Effects of Climatic Change on a Water Dependent Regional Economy: A Study of the Texas Edwards Aquifer

Chi-Chung Chen
Assistant Professor
Dept. of Agricultural Economics
National Chung-Hsing University
Taichung, Taiwan
(886-4) 284-0349

Dhazn Gillig
Assistant Research Scientist
Department of Agricultural Economics
Texas A&M University
College Station, TX
dgillig@taexgw.tamu.edu
(979) 845-3153

and

Bruce A. McCarl
Professor
Department of Agricultural Economics
Texas A&M University
College Station, TX
mccarl@tamu.edu
(979) 845-1706

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Abstract

Global climate change portends shifts in water demand and availability which may damage or cause intersectoral water reallocation in water short regions. This study investigates effects of climatic change on regional water demand and supply as well as the economy in the San Antonio Texas Edwards Aquifer region. This is done using a regional model which portrays both hydrological and economic activities. The overall results indicate that changes in climatic conditions reduce water resource availability and increase water demand. Specifically, a regional welfare loss of $2.2 - $6.8 million per year may occur as a result of climatic change. Additionally, if springflows are to be maintained at the currently desired level to protect endangered species, pumping must be reduced by 9 - 20% at an additional cost of $0.5 to $2 million per year.

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Global climate change portends shifts in water demand and availability which may damage or cause intersectoral water reallocation. This study examines the implications of recent climate change projections for the San Antonio Texas Edwards Aquifer (EA) region concentrating on changes in water use patterns and the economy.

The EA supplies the needs of municipal, agricultural, industrial, military and recreational users. The EA is a carstic aquifer which has many characteristics in common with a river. Annual recharge over the period 1934 -1996 averaged 658,200 acre feet (af) while discharge averaged 668,700 af (USGS,1997). EA discharge is through pumping and artesian spring discharge. Pumping rose by 1% a year in the 1970's and 1980's (Collinge et al. 1993) and now accounts for 70% of the total discharge. Pumping in the western part of the EA is largely by agricultural users (AG) whereas eastern pumping is mainly by municipal and industrial water users (M&I). Spring discharge, mainly from San Marcos and Comal springs in the East, supports a habitat for endangered species (Longley 1992), provides water for recreational use, and serves as an important supply source for water users in the Guadalupe-Blanco river system. The aquifer is now under pumping limitations due to actions by the Texas Legislature (Texas Senate,1993) and because of a successful lawsuit by the Sierra club to protect the endangered species (Bunton,1996). A number of efforts have examined economic, hydrological, and environmental issues regarding the EA (Dillion (1991), McCarl et al. (1993), Lacewell and McCarl (1995), Williams (1996), Keplinger et al. 1998, McCarl et al. (1998), Schiable et al. (2000) and Watkins and McKinney (1999)).

Reduced water availability or increased water demand caused by climate change could exacerbate regional water scarcity. This study utilizes an existing EA hydrological and economic systems model – EDSIM (McCarl et al. 1998) to examine the implications of climate induced changes in recharge, and water demand.

Climatic Change in the Edwards Aquifer Region

The U.S. Global Climate Change Research Program, National Assessment Team (USGCRP-NAT) has been working on an integrated multisectoral assessment of climate change and has selected two global circulation models as the primary source of future climate projections. These are the Canadian Climate Center Model (CCC) and the Hadley Climate Center Model (HAD) run under the IPPC1992a greenhouse gas and sulfate emission scenario proposed by the Intergovernmental Panel on Climate Change. The results from the CCC and HAD models for the GCM grid cell in which the EA region climate falls will be used for the climate change estimate in this study. Specifically, the historical climatic data including temperature and precipitation data from the period 1966 to 1995 and the forecast climatic data for the period 2001 to 2100 generated by the CCC model and the HAD model for the specific San Antonio region were obtained from USGCRP files (2000). Then the average changes in regional temperature and precipitation were calculated for the 10 year periods centered on 2030 and 2090. The resultant estimates are listed in Table I.

Changes in climatic conditions in the EA region would alter water demand and supply. An increase in temperature will cause an increase in water demand for irrigation and municipal use, but would also increase evaporation, lowering runoff and in turn EA recharge. A decrease in rainfall would increase crop and municipal water demand, lower the profitability of dryland farming, and reduce the available water for recharge. Each of these terms was independently estimated.

