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Self-help housing and informal homesteading in peri-urban America: Settlement identification using digital imagery and GIS ☆

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Abstract

This paper develops a methodology for integrating remote sensing/aerial photographs and GIS techniques to identify low-income informal homestead subdivisions (IFHS, also known as *colonias*) in peri-urban areas of US metropolitan areas. Unlike their self-build counterparts in Latin American cities which start as illegal occupations of totally un-serviced lots, in the USA housing production is largely self-managed (embracing trailer homes, manufactured homes, modular units with self-help home improvement, etc.), placed on legally developed lots, albeit poorly or minimally serviced. As researchers begin to understand the logic and rationale underpinning their existence, and better appreciate where (spatially), and what (physical) "footprints" to look for, it becomes possible to identify and quantify the full extent of these peri-urban settlement phenomena. This paper reports on a three Metropolitan Statistical Areas in the USA to demonstrate the methodology and argues that this has wider application both in the USA and elsewhere. Specifically for the US, the paper outlines some of the policy implications that arise from using integrated techniques to develop an inventory of IFHS and from a deepening of public recognition of the phenomenon.

Keywords: Housing; *Colonias*; Remote sensing; GIS; Peri-urban sprawl; Housing policy

Introduction

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 & Holz, 1992; Donelson & Holguin, 2001; Larson, 1995, 2002; Office of Attorney General, 1993; Ward, 1999, 2003). 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,

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even though their actual locations are often buried in the rural hinterland of cities, from which these low-income workers commute to engage in low-paid service employment activities. Although *colonias* are indeed concentrated in the US-Mexico border cities where they are also characterized by some of the worst housing conditions, the point of departure in this paper is they are not exclusive to that region. Instead, we argue that the spread of similar housing types is occurring in the many urban hinterlands of the United States, and in this paper we develop a methodology for the identification and classification of various types of informal settlement.

The context: self-help, *colonias*, and informal homesteading in the USA

The starting point for this analysis breaks out from recent research, which suggests that *colonias* and similar types of low-income (homestead) subdivisions are widespread in the peri-urban areas outside of a wide range of cities, and are not just restricted to US–Mexico border cities. Today, so-called Informal Homestead Subdivisions (IFHS) have been identified in places as diverse as Austin, Dallas/Fort Worth and Lubbock in central and north Texas; Albuquerque and Santa Fe in New Mexico; in Tucson and Phoenix in Arizona; in so-called ''gateway'' cities such as Charlotte and Greensboro in North Carolina; and in Dalton and Atlanta, in Georgia. While these interior US communities do not show the extreme poverty levels and improvised and impoverished housing conditions associated with classic border *colonias*, it seems likely that these IFHS are, in fact, ubiquitous to many parts of the United States. As is well known for many Latin American cities where squatting and irregular self-build settlements are the norm, in the USA, too, there is a *prima facie* argument to expect that self-managed housing may be found wherever relatively low-cost land markets exist, and where there are low-income populations wishing to embrace home ownership, yet are unable to do so through formal market mechanisms. Of course, not everyone (poor or not) aspires to home ownership: rental trailer parks, mobile home subdivisions, and low-cost apartments and sharing remain an important housing option for many households. And many others who own their dwelling unit in trailer parks, do not, of course, own the land and utilities (see also Note 1). However, for those who wish to become full property owners (land and dwelling) and to build some level of wealth through property ownership, IFHS are often the only viable option given low absolute household incomes and/or the irregularity of workers' earnings, and their subsequent ineligibility for formal finance (mortgage) assistance. The parallels to self-help activities in cities in Latin American and other developing countries are obvious, even if the actual mechanisms of land and housing production are substantially different (Ward, 1999).

Two-thirds of households in the United States are classified as home owners.[1] However, unsurprisingly, poorer people are less likely to own, and are more likely to rent or share accommodation: of the 12.5 million households living below the poverty line, 65% are renters. The creation of new opportunities for home ownership among the poor can be an important vehicle to reduce inequality. Moreover, for Hispanics generally and for Mexicans in particular, the culture of home ownership is especially important even among the poorest households, for many of whom *colonias* and informal subdivisions such as those analyzed here represent the primary way in which very poor would-be homeowners break into the property market. However, only an estimated 56% of families (owners and renters) could afford to purchase a modestly priced house in the area in which they lived, and that proportion appears to be declining (Savage, 1999), and even the multiple federal government programs and subsidies aimed at improving generalized housing affordability have not been able to overcome the problem of restricted access to home ownership for the poor and very poor.

For many low-income households, therefore, so-called ''manufactured'' housing has been suggested as offering an important lower-cost alternative to home ownership (Ward, 2003). Manufactured housing is defined as being built entirely in the factory under a federal building code administered by the US Department of Housing and Urban Development. Homes may be single or multisection, and are transported to the site for

[1] By international standards this is actually quite a high level of ownership, but one caveat should be noted namely that the US Census definition of home ownership includes those who own (or are purchasing) a trailer or a mobile home, but without having any claim of ownership of the site, or the valorization that accrues as a result of full ownership and neighborhood improvements and upgrading. Not surprisingly, trailer homes are more likely to present a housing option for low-income populations.

installation. Manufactured homes do not include vehicle/travel trailers, motor homes, or modular housing. Modular homes, while also manufactured either in units or as prefabricated parts, are considered different in so far as they are built to the state or local building codes and are transported to the site and installed, but they do not possess integral transportation gear under their structures (i.e. frame and wheel base). Both types of structure are common in *colonia* type subdivisions and the IFHS examined here. Indeed, for many would-be homeowners in the USA, manufactured home units on lots in informal housing subdivisions are the only option. This housing type is becoming an area of greater importance in academic and policy research, but it should be recognized as only representing one portion of this market segment, and the following section outlines a typology for different types of IFHS and *colonias*, characterizing each subtype by its physical, economic, and social characteristics.

