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SPATIAL DIMENSIONS OF FAMILY PLANNING IN COSTA RICA: THE VALUE OF GEOCODING DEMOGRAPHIC SURVEYS

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The article illustrates the value of geocoding demographic surveys and conducting spatial analyses to understand the service supply environment and contraceptive behavior. Three Costa Rican data sets are geocoded and pooled in a Geographic Information System (GIS): a demographic survey, an inventory of family planning facilities, and a census. Displaying survey's results on maps enhances the understanding of the spatial configuration of family planning services and users' behavior. Trend surface analyses improves survey's estimates for small areas and pin-points spatial differences. Cartographic-based measures of accessibility and of contextual characteristics have an edge in objectivity, comparability and flexibility. Multilevel models on contraceptive use and method choice suggest mixed effects of density of services and diffusion effects from neighbors. A model for the choice of family planning outlet arrives at a classic gravity formulation in which larger and closer clinics are more likely to be chosen. Demographic surveys should consider geocoding their sampling units as a routine procedure.

INTRODUCTION

This chapter uses Costa Rican data to illustrate the value of geocoding a demographic survey and conducting spatial analyses to understand the service supply environment and contraceptive behavior. The article first delineates alternative procedures for geocoding a survey and then illustrates five uses of this information, namely: (1) visual display of spatial relations; (2) spatial trends and small area estimates; (3) measuring the family planning service supply environment; (4) studying contextual and neighborhood effects; and (5) analyzing service utilization.

The last two decades have seen a substantial increase in the data available on population and family planning in developing countries. The massive World Fertility Survey (WFS) and Demographic and Health Surveys (DHS) projects are examples of this data explosion. Data sets, however, are usually used in isolation from each other under-utilizing their potential. This article addresses the issue of linking data sets in connection with: (1) demand of family planning usually from DHS-type surveys; (2) supply of services, including inventories of facilities, administrative records and Situation Analysis-type surveys (Fisher et al. 1992), and (3) the socioeconomic and physical environment as described by censuses and digital cartography. The article posits that geocoding is a cost-effective strategy to relate these data sets to each other, especially when these are pooled in a Geographic Information System (GIS) (Scholten et al 1991). Beyond data managing issues, geocoded information facilitates a multilevel strategy for studying contraceptive and other behaviors, i.e. a strategy that combines information about individuals or households (micro data) with contextual information (macro data) about the community or other aggregates (Hermalin 1986).

SETTING

Costa Rica has one of the highest Contraceptive Prevalence Rates (CPR) in the developing world: 76% according to the 1992-93 Reproductive Health Survey (ESR Spanish acronym). Its Total Fertility Rate of 3.1 births in 1991-93 is not, however, low. This combination of very high contraceptive practice and somewhat high fertility has puzzled demographers for decades. Contraceptive practice is high across all regions and social strata. The lowest CPR, which occurs among illiterate women and in rural areas outside the Central Valley, is about

70%: a figure that is not substantially different from the national average. The major provider of family planning in Costa Rica is, by far, the government, through its clinics of the Social Security Office and the Ministry of Health. Public health facilities provide for more than three-fourths of all modern contraception in the country. