Using GIS-Based Property Tax Records as an Alternative to Traditional Household Listing in Area Samples

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Background and Objective

A frame in probability sampling for studies of human populations is a list of persons or other entries from which the study sample, or a sample leading to the identification of the study sample, is drawn. A key step in probability sampling is the construction of the frame, or frames, that are needed for sample selection. Moreover, the utility of a frame in sample selection partly depends on the nature of the linkage that exists between entries on the frame and members of the population (Kalsbeek and Heiss, 2000). For complete sample coverage of the population, one wishes for each population member to be linked to a frame entry. When frame entries are not population members, the frame's utility also may depend on the sampler's ability to identify or locate selected entries, and to identify population members corresponding to selected frame entries.

For more than 50 years area probability samples for household interview surveys have used lists of housing units (HUs) as sampling frames for selection in the latter stages of the selection process (Hansen, Hurwitz, and Madow, 1949; Monroe and Finkner, 1959; and Kish, 1965.[1] A national household sample during this period might, for example, have called for designating counties, census block groups (BGs), "list segments" (subareas of BGs), and HUs as sampling units in four successive stages of selection. The frame for sampling HUs in the last stage was often constructed by hiring specially trained fieldworkers to create these frames.[2] These frames might be generated for dozens, hundreds, or even thousands of list segments in surveys. As computer hardware has become more portable and powerful, hardcopy lists and maps generated in HU listing are being replaced by digital forms that can be more easily stored and used.

Despite the introduction of computer technology into this part of the frame construction process, HU listing remains a very labor-intensive, time-consuming, and thus expensive task in face-to-face household surveys.[3] Moreover, its quality remains vulnerable to human error and to the passage of time, thus leading to various sample coverage errors (Lessler and Kalsbeek, 1992).

The general purpose of our research was to conduct a preliminary assessment of an alternative approach to frame construction for household sampling. The principal utility of this alternative is that it would eliminate the need for fieldwork and could thus dramatically reduce the cost of frame construction in area household samples. The proposed approach calls for constructing the frame for HU selection from a readily available listing of property tax parcels that are available in all U.S. counties and to which HUs can be linked. A modern adaptation of an old idea, the plausibility of this approach is enhanced by the increasingly common maintenance of these tax records in Geographic Information System (GIS) format.[4] We begin by reviewing relevant features of HU listing and the proposed strategy, which we will call the "parcel linkage" approach. We then describe the design of a small field test whose general goal was to examine the practical feasibility of parcel linkage in comparison to HU listing. After presenting the findings from this experiment we briefly raise some of the questions that remain to be answered about the parcel linkage approach.

HU Listing Approach

The U.S. Census Bureau defines a "housing unit" as "*a house, an apartment, a mobile home or trailer, a group of rooms or a single room occupied as separate living quarters or, if vacant, intended for occupancy as separate living quarters ….*(Census Bureau, 2000a) A census "household" refers to the occupants of an HU.

Like survey data collection, HU listing is a part of the survey operation that requires hiring, training, and supervising a cadre of field staff to complete the listing task which is usually done as a separate activity, just prior to the start of data collection when listing is done for a particular study exclusively. Listers living in proximity to the areas to be listed are usually hired to do the work, with staff oversight provided by supervisors having regional responsibility for the area covered by the population.

HU listing requires trained field staff to travel to selected areas to be listed, and to map and record an

[1] Note that the terms, "housing unit" and "household," are often used synonymously in these types of samples.

[2] In the sequel, we limit our attention to frame construction within BGs, although the issues and implications of our work can be extended to other area units.

[3] Informal estimates from colleagues in the survey research industry suggest that from a fifth to a third of the field operation budget can be spent on HU listing in major national household surveys.