The increase in colonias and homestead subdivisions

Few people have a clear notion of what constitutes a *colonia*, let alone comprehend the large numbers of low-income households that reside in them. In Texas alone there are estimated to be over 400,000 people living in some 1600 or more *colonias* (Ward, 1999; see also OAG, 1996), 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 than Texas, but are nevertheless substantial: In Arizona, the 1990 Census suggested that approximately 162,000 people lived in 77 so-called "*colonia* designated areas," while in New Mexico, it indicated that 70,000 lived in 141 settlements. Beginning in the 2000 Census, the US Census Bureau implemented the additional category of census-designated places (CDPs), allowing for the identification, location, and quantification of *colonia*-type residential areas. Table 1 displays summary statistics for several well-known CDPs in Texas, New Mexico, and Arizona. These data provide the basis for developing a typology of IFHS developments.

Elsewhere (Ward & Koerner, 2005) the work of one of us has developed a detailed typology to identify the existence of different types of *colonia* and homestead subdivisions, based upon a number of variables: location; primary residential purpose; populations served; tenure; and lot and housing footprints. The common thread, however, is that they are low-cost affordable modes of housing acquisition for lower-income households in peri-urban and in semi-rural areas. In summary, the following types of self-help/managed housing may be identified:

1. *Classic border colonias* have been most widely identified and have been a major focus of research and policy attention. Located mostly in the border region, almost always beyond the city limits and buried in the rural hinterland, the population of these settlements generally comprises very low-income Mexican or Mexican-origin populations. The settlement size varies from just a few lots on a single street or cul-de-sac, to large settlements comprising 300 lots or more. Dwelling types are mixed, often showing considerable innovation as a trailer unit melds with a self-help extension, or as a false second roof is added above the structure to provide shade and protection from the elements.
2. *Non-border peri-urban informal subdivisions* are in fact very similar to *colonias*, although they have not traditionally been seen to constitute the problem in the same way as have *colonias*. Non-border informal subdivisions can be readily observed from the air, located several miles into the rural hinterland from major cities. Settlements are especially distinctive given their low density, larger individual lots, idiosyncratic dwelling arrangements and placement on lots, unpaved streets, and, when seen from above, from the numerous "lozenge"-shaped trailer home roofs (Fig. 1). It is this less well-recognized housing alternative that is the primary focus of identification and data collection in this paper. Compared to their *colonia* "cousins," these homestead subdivisions are usually not quite as poor, and being further from the border they are less likely to be exclusively or predominantly Hispanic, but contain mixed ethnicity and races, and sometimes may even be dominantly Anglo. Servicing levels, while austere, are much less likely to be entirely absent.
3. *Semi-urban or rural housing subdivisions* are often very extensive low-density settlements with similar physical dwelling structures and serious servicing deficiencies. The principal difference between these settlements and the previous two types is the period of their development: they are often very old (nineteenth century or early to mid-twentieth century), and their populations are more likely to be elderly,

Table 1
Census-defined places (CDPs) summary statistics for Texas, New Mexico, and Arizona

	Population	Median income	Population aged < than 15 years	Hispanic (%)	Family HH (%)	HH size	Percent ownership (%)	Percent rental (%)
Texas								
Texas border colonias								
Alto Bonito CDP	569	17,396	38.3	97.4	94.5	4.45	85.2	14.8
Cameron park CDP	5961	16,934	37.0	99.3	94.5	4.70	72.5	27.5
El Cenizo City	3545	13,333	41.3	98.9	93.2	4.86	81.1	18.9
Las Lomas CDP, Starr County	2684	10,927	37.8	99.4	95.2	4.27	82.2	17.8
Rio Bravo City	5553	17,149	38.7	97.7	93.2	4.61	81.8	18.2
Sparks CDP	2974	21,964	35.8	99.5	91.2	4.14	84.3	15.7
Non-border colonias								
Stony Point, Bastrop County	703	—	31.7	88.8	83.3	4.34	80.9	19.1
University Park Estates, Lubbock	631	—	27.7	28.7	73.7	2.96	88.7	11.3
Shallowwater, Lubbock	171	—	28.1	15.2	69.7	2.59	69.7	30.3
Hillside Terrace, Hays County	652	—	35.7	79.4	89.5	4.02	72.2	27.8
New Mexico								
Border (urban) colonias								
Anthony (CDP)	7904	22,547	32.9	96.4	89.5	3.81	68.1	31.9
Chaparral (CDP)	6117	22,692	30.1	64.5	81.5	3.33	81.4	18.6
Dona Ana (CDP)	1379	27,292	25.2	87.1	81.4	3.09	76.7	23.3
Sunland Park city	13,309	20,164	30.9	96.4	88.5	3.97	68.6	31.4
Border (rural/non-MSA) colonias								
Lake Arthur town	432	22,386	31.3	70.1	79.9	3.22	83.6	16.4
Radium Springs (CDP)	1518	33,167	25.2	49.4	76.7	2.79	91.5	8.5
Timberon (CDP)	309	24,519	12.0	12.6	67.6	2.13	92.4	7.6
Non-border quasi-formal IFHS								
Carnuel (CDP), Albuquerque	872	37,813	16.4	51.1	66.0	2.35	82.7	17.3
La Cienega (CDP), Santa Fe	3007	38,028	26.0	70.8	73.7	2.91	77.4	22.6
Madrid (CDP)	149	21,905	12.1	20.8	34.1	1.82	63.4	36.6
Arizona								
Border colonias or towns								
Pirtleville CDP	1550	19,355	—	—	—	—	—	—
Somerton CDP	7266	26,544	—	—	—	—	—	—
Non-border								
Ajo CDP	3705	25,618	—	—	—	—	78.2	21.8
Tucson area								
Tucson, Marana area	314	—	20.1	12.7	72.8	2.51	83.2	16.8
Old Nogales Highway area,	1096	18,687	26.9	53.9	72.4	3.05	74.7	25.3
Littletown	730	24,464	28.1	48.6	80.9	3.24	89.3	10.7

