URBANIZATION OF IRRIGATION DISTRICTS IN THE TEXAS RIO GRANDE RIVER BASIN

Gabriele Bonaiti, Ph.D.[1]
Guy Fipps, Ph.D., P.E.[2]

ABSTRACT

The region of Texas along the Mexican border has been experiencing rapid urban growth. This has caused fragmentation of many irrigation districts who are struggling to address the challenges resulting from urbanization. This paper presents an analysis of the growth of urban area in five Texas border counties with irrigation districts. Over the ten year period, 1996 to 2006, urban area within these counties increased at a regional average of 21%. The urban area within districts increased an average of 44% based on total district service area. The paper also presents a density analysis of urbanized area and analysis of the impacts on water distribution networks. Urbanization issues related to the operation, management, and planning within districts are also discussed.

INTRODUCTION

Industrial, commercial and retirement community development are resulting in rapid urban growth within portions of the Texas Rio Grande River Basin. The fastest growing areas are Hidalgo and Cameron Counties. The four largest cities of Alamo, McAllen, Brownsville and Harlingen are among the fastest growing cities in the USA (Stubbs et al., 2003; City of McAllen, 2010).

Irrigation districts hold the vast majority of the agricultural water rights (i.e., Texas Class A or similar allocations) in the border region which accounts for about 70% of the total available surface water in the seven counties of El Paso, Hudspeth, Maverick, Kinney, Hidalgo, Willacy, and Cameron (TCEQ, 2010). As districts urbanize, Texas water laws and regulations require that the associated water rights are transferred from agricultural to municipal water use. Thus, not only does urbanization reduce the size of their service areas, but the amount of water the districts have access to and which flows through their canals and pipelines.

Most districts in the region do very little analysis of the effects of urbanization on their operation and management procedures, or incorporate urbanization trends into planning for future infrastructure improvements.

This paper discusses the potential impacts of urbanization and identifies methodologies that can help to interpret the urban growth dynamics and effects.

[1] Extension Associate, Department of Biological and Agricultural Engineering, 2117 Texas A&M University, College Station, Texas 77843-2117; gbonaiti@ag.tamu.edu
[2] Professor and Extension Agricultural Engineer, Department of Biological and Agricultural Engineering, 2117 Texas A&M University, College Station, Texas 77843-2117; g-fipps@tamu.edu

MATERIALS AND METHODS

Study area

Results are presented on five of the six counties along the Texas-Mexico border, which contain irrigation districts with Texas Class A water rights, and the El Paso Water Improvement District, which has a water allocation based on the Rio Grande River Compact (Fig. 1). Presidio Water Improvement District No.1 does not contain any urbanized areas so this district and county are not included in the results presented here.

El Paso and Maverick Districts have a total service area of 279,713 acres and 606 miles of main canals. The Lower Rio Grande Valley contains 29 irrigation districts with a total service area of 759,481 acres, and a canal system 3,174 miles long.

The authorized Class A water rights of the irrigation districts in the Lower Rio Grande Region are listed in Table 1 along with the reported water allotment for the El Paso district under the Rio Grande Compact. Based on water rights, the districts vary greatly in size. In the Lower Rio Grande Basin, the smallest active district has 1,120 ac-ft of Class A Water Right, while the largest district has 177,151 ac-ft. Actual water allocations in any given year depend on the amount of water stored in Amistad and Falcon Reservoirs for region B and C.

