Integrating Remote Sensing/GIS Methods in Housing Analysis

Peter M. Ward Ph.D and
Mr. Paul Peters
peter.ward@mail.utexas.edu
"Paul A Peters"
papeters@prc.utexas.edu

Institution(s), Unit Name(s), Country.
(Ward) University of Texas at Austin, Lyndon B. Johnson School of Public Affairs, USA
(Peters) University of Texas at Austin, Dept. of Sociology, USA

Abstract Code 50
This paper develops a methodology for integrating Remote Sensing and GIS techniques to identify low income informal homestead subdivisions (AKA colonias) in peri-urban areas of US metropolitan areas. Unlike their self-build counterparts in Latin American cities, housing production is self-managed (trailers and manufactured homes), situated on poorly or un-serviced lots. Now that we have begun to understand the logic and rationale underpinning their existence, and know where (spatially), and what (physical) "footprints", to look for, this paper will present data for central Texas in order to report on the methodology adopted to identify and quantify these peri-urban settlement phenomena.

Keywords: Colonias, remote sensing, GIS, peri-urban sprawl,

1. Poverty, "The American Dream" and the Rise of Informal Homestead Subdivisions

Relatively little systematic research exists about how low-income urban populations in the United States gain access to residential land and participate in the American Dream by becoming home owners. Since the 1990s an exception has been the growing concern and analysis of so-called colonias in Texas and other border states (Davies and Holz, 1992; Office of Attorney General, 1993, Ward, 1999, 2003; Larson, 1995, 2002; Donelson and Holguin 2001). However, almost exclusively this is construed primarily as a rural border-housing phenomenon for Mexican-origin populations. In fact, the majority of these colonias house urban populations, even though their actual locations are often buried in the rural hinterland of cities, from which these working poor commute to engage in low-paid service activities. And although colonias are indeed concentrated in the US-Mexico border cities where they are also characterized by some of the worst housing conditions, they are not exclusive to that region. In Texas alone there are estimated to be over 400,000 people living in some 1600 or more colonias (Ward, 1999; Ward et al, 2003; see also http://twdb.state.tx.us-/colonias/index/htm), and if one extends the definition to areas outside of the border, the numbers rise still further. In New Mexico and Arizona the numbers are lower. In Arizona, the 1990 Census suggested that approximately 162,000 people lived in 77 so-called "colonias designated areas," while in New Mexico, it indicated that 70,000 lived in 141 settlements.

The starting point for this analysis is that preliminary research suggests that colonias and similar types of low-income (homestead) sub-divisions are widespread in the peri-urban areas outside of a wide range of cities such as Austin and Lubbock in central and north Texas; Albuquerque and Santa Fe in New Mexico; Tucson and Phoenix in Arizona; in so-called "gateway" cities such as Charlotte and Greensboro in North Carolina; and Dalton and Atlanta, in Georgia. And while these interior US city communities do not show the extreme poverty levels associated with classic border colonias, informal homestead subdivisions (IFHSs for short) are, in fact, ubiquitous throughout the United States and are likely to be found wherever relatively low cost land markets exist and there are low-income populations wishing to embrace home ownership. For them informal homestead sub-divisions (a.k.a. colonias) are often the only viable option given their low absolute household incomes and/or the irregularity of workers' earnings, and their subsequent ineligibility for formal finance (mortgage) assistance. For many of these households, so-called

"manufactured" housing represents one lower cost alternative to home ownership (Ward, 2003). Manufactured housing is built entirely in the factory under a federal building code administered by the U.S. Department of Housing and Urban Development and homes may be single or multi-section, and are transported to the site for installation. Manufactured homes do not include travel trailers, motor homes, or modular housing. The latter "modular" homes while also manufactured either in units or as prefabricated parts, these are built to the state or local building codes and are also transported to the site and installed, but they do not possess integral transportation gear. Both types of structure are common in colonia type subdivisions examined here.