with extended households, or "truncated" (widowed/widower) household structures. The population is also less likely to be Hispanic.

4. *Recreational 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

Fig. 1. Orthophoto of a semi-urban/rural IFHS in the peri-urban area of Austin.

working-class populations whose hobbies or preferences are for outdoor life (keeping horses for example), as well as those wishing to have an affordable second home residence for weekends and vacations (even if this is a trailer or mobile home-type unit).

5. *Retirement subdivisions* are often physically similar to recreational subdivisions 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 & Becker, 2001). These settlements differ from retirement trailer parks or communities within the city limits in so far as the amenities provided to residents are generally minimal, and are not a primary feature of the development.

The final two categories comprise manufactured homes not involving self-help and which are located in formal subdivisions, usually within city jurisdictions rather than in the peri-urban (rural) area. However, we include them here because they form an important mode of manufactured housing acquisition and residence for low-income groups, and it is important to differentiate them from their IFHS that we are proposing to examine here. They are:

6. *Mobile home communities* which offer an option for the moderately poor whose incomes or credit rating do not make them eligible for conventional mortgage finance or state insured housing, but who can afford to buy a modular home or a new trailer home and lease or purchase the fully serviced lot site. Given that these are developed within code, they usually occupy low-cost peripheral locations of cities and enjoy full services. Residents within these communities are more likely to be homeowners than those in trailer parks (see 7 below). Seen from the air, the ''footprint'' is likely to show larger lots than for trailer parks.
7. *Trailer parks* are an understudied yet widespread housing alternative for low-income households. Located within the city limits or its extra territorial jurisdiction (ETJ), they offer low-cost rental for the site and services. The trailer home itself may be owned or it, too, may be rented from the site manager/owner. Seen from the air, lot ''footprints'' are clearly different from those of *colonias*, showing very high densities, small sites, standard ''lozenge'' shape trailers arrayed in a regular layout, with a vehicle ''pad'' at the front of the lot. In aerial photographs these are very easily identified and differentiated from the previous settlement types.

Data and methods

One of the principal goals of this paper is to demonstrate that there has been a significant spread of IFHS-type development across the United States, and to offer a methodology that will assist researchers and planners in creating an accurate inventory both of the number of settlements and of the households/population that are living within each IFHS segment that we have outlined above. We propose that the identification of IFHS can most efficiently be achieved through aerial photo interpretation, integrated and combined with GIS analysis of national census data (Fig. 2). The results from this combined method will assist policy makers and planners in conducting analysis and creating housing policy for communities and regions across the nation. Only with a comprehensive view of housing types and location patterns will we begin to know the true extent of this entirely under-studied housing market. We also anticipate that the methodology will assist researchers in other countries to interpolate the increasingly available digital photographic data sources with spatially configured census data.

The methodology comprises four principal stages and proceed along two parallel, and ultimately triangulated, data search procedures: one that draws upon on-line census data; the other drawing upon aerial photographic imagery. Stage one is the identification of the study area. In this case, we are usually interested in areas within 10 miles of the urban area as defined by the US Census Bureau in 1999 before the 2000 Census. The search area polygon was created by a simple buffer of the available urban area Tiger/Line® files. The second stage begins with the interpretation of high resolution visual imagery and allows for the visual identification of typical IFHS features. The third stage comprises a census database search of possible IFHS given a set of population characteristics, followed by a final integration of the two identification methods, creating an output database of IFHS for the selected MSA. The following discussion elaborates on these stages, and is followed by an application of the methodology for case study cities in two states (one of which is non-border): those of Austin and San Antonio in Texas, and Greensboro, North Carolina. Both Austin and Greensboro are ''new gateway'' cities of Hispanic immigration which have experienced dramatic ''spikes'' in immigration since 1990 and for whom IFHS's are an important route to homeownership among those who have settled permanently in the USA (Rogers, 2006). On the other hand, San Antonio is an example of an established ''gateway'' city, which has a large Hispanic population, many of whom arrived in earlier migration streams, and are often second and third generation Americans.

Visual interpretation of high resolution imagery

This process of visual interpretation (e.g., aerial photos or high spatial resolution multispectral-IKONOS) is not automated, but requires the systematic search, identification, and delineation of the target features (i.e., IFHSs) by the analyst. Thus individual images must be acquired, downloaded, and systematically viewed, and require expert knowledge and additional data to ensure effective identification of these features. It is very time consuming and is not feasible for searching over extensive areas. However, 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, if only in black and white. However, these photos are often dated (ten or more years), and, therefore, miss many recently developed settlements. In addition, the resolution does not always allow for a definitive identification of a settlement within the typology, such that it is necessary to cross check with (higher cost) images (e.g., commercially available up-to-date aerial photographs) purchased for particular areas (settlements), or other images that are available for consultation free on line (http://maps.google.com for example).