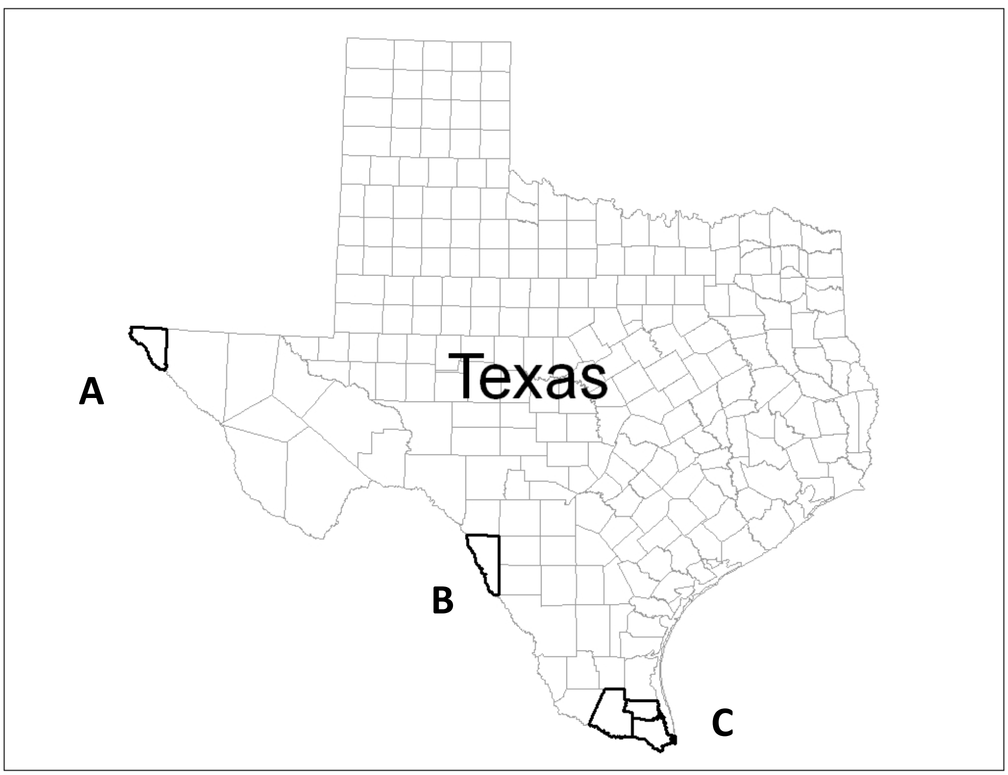

Figure 1. Area of study. A: El Paso County; B: Maverick County; C: Hidalgo, Willacy, and Cameron Counties

Table 1. Class A Water Rights of districts in the Lower Rio Grande Basin and Water Allocation for El Paso under the Rio Grande Compact

District	Class A Water Right (Acre-Feet)
Adams Garden Irrigation District No.19 (Adams Garden)	18,738
Bayview Irrigation District No.11 (Bayview)	16,978
Brownsville Irrigation District (Brownsville)	33,949
Cameron County Water Improvement District No.16 (CCWID16)	3,713
Cameron County Irrigation District No.2 (CCID2)	147,824
Cameron County Irrigation District No.6 (CCID6)	52,142
Cameron County Water Improvement District No.10 (CCWID10)	8,488
Delta Lake Irrigation District (Delta Lake)	174,776
Donna Irrigation District-Hidalgo County No.1 (Donna)	94,064
El Paso County Water Improvement District No.1 (El Paso)	388,000*
Engelman Irrigation District (Engelman)	20,044
Harlingen Irrigation District-Cameron County No.1 (Harlingen)	98,233
Hidalgo and Cameron County Irrigation District No.9 (HCCID9)	177,152
Hidalgo County Irrigation District No.1 (HCID1)	85,615
Hidalgo County Irrigation District No.13 (HCID13)	4,857
Hidalgo County Irrigation District No.16 (HCID16)	30,749
Hidalgo County Irrigation District No.19 (HCID19)	9,048
Hidalgo County Water Control and Improvement District No.18 (HCWCID18)	5,318
Hidalgo County Irrigation District No.2 (HCID2)	137,675
Hidalgo County Water Improvement District No.5 (HCWID5)	14,235
Hidalgo County Irrigation District No.6 (HCID6)	34,913
Hidalgo County Municipal Utility District No.1 (HCMUD1)	1,120
Hidalgo County Water Improvement District No.3 (HCWID3)	9,753
La Feria Irrigation District-Cameron County No.3 (La Feria)	75,626
Maverick County Water Control & Improvement District No.1 (Maverick)	134,900
Presidio County Water Improvement District No.1 (Presidio)	2,780
Santa Cruz Irrigation District No.15 (Santa Cruz)	75,080
Santa Maria Irrigation District-Cameron County No.4 (Santa Maria)	10,183
United Irrigation District of Hidalgo County (United)	57,374
Valley Acres Water District (Valley Acres)	16,124
Valley Municipal Utility District No.2 (VMUD2)	5,511

* Water allocation under the Rio Grande Compact

El Paso County Water Improvement District No.1 is allocated water according to the Rio Grande Compact. The District receives 388,000 ac-ft ("full allocation") or 43% of the available water supply in Elephant Butt and Caballo Reservoirs, whichever is less. Hudspeth County Conservation & Reclamation District No.1 has Texas Class B water rights and is not included in this analysis.

Urbanization Analysis

Urban area expansion. The maps and calculations of urban area were done using the Geographic Information System (GIS) software ArcView 9.3 and are based on aerial photography taken in 1996 and 2006. This aerial photography or Digital Orthophoto Quadrangle Imagery (DOQs) was obtained from the Texas Natural Resources Information System (http://www.tnris.state.tx.us). The 1996 DOQs have a resolution of 1 meter, while the 2006 DOQs have a 2 meter resolution.