[4] In very general terms, GIS is a computer-based tool used to store, retrieve, and learn from (two-dimensional) spatial and environmental information.

address and/or description for every encountered HU. Training for this task begins with the development of specific listing instructions by central office staff. Among other things, these instructions help the lister to identify HUs, as well as to explain how to locate the areas to be listed, where in the area to begin listing, what route to follow in traversing all of the internal and border roads of the area to be listed, and how to record the results (usually a list and map indicating where listed HUs are located). In some instances these results are entered into handheld computers. Trained listers then complete their listing over a period of several weeks or months, depending on the number of sample areas to be listed. Once the sample of HUs is chosen, available information from the lists and maps is used to prepare the work assignments for the interviewers to help them locate members of the sample during data gathering. Instructions on how to locate selected HUs are included in the interviewer training manual.

Impact on the statistical error of survey estimates is an important consideration in evaluating the frame resulting from HU listing. Three types of frame errors are possible (Kish, 1965; Lessler and Kalsbeek, 1992). *Undercoverage* occurs when HUs that should have been listed are missed. This can happen the HU is difficult to find (e.g., set far away from the road and not readily seen – a common occurrence in rural areas). *Overcoverage* occurs when entries on the frame list are not part of the target population (e.g., a vacant uninhabitable residential structure). Finally, frame *multiplicity* occurs when an HU is listed more than one time on the frame (e.g., the lister unintentionally returns to list an HU located on a corner lot). All of these types of frame errors diminish the quality of the frame and contribute to error in estimates derived from the chosen sample.

Given the cost of HU listing in an age of increasing pressures for high quality at limited cost, it is important to seek more cost-effective options to frame construction for HU sampling. This search led us to explore and propose another option for within-BG frame construction. Our approach utilizes public tax records, where the GIS environment in which they are maintained makes frame construction much easier. In the next section we describe an alternative to HU listing that is predicated on the use of GIS-based tax records with links to boundary information on the geo-political areas often used in area sampling.

Parcel Linkage Approach

Land property taxes in the U.S. are collected primarily at the county level.[5] Tax record systems are established in these jurisdictions to document information for each piece of property. This information is needed to enable local governments to request periodic tax payments from those owning these properties. Significantly, the hardcopy tax record systems that were commonplace 20 years ago are rapidly being replaced by digital systems, especially those utilizing GIS methodology and software.

The basic unit in property tax record systems is the land "parcel," a piece of land usually in the shape of a simple two-dimensional polygon that defines the legal boundaries of each owned property. A land parcel may contain an individual household, an apartment complex, or a business. It may also be a publicly owned area, an agricultural field, or be completely vacant. In addition to a unique identifier, the data record for each parcel contains a variety of information, some of which is useful for sampling purposes. For example, the parcel's use type (i.e., whether the parcel is zoned for residential, commercial, government use, etc.) or the tax valuation of structure(s) located on the parcel may be used to screen out those parcels that would be unlikely to contain an HU (e.g., Federal land) or to identify those with multiple HUs (e.g., apartment buildings). Owner information, such as name and address, might be used by interviewers to locate the parcel. Latitude-longitude coordinates for the parcel's "centroid" may also be available in GIS-based record systems to aid in parcel location.[6]

The availability of GIS mapping software in tax record systems allows one to overlay maps of parcels with established reference points of the type that are recorded by TIGER files for the jurisdiction. TIGER (for Topologically Integrated Geographic Encoding and Referencing) files are digital databases of geographic features, such as roads, rivers, and census statistical boundaries (such as block groups), covering the entire United States. The files were developed at the U.S. Census Bureau (2000b) to support its mapping needs for the decennial census and other Bureau functions. TIGER files can be accessed and downloaded for every state, as well as for individual counties within states, at no charge from various sources. In some instances they are available as a feature of the GIS software.

A view of parcel information from the property tax office in Orange County, NC (Figure 1) illustrates several of the features of a GIS-based record keeping system. The map there shows several hundred parcels for a portion of the system, with census BG boundaries overlaid (the darker lines). The window in the lower left corner shows a portion of the data that are linked to the highlighted parcel on the map.