Elsewhere (Ward and Koerner, 2004) we identified a typology of different types of colonia and homestead subdivisions:

1.1 Classic border colonias in the border region, comprise very low-income, often Mexican or Mexican-origin populations.

1.2 Non-border peri-urban informal subdivisions are very similar to colonias, although they have not they are usually not quite as poor, and being further from the border they are less Hispanic and more mixed, or even dominantly Anglo. Servicing levels, while austere, are much less likely to be entirely absent. These subdivisions are buried in the peri-urban rural areas, are low density, with homes located on large individual lots, and streets are often unpaved (see Image 1). This less well recognized housing alternative is the primary focus of this study.

< Image 1. About here. Typical informal homestead subdivision in the peri-urban area of Austin, (Bastrop County, Texas)>

1.3 Semi-urban or rural housing subdivisions are usually extensive low-density settlements with similar physical dwelling structures and serious servicing deficiencies; they are often much older (nineteenth century or early to mid-twentieth century), and their populations are more likely to be elderly.

1.4 Recreational colonias and subdivisions come in various shapes, sizes, and types. While they share the remote rural locations, low level of servicing, and trailer-type dwellings, they provide housing for better off working-class populations whose hobbies or preferences are for outdoor life or those wishing to have an affordable second residence for weekends and vacations.

1.5 Retirement colonias are often physically similar to recreational ones, but provide relatively low cost options to so-called downsizers-parents whose children have left home and who are now living on modest or limited savings and pensions (Huntoon and Becker, 2002).

The next two categories comprise manufactured homes that are located in formal subdivisions, usually within city jurisdictions rather than in the peri-urban (rural) area but we mention them here because they form an important mode of manufactured housing for low income groups, and are readily differentiated from the housing that we examine in this paper. They are:

1.6 Mobile Home Communities which offer an option for the moderately poor who can afford to buy a modular home or a new trailer home and lease or purchase the fully serviced lot site. Developed within code, they usually occupy low cost peripheral locations of cities and enjoy full services.

1.7 Trailer parks are also located within the city limits or its Extra Territorial Jurisdiction (ETJ), and homes that are owned or rented, on small sites with full services that are rented.

2. The Methodology: Triangulating Remote Sensing and GIS Methods

Our principal aim is to develop a national inventory of the aforementioned settlements and we argue that a national needs assessment can best be achieved by triangulating informal subdivisions identified through remotely sensed systems of data capture (satellite and aerial photographs) with Geographic Information Systems data retrieved from the National Census at the "block" or "block group" level.

The following discussion summarizes the procedures and stages in the testing and refinement of the methodology. Stage One of the strategy was to review and measure the results of various methods against known examples of settlements in the typology discussed above. By referencing data for a spectrum of known examples, we hoped to be able to develop "search-and-identify" protocols that could be applied generically to the peri-urban hinterlands of metropolitan and other major urban areas. The goal was to tie these procedures to GIS data that could be mobilized for the pinpointed settlements. Stage Two was designed to apply the methodology to a number of previously un-researched environments beyond the border region. The aim here was to test whether our procedures would work, and determine the kind of data that we could expect to generate.

2.1. Stage One: Development of the Methodology.

Remote sensing offers both automated (digital) and visual (digital or analog) based approaches for extracting thematic information from satellite imagery and aerial photography.

2.1.1. Automated Classification of Multispectral imagery present a characteristic "texture" of spectral response in order to identify particular search protocols that might be used to: i) identify; and ii) distinguish between the IFHSs in different parts of the country, working at different spatial resolutions (e.g., Landsat systems [MSS, TM, and perhaps ETM+], IKONOS). The latter provide spatial resolution down to 1 and 4 meters, whereas the former provides 30 and 60 meter resolutions. However, a trade-off exists between spatial resolution and the spatial extent covered by a single image.

A high-resolution satellite image covers a smaller extent (e.g., an IKONOS scene covers a 10 km by 10 km area) than a coarser resolution image (e.g., a Landsat image covers an area of 185 km by 185 km). It quickly became apparent that it would not be feasible to use automated search protocols as a starting point (Messina et al.) as we had hoped, and that we need to begin with other image and data sources for known (or suspected) IFHS sites).

2.1.2. Visual interpretation of High Spatial Resolution Images (e.g., aerial photos or high spatial resolution multispectral-IKONOS) is not automated, but requires systematic search, identification, and delineation of the target features (i.e., IFHSs) by the analyst. Thus individual images viewed systematically and require expert knowledge and additional data to ensure effective identification of these features. However, it is highly time consuming and is not feasible for searching over extensive areas. But once possible settlements are identified, the high spatial resolution images do offer an excellent basis for confirming and characterizing the settlements within the typology. In many cases this is feasible using standard digital orthophotos that are available in most states or (higher cost) images (e.g., commercially available up-to-date aerial photographs) which may be purchased or often consulted free on line.

Once suspected IFHSs are identified these can be triangulated to census data using data from Summary File 1 (SF1) linked to TIGER/Line(r) files provide the primary source of information about settlements. TIGER/Line(r) files have been stored in ESRI's Personal Geodatabase format to facilitate rapid spatial and database queries.1 Alternatively, the procedure can be reversed with variables in the SF1, combined with spatial analysis techniques in ESRI's ArcGIS 8.3, allow peri-urban areas to be searched systematically in order to identify possible locations of IFHSs. Population variables using block-level summary data from the SF1 are dynamically linked to block polygon and block centroid spatial data layers created from TIGER/Line(r) files. From these linked data, possible IFHSs can be identified through tabular queries on key Census variables such as those we developed in Table 1, which were weighted in such a way as to allow the identification of different types of settlement in the typology. Thus, clusters of like population groups can be identified through geospatial techniques, and the results can be mapped thematically for visual inspection. Once Census blocks in the peri-urban area that characterize likely IFHSs have been identified, these can then be triangulated with corresponding locations from the images acquired from 2.1.1 and especially 2.1.2 (above).

readily identified, we sought to develop the analysis for central Texas, using in the first instance the peri-urban area of Austin, Texas as follows:

First, an orthorectified Landsat 7 ETM+ scene (28.5m resolution, acquired on October 25, 2001) covering the peri-urban area of Austin was classified using an unsupervised ISODATA classifier. But, as outlined above, it quickly became apparent that the level of spatial resolution offered by these images alone was too imprecise to provide a nuanced identification of different settlements in our typology. In contrast, However, this will require further research and we resolved only these images as one element, in combination with our other techniques.

Table 1. Census Query Search Criteria Used in the Census Data Research Protocol

Variables* and Selection Thresholds (min. 20 persons in Census block)	Classic Border *colonias*	Non-border peri-urban IFHS	Semi-urban/ Rural self-designated	Recreational	Retirement	Mobile Home Communities	Trailer parks
Percent Hispanic	>70	>50	>30	<50	<50	>50	<50
Percent Owner	>60	>50	>50	>60	>60	<60	>60
Percent vacant dwellings	<15	<15	<30	<25	<10	<15	<15
Average Household size	>3.5	>3	<3	>3	<3	<3	>3
Average Family size	>4	>4	<4	<4	<4	<3.5	>3
Percent single person households	<35	<35	<20	<20	>20	>20	<35
Percent households no children	<15	<20	<25	<25	>35	>25	<25
Percent population below 17 yrs. age	>25	>20	>20	>20	<20	<25	>20
Percent population over 65 yrs. age	<15	<20	<25	<25	>45	<20	<25

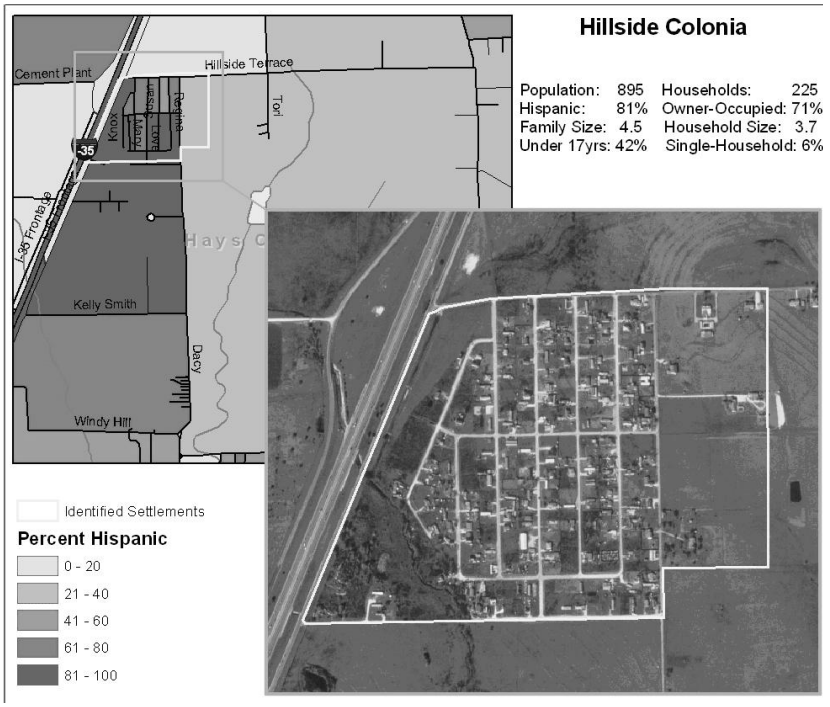
*Variable threshold may be adjusted by region (e.g. percent Hispanic…)

Table 1. Census Query Search Criteria>

2.2. Testing and Developing the Application Framework.

These techniques were applied to a number of known colonias and IFHSs in a variety of different contexts of Texas: border-v-interior; arid, semi-arid, and sub-tropical; intensive-v-extensive agricultural; large-v-small metropolitan, etc. Triangulation of the two techniques, complemented where necessary by commercially available high spatial resolution photographs, allowed for confirmation of IFHS status and the type of settlement observed. The results and data were then integrated into a preliminary database.

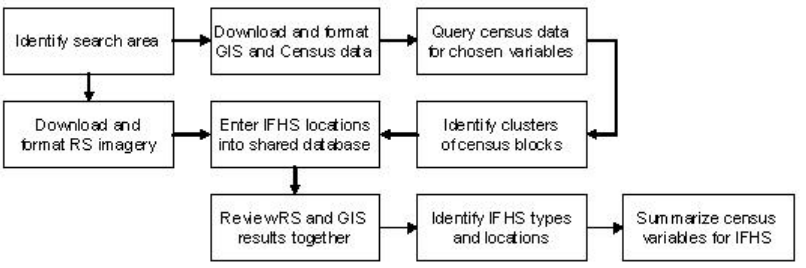
Given that the main goal of this research project is to identify and develop an inventory and understanding of IFHSs outside of border regions where we have little experience of how these might be



<ABOUT HERE Image 2: Digital orthophoto quadrangle (DOQ) and Census data for an identified IFHS (Hillside Terrace) alongside HI 35, Hays County, outside of Austin.>

Instead, using Census database queries, spatial querying, thematic mapping, and identification of population clusters we identified a number of search-and-identify possibilities (see Table 1). Census data are analyzed using these screening criteria, and, where seven of the nine criteria are found to apply for a settlement, that settlement is then located and cross checked against the high spatial resolution spatial image. One difficulty encountered is that some definitive classificatory variables (e.g., income levels, dwelling type and value, etc.) are only available at the Block Group level only which invariably embraces several other settlements.2 However, although the results from Census database queries and spatial analysis are not definitive, they become so when triangulated and interpreted against high spatial resolution images. Image 2 is an example of the level of detail that is available from digital orthophotos. It shows the clear initial identification of possible IFHS/colonia sites from the Census data, and offers a close up of one of the settlements confirming that it is, indeed, an IFHS. However, not all cases are so clear-cut, and where more precise resolution is required (or a more recent image), then these may be viewed at no cost on the Internet (e.g., GlobeExplorer, Terraserver), and can be purchased and downloaded from commercial Web sites, costing between $15 and $45. This provides resolution down to approximately 0.5 meter.

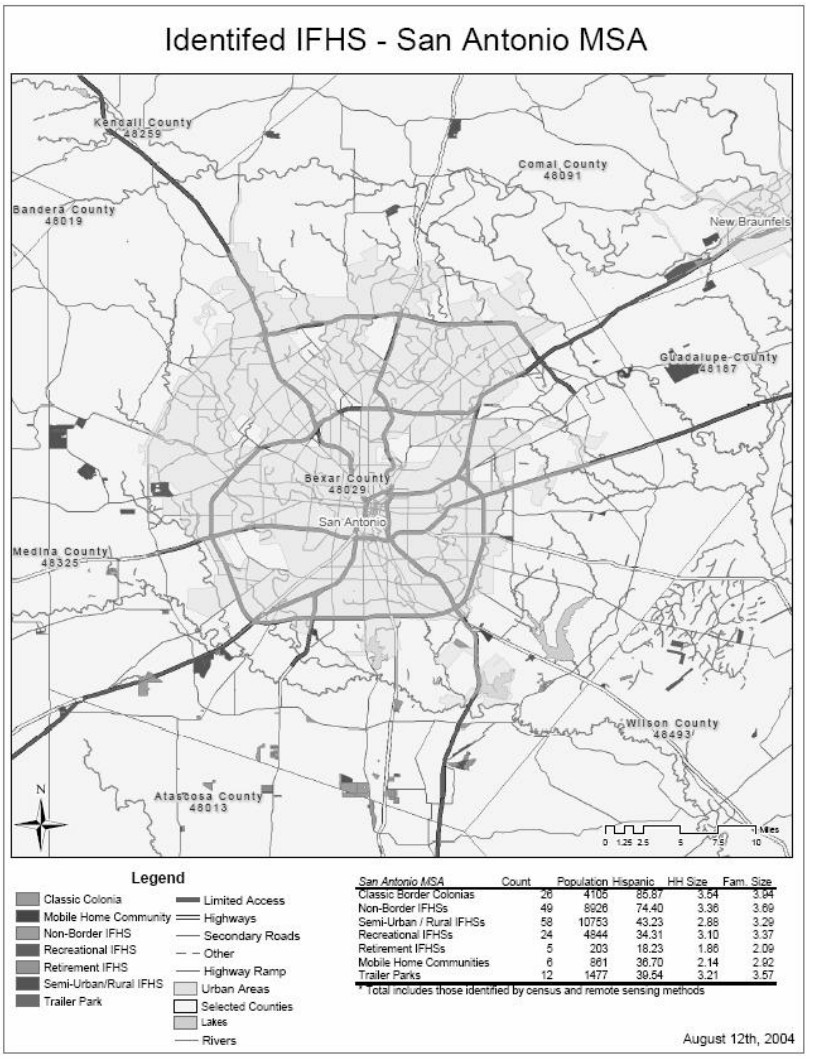
The flow chart in Image 3 portrays the various stages adopted to integrate the two principal techniques. These results can then be visually inspected using overlaid imagery and thematic maps and the specific settlement type can be identified. Users with minimal GIS experience can fairly quickly develop this level of expertise of analysis, and, working in pairs, can combine remote sensed images to GIS data, identify preliminary settlement locations, engage in cross checks to ascertain IFHS type, and store the results in a shared database.