For this paper, "urban area" is loosely defined as a continuous developed and/or developing area that is no longer in agricultural use. We included all residential communities and subdivisions (with or without homes) that are clearly identifiable from aerial photographs. We also included properties with more than one dwelling or other structure on a single piece of property. Single dwellings on large properties outside the city limits were excluded (Leigh et al., 2009).

The results may be viewed as a density analysis. A similar density analytic approached was used by Ritters (2000) in determining fragmentation of forests through an automatic pixel analysis of aerial photography. Ritters' analysis was used to determine the progressive intrusion of urbanization classified into the categories: edge, perforated, transition and patched.

Overlap of urban area with water distribution networks. A further analysis was done to determine the overlap of urbanization with the water distribution network. We used the option of the Kernel density to count the times in a given area that the canals were overlapped by urbanization. This method is a data smoothing technique that gives more weight to points near the center of each search area and allows for creating a more continuous surface that is easier to interpret (Kloog et al., 2009). To facilitate comparison among the different study areas, we normalized the Kernel density based on the highest observed value. We obtained a scale that ranges from 0 to 1, and we called it Network Fragmentation Index (NFI).

For each district, we calculated the ratio between the times that the canals were overlapped by urbanization and the total length of canals. This computation has the advantage of giving one number for each irrigation district. We called this ratio District Fragmentation Index (DFI).

RESULTS

Urbanization Analysis

Table 2 lists the increase in total urban area between 1996 and 2006 by county. The highest increase in both area and as a percentage of total area was in Hidalgo County. Table 3 lists the percentage of urban area within 30 irrigation districts in 1996 and 2006. As a percentage of the district, the most urbanized district is HCMUD1 at 89.5%, while Valley Acres and Bayview are the least urbanized. Table 4 lists our estimate of the total urban area within each district in terms of both acres and percentage increase from 1996 and 2006. HCID2 has the largest number of urban acres, while the largest increases in urban area as a percentage of the district were in HCID16, HCWCID18 and HCID19. There were no increases in VMUD2 and Valley Acres.

Table 2. Urban area within Counties in 1996 and 2006

County	Total Area (Acres)	Urban Area 1996 (Acres)	Urban Area 2006 (Acres)	Increase (%)
Cameron	613,036	66,189	81,635	23
El Paso	656,492	208,180	234,155	12
Hidalgo	1,012,982	118,466	160,095	35
Maverick	826,915	9,816	12,019	22
Willacy	393,819	3,084	3,509	14

Table 3. Urban area within districts as a percentage of total district service area in 1996 and 2006

District	Approx. District Area (Acres)	Percentage of District Area: Urban Area 1996	Percentage of District Area: Urban Area 2006
Adams Garden	9,600	5.5 %	14.4 %
Bayview	10,700	0.2 %	1.1 %
Brownsville	22,000	40.0 %	45.3 %
CCWID16	2,200	12.0 %	19.2 %
CCID2	79,000	10.6 %	13.8 %
CCID6	33,000	13.3 %	23.8 %
CCWID10	4,700	3.0 %	4.8 %
Delta Lake	85,600	1.3 %	2.2 %
Donna	47,000	9.3 %	15.5 %
El Paso	92,800	35.5 %	38.2 %
Engelman	11,200	1.3 %	2.9 %
Harlingen	56,500	26.0 %	30.0 %
HCCID9	87,900	19.0 %	26.0 %
HCID1	38,600	58.7 %	66.0 %
HCID13	2,200	5.4 %	21.5 %
HCID16	13,600	0.6 %	7.4 %
HCID19	4,800	0.0 %	40.0 %
HCWCID18	2,400	0.6 %	12.6 %
HCID2	72,600	45.5 %	54.0 %
HCWID5	8,100	14.1 %	17.6 %
HCID6	22,900	24.8 %	42.0 %
HCMUD1	2,000	50.3 %	89.5 %
HCWID3	9,100	72.4 %	76.0 %
La Feria	36,200	7.3 %	10.5 %
Maverick	148,700	0.1 %	8.1 %
Santa Cruz	39,500	7.3 %	9.4 %
Santa Maria	4,000	6.0 %	9.1 %
United	37,800	40.6 %	47.1 %
Valley Acres	11,200	1.4 %	1.4 %
VMUD2	4,800	23.8 %	23.8 %

