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Remote Sensing Technology and the U.S. Census

This article is a comment on "The Census: It Can be Done More Accurately with Space-Age Technology."

INTRODUCTION

DINO A. BRUGIONI's article, "The Census: It can be Done More Accurately with Space-Age Technology" (Brugioni, 1983), brings up some interesting questions; we were glad to see the Journal, *Photogrammetric Engineering and Remote Sensing*, publish a commentary on the use of remote sensing within a field of the social sciences. Given the myriad uses of census data, it is especially appropriate to examine ways in which the census can be improved. It is well known that the data generated

census survey from the point of view of some user communities. Second, remote sensing methods are less likely to have a systematic bias against illegal residents and other people who avoid the census enumerations. In general, we feel, as Mr. Brugioni does, that remote sensing should command a place in the arsenal of the Census Bureau. We are further convinced that it may be especially suited for intercensal updates for fairly small areas and for spot checks of the more visible census information.

Given the above comments and Mr. Brugioni's enthusiasm for "space-age technology," his closing

ABSTRACT: This paper is a comment on Dino Brugioni's article, "The Census: It Can be Done More Accurately with Space-age Technology." After citing points of agreement, the authors criticize the proposed use of remote sensing techniques to replace the census survey on the grounds of technical problems (imagery, variable definitions, and lack of knowledge), data problems, the uses of the information (private and public), and ethical problems. They conclude that remote sensing techniques have a place with the census but that they cannot be the principal survey method.

during the decennial census surveys are not without their shortcomings in terms of accuracy and completeness, and the many census workers will no doubt be among the first to admit that a prompt finished product from the enumeration seems to become more elusive with each passing decade.

We feel that Mr. Brugioni's suggestions on the use of "space-age technology," assumed here to mean modern remote sensing technology, have several positive aspects that merit attention. First, it may be that remote sensing could offer a less expensive and quicker alternative to the present

question, "Why not use it?" deserves a thorough answer. Our interest in and credentials for comment on this topic derive from our academic specialties. We are both human geographers with population geography and remote sensing as two of our primary fields. We believe that remote sensing should be given an acknowledged place in the social sciences. However, Mr. Brugioni's commentary on the census illustrates one field where the level of application suggested is tenuous. The following sections of this response offer several broad categories of reasons why remote sensing technology would not be ap-

appropriate as the mainstay of the Census Bureau's information gathering techniques.

TECHNICAL PROBLEMS

IMAGERY CONSTRAINTS AND EQUIPMENT

There is a variety of potential technical problems inherent in using remote sensing methods as the principal data gathering mechanism for the census. The author cites a long list of fields in which remote sensing is used to collect data. Many of these topics are covered at a regional scale (not the micro scale of census data) and are of nonhuman objects that are relatively immobile and tend to obey consistent rules of behavior. The users of these data are generally happy with reasonable estimates of the numbers, sizes, or locations of objects. They do not often need the more specific data on characteristics which are integral to most social research (the most common use of census data). To fill these gaps in remotely sensed census data would require much more extensive ground truth than Mr. Brugioni seems to envision. This step would be both time consuming and expensive. These data needs are discussed further in a later section of this comment.

Another problem is found in the length of time involved in imaging an entire nation. The present census is conducted as of a single day, the first of April, in an attempt to get a snapshot of one moment of population and housing history and to allow for maximum comparability within the data set. It is unlikely that an imaging system of high enough resolution for Census Bureau purposes could effectively cover the United States in one day. The orthophoto maps mentioned by Mr. Brugioni have taken years to collect and are still not complete. Even Landsat takes 18 days to cover the whole of the North American landmass. Assuming the Bureau of the Census had very high resolution photo equipment on a very fast platform, it is a rare occasion when the entire nation has a cloud-free day.

The article notes that much of the necessary imagery is already collected by groups other than the census. This may be true, but these images are acquired for some places at some times—not for all places at one time to facilitate comparison. Repetitive coverage is an excellent idea, and one of the reasons remote sensing is good for intercensal estimates, but it would take an incredible length of time to cover the entire nation once every ten years, let alone more often than that.

The article appears to assume that the Census Bureau has made no effort to modernize its procedures. On the contrary, it has attempted to streamline the enumeration process and improve the overall precision and usefulness of its products. Obviously, it would be unable to process the huge amounts of data that it receives if it were not using reasonably modern (i.e., space age) computer hardware and software. Data products are still slow in

appearing, but the data processing technology is by no means antique.

REDEFINITION OF VARIABLES

A second consideration in replacing the census survey with remotely sensed information would be the alteration in the meanings of census variables. Any comparability with past censuses would be lost, interrupting an exceptionally valuable source of evenly spaced historical data.