<About Here Image 3: Search and identification methodology.>

3. Case Study Test Application: IFHSs in the peri-urban area of San Antonio, Texas.

The aforementioned methodology was applied in several of the 362 metropolitan areas as defined by the US Census. In addition to Austin, these included San Antonio, TX; Dalton, GA; and Greensboro, NC. In each case, the research procedure followed the following steps. 1) The peri-urban "search area" (SA) was identified as the area outside the Central City, but within the Metropolitan Statistical Area (MSA).3 2) Next, we identified and downloaded the digital orthophotos for the relevant quadrants (DOQs) corresponding to the SA, and then 3) systematically examined all sections of the DOQs in the SA, marking-out possible IFHSs. 4) Meanwhile, we ran queries on selected Census variables for different types of settlement in the typology (as per Table 1 above) and identified clusters of Census blocks possibly corresponding to an IFHS. Where the DOQs were not (immediately) available, or where it proved too time consuming to scan all of them exhaustively, this "Census query methodology" provided a guide to the selection of the relevant DOQ or commercial images. 5) The results of the two analyses were then compared and reviewed systematically in order to arrive at a definitive identification by type of IFHS, and then the detailed data relating to the block group containing the specific Census blocks identified was downloaded from American FactFinder.4 6) Where necessary other high spatial resolution images were also reviewed (and sometimes purchased) in order to make a more accurate determination.5 7) Once identified, IFHS locations and linked Census summary data were stored in a Microsoft Access database, allowing for simple data retrieval and export to formats such as Microsoft Excel. 8) Given the dynamic relational database structure that we are proposing to use, additional data can be added to the inventory at the block or block group level as needed.



<Image 4. Map of Informal Homestead Subdivisions Identified Using the Integrated Methodology in San Antonio, Texas, and tabulated results>

Our aim in this paper has been primarily methodological, and lack of space prevents us from elaborating the detailed database structures or findings either in tabular or graphical form, but examples of these and of other images are available for review upon application to the author. Image #4 and the integrated summary Table give an example of the findings for this particular case study of the San Antonio peri-urban analysis. In summary it reveals 168 separate IFHSs and a total population of 29,692 (with a further 12 trailer parks containing a population of 1477). This constitutes almost an additional 2 percent of the San Antonio metropolitan population that for all intents and purposes are "invisible" within contemporary urban analysis.

In conclusion the authors are satisfied that we have the method and procedures described here work well (although they will benefit from further fine tuning especially in the area of automated classification of multi-spectral imagery). If this research application were applied to all 362 metropolitan areas, as we propose, it will possible to develop a comprehensive and spatially referenced database about the nature and extent of informal homestead subdivisions nationwide - our initial rough estimates suggest between 3-5 million people-and how such developments can be monitored through au-

tomated remote sensing techniques. Additionally, the data will offer an important first step in analyzing the legal and land market factors that shape IFHS, paving the way for more informed policy-making in those metropolitan areas where they form an important feature of the peri-urban low-income housing landscape.