Recharge implications

To project climatic change effects on EA recharge, a regression analysis was employed to estimate the effects of alternative levels of temperature and precipitation on historically observed recharge. Namely, USGS estimates of historical recharge data by county were drawn from the Edwards Aquifer Authority annual reports for the years 1950 to 1996. County climate data for the same years were obtained from the Office of the Texas State Climatologist and a University of Utah web page.

The functional form used was determined through examination of the statistical significance of the power transformation parameters associated with the dependent and independent variables via the Box Cox Transformation (Box and Cox 1964). Based on a likelihood ratio test the preferred regression model for this data set was a loglinear model. Serial correlation was also tested for but was not found to be significant. Thus monthly recharge was forecast as a loglinear function of temperature and precipitation. The significant recharge regression coefficients all exhibited the expected sign (see Appendix A).

Summary measures of the effect of the projected climate changes on annual recharge for the years 2030 and 2090 under different climate scenarios are displayed in the top of Table II and show that climate change, as projected causes, recharge from 20.59 to 32.89% for drought years and from 23.64 to 48.86% for wet years.

Municipal water use implications

Griffin and Chang (1991) present estimates on how municipal water demand is shifted by changes in temperature and precipitation. In particular, they estimate an elasticity of municipal water demand with respect to a one percent increase in the number of days that temperature exceeds 90 degrees and precipitation falls below 0.25 inches. To obtain the anticipated shifts for the 2030 and 2090 climate conditions, the daily climate record from 1950 to 1996 is adjusted by altering the temperature and precipitation by the projected climate shifts from the climate simulators. In turn the municipal water demand is recomputed. The results (Table II) are that the forecasted climate change is shown to increase municipal water demand by 1.5-3.5%.

Crop yields and irrigation water use

Changes in climatic conditions influence crop yields for irrigated and dryland crops as well as irrigation crop water requirements. For this study, the shift in water use and yield under the projected climate changes was estimated using the Blaney-Criddle (BC) procedure (Heimes and Luckey (1983); Doorenbos and Pruitt (1977)). In particular, the BC procedure is used to alter yields and water use for the 9 recharge/weather states of nature present in the EDSIM model. Summary measures of the resultant effects are presented in Table II which shows a decrease in crop and vegetable yields and an increase in water requirements. For example, under the Hadley climate simulator scenario in 2090, the irrigated corn yield decreases by 3.47% while the irrigation water requirement increases by 31.32%.

. **Methods for Developing Regional Impact**

Once the climate induced changes in water demand and supply were estimated, a regional aquifer model was used to examine the climate change implications. The model that we employed is an existing EA region economic and hydrological simulation model called EDSIM (McCarl et al. 1998). EDSIM depicts pumping use by the agricultural, municipal, and industrial sectors while simultaneously calculating pumping lift, ending elevation, and springflow. EDSIM operates across a 9 state representation of the probability distribution of precipitation, EA recharge, and crop water demand/yield. The model computes regional welfare which is the sum of net farm income and municipal and industrial (M&I) consumers' surplus.

EDSIM is the unification of cumulative developments by Dillon (1991); McCarl et al. (1993); Lacewell and McCarl (1995); Keplinger and McCarl (1995); Keplinger (1996) and Williams (1996). EDSIM simulates regional municipal, industrial and agricultural water use, irrigated versus dryland production and choice of irrigation delivery system (sprinkler or furrow) such that overall regional economic value is maximized subject to legislatively imposed pumping limits. Regional value is derived from a combination of perfectly price elastic demand for agricultural products, agricultural production costs, price elastic municipal demand, price elastic industrial demand, and lift sensitive pumping costs. The municipal demand elasticity is drawn from Griffin and Chang (1991) while the industrial elasticity is obtained from Renzetti (1988). The quantity demanded by municipal users depends upon rainfall and climatic conditions following Griffin and Chang (1991). Agricultural water use dependency on climate is developed using EPIC (Williams et al. 1989).

In terms of its implementation EDSIM is a mathematical programming model which employs a two-stage stochastic programming with recourse formulation (Dantzig 1955). The multiple stages in the model depict the uncertainty inherent in regional water use decision-making. Many water related decisions are made in advance of the time when water availability is known. For example, the decision whether or not to irrigate a particular parcel of land and the choice of the crops to put on that parcel are decided early in the year whereas the true magnitude of recharge is not known until substantially later during the year[1]. Additional details on the algebraic representation of the fundamental relationships in EDSIM can be found in McCarl et al. (1998).