The latter sources of digital imagery such as Google Earth™ provide the best (and fast evolving) opportunity for identification of housing settlement types, integrating multiple data sources within a common computer interface and framework. Provided free of charge in its basic form for individual cities and city-regions, it is possible to quickly scan through available imagery on-line, identifying areas that appear as likely IFHS location points. Then, using the commercial version of Google Earth™ it is possible to create a spatial layer of IFHS via on-screen ''heads-up'' digitizing. These data layers can readily be exported into most commercially available GIS software for display alongside census data.

Google Earth™ has only become widely available since 2005, but it offers the easiest and cheapest means of reviewing aerial images at a good scale of resolution. Since its inception several add-on websites utilizing Google Earth™ technology have appeared, combining satellite and aerial imagery with additional data sources. However, it does not cover all cities in the USA (and in other countries) in the same level of detail, and sometimes for our purposes it does not extend high-quality imagery sufficiently far into the peri-urban area. However, as a first stop (and often the only stop required), it is an excellent resource. Fig. 2 provides the results of a Google Earth™ scan at different levels of resolution and shows how by zooming in and out, even using the non-commercial version (as in this case), possible IFHS sites may readily be identified.

Initially, though, in order to develop the methodology for widespread applications and testing, the possibilities of using Landsat imagery were explored. To accomplish this, an orthorectified Landsat 7 ETM + scene (28.5 m resolution, acquired on October 25, 2001) covering the peri-urban area of Austin was classified using an unsupervised ISODATA classifier. However, although useful for identifying built-vs-unbuilt areas at the aggregate level, the spatial resolution offered by the Landsat images alone was too imprecise for the detailed identification of different IFHS in the typology. In contrast, the interpretation of one-meter resolution digital orthophotos was an effective means of discrimination of IFHS. The main advantage of using high-resolution imagery is that specific structural traits of the settlements can be assessed (e.g., lot configuration, distribution of individual homes) facilitating its classification within the typology that had been developed. Nevertheless, given the strong spectral contrasts between rural land use and nucleated settlements, multispectral imagery does not currently offer great scope for identifying IFHS, and will require substantial further research before applications can be applied effectively. In the meantime, for this study, these images were incorporated as one element, in combination with our other techniques.

Identification of IFHS via GIS

Once likely sites are identified it is then possible to link these locations and images to corresponding census and spatial data. Population variables are constructed using block-level summary data from the SF1 stored in a relational Microsoft Access database. These variables are dynamically linked to block polygon and block centroid spatial data layers created from TIGER/Line® files. From these linked data, possible IFHSs can be identified through tabular queries on key census variables such as level of owner occupancy; household size; proportion of vacant lots; and other socio-economic status attributes that tend to be closely associated with low income subdivisions, which may be weighted in such a way as to allow the identification of (likely) different types of settlement within the typology. Thus, clusters of similar neighborhoods and populations can be identified through geospatial techniques, and the results can be mapped thematically for visual inspection.

Specifically, the model outlined above used several key census demographic variables taken from the Summary File (SF-1) data available aggregated at the block level. The first of these variables (owner-occupied and vacancy rate) relate to characteristics of the home. The percentage of homes that are owner-occupied is a key variable in distinguishing between settlement types, particularly between non-border and semi-urban/rural IFHS; and between mobile home communities and trailer parks. Related to this variable is the vacancy rate, indicating the percentage of homes that are vacant. This variable may be especially helpful often key in identifying recreational IFHS, where a significant proportion are vacant, or are not the primary residence of the owner.

The second group of variables (household size, family size, and single-headed households) relate to characteristics of the household itself. In previous work household size was found to be a key factor in distinguishing IFHS types, corresponding closely with family size (Ward & Koerner, 2005). In general, the more informal low-cost settlement types tend to have younger families with more children and have extended family living in the same household. Conversely, single-headed households remain low Black for most of these settlement types with the exception of mobile home and retirement communities.

The final group of variables (percentage of households with no children, the percentage of retired-age individuals, percentage Hispanic, and percentage Blacks) are largely demographic. The percentage of households with no children and the percentage of retired-age individuals are closely linked, distinguishing between IFHS types with younger families and those that are more adult-oriented housing options. The variables related to census racial categories are largely descriptive, with the exception of the Hispanic variable