GIS is becoming an increasingly common feature of tax record systems in the U.S. Some indication of this is

[5] Although other jurisdictions (e.g., some states and municipalities) collect property taxes, we will refer only to counties as the jurisdictions of interest in the sequel.

[6] The centroid is essentially the two-dimensional "center" of the parcel, determined as the geometric mean of the (x,y) coordinates internal to the parcel.

seen in the results from a July 2004 straw poll on the use of GIS in tax systems that we did for the 100 counties in North Carolina. There we found that 83 counties currently use GIS and 6 more are in the process of adding it. We also found that 73 of the current users are using the same family of GIS software products developed by ESRI (e.g., ArcView, ArcInfo, etc.). There are at least two other vendors of GIS software (Intergraph and Bentley).

Our North Carolina results are similar to those from a national inventory of GIS usage by over 10,000 local governments (BTI, 2003). Although the response rate in this assessment was very low (around 10%), its findings also suggest relatively high usage of GIS technology by these jurisdictions (over 90% for jurisdictions with 50,000 or more inhabitants; about 50% for smaller ones).

If sampling of HUs were to be done within a group of BGs chosen by area sampling, a parcel linkage approach to frame construction might work something like the following. After identifying all counties in which the sample of BGs is located, a digital file of parcels in each BG would be assembled from those counties. The list of parcels for each BG would be the sampling frame for this stage of sampling. [7] Separate samples of parcels would then be randomly chosen from each file. Finally, selected parcels would be assigned to field interviewers, who would locate each parcel and attempt to complete interviews in eligible HUs/households that are linked to their assigned parcels. Sub-sampling would be needed in parcels with a large number of linked HUs (e.g., high-rise apartment buildings).

Several features of GIS-based tax record systems make them potentially useful for frame construction in area samples. First, all residential households in a county are subject by law to tax assessment and thus would be found in a county tax record system. The set of parcels in the each system as a whole thus account for all households as well, although some parcels (e.g., for businesses) would have no parcels linked to them. Second, although specific data items vary among counties, the tax data from their tax record systems are available to the public. Indeed, it has been our experience that county tax offices are more than willing to comply (at little or no cost) with reasonable requests for their tax data. Third, parcel data are easily accessed and manipulated in GIS-based systems. For instance, the process of creating and exporting a machine-readable file of linked tax data for all parcels in a BG is a simple task (i.e,. manually point and click to highlight the area within the BG, then save the highlighted parcel records to a separate file; or write a simple macro to isolate and save all parcels in the BG). In addition, some GIS software allows one to easily create new data items that may be needed (e.g., the centroid of the parcel).

There are also potential limitations in using GIS-based tax records to build frames for HU selection. One is that not all tax offices currently use GIS, implying that conventional HU listing or some other alternative (e.g., use of postal lists) would be needed for frame construction in those areas. Also, not all counties with GIS use the same software vendor, although most appear to use one of the ESRI products. From a practical standpoint, variation in software adds complexity and cost to the process of assembling sampling frames. Third, some linkages between parcels and HUs could be problematic. As previously noted, some parcels (e.g., businesses, public land, agricultural land, and vacant lots in residential areas) will have no linked HUs. These "zero-unit" parcels would best be pre-screened out of the frame if possible. Another aspect of this linkage is that the lots on which HUs are built may consist of several neighboring parcels. This multiplicity problem can be remedied by uniquely linking the HU to the parcel on which the HU structure is actually found, thus treating the other parcels as zero-unit parcels. In addition, (most likely urban) parcels with large numbers of HUs could contribute to problems with variable sample weights due to subsampling, unless statistically effective methods for within-parcel sampling were developed. Finally, although in principle the set of parcels comprising a county tax record system all exist and can be linked to the set of HUs that exist in the county at the same time, practical questions may be raised as to whether: (i) selected parcels can be located and (ii) any HUs on them would be correctly identified. The last two questions, along with the need for other related indicators of the statistical quality of samples chosen from a parcel frame, supplied the motivation for a small field test which, among other things, compares HU listing with the parcel linkage approach.