Table 4. Urban acreage within districts in 1996 and 2006

District	Urban Area 1996 (Acres)	Urban Area 2006 (Acres)	Percent Increase
Adams Garden	532	1,380	160 %
Bayview	24	120	392 %
Brownsville	8,724	9,915	14 %
CCWID16	260	415	60 %
CCID2	8,384	10,925	30 %
CCID6	4,439	7,948	79 %
CCWID10	135	224	66 %
Delta Lake	1,127	1,841	63 %
Donna	4,357	7,310	68 %
El Paso	32,967	35,443	8 %
Engelman	144	331	130 %
Harlingen	14,662	16,955	16 %
HCCID9	16,721	22,716	36 %
HCID1	22,633	25,327	12 %
HCID13	117	469	302 %
HCID16	83	1,005	1109 %
HCID19	0	1,908	–
HCWCID18	15	300	1924 %
HCID2	33,006	39,107	19 %
HCWID5	1,142	1,424	25 %
HCID6	5,677	9,595	69 %
HCMUD1	1,016	1,811	78 %
HCWID3	6,618	6,936	5 %
La Feria	2,626	3,809	45 %
Maverick	9,794	11,972	22 %
Santa Cruz	2,889	3,715	29 %
Santa Maria	242	365	51 %
United	15,336	17,794	16 %
Valley Acres	162	162	0 %
VMUD2	1,142	1,142	0 %

Table 5. Percent (%) increase in the length of canals and pipelines overlapped by urbanization from 1996 to 2006

	Category		Material			Type		
Irrigation District	Secondary	Main	Concrete	Earth	PVC	Canal	Pipeline	Total
Adams Garden	53	163	62	588	33	210	51	66
Bayview	432	39		130		225	279	255
Brownsville	28	8	21		44		22	21
CCWID16		5		5		5		5
CCID2	69	37	42	50	163	52	51	52
CCID6	58	21	49	40		48	35	45
CCWID10		168		72		72		182
Delta Lake	104	107	111			94	110	104
Donna	41	74	49	14		70	18	46
Engelman	62	148	76			129	70	76
Harlingen	37	9	35	7		9	37	28
HCCID9	22	12	20	9		12	22	20
HCID1	11	12	12	6	22	8	13	11
HCID13	0	93	0		161		93	84
HCID16	780	294	752		262	387	808	648
HCID2	12	20	12	55	3	27	13	15
HCWID5		1	1				1	1
HCID6	28	38	37			32	27	29
HCWID3		22		81		31		21
La Feria	32	31	37	4		24	35	32
Santa Cruz	16	29	19			17	19	19
Santa Maria	103		103				103	58
United	9	18	10		41	14	9	10
Total	29	24	27	30	36	34	24	27

Effects on the water distribution network

The distribution networks are also increasingly engrossed by urban areas (Table 5). During this ten year period, about eight hundred more acres (28% increase) of storage facilities (reservoirs and *resacas*[3]) became a part of urban areas and an additional 27% of canals (360 miles) flow through urban areas. Figure 2 shows the urban areas in Hidalgo County in 1996 and 2006, along with the service area boundaries of the irrigation districts. Figure 3 shows the network overlapped by urbanization and the NFI (Network Fragmentation Index), where an index of 1 represents the greatest fragmentation of canals.

Figures 4 and 5 show the DFI (District Fragmentation Index) for 1996 and 2006, respectively, as a single number for each district. Also shown are the NFI. We found that the two indexes are consistent.

---

[3] An area of river bed that is flooded in periods of high water; an artificial reservoir (Dictionary of American Regional English, 2011)