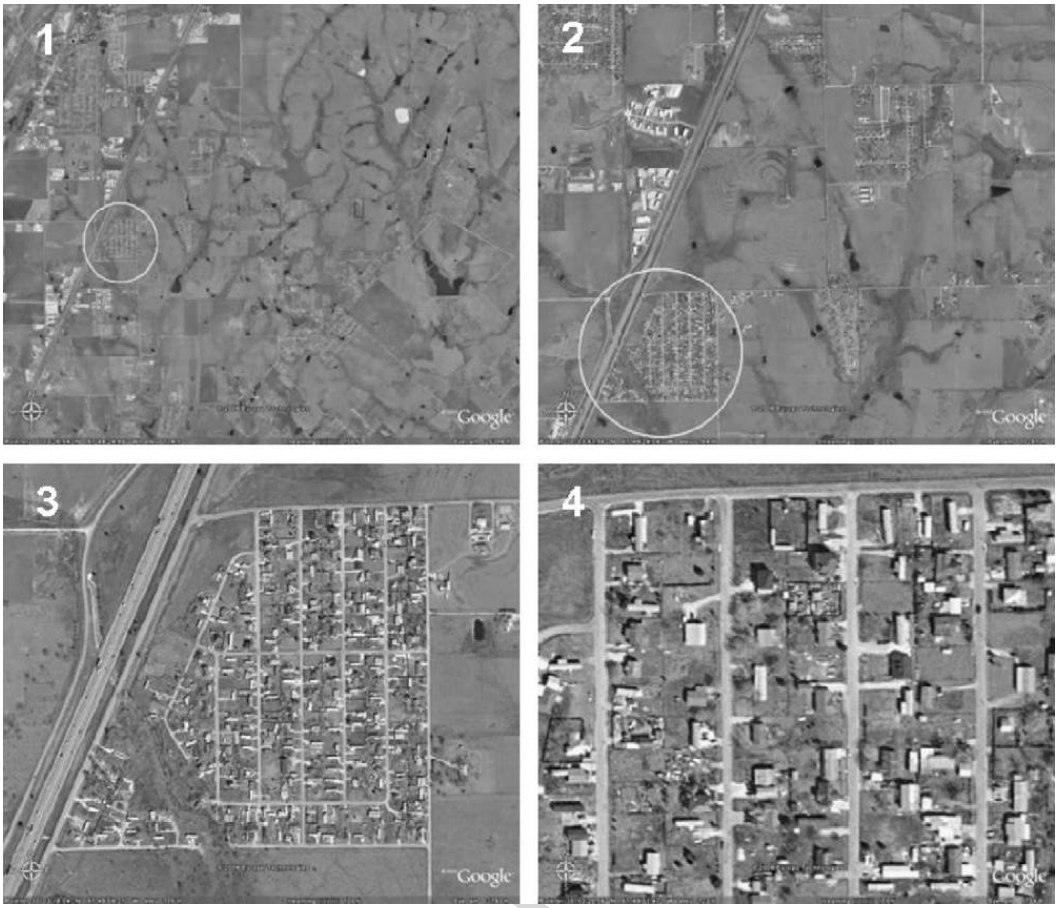

Fig. 2. Google Earth™ images at different spatial resolutions for Austin MSA.

which is especially likely to highlight classic *colonias* and IFHS type subdivisions in peri-urban areas of gateway or dynamic service-oriented cities. In border areas, of course, it may be may be necessary to raise the threshold of the Hispanic occupancy variable since such a high overall percentage of the regional population is Hispanic. Indeed, in *colonias* the proportion is close to 100 per cent Hispanic. Outside of this area, as is shown later for the case of Greensboro, the percentage of Hispanic individuals declines.

The combination of the above variables provide an important key to the identification of census blocks that characterize likely IFHS locations. Once possible census blocks in the peri-urban area have been identified, these can then be combined with corresponding locations from the aerial photo interpretation and cross-referenced. For the cases described below, this cross-referencing was accomplished by visual comparison of locations identified by photo interpretation and those from census query. The following section expands upon these stages drawing upon our three case study sites of Austin, San Antonio, and Greensboro.

Application of the Methodology: San Antonio, Austin, and Greensboro

To test the methodology for IFHS identification, case study cities were chosen from three distinct areas. The first, San Antonio, Texas, is a large metropolitan area located less than 200 miles from the Mexico-US border. It is an established immigration "gateway" and has a large Hispanic population (57.4%), many of whom are second and third generation, but remain engaged in low-wage jobs in the services, manufacturing, and agricultural sectors. The second area is Austin, Texas, located 70 miles to the north of San Antonio in central Texas, and which has experienced rapid growth between 1990 and 2000, as well as significant growth in the proportion of its population that is Hispanic (rising from 26% to 32%). The state capital, Austin has a dynamic employment base and has grown substantially in recent years. It was also a city where recent research provided a detailed knowledge of IFHS locations embracing all of the types described outlined earlier. The

third area is Greensboro, North Carolina, a fast-growing metropolitan area in the South-East that is not normally considered an area of *colonia*-type or IFHS development. The total populations of these metropolitan areas are very similar, with San Antonio having a population of 1,592,383, Austin 1,249,763, and Greensboro 1,251,509 according to the 2000 National Census. Combined with previous work on the US border-region (Ward, 1999; Ward, 2005), these three cases provide an opportunity to extend the IFHS typology and to test its validity for other US metropolitan areas.

Table 2 includes a summary for the three selected MSA study areas, indicating the totals for each IFHS type. Of the three MSAs, San Antonio has by far the largest number of identified IFHS, followed by Austin and then Greensboro. The classic *colonia* type which is considered almost exclusively a border phenomenon does appear in San Antonio, alongside IFHS type settlements. However, non-border IFHS that display similar population and development characteristics as classic *colonias* are found in all three areas. The most common type of IFHS found are semi-urban/rural settlements for San Antonio and Austin, and Trailer Parks for Greensboro. The total number of IFHS in San Antonio and Austin are much higher, with fewer of these settlement types found outside of Greensboro. This probably reflects Greensboro's relatively recent emergence as a gateway city with large numbers of recently arrived migrants who are still largely "sojourners" and would opt for cheap rental accommodations—shared or single family (Rogers & Ward, 2007). In Austin and in other similar cities, these recent immigrants usually seek cheap apartment housing, often multiple sharing with other families that are located in the "innerburbs" of the city. It is usually those migrants who are longer established, and second generation households who opt for peri-urban residence in IFHS (Rogers, 2006).