REFERENCES

- Crews-Meyer, K.A. 2002. Characterizing Landscape Dynamism via Paneled-Pattern Metrics. Photogrammetric Engineering and Remote Sensing 68(10):1031-1040.
- Crews-Meyer, K.A. 2002. Challenges for GIScience: Assessment of Policy Relevant Human-Environment Interactions, in Linking People, Place, and Policy: A GIScience Approach. (eds.) S.J. Walsh and K.A. Crews-Meyer. pp. 1-5. Boston, MA: Kluwer Academic Publishing.
- Davies, C.S. and Holz, R. 1992. Settlement evolution of 'colonias' along the US-Mexico border: the case of the Lower Rio Grande Valley of Texas. Habitat International, 16, 4, 119-142.
- Donelson, Angela and Esperanza Holguin, 2002. Homestead Subdivision-/Colonias and Land Market Dynamics in Arizona and New Mexico, pp. 39-41. Memoria of a Research Workshop "Irregular Settlement and Self-Help Housing in the United States", Lincoln Institute of Land Policy, September 21-22, Cambridge, Mass.
- Fields, Jason and Lynne M. Casper, 2001. U.S. Census Bureau, Current Population Reports, p20-537 America's Families and Living Arrangements: 2000. Washington, D. C.: U.S. Government Printing Office.
- Fox, Jefferson, Ronald R. Rindfuss, Stephen J. Walsh, and Vinod Mishra, 2003. People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS. Boston, MA: Kluwer Academic Publishing.
- Huntoon, Laura and Barbara Becker, 2001. "Colonias in Arizona: A Changing Definition with Changing Location", pp. 338-41. Memoria of a Research Workshop "Irregular Settlement and Self-Help Housing in the United States", Lincoln Institute of Land Policy, September 21-22, Cambridge, Mass.
- Jenson, John, R. 2000, Remote Sensing of the Environment, NJ. Prentice Hall.
- Lo, Chor Pang, and Albert K. W Yueng, 2002. Concepts and techniques of geographic information systems, Upper Saddle River, N.J : Prentice Hall,
- OAG Office of the Attorney General, Texas. 1993. Socio-economic Characteristics of Colonia Areas. White Paper. , Austin, Texas: Office of the Attorney General.
- _____. 1996. Forgotten Americans: Life in Texas Colonias. Texas: OAG.
- Messina, J.P., Crews-Meyer K., and Walsh S.J. 2000. Scale dependent pattern metrics and panel data analysis as applied in a multiphase hybrid land cover classification scheme, Proceedings of the 2000 American Society for Photogrammetry and Remote Sensing Conference.
- Proctor, Bernadette D. and Joseph Dalaker. 2002. U.S. Census Bureau Current Population Reports, p60-219, Poverty in the United States: 2001. Washington, D.C.: U.S. Government Printing Office.
- Savage, Howard A. 1999. U.S Census Bureau, Current Housing Reports, h121/99-1, Who Could Afford To Buy a House In 1995? Washington, D. C.: U. S Government Printing Office.
- Ward, Peter M. 1999. Colonias and Public Policy in Texas and Mexico: Urbanization by Stealth. Austin: University of Texas Press.
- _____. 2003. "Informality of housing production at the urban-rural interface: the not-so-strange case of colonias in the US: Texas, the border and beyond" In Urban Informality, Annanya Roy and Nezar AlSayyad, (eds) Lexington-/Center for Middle Eastern Studies, UC Berkeley. (pp. 243-70)
- _____, "Colonia Land and Housing Market Performance and the Impact of Lot Title Regularization in Texas", Urban Studies 41, 13. pp. ** (Lead author with C. Guisti and F. de Souza)
- Ward, Peter M. and Koerner, Mona. 2004. "Informal Housing Options for the Urban Poor in the US: A Typology of Colonias and Other Homestead Subdivisions". Under review J. Am. Planning Association.

1 Note: Census 2000 SF1 summary data were obtained through ESRI from their Census Watch website (http://www.esri-.com/Censuswatch/datares.html), and these logos are registered trademarks of the U.S. Bureau of the Census.

2 Only in the border region of Texas has there been any significant attempt (in the 2000 Census) to configure the blocks that correspond to colonias into single settlement Census Defined Places (CDPs).

3 Note: the analysis search area is defined by those counties that are within ten miles of the central city of each MSA, as defined by the US Census Bureau in 2003.

4 The inclusion of this step allowed for further characterization of the selected IFHS according to detailed Summary File 3 and Summary File 4 Census Block Group data available via American FactFinder, which also provided background information to assist in identifying the particular IFHS type.

5 This was necessary where the RS images were more than several years old, and did not show corresponding settlements clearly identified by the Census and GIS analyses.