One example of this difficulty is in the answer to the problem of where a census counts individuals. In general, censuses make the distinction between counting by the *de jure* (place of legal residence) method or the *de facto* (place where the person happens to be at the time of the count) method. The U.S. Census has used the *de jure* method. On what assumption would the remotely sensed information be based? It is neither a *de jure* nor a *de facto* census, and hence is comparable to neither. In fact, it makes no explicit reference to individuals at all. It is entirely based on assumptions about human structures and the way in which people occupy them. Certain census variables, such as house size, value, and quality, might be no less accurately portrayed by the new method, but the point remains that their meanings would be changed to the detriment of long term comparative research.

LACK OF KNOWLEDGE

The remote sensing method of collecting census data assumes a vast reservoir of knowledge about the relationship between features that are observable on an image and those that are not (analogous to the distinction between land cover and land use). Unfortunately, our knowledge is simply not that good.

One example are the present attempts to use remotely sensed data to estimate the population size of small areas within cities (there is a fairly extensive literature on the topic). These experiments often require parameters, such as average household size, which are derived from the census. In addition, the methods are still very far from perfect, with accuracy (as measured against the census in most cases) ranging from moderately good for single family homes in tract developments to very poor for multifamily units in large cities. In general, multifamily units cause the largest problem in these studies—the very type of unit that would be crucial to the census counts.

The use of digital techniques is promising, but it is also a long way from being operational. Again, we simply do not have the knowledge to go from spectral characteristics to the human implications of those characteristics. As an example, Mr. Brugioni's assumption that density (number of people resident per square foot) is always highest in central cities is simplistic and very seldom true. The actual rela-

tionship is far more complex and not well understood. If advanced research in remote sensing cannot yet offer solutions to some of these problems, the census can not be expected to use the technique.

THE DATA

A fundamental element in any field of remote sensing application is a firm knowledge of the data requirements within that field. The population and housing data collected by the Census Bureau are not, as Mr. Brugioni implies, simply a matter of numbers of people and numbers of housing units. They encompass a detailed evaluation of population and housing characteristics that extends far beyond what is perceptible to the eye, an aerial camera, or an advanced radar system. A statement from the article will show the importance of this misunderstanding. "Using comparative photographic coverage, new change detection computer techniques can spot, delineate, and map *all population changes* that have occurred . . ." (emphasis added). The difficulty is in the definition of population change. Can these methods tell us the change in age structure, household composition, family income, race, sex ratio, or other *characteristics* of the people? This is a crucial part of the census, and the largest drawback to the suggested method of improving it.

Table 1 gives a list of the types of variables available in the present census. A quick survey of these items indicates that remotely sensed data cannot supply the majority of them, however useful it may be for some information. To take an example from the 1980 census, remote sensing techniques would probably have found that nonmetropolitan population was growing. It would have been extremely difficult (given the long life of structures, even after they have been abandoned) to show that much of this growth was at the expense of large urban areas. We would have seen the growth of amenity areas, but could remote sensing have told us which areas were primarily populated as retirement communities or what the sex ratio had become because of the migration? This kind of information is crucial to the users of census data.

TABLE 1. TOPICS COVERED BY THE 1980 CENSUS FOR EVERY HOUSEHOLD (AFTER THE POPULATION REFERENCE BUREAU, 1980)

Population	Household
Household relationship	Number of units at address
Sex	Complete plumbing
Race	Number of rooms
Age	Unit owned or rented
Marital status	Condominium identification
Spanish/Hispanic origin or descent	Value of home
	Rent
	Vacancy for rent, for sale and period of vacancy

Perhaps remote sensing could be used for the primary collection of total numbers, with a sample survey (like the present long form of the census) investigating certain characteristics. We are not convinced, however, that this would significantly lower survey cost or increase speed. More importantly, such a strategy would destroy the very useful block data in large cities and would remove the present statistical advantage of dealing with a population rather than a random sample.

USES OF CENSUS INFORMATION

The Constitutionally advanced reason for the census is to apportion representation among the states. Mr. Brugioni covers this use of census data very well in his commentary. Over the years, however, the census has developed a huge user community which is consulted whenever a change is planned. This community has certain needs that differ from those initially envisioned for the census to fill, needs which the remotely sensed data could not meet.

PRIVATE SECTOR

Businesses in the United States have many uses for census information. One of these is research and development for new products. For example, as the census has shown a change in the age structure of the American population, different types of products have been developed. The private sector also makes enormous use of the census in marketing. It uses census data on population characteristics to segment the market (at a variety of scales), to help define trade areas, and to aid in the selection of locations for plants. Location decisions also depend to some degree on the characteristics of the local labor force.