Table 2
Summary results for Greensboro, Austin, and San Antonio

	Total	Population	Households	Ownership (%)	Vacancy (%)	HH Size	Family Size	Hispanic (%)	Black (%)
Greensboro									
Classic *colonia*	—	—	—	—	—	—	—	—	—
Non-border	11	904	370	67	7	2.44	3.40	1	5
Semi-urban/rural	20	1837	762	87	6	2.41	3.32	1	2
Recreational	10	1768	702	76	6	2.52	3.67	4	19
Retirement	1	37	27	85	19	1.37	5.29	0	0
Mobile Home	19	2668	1123	75	14	2.38	3.67	6	13
Trailer park	35	4975	1890	89	10	2.63	3.64	4	14
Totals	96	12,189	4874						
Austin									
Classic *Colonia*	—	—	—	—	—	—	—	—	—
Non-border	58	5961	1738	68	7	3.43	4.22	54	3
Semi-urban/rural	136	18252	5483	89	6	3.33	4.17	43	3
Recreational	18	2078	705	83	6	2.95	3.72	16	1
Retirement	—	—	—	—	—	—	—	—	—
Mobile home	6	631	176	67	13	3.59	4.18	71	1
Trailer park	18	3018	816	88	4	3.70	4.65	76	4
Totals	236	29,940	8,918						
San Antonio									
Classic *Colonia*	95	4105	1113	79	12	3.69	4.46	86	1
Non-border	59	4218	1370	64	16	3.08	3.98	56	1
Semi-urban/rural	225	15470	5006	88	10	3.09	3.96	58	2
Recreational	39	4844	1549	88	9	3.13	3.68	34	7
Retirement	3	194	91	98	43	2.13	2.85	14	0
Mobile home	16	1563	548	53	10	2.85	4.37	39	5
Trailer park	10	775	230	91	16	3.37	4.14	38	6
Totals	447	31,169	9907						

The locations of the identified IFHS are similar for each MSA, and are generally concentrated on one side of the metropolitan region in low-density areas. Fig. 3 displays the location of IFHS outside the selected urban areas. In San Antonio, the majority of these settlements are located to the south of the urban area and outside the formal municipal city limits. The primary population growth in San Antonio is located to the north of the city with the highest population densities found inside the Interstate 41 ring road and near the north Interstate 10 and Interstate 35 corridors. San Antonio is unique in this study as it is nearly a contained urban area with a clearly defined urban center. The population of the defined "City of San Antonio" (rather than the MSA) was 1,144,646 according to the 2000 Census with 58% of the population of Hispanic American origin or Latino of any race. The surrounding urban areas are mostly very small, with the closest major urban area being that of Austin/San Marcos to the north-east.

The Austin MSA displays a similar pattern of IFHS development to San Antonio, where settlements are located to one side of the urban area, in this case to the south-east. Formal suburban development in the Austin area is primarily concentrated to the north and north-west of the city with the highest population densities along the Interstate 35 corridor and extending along the very north-west edge of the urban area. The population of the City of Austin was 656,652 according to the 2000 Census, with more than 30% of the population Hispanic American origin or Latino or any race. IFHS development on the other hand is occurring primarily in the rural areas outside the Austin city limits and in the opposite direction of most recent northerly suburban development namely south and south east.

The development of IFHS in the Greensboro MSA reflects a similar pattern to those found in San Antonio and Austin. The majority of development surrounding Greensboro occurs to the south and east of the urban area near the Interstate 73 and Interstate 85 corridors. The population characteristics of Greensboro are much different than with San Antonio and Austin. While the total MSA population is similar to that of the other two metroplexes, the actual urban area of Greensboro is only 223,891 with the remaining population located in the adjacent cities of Winston-Salem and High Point. The ethno/racial composition of the Greensboro MSA is very different to San Antonio or Austin, with only 6% of the population of Hispanic American origin or Latino or any race, 21% Black or African American, and 73% White non-Hispanic. In 2004, the previous Greensboro/Winston-Salem/High Point MSA was split by the US Census Bureau, creating the Greensboro/High Point MSA and the Winston-Salem MSA. This resulted in a 2004 population estimate of 667,542 for the Greensboro/High Point MSA and a 2005 population estimate of 1,490,886 for the Greensboro/Winston-Salem/High Point combined statistical area.

Detailed results of the census analysis for each MSA are presented in Table 2. From this table the differences between IFHS types are readily apparent, and the full extent of this settlement phenomenon may be seen. Of the three study areas, San Antonio has the largest IFHS population, with over 30,000 individuals and 9900 households. Within this population, the largest contributor is the Semi-Urban/Rural IFHS type. Distinguishing features of this IFHS type are a high percentage of owner-occupied residences and a moderate family size. The population within this subtype are frequently middle-aged homesteaders with a small family

