the result of water penalty mean to the agricultural water used in the region?

As water becomes more scarce in crop production, the economic losses to producers become greater in some areas than in other areas. To prevent significant negative impacts to the economy , irrigation water should be allocated to those areas with higher penalty than lower penalty.

Water Penalty ($ millions) in 1,000 Acre-ft Per Year and Crop Type



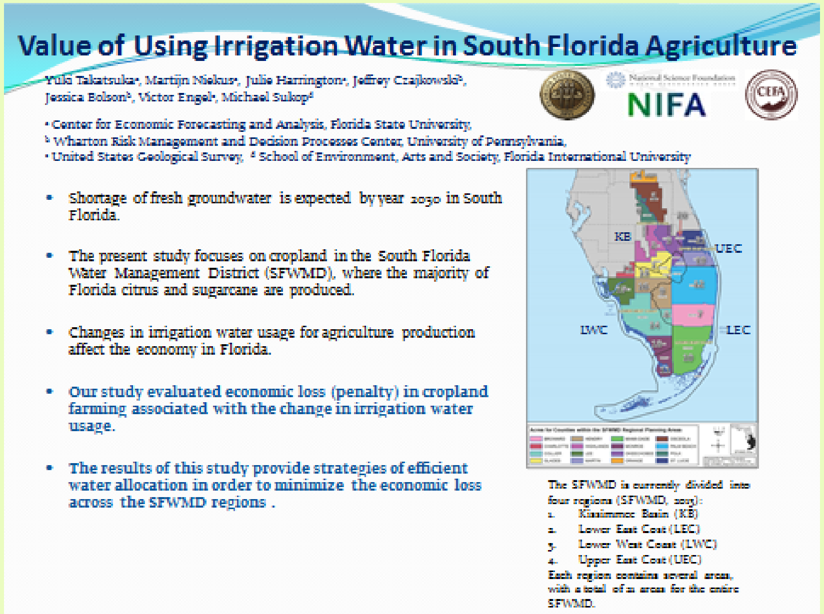
Source: ARC-GIS Figures by Stephen Hodge, Dean, FSU ISPA and Director, FSU FREAC. January 2015

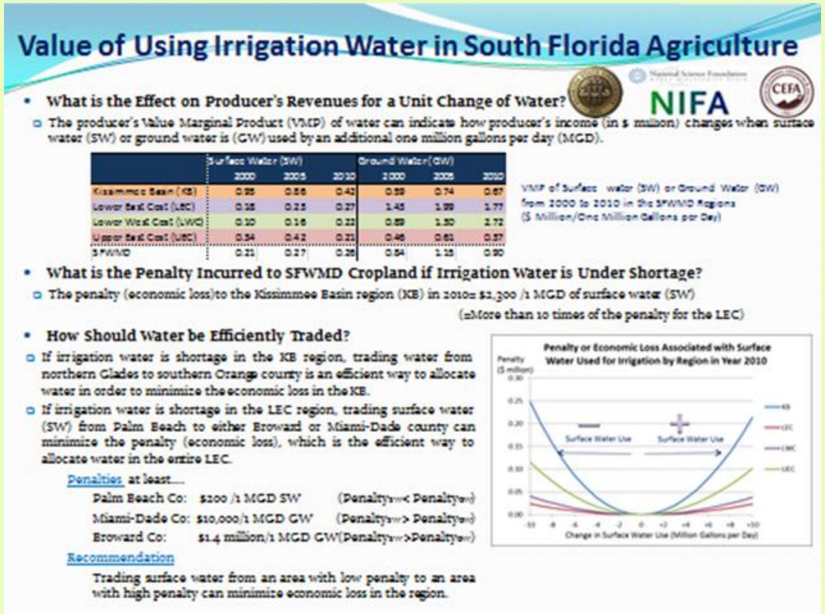
Summary

1. Areas with lower penalties (Palm Beach, Glades, Hendry Counties) are located around Okeechobee Lake. Those areas produce sugarcane as major crop products and rely more on surface water than ground water.

2. If there is a shortage of irrigation water, Orange, Polk, and Miami-Dade Counties will experience the higher penalty, which indicates those areas have higher priority to use irrigation water, compared to other regions.

3. The water penalty results by various areas exhibit an economically efficient way to allocate water in the SFWMD region.





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