Model Experimentation, Regional Results and Discussion

Five scenarios were considered in this study: 1) BASE without climate change; 2) climate change as predicted by HAD for 2030; 3) climate change ala CCC for 2030; 4) climate change ala HAD for 2030; and 5) climate change ala CCC for 2090.

EDSIM produces economic and hydrological results (Table III). BASE scenario results portrays in Table III are displayed as actual values whereas results under the other scenarios are displayed in terms of percentage change from the BASE. Total water usage is constrained to be less than or equal to the 400,000 af pumping limit as mandated by the Texas Senate for years after 2008. Under the BASE condition agriculture uses 38% of the total pumping while M&I pumping usage accounts for the rest. Total welfare is $355.69 million consisting of $11.39 million from agricultural farm income and $337.65 million from M&I surplus. Additionally, $6.64 million accrues to the Edwards Aquifer Authority (EAA) or water use permit holders and is called authority surplus in the table. This authority surplus can be viewed as the rents to water rights to the 400,000 af available. Comal and San Marcos springflows are 379.5 and 92.8 thousand af, respectively, and are greater than recent average historical levels but recent water use is in the 470-500 thousand af range.

The strongest effect of climate change falls on springflow and the agricultural sector. Under the

[1]This uncertainty is perhaps best illustrated by referring to the Irrigation Suspension Program implemented by the EA authority a couple of years ago where early in the year an irrigation buyout was pursued but the year turned out to be quite wet in terms of recharge.

climate change scenarios springflows at Comal (the most sensitive spring) decrease by 10-16% under the 2030 scenarios and 20-24% under 2090. In terms of agriculture, farm income falls from 16-30% under the 2030 scenarios and 30-45% under 2090. The shift in agricultural water use to M&I water use indicates that the city users will buy out some agricultural usage through water markets.

Despite an increase in M&I water use, the M&I surplus decreases. This is because of an increase in pumping lift and cost due to lower recharge and falling EA levels. The value of water use permits increases by 5-24%. Water use in the nonagricultural sector is less variable and a shift to that sector actually makes water use slightly greater with corresponding declines in springflow.

The reduction in springflow would put the endangered species supported by springflow in additional peril. Thus a reduction in the allowed pumping may be required to protect the springs, endangered species, and other environmental amenities. Table IV presents the results of an examination of how much pumping would need to be reduced to preserve the same level of the Comal and San Marcos springflows as in the BASE situation. This shows that the EA pumping limit level needs to decrease by 35 to 50 thousand af under the 2030 scenarios and 55 to 80 thousand af under 2090. Such further decreases in pumping impose substantial economic costs, reduced agricultural usage and less municipal usage.

Concluding Remarks

Projected changes in climatic conditions cause a reduction in the available water resources and a water demand increase in the San Antonio Edwards Aquifer region. The incidence of this change largely manifests itself in reduced springflows, less irrigation, and a regional welfare loss of $2.2 -$6.8 million per year. If springflows are to be maintained at the current desired level to protect endangered species, pumping must be reduced by 9 - 20% at an additional cost of $0.5 to $2 million per year.

Table 1. Projected Percentage Changes in Edwards Aquifer Region Temperature and Precipitation under Climate Change Scenarios

Climate Change Scenario	Temperature (^{0}F)	Precipitation (Inches)
HAD 2030	3.20	-4.10
HAD 2090	9.01	-0.78
CCC 2030	5.41	-14.36
CCC 2090	14.61	-4.56

Table II. Selected Effects of Climate Scenarios on EA Regional items

Result	Climate Scenario			
	HAD-2030	HAD-2090	CCC-2030	CCC-2090
	-- Percentage Change from without climate change case --			
Recharge in drought years	-20.59	-32.89	-29.65	-31.96
Recharge in normal years	-19.68	-33.46	-28.99	-36.23
Recharge in wet years	-23.64	-41.45	-34.42	-48.86
Municipal Water demand	1.539	2.521	1.914	3.468
Irrigated Corn Yield	-1.93	-3.47	-4.26	-5.61
Irrigated Corn Water Use	11.95	31.32	23.47	54.03
Dryland Corn Yield	-3.93	-6.78	-8.17	-10.79
Irrigated Sorghum Yield	-1.75	-3.35	-2.79	-4.17
Irrigated Sorghum Water Use	15.12	38.16	42.65	79.36
Dryland Sorghum Yield	-5.93	-13.07	-10.82	-16.76
Irrigated Cotton Yield	-9.06	-15.82	-19.80	-24.64
Irrigated Cotton Water Use	16.88	40.82	34.58	71.50
Dryland Cotton Yield	-7.13	-11.60	-13.95	-17.76
Irrigated Cantaloupe Yield	-1.34	-2.33	-2.86	-3.58
Irrig. Cantaloupe Water Use	18.95	46.47	41.41	82.68
Irrigated Cabbage Yield	-5.57	-12.05	-9.63	-14.72
Irrigated Cabbage Water Use	14.80	30.95	36.36	71.30