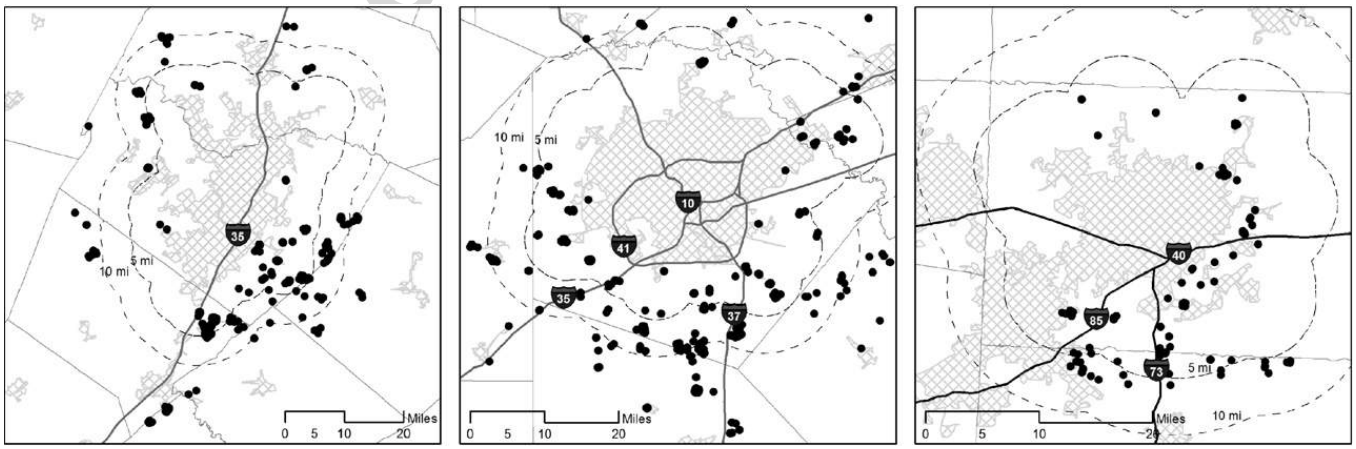

Fig. 3. IFHS locations in San Antonio, Austin, and Greensboro with 5 and 10 mile buffers.

and moderate income. The decision to live outside the city center is often as much a lifestyle choice as a financial one.

Owner occupancy is a key difference between the different IFHS types developed here. In this regard, the semi-urban/rural IFHS type contrasts with classic *colonias* and non-border IFHS. Classic *colonias* have been described in detail in the literature (Ward, 1999) but are generally informal settlements of a largely Hispanic American or Latino population, the majority of which are owner occupied. Semi-urban/rural IFHS have average owner occupancy rates nearing 90%, in contrast to non-border IFHS which average lower than 70%. This same difference in occupancy is visible between mobile home communities and trailer parks, with the latter having much higher owner occupancy and thus lower rental rates.

Family and household sizes are a weaker distinguishing factor between the IFHS types. There appear to be larger differences regionally between MSA than between IFHS types, with IFHS identified in Greensboro having much lower mean household and family sizes (again, a reflection of their more recent establishment and tendency to live in trailer park type accommodation). As one can observe, families recorded as living in classic *colonias* are generally much larger and there is a greater median household size than their non-border counterparts and those in semi-urban/rural IFHS. Non-surprisingly, the settlements identified as retirement IFHS (although there were few) had much lower mean household sizes than the other types, as did those in mobile home communities as compared to trailer parks.

Ethnic and Racial differences are strongly visible in the cases of San Antonio and Austin, where population of Hispanic origin are far more likely in classic *colonias*, non-border, and semi-urban/rural IFHS than in the other types. The population of Hispanic origin in Greensboro is much lower, and differences are more apparent in the percentage of African American population with mobile home communities and trailer parks displaying a higher percentage from these racial groups. It should be noted however, that the mean percentages for each of these minority racial categories are lower than for the greater MSA population, each of which is more likely to reside in the inner-city, rather than the peri-urban area.

The implications for housing and planning policies

We hope that the methods and procedures outlined in this paper will provide a useful and timely opportunity to assess the nature of informal housing patterns in peri-urban areas of the United States. The research presented here has begun to show conclusively that the presence of IFHSs is far more common across the US than previously imagined: an initial rough estimate suggests that somewhere between three and five million people live in such areas across the continental United States. If this methodology were applied systematically to all 362 metropolitan areas in the USA, then it should be possible to develop a comprehensive and spatially referenced database about the nature and extent of IFHS nationwide. And if IFHS are found to exist in the magnitude that we hypothesize, then developing policy guidelines for their regulation and development will be essential in the coming years. In the final section of this paper we identify several broad policy implications for housing and planning development.

First, are the policy implications derived from the GIS methodology presented here. Bishop et al. (2000) have argued that the value of GIS applications lies in relatively small strategic policy areas, such as the integration of remote sensing /GIS to improve land suitability analysis. The growth of new data sources such as those used in this paper from the US Census Bureau, the US Geological Survey, and Google Earth™, allow for the integration of these technologies and their low-cost use by an expanding number of users. Granted some difficulties remain: data availability are uneven across the country, especially in rural areas, although this is changing as the costs of collection continue to decrease and as technology improves. Moreover, especially outside of the border region many informal settlements are not yet effectively disaggregated or defined as separate entities (CDPs) within the census data, making them less visible and amenable to policy targeting. Often, too, the software and systems remain difficult for basic users and are generally only managed by technicians, although this, too, is changing as Google and other software applications that are easy to use become available. Nor does the integration of spatial analysis methods described here coincide with the level and jurisdiction of current land use planning structures across the country: they work for cities and metropolitan areas, but work less well in peri-urban and rural areas.

However, GIS are only tools, the value of which will depend upon the support and implementation of the information that they generate (Rakodi, 2003). As such, the integration of information outputs into governance structures will be a key to their success. As illustrated here, even the definitions of informal housing subdivisions remain poorly developed, and local governments may be unwilling or unable to recognise these housing types, let alone adequately begin to respond to their specific needs. One of the aims of this paper is to demonstrate that IFHS are widespread across the United States, and that their identification by state and local policy makers is an important first step for effective land use management and housing policy development.