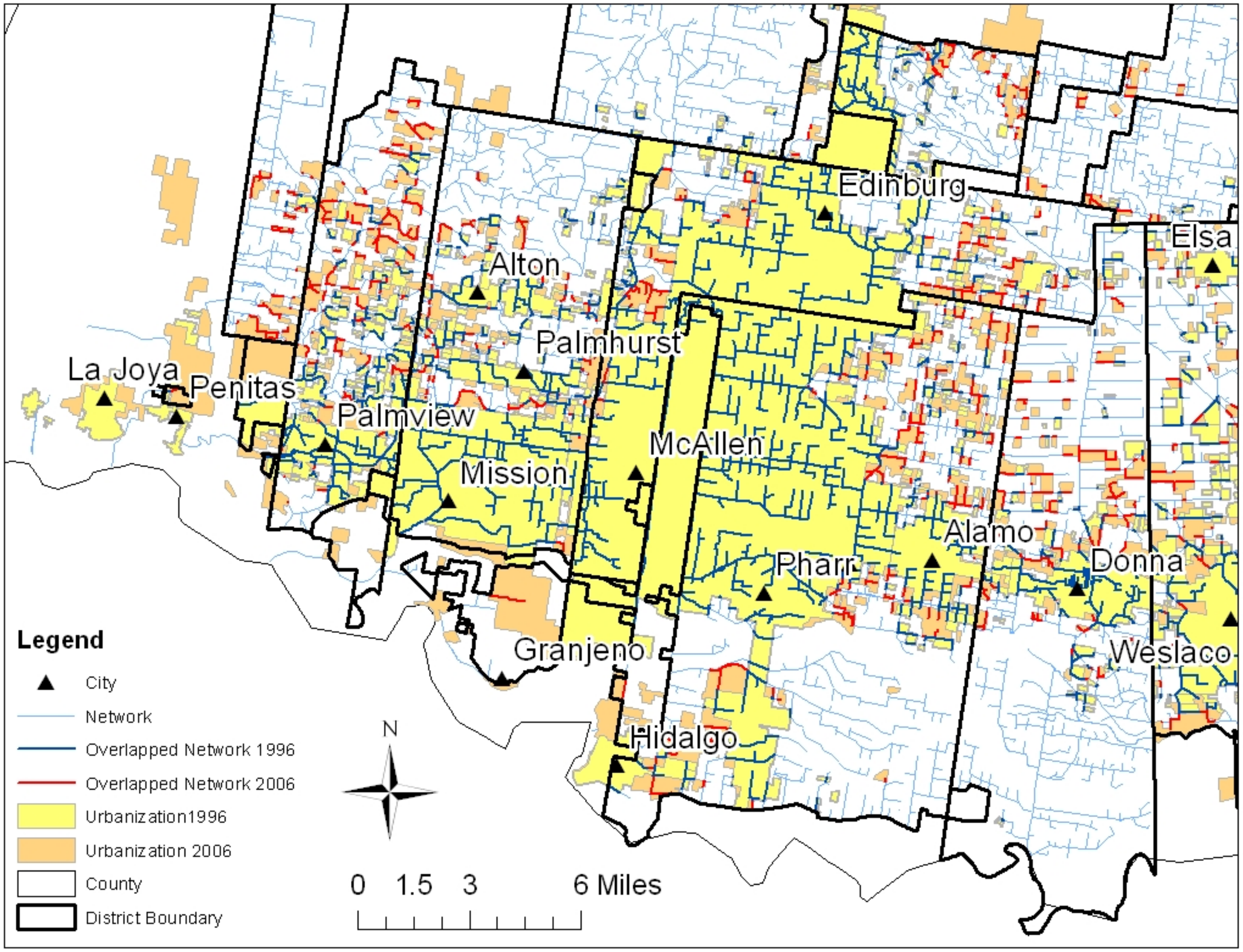

Figure 2. Urbanization in the McAllen area of the Hidalgo County in 1996 and 2006