Field Test in Rural North Carolina [8]

Impetus for exploring the use of tax records as a frame source arose during the development of ideas for sampling in a large statewide face-to-face survey of households that was planned for North Carolina. Ambitious goals for this study combined with limited financial resources made it important to find ways to retain scientific integrity while controlling cost. Frame construction connected to HU sampling was one component of survey design where we sought diligently

[7] As an intermediate step prior to sample selection, the complete set of parcels in the BG might also be screened to exclude zero-unit parcels, if they are readily identifiable, or to deal with other linkage complications for the parcels in the BG.

[8] The authors gratefully acknowledge Phillip H. Page and other members of the GIS support staff at the UNC-CH Carolina Population Center for their assistance in conducting this research.

to find a more cost-effective approach. Our search led to our GIS-based parcel linkage approach and to a modest first-attempt to address some questions about its utility as an alternative to HU listing.

Goals and Design

Our field test of the parcel linkage approach was conducted in a rural county (Edgecombe) in eastern North Carolina in the late fall of 2000 by a 10-person UNC field team that included students in an advanced sampling class and staff affiliated with the Survey Research Unit. The primary reason for choosing this particular county is that the first phase of the proposed survey was to investigate the health and economic impact of a recent hurricane (Floyd) in which Edgecombe County was one of the hardest hit areas. The field test had two main goals:

Goal 1 --- To evaluate the ability of field staff to locate and link HUs to sampled parcels, and

Goal 2 --- To compare the quality of the parcel linkage and HU listing approaches.

To provide a more diverse perspective in meeting these goals, some testing was done "in town" in Tarboro, NC (population about 12,000) and the rest was done in "rural farm" areas in the agricultural area surrounding Tarboro. The test area did not extend into any metropolitan areas of the state because of lack of time and cost constraints.

The design to meet Goal 1 called for the selection of a simple random sample of 25 parcels in each of four subjectively chosen BGs, two in town and two in the rural farm area. To add further diversity to the sample, one BG in each pair was chosen from an area especially affected by the hurricane (presumably a more difficult setting for frame construction), and the other was in a largely unaffected area. Then within each BG, two teams (most frequently comprised of two field staff each) independently located and linked HUs to each sample parcel. Each team was given the following devices to help them locate their assigned sample parcels: (i) a portable Global Positioning System (GPS) receiver [9] containing a downloaded file with the latitude-longitude coordinates for the centroid of each sample parcel, (ii) a printed parcel map of the BG (including street names) that highlighted the selected parcels, as well as a listing of the selected parcels that included for each parcel the (iii) the owner's address, (iv) the tax valuation of buildings on the property, and (v) the parcel's "use type." As part of the location step, each team was asked to record (in order of use) which of these devices was/were used to locate the parcel. They also recorded a 1-10 indicator of how confident they were in having found the correct parcel (1 = likely to be incorrect, … , 10 = absolutely certain to be correct). Once the parcel was located, the team recorded the parcel's unique identification number, address, and a description of what was located on the parcel (i.e. one or more HUs, a business, an agricultural field, etc.) based on their search of the property. Immediately after the two teams completed their work, a third (adjudication) team reconciled the teams' results to produce a final "correct" result for the exercise. All of these team results were recorded on specially devised paper forms.

To meet Goal 2 we used results from the Goal 1 design as well as the results of HU listing and linkage in four different subjectively chosen BGs. Only parts of these BGs, with GIS-recognized boundaries (and subsequently called "area segments"), were used for this part of the test. The BGs we chose each contained between 363 and 473 parcels, with each of the area segments containing approximately 70 parcels. As before, two were in town and two were from the surrounding rural farm area. In each of these segments 2 two-member teams independently listed all HUs using conventional HU listing methods (see above). Next, two different teams (also differing for each segment from the team that did the listing) independently linked all team-listed HUs to a GIS listing of all parcels in the segment. Two class sessions prior to the field test were devoted to learning and practicing the written procedures for HU listing and parcel linkage (based on RTI, 1976). In addition, each class member completed an HU listing exercise in a local residential area. A specially modified HU listing form was used, and both sets of listing and linkage team results were adjudicated by a third team in the same manner as described for the Goal 1 design.