Thus far, however, specific housing policy development for informal subdivisions has been almost exclusively formulated for application in *colonias* in the Texas/Mexico border region (Ward, 1999). However, for more than a decade public officials in many interior counties of Texas and other border states have expressed concerns about low income residential "sprawl" in rural and semi-rural areas adjacent to cities, and have warned of the county's regulatory and fiscal incapacity to prevent the growth or to provide adequate services to such "wildcat" subdivisions. Cities, on the other hand, are better endowed in fiscal terms, and have planning systems and regulatory control mechanisms and laws in place to prevent informal subdivisions from developing within the city limits and the ETJ.[2]

A second major implication for policy that emerges from this study is a generic one and hinges upon how these newfound homestead subdivisions will be viewed by policy makers: as a problem or as a solution? In Latin America and elsewhere since the late 1970s, the policy paradigm towards irregular self-help housing shifted 180° from that of settlement eradication and substitution with formal housing projects towards one of pragmatic support that embraced regularization, upgrading, and even planned sites-and-service settlement (Payne, 1984; UNCHS, 1996; Ward, 2005). However, unlike governments in less developed nations, the arguments that one might look positively at informal land development processes, low levels of servicing, and self-help and self-managed housing in *colonia* type subdivisions does not play well with policy makers in the USA. Unlike their government counterparts in less developed nations who have sought to develop policy making approaches that assist upgrading and settlement improvement, the tendency in the United States is to take a remedial "task force" approach, targeting certain larger settlements for infrastructural provision on the one hand, while regulating and preventing future settlement development on the other (Ward, 1999, 2005). US policy makers also need to adopt a more positive view of IFHS and appreciate the underlying rationale for the creation of such settlements, and the structural factors that lead to their development in the first place (Mukhija & Monkkonen, 2007). This is not to argue that policy makers should see such areas and poor housing conditions as acceptable, or that they should do nothing. Rather, it urges creativity in the way in which we think about policy solutions, and to adopt regulations predicated upon minimum standards, and upon gradual (rather than immediate) compliance with state and county housing and residential development norms. Otherwise, the outcome will be one of regulating homestead subdivisions out of existence—a misplaced and misconceived planning goal in our view—but one that is closer to the conventional policy approach than that which we are advocating here, and which has underpinned housing policy in less developed countries. By using the methodology outlined here in order to identify the extent of informal settlement in their jurisdictions, the hope is that it may encourage more positive pragmatic responses, and not those of repressive regulatory control and criminalization of informality.

In this positive approach, a third policy implication will be to think creatively about specific policies to be applied in the IFHSs and *colonias* that we can now identify using GIS and digital remotely sensed images. Unlike their irregular settlement counterparts in Latin America which begin as illegal land incursions and often require ex-post title regularization, lots in homestead subdivisions are generally sold legally, but purchasers would benefit from greater levels of title protection than "Title for Deed" traditionally offers (Ward & Carew, 2001).[3] In Texas, this is being achieved by statutory conversion to "Warranty Deeds" which provide residents with a greater level of security. But away from the border counties homestead subdivisions

[2]Indeed, where a *colonia* abuts onto the city limits or falls within the ETJ, officials may even redraw the city limits to avoid incorporating the settlement, as occurred in the case of Cameron Park Colonia, in Cameron County on the edge of Brownsville, Texas (Ward, 1999).

[3]Purchasers do not receive deeds until they have completed payments on the lot, and may forfeit the lot entirely and without recompense if they fall behind in their payments.

are invariably developed under Title for Deed arrangements. Similarly, infrastructure policies will need to adapt to the low density and large lot sizes that we have observed for most homestead subdivisions, and embrace "intermediate technology" and lower level servicing and infrastructure such as septic tank and evaporation drainage field systems; "austere" street lighting; hard-core and partially paved streets, etc., (Stevenson, 2001; Carew, 2001). But again, such "second tier" infrastructural policies and a gradual movement towards compliance with local codes are anathema to most policy and lawmakers in the US.

Also, within a context of planning for infrastructure development and social service provision it is important that local and state governments better understand the vulnerability of these settlements and their populations. Often they provide homes for elderly populations and for aged parents living with their children who cannot afford formal residential care (Ward, 2007). Moreover, the trailer homes that predominate Iin these subdivisions make their populations are especially vulnerable to tropical storm and tornado weather conditions, such that local authorities also need to develop disaster management programs, and consider the construction of tornado shelters such as those we have observed built by individual homeowners in homestead subdivisions in the peri-urban area of Little Rock, Arkansas—part of "Tornado Alley" in the US heartland.

Conclusions

The methodology outlined in this paper offers insights about: (i) the feasibility of different techniques for data collection via digital orthophotos and other image sources for measuring IFHS in peri-urban America; (ii) the viability of approaches for linking existing image sources with GIS-derived data; (iii) the design and replicability of detailed methods using both sets of techniques; and (iv) the improvement of spatial depiction and understanding of census block data in low population (rural and semi-rural) areas. The methodology is relatively straightforward and can be applied easily by practitioners, policy analysts, and researchers. While we anticipate that the identification of IFHSs may eventually be achieved through automated remote-sensing techniques, current availability of high-quality imagery limits the development of these advanced methods to pre-selected areas. Ultimately these approaches and the data they generate 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. Indeed, past concerns with urban sprawl, and contemporary patterns of metropolitan growth into peri-urban rural areas are likely to become an important part of the planning and research agendas in developed and less developed countries alike.

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