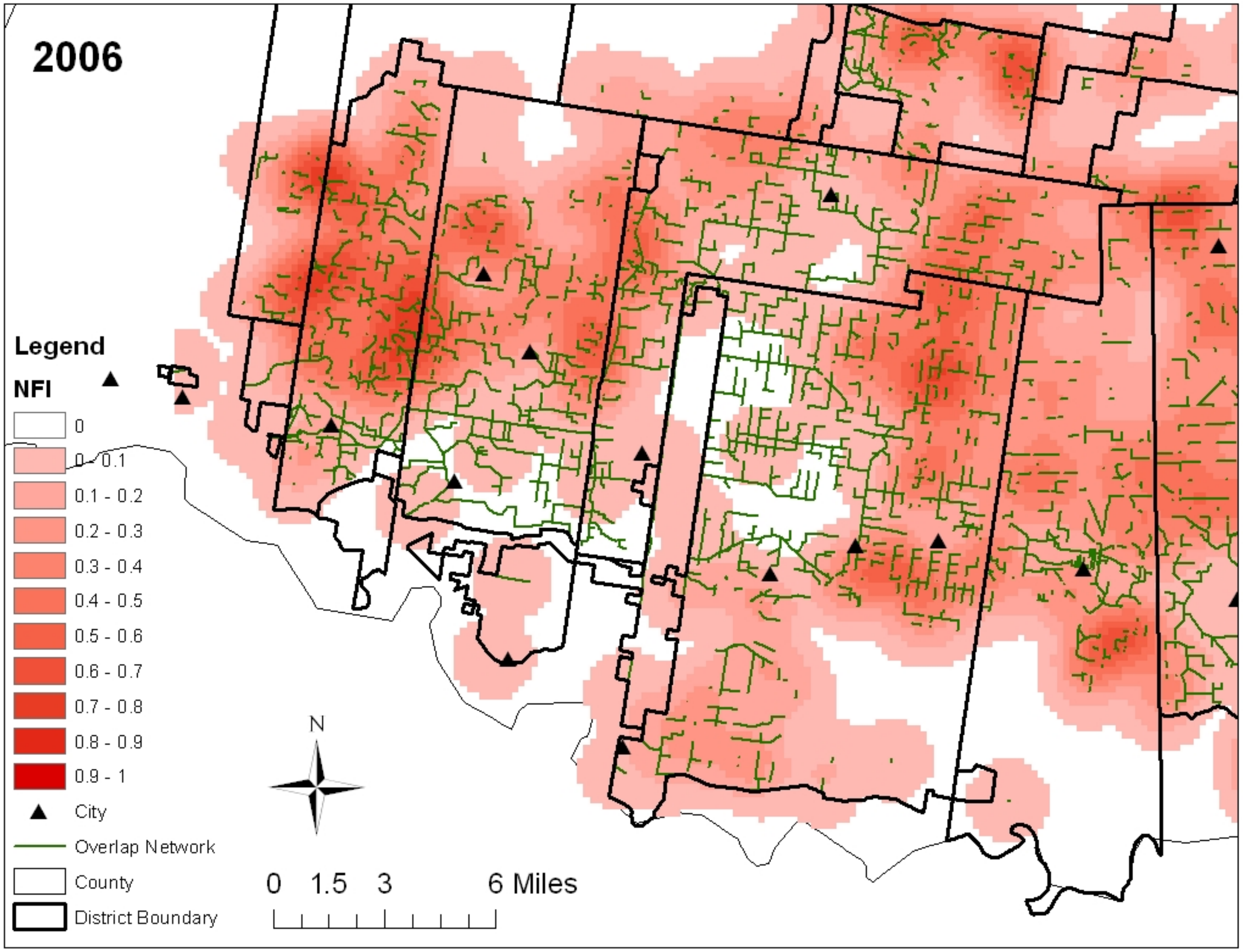

Figure 3. Overlapped network by urbanization (green lines) and Network Fragmentation Index (red areas) in the McAllen area of the Hidalgo County, in the year 2006