Table III. Aquifer Regional Results under Alternative Climate Change Scenarios

Variable	Units	Base	Climate Scenario			
			HAD-2030	HAD-2090	CCC-2030	CCC-2090
			------------ Percent change from Base Scenario ------------			
Ag Water Use [a]	1000 af	150.05	-0.89	-2.4	-1.35	-4.15
M&I Water Use [b]	1000 af	249.72	0.63	1.54	0.9	2.59
Total Water Use	1000 af	399.77	0.06	0.06	0.06	0.06
Net AG Income [c]	1000 $	11391	-15.85	-30.34	-29.41	-44.97
Net M&I Surplus [d]	1000 $	337657	-0.2	-0.58	-0.36	-0.92
Authority Surplus [e]	1000 $	6644	3.76	12.73	7.07	21.6
Net Total Welfare	1000 $	355692	-0.64	-1.3	-1.16	-1.93
Comal Flow [f]	1000 af	379.5	-9.95	-20.15	-16.62	-24.15
San Marcos Flow [g]	1000 af	92.8	-5.07	-10.09	-8.3	-12.06

a Total agricultural water use.
b Total municipal and industrial water use.
c Net farm income.
d Net municipal and industrial surplus.
e Welfare accruing to the pumping or springflow limit -- the rental value of all permits
f Total Annual flow at Comal springs
g Total Annual flow at San Marcos springs.

Table IV. Results of Analysis on Needed Pumping Limit to Preserve Springflows at Base, without Climate Change Levels

Variable	Units	Base	Climate Scenario			
			HAD-2030	HAD-2090	CCC-2030	CCC-2090
			------------ Percent change from Base Scenario ------------			
Pumping Limit	1000 af	400	365	350	345	320
AG Water Use	1000 af	150.05	-16.46	-22.74	-23.69	-46.08
M&I Water Use	1000 af	249.72	-4.03	-6.27	-7.7	-4.26
Total Water Use	1000 af	399.77	-8.7	-12.45	-13.7	-19.95
Net AG Income	1000 $	11391	-18.43	-33.44	-34.6	-58.28
Net M&I Surplus	1000 $	337657	-0.78	-1.3	-1.86	-1.88
Authority Surplus	1000 $	6644	32.33	52.53	73.66	68.34
Net Total Welfare	1000 $	355692	-0.78	-1.41	-1.62	-2.47
Comal Flow	1000 af	379.5	1.47	0.52	1.22	-1.06
San Marcos Flow	1000 af	92.8	-0.28	-1.13	-1.11	-2.48

Note: The pumping limit row gives the maximum amount of pumping that could occur if one were to maintain the Base Model springflow levels (within 2%)

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Appendix A: Regression Results for the Edwards Aquifer Recharge Prediction

The climate dependent recharge regression is estimated by county and month and is specified as a loglinear function of temperature (*Tempt*) and precipitation (*Precip*):

$$\ln \text{Recharge}_{ijk} = \alpha_{ij} + \beta_{ij} \ln \text{Tempt}_{ij} + \delta_{ij} \ln \text{Precip}_{ij} + \varepsilon_{ijk}$$

for i = Kinney, Uvalde, Medina, Bexar, Comal, and Hays, j = January, February, ... , December, and k for the repeated observations for the years 1950 to 1996. Thus there are 47 observations used to estimate each regression and 72 equations are estimated.