In advance of the field test, we accessed the TIGER files and tax parcel data file for Edgecombe County. The TIGER files were accessed and downloaded from the Environmental Systems Research Institute website for free (ESRI, 2000). We requested a tax parcel data file from Edgecombe County. This file was sent to us in a digital format using a program called Oasis (produced by the company Understanding Systems, Inc.). This program presented a challenge when we attempted to format the information so as to make it compatible with ArcView. Once the files were overlaid using ArcView,

[9] A GPS device is a hand-held receiver that picks up signals from satellites orbiting the earth, and uses this information to calculate the geographic position of the person holding the receiver. At the time of the field test there were 24 GPS satellites continuously orbiting the earth, each transmitting a time signal that the GPS receiver can pick up and use to calculate the holder's latitudinal and longitudinal coordinates. GPS units of the type we used are usually accurate to 15 meters, although we found them to be more accurate than this. The devices were used to direct field staff to the location of a specific parcel, by way of a 'digital compass' displayed on the receiver screen. The compass would literally point staff in the direction of the parcel as they approached by car or on foot.

we were able to produce maps for the BGs and area segments of interest and to determine the sets of parcels in these areas. The ArcView software allows one to highlight a specific BG simply by double clicking on it. All land parcels in the highlighted area are simultaneously highlighted on the digital tax parcel data file. One can then export the highlighted parcels into a text file. ArcView also allowed us to digitally draw a line around each area segment, to highlight all parcels contained within, and to export them into a text file.

The field test was largely conducted on December 7-8, 2000. Fieldwork for both goals occurred simultaneously, although some of the Goal 1 work was completed a few days after this two-day period.

Findings for Goal 1

We addressed two basic questions about operational aspects of the parcel linkage approach. One asked which of the provided devices would be most useful in locating the samples of parcels assigned to field staff. Our percent profiles of overall and first use of the location devices provided to field staff reveals that the GPS receiver containing the centroid's lat-long coordinates, the GIS-generated map with selected parcels highlighted, and the owner's address were essential devices in locating parcels. The map was needed for virtually all (99% of) parcels, although it was the device first used much less frequently in rural BGs (16% in rural farm vs. 97% in town). The GPS device was also very important in rural farm parcels (98% used; 82% first used), although its use was considerably more important for rural farm parcels than for those in town. Third in importance was the address of the property owner (53% used; 1% first used), it being somewhat more likely to be used in town (60%) than in the rural farm area (42%). Rural farm parcels were the only place where building valuation (18%) and type of property (16%) were of any use.

Another operational question we asked was how well would field staff do in locating sample parcels with the aid of these devices. Table 1 provides two answers to this question. One is that the fieldworkers tended to be quite certain that they had found the correct parcel (average confidence scores near a "perfect 10." We also found that field staff were highly successful in locating a parcel with the exact same HUs as found during adjudication. For both of these measures of location success there was little difference between parcels in town or in rural farm areas, with those in town being higher. Table 1 also presents two answers to the question as to how successful field staff was in linking sample parcels to HUs found on those properties. One measures the percent of parcels where both teams found the same set of HUs as the adjudicated finding, while the other is based on the team average of the number of HUs linked to the sample parcel, divided by the adjudicated number of HUs linked to the same set of parcels. Findings again indicate high levels of successful linkage for sample parcels, especially for the latter measure, with the same tendency for somewhat greater success in town.