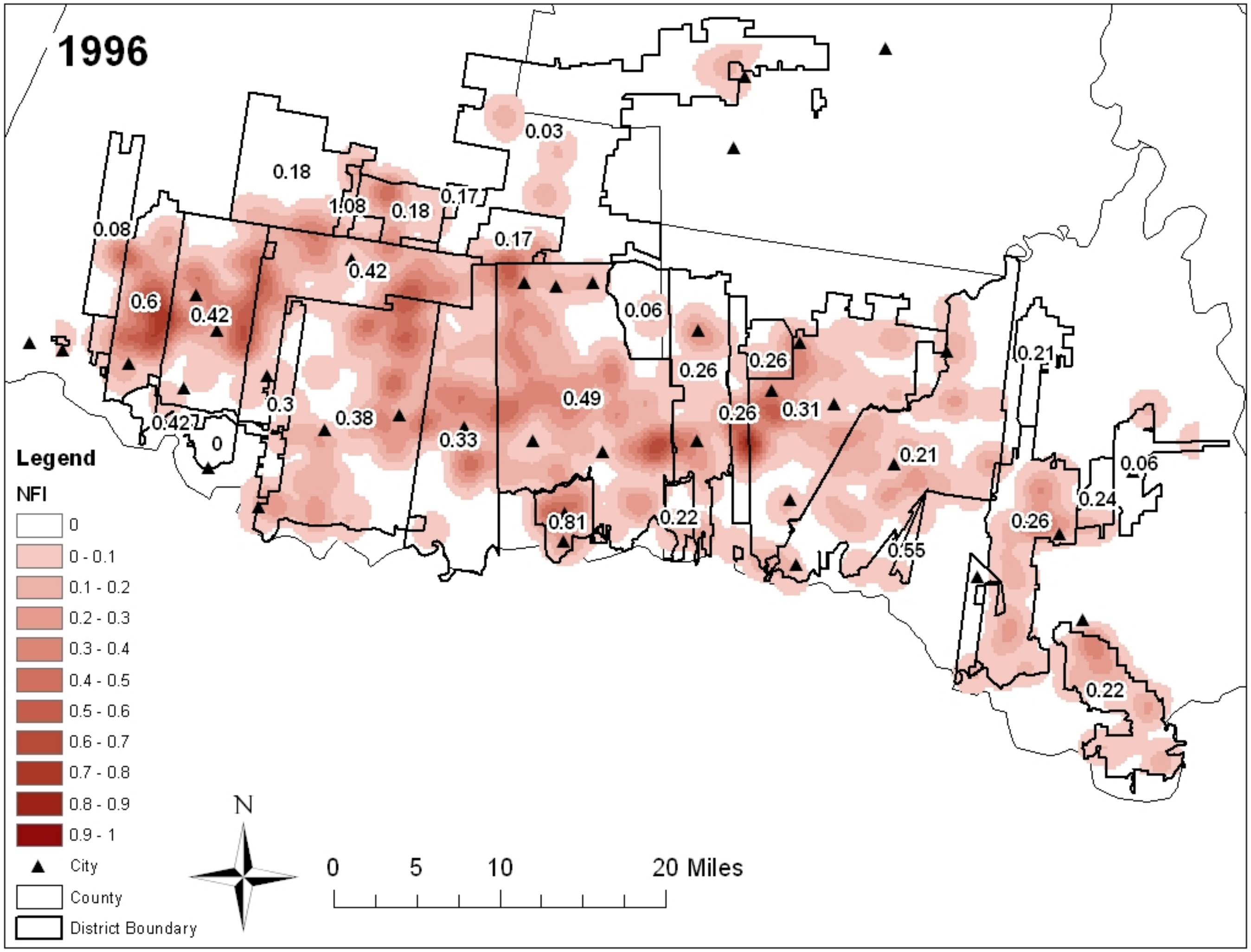

Figure 4. District Fragmentation Index (DFI) for each district along with the NFI (Network Fragmentation Index), shown as a density map, in the year 1996