The regression results for the EA recharge prediction are given in Table A-I. Results indicate the effect of the climatic variables (temperature and precipitation) on EA recharge by time period (month). One would expect a negative temperature coefficient since increased temperature would increase evaporation and plant water use thus reducing the amount of recharge to the aquifer. On the other hand, a positive precipitation coefficient indicates that the recharge to the aquifer increases as rainfall increases. Most of the temperature coefficients are negative as expected and those with unexpected signs are statistically insignificant. All the precipitation coefficients have positive signs. Furthermore, the results show that temperature during the summer time (June-August) has a stronger impact on recharge than the other periods and the Uvalde and Medina Counties (where the bulk of the recharge occurs) are more sensitive to changes in temperature than the other Counties. The R^2 goodness of fit measures are small which is a result of omitted variables which influence Edwards Aquifer recharge above and beyond temperature and precipitation.

Table A-I. Regression Results for the Edwards Aquifer Recharge Prediction

Variables	Units	Kinney County	Uvalde County	Medina County	Bexar County	Comal County	Hays County
January:							
Intercept		5.91 (0.89)[a]	15.47* (2.06)	16.19* (2.29)	26.49* (2.86)	31.40* (1.95)	13.12* (1.99
Temperature	ºF	-1.30 (0.77)	-3.32* (1.74)	-3.62* (2.01)	-6.30* (2.67)	-7.93* (1.92)	-3.12* (1.82)
Precipitation	Inch	0.12* (1.99)	0.10* (1.55)	0.10* (1.66)	0.20* (2.26)	0.11 (0.76)	0.05 (1.08)
R-Square		0.1261	0.1549	0.1862	0.2464	0.0934	0.0911
February:							
Intercept		5.14 (1.52)	20.35* (2.92)	18.05* (2.02)	13.97 (1.09)	-0.09 (0.01)	8.29 (1.14)
Temperature	ºF	-3.40* (1.45)	-4.48* (2.58)	-3.99* (1.79)	-3.02 (0.95)	0.25 (0.12)	-1.75 (0.96)
Precipitation	Inch	0.06* (1.45)	0.03 (0.90)	0.02 (0.45)	0.09 (0.85)	0.069 (1.47)	0.10* (2.79)
R-Square		0.1365	0.2101	0.1046	0.0481	0.0469	0.1751
March:							
Intercept		9.72 (0.42)	10.55 (1.29)	16.14* (1.84)	17.78 (1.28)	-3.82 (0.17)	20.42 (0.87)
Temperature	ºF	-2.10 (0.39)	-1.94 (0.98)	-3.40 (1.60)	-3.88 (1.15)	1.10 (0.20)	-4.75 (0.83)
Precipitation	Inch	0.27 (1.23)	0.22* (2.91)	0.20* (2.48)	0.53* (3.84)	0.30* (3.32)	0.09 (0.82)
R-Squared		0.0515	0.2344	0.2336	0.3036	0.2047	0.0367

Table A-I: Continued.

Variables	Units	Kinney County	Uvalde County	Medina County	Bexar County	Comal County	Hays County
April:							
Intercept		6.28 (0.16)	46.32* (3.37)	44.10* (3.00)	10.61 (0.51)	-44.68 (0.75)	-3.07 (0.11)
Temperature	ºF	-1.33 (0.14)	-10.32* (3.19)	-9.87* (2.86)	-2.19 (0.45)	10.56 (0.75)	1.02 (0.15)
Precipitation	Inch	0.05 (0.35)	0.10* (1.80)	0.12* (2.06)	1.15* (6.43)	0.21 (1.33)	0.09 (1.06)
R-Square		0.0038	0.2636	0.2492	0.5024	0.0554	0.0250
May:							
Intercept		51.80* (2.99)	73.77* (4.63)	77.00* (4.51)	88.80* (3.34)	71.10 (1.29)	21.05 (1.27)
Temperature	ºF	-11.69* (2.93)	-16.39* (4.47)	-17.17* (4.36)	-20.13* (3.29)	-16.39 (1.29)	-4.51 (1.18)
Precipitation	Inch	0.07 (1.56)	0.01 (0.33)	-0.04 (1.00)	0.53* (2.68)	0.50* (3.57)	0.15* (2.36)
R-Square		0.2284	0.3386	0.3277	0.4365	0.2710	0.1515
June:							
Intercept		92.41 (1.12)	113.80* (4.77)	116.13* (4.37)	64.88* (1.67)	26.11 (0.32)	-15.09 (0.31)
Temperature	ºF	-20.84 (1.11)	-25.22* (4.66)	-25.81* (4.29)	-14.32 (1.63)	-5.74 (0.31)	3.76 (0.34)
Precipitation	Inch	0.05 (0.34)	0.06 (1.25)	0.01 (0.28)	0.57* (3.35)	0.14 (1.21)	0.10 (1.24)
R-Square		0.0452	0.4424	0.3580	0.3243	0.0374	0.0365

Table A-I. Continued.