We were also interested in knowing what types of parcels would be the most difficult in which to identify HUs. To answer this question we classified parcels into three groups according to the number of HUs linked to them: zero-unit (with no linked HUs), single-unit (with one HU), and multi-unit (with two or more HUs). To give us larger sample sizes for this analysis we used data from the linkage of HUs to parcels that was done after HU listing in the area segments for Goal 2. Using the percent of parcels with listed HUs that were correctly linked (as compared to the adjudicated results), we found (Table 2) that there seemed to be relatively little difficulty with single-unit parcels but somewhat greater difficulty with the zero- and multi-unit parcels. Problems with zero-unit parcels were largely due to one of the teams that had a particularly difficult time in distinguishing vacant lots from lots with vacant HUs. The lowest linkage success rate occurred with multi-unit parcels in the rural farm area, although the sample size may have been too small for solid generalization there.

Findings for Goal 2

To meet Goal 2 we were primarily interested in gauging and comparing reliability (i.e., team to team agreement in results) and validity (i.e., average of team results compared with adjudicated results) between the HU listing and parcel linkage approaches. We measured reliability as the percent agreement in individual HUs identified between teams, relative to the adjudicated result. Findings (Table 4, left columns) reveal similarly high levels of reliability for the two frame construction approaches, with somewhat lower levels in the rural farm area, where the parcel linkage results are a bit better, than in town, where HU listing was superior. A Kappa score was also produced for parcel linkage from the two-way comparison of team results for sample parcels according to the categorization of the number of linked HUs per parcel (zero-, single- and multi-unit). Generally high values of Kappa are observed in all areas, indicating a high level of agreement between the types of parcels each pair of teams found. The measure of validity we used for our comparison was the average count of HUs listed or linked as a percent of the corresponding adjudicated count. Once again, validity as measured in this way was similarly high for both approaches, though with the same reversed pattern of superiority between approaches for BGs in town and rural areas that was observed with reliability.

Tentative Conclusion and Some Remaining Questions

Our findings suggest that field staff following a parcel linkage approach to frame construction for local area would be able to successfully locate selected parcels and then do a good job of finding any HUs that may be located on these properties. Moreover, this approach displayed similarly high levels of reliability and validity as HU listing in a limited field test. Thus, with comparable statistical outcomes, the parcel linkage approach would be a more cost-effective to the extent that it is less costly.

As regards cost, parcel linkage has one important advantage in that it requires no fieldwork, although there are cost considerations that would affect the net cost comparison between it and the HU listing approach. Since no formal comparison of costs was done in our field test, we can only attempt a quasi-quantitative comparative assessment of the cost of the two approaches. We present (Table 3) reasoned levels of cost for components of frame construction and survey interviewing that would be differentially affected by the two approaches. Those components thought to be negligible or zero are denoted by a "**0**," while the relative size of each non-zero component is indicated by the font size of a "**+**." As expected, the largest differential in field cost occurs with the recruitment, training and salaries of field staff for HU listing, for which there would also be moderately large costs for computer hardware and software if handheld or other portable computers were used to record the listing results. Other than computers and software to process requested GIS files from tax offices, parcel linkage has no comparable field costs, although it would have unique costs associated with the assembly of information and equipment to assist interviewers in locating selected parcels. No comparable costs would exist with HU listing. Also, the pre-selection personnel costs to assemble frame lists from the county tax offices and any screening and processing of the obtained digital files are likely to be somewhat greater than the cost of converting the HU listing results into a form that would be suitable for sample selection. Parcel linkage is likely to require somewhat higher costs to train interviewers, mainly to locate parcels and identify HUs linked to them. When combined it seems clear that the total cost of HU listing will be notably greater than the cost of the parcel linkage approach.

Despite the favorable first impression by this GIS adaptation to the old idea of using tax records for frame construction in sampling HUs, there remain some unanswered questions concerning the relative utility of the parcel linkage approach. First, the relative cost differentials between this approach and HU listing must be more rigorously determined through a formal and detailed cost comparison. Second, until all counties utilize GIS to maintain their property tax records, it will be necessary to follow an alternative approach to frame construction at the latter stages of area samples. Clearly HU listing would be an option, but so too might be an approach using postal service lists. Third, parcel linkage needs to be tried in large metropolitan areas to establish the ability to locate and, if necessary, sample HUs in large high-rise apartment buildings and other complex multi-unit parcels that would be found there. Regardless of these outstanding issues, our findings suggest that the use of county property tax records maintained by GIS technology should be given a closer look as a less expensive and comparably effective alternative to HU listing for sampling in face-to-face household surveys.