PUBLIC SECTOR

As mentioned above, the census is used to apportion votes. It is also used to allocate funds in many federal programs, as noted in Mr. Brugioni's article. One of the arguments for using remotely sensed data is that its improved accuracy would forestall critics of the census who claim that it has robbed their cities of needed federal funds. First, it is questionable whether remote sensing could provide more accurate counts in the cities. Second, it is very important to realize that the allocation of federal funds is primarily a political question. The actual accuracy of the census does not necessarily have anything to do with the alleged errors in its figures. In the attempt to do the best possible job for one's own constituents, it is immaterial whether the census information is accurate or not. It must be alleged to be inaccurate in the attempt to secure more federal dollars. The complaints, lawsuits, and so on will continue as much because of the political

process involved as because of the Census Bureau's difficulties in counting certain kinds of people.

In addition, the problem of population characteristics remains. Federal funds are not given out on the basis of how many people the city has. They are given out on the basis of how many people the city has *that have certain characteristics*. These kinds of data are needed for such things as allocating public housing, distributing antipoverty funds, giving school aid, and so on. According to the Population Reference Bureau (1980), 50 billion dollars of federal money is disbursed annually on the basis of the 1 billion dollar per decade census. That figure makes the census cost appear more reasonable.

Mr. Brugioni notes that census counts are especially deficient in minority areas. This is true and is a problem on which the Census Bureau is constantly working. However, the implication in the article is that remotely sensed data would improve this count. It follows that all minorities (or at least those eligible for the various federal programs) are to be found in discrete, homogeneous areas that can be clearly identified from overhead reconnaissance systems. This does not seem likely, given current research on the social and spatial structure of cities.

Finally, the author claims that information collected by remote sensing would be more representative of what governments need. This is clearly an exaggeration of the quality of those data. Until remote sensing can tell us the characteristics of people and their housing units, it will not be as useful to governments as is the census in its present form, in spite of its drawbacks.

ETHICAL CONSIDERATIONS

There is one final item that we would like to mention briefly; that is the ethical considerations involved in the kinds of sensing systems that would be required to actually gather the data that the Census Bureau now collects with surveys.

First, we think that most people are presently unaware of the extent to which they are surveyed by remote methods. If remote sensing systems exist that have the necessary resolution and other abilities to adequately perform a census, and if those can be declassified for Census Bureau use, will these methods be acceptable to most people? An example of this is the complaints made by farmers whose compliance with federal regulations is often examined by overflight. The whole concept may seem too much like "big brother" watching to appeal to many people in the U.S.

The confidentiality of data collected by remote sensing systems also seems to be in question. This is even more important if the images used are collected and used for other applications that involve putting them in the public domain.

These questions of ethics may seem to be a philosophical diversion from the real issues, but we feel that they are questions not often enough addressed

in the field of remote sensing. They are at least worth examining in the context of a situation such as the census.

CONCLUSION

The article states that, in order for the Census Bureau to agree to use remote sensing methods, it must be convinced that ". . . the census can be done more accurately, cheaper, faster, and better than by previous methods." This is a fair statement.

It is possible that remote sensing methods would be cheaper and faster than the present census, though we would like to examine some figures for comparison. Even if this is the case, however, the tradeoff would mean a great deal less information.

The question of accuracy troubles us for similar reasons. Even if the new method for the census were more accurate, the tradeoff of very accurate counts for questionable accuracy in characteristics does not seem to be a very good one. We also have serious doubts, after having examined the literature on population size estimation from remotely sensed data, about the accuracy of this kind of method for counts.

Finally, "better" is in the eye of the beholder. We cannot imagine a census without data on population characteristics—at least we cannot imagine one that would be of much use. Mr. Brugioni states that "Records created from aerial photographic analysis are far more valuable for historical purposes than the records created by the past and present census systems." Surely this depends on what one is studying! Aerial photos have their uses as historical records, but, as we have shown, they have shortcomings that greatly inhibit their use in the arena of the social sciences. Remote sensing can do many things, but it is a mistake to assume that it can do everything.

It is quite plausible for the Census Bureau to use some remote sensing technology in its surveys (there have been similar applications in developing countries). These techniques are appropriately considered as one of the tools necessary to achieve accurate population information. Perhaps they are not used enough (Mr. Brugioni's suggestion of a demonstration project in one city is an excellent one), but they have their place. To suggest, however, as we believe the author does, that remote sensing can replace the present census survey is to take that survey, its results, and its uses far too casually.

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