Variables	Units	Kinney County	Uvalde County	Medina County	Bexar County	Comal County	Hays County
July:							
Intercept		-52.77	149.60*	125.13*	95.14	28.21	10.36
		(0.48)	(5.23)	(4.88)	(1.58)	(0.35)	(0.51)
Temperature	ºF	11.97	-33.21*	-22.78*	-21.10	-6.26	-2.09
		(0.48)	(5.14)	(4.80)	(1.55)	(0.34)	(0.45)
Precipitation	Inch	0.21*	0.01	0.01	0.40*	0.37*	0.12*
		(1.70)	(0.47)	(0.63)	(4.14)	(3.69)	(2.68)
R-Square		0.0715	0.4955	0.4073	0.3913	0.2437	0.1749
August:							
Intercept		129.87	93.42*	97.51*	259.38*	81.88	20.58
		(0.89)	(3.65)	(4.64)	(2.35)	(0.99)	(1.11)
Temperature	ºF	-29.32	-20.58*	-21.56*	-58.28*	-18.47	-4.43
		(0.77)	(3.56)	(4.55)	(2.34)	(0.99)	(1.06)
Precipitation	Inch	0.03	0.14*	0.01	0.32*	0.55*	0.88*
		(0.18)	(2.81)	(0.40)	(1.74)	(3.39)	(1.99)
R-Square		0.0766	0.4874	0.4180	0.2258	0.2505	0.1148
September:							
Intercept		25.40	26.59	36.20*	100.08*	-48.74	1.15
		(0.36)	(1.02)	(2.10)	(1.68)	(0.52)	(0.28)
Temperature	ºF	-5.85	-5.59	-7.84*	-23.00*	10.88	-0.008
		(0.37)	(0.94)	(1.99)	(1.69)	(0.51)	(0.008)
Precipitation	Inch	0.93*	0.54*	0.31*	1.66*	0.58	0.09*
		(2.11)	(3.27)	(2.10)	(3.83)	(0.92)	(2.04)
R-Square		0.1208	0.2666	0.2942	0.3296	0.0217	0.0873

Table A-I. Continued.

Variables	Units	Kinney County	Uvalde County	Medina County	Bexar County	Comal County	Hays County
October:							
Intercept		52.30 (0.85)	31.12* (2.02)	40.27* (2.91)	61.69 (1.58)	-46.62 (1.14)	34.76* (2.24)
Temperature	ºF	-12.35 (0.85)	-6.69* (1.85)	-8.97* (2.76)	-14.25 (1.55)	10.90 (1.13)	-7.96* (2.18)
Precipitation	Inch	0.60* (3.45)	0.14* (3.35)	0.10* (2.64)	0.46* (2.67)	0.42* (2.18)	0.04 (1.08)
R-Square		0.2468	0.2792	0.2802	0.1668	0.1222	0.1100
November:							
Intercept		57.30 (1.52)	0.16 (0.01)	13.86 (1.29)	11.94 (0.68)	89.29* (2.12)	9.63 (0.96)
Temperature	ºF	-13.98 (1.51)	0.54 (0.15)	-2.91* (1.11)	-2.60 (0.61)	-21.90* (2.13)	-2.06 (0.84)
Precipitation	Inch	0.01 (0.10)	0.05 (1.09)	0.05 (1.13)	0.37* (3.82)	0.61* (4.25)	0.13* (2.97)
R-Square		0.0579	0.0291	0.0840	0.2726	0.3110	0.1852
December:							
Intercept		2.82 (0.32)	-0.21 (0.02)	-1.64 (0.18)	4.25 (0.40)	10.81 (0.66)	1.01 (0.10)
Temperature	ºF	-0.50 (0.22)	0.68 (0.27)	0.94 (0.41)	-0.64 (0.24)	-2.55 (0.61)	-0.05 (0.02)
Precipitation	Inch	0.10* (2.54)	0.11* (2.47)	0.13* (3.25)	0.64* (4.26)	0.15* (1.71)	0.14* (2.29)
R-Square		0.1520	0.1337	0.2107	0.2941	0.0698	0.1109

Asterisk (*) indicates significance at the 0.10 level
[a] Absolute values of the t-ratio are given in parentheses.