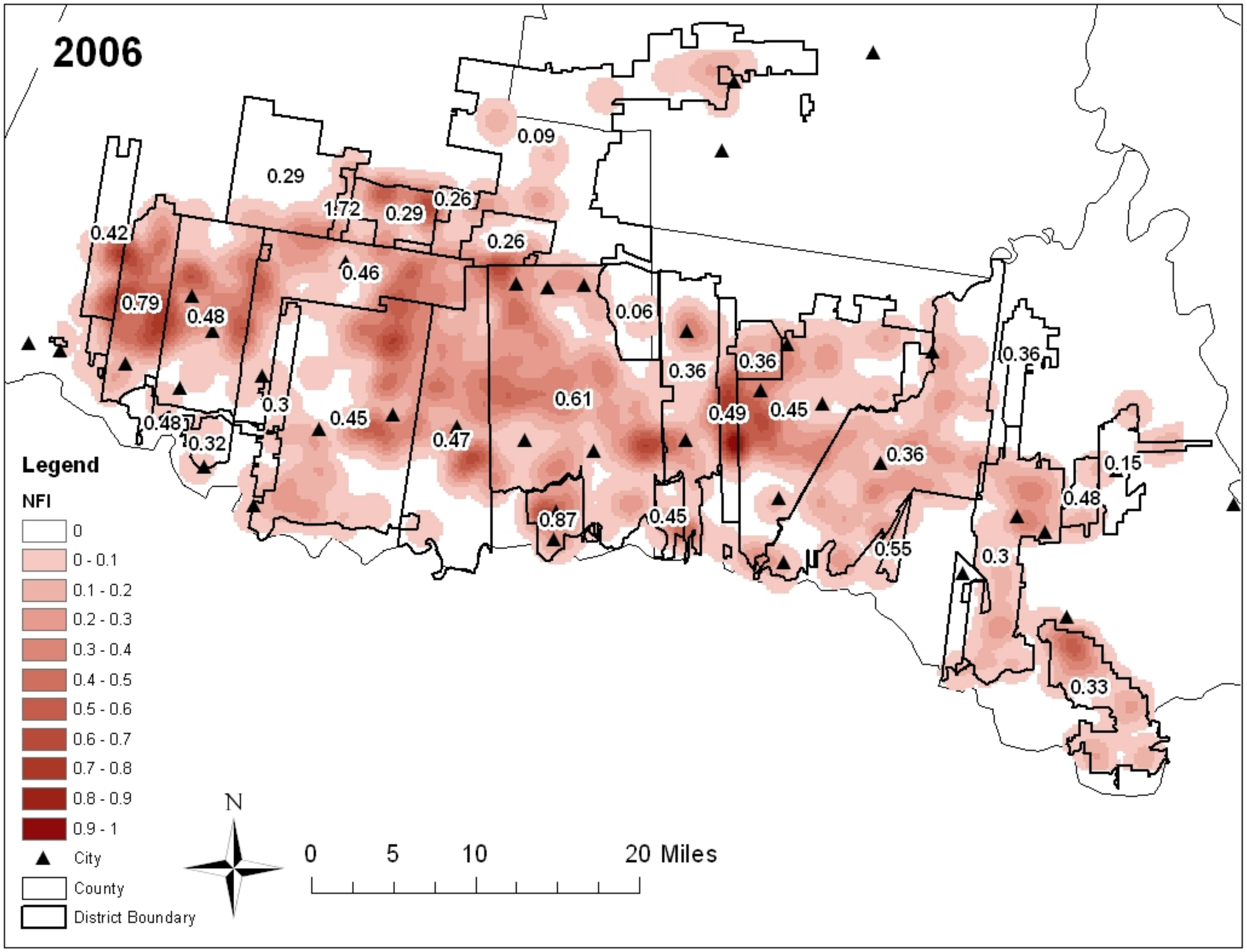

Figure 5. District Fragmentation Index (DFI) for each district along with the NFI (Network Fragmentation Index), shown as a density map, in the year 2006

DISCUSSION

Potential Impacts

Impacts of urbanization can affect Districts in several different ways.

Access to network and structures. Districts in this region primarily operate their systems manually, with a canal rider personally moving from site to site. An increasing presence of subdivisions or isolated houses can create access to and maintenance of facilities difficult or more time consuming. As a consequence, operations might take more time due to discontinuous access to structures or requiring the district to construct new facilities to operate the network correctly.

Transfer of water rights from agricultural to other uses. Transfer of water rights from agricultural to other uses reduces the total amount of water flowing through the water distribution networks, which typically decreases conveyance efficiency and increases losses.

Increasing liability for canal breaks and flooding. The increasing presence of subdivisions and industrial areas in the vicinity of the delivery network increases liability for canal breaks and flooding. Such areas may suffer significant damages from minor flooding events. This is not a new phenomenon in most districts, but such situations are rapidly increasing, requiring investments in studies and structural changes. Subbasins must be identified, and flood management plans put in place to clearly define risks, potential impacts, emergency action, and short and long term measures and investments.

Fragmentation and shrinking of irrigation area. Urbanization is causing the fragmentation and loss of agricultural land. Districts eventually will have to abandon structures that are no longer needed and invest in new ones to ensure good operations. Urbanization causes canals to become oversized, thereby affecting: how the system operates, operational efficiency, and the ability to deliver increasing smaller volumes of water. In addition, revenues from water sales decrease, requiring districts to increase rates.

CONCLUSIONS

Methodologies were presented to interpret the fast urban growth dynamics in the region of Texas along the Mexican border. They show promise in helping irrigation districts identify the impact of urban growth. The density analysis produces maps that clearly identify and quantify urbanization and that are easy to use and interpret. Two new indexes, the Network Fragmentation Index (NFI) and District Fragmentation Index (DFI) are used to describe the impact of urban growth on water distribution networks. These values are consistent with the density analysis. The NFI has the advantage of identifying detailed locations of impact, while the DFI is able to synthesize such information in one value per district.

ACKNOWLEDGEMENTS

This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement No. 2008-45049-04328 and Agreement No. 2008-34461-19061. For program information, see http://riogrande.tamu.edu.

The authors would like to acknowledge the contributions of Martin Barroso Jr., Extension Associate, and Eric Leigh, Extension Associate.

REFERENCES

City of McAllen website, 2011.Chamber of Commerce web page. [online] URL: http://www.mcallen.org/Business-Community/McAllen-Overview

Dictionary of American Regional English, 2011. [online] URL: http://dare.wisc.edu/?q=node/144

Kloog, I., Haim, A., Portnov, B.A., 2009. Using kernel density function as an urban analysis tool: Investigating the association between nightlight exposure and the incidence of breast cancer in Haifa, Israel. Computers, Environment and Urban Systems 33, 55–6.

Leigh, E., Barroso, M., Fipps, G., 2009. Expansion of Urban Area in Irrigation Districts of the Rio Grande River Basin, 1996 - 2006: A Map Series. Texas Water Resources Institute Technical Report EM-105.

Ritters, K., J. Wickham, R. O'Neill, B. Jones, and E. Smith, 2000. Global-scale patterns of forest fragmentation. Conservation Ecology 4(2): 3. [online] URL: http://www.consecol.org/vol4/iss2/art3/

Stubbs, M.J., Rister, M.E., Lacewell, R.D., Ellis, J.R., Sturdivant, A.W., Robinson, J.R.C., Fernandez, L., 2003. Evolution of Irrigation Districts and Operating Institutions: Texas, Lower Rio Grande Valley. Texas Water Resources Institute, Technical Report No. TR-228.

TCEQ, 2011. "Water Rights Database and Related Files" web page, Texas Commission on Environmental Quality website. [online] URL: http://www.tceq.state.tx.us/permitting/water_supply/water_rights/wr_databases.html