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TABLE 1 Success in Locating and Linking HUs to Sample Parcels

Measure ***(Sample size)***	*In town*	*Rural farm*	*Overall*
Locating:			
Average confidence score (1-10) [a] *(n)*	9.9 *(79)*	9.2 *(50)*	9.6 *(129)*
% correctly located parcels [b] *(n)*	100% *(100)*	95% *(100)*	98% *(200)*
Linking:			
% linkage ratio for parcels relative to adjudicated results [c] *(n)*	94% *(50)*	88% *(50)*	91% *(100)*
% linkage ratio for HUs relative to adjudicated results [d] *(n)*	96% *(84)*	95% *(76)*	96% *(160)*

[a] Confidence rating: 1=likely to be wrong; …; 10 fully certain; missing ratings from three teams of field workers.

[b] A parcel is considered to be "correctly located" if the recorded address(es) for the discovered HU(s) match those corresponding address(es) on the adjudicated list.

[c] Measures the % of parcels where both teams identified the same set of HUs as in the adjudicated results.

[d] [Team average # of HUs linked to the sample parcel] / [adjudicated # of HUs linked to the same set of parcels].

TABLE 2 Success in Linking Parcels to Listed HUs by Type of Parcel

Type of Parcel ***(Sample size)***	***% of parcels with listed HUs correctly linked:*** [a]		
	In town	*Rural farm*	*Overall*
Zero-unit *(n)*	85% *(33)*	100% *(35)*	93% *(68)*
Single-unit *(n)*	100% *(73)*	91% *(44)*	97% *(117)*
Multi-unit *(n)*	100% *(3)*	33% *(6)*	56% *(9)*
All types *(n)*	95% *(109)*	91% *(85)*	93% *(194)*

[a] "Correct" linkage for a parcel here means that the linked HUs are exactly the same as the adjudicated result.

TABLE 3 A Field Cost Comparison Between Frame Construction Approaches

Cost Component	*HU Listing*	*Parcel Linkage*
Frame construction:		
• Field staff recruitment/training	+	**0**
• Field work operations/ supervision	**+**	**0**
• Computer hardware needs [a]	+	+
• Computer software/ programming needs [a]	+	+
• Other pre-selection frame processing tasks	+	**+**
Survey interviewing:		
• Interviewer training	+	**+**
• Assemble locator information/ equipment	**0**	**+**
OVERALL COST	**Very High**	**More Modest**

[a] Assumes that the lists of HUs constructed in the field are entered onto portable digital devices.

TABLE 4 Comparative Reliability and Validity of HU Listing and Parcel Linkage

	Reliability			*Validity*	
Type of location (Sample size)	*HU listing: % Agreement* [a]	*Parcel linkage: % Agreement* [a]	*Parcel linkage: Kappa* [b]	*HU listing: Average team count as % of adjudicated count*	*Parcel linkage: Average team count as % of adjudicated count* [c]
In town *(n)*	99% *(79)*	93% *(42)*	0.86 *(50)*	100% *(158)*	96% *(84)*
Rural farm *(n)*	72% *(65)*	89% *(38)*	0.89 *(50)*	92% *(130)*	95% *(76)*
Overall *(n)*	87% *(144)*	91% *(80)*	0.87 *(100)*	97% *(288)*	96% *(160)*

[a] Reliability measured as the % team agreement in HUs identified relative to adjudicated result.

[b] Kappa from two-way for sample parcels by team according to type of linkage: zero-unit, single unit, or multi-unit.

[c] "Team count" of HUs linked to sample parcels.

FIGURE 1 A View of GIS-Linked Property Tax Parcels Maps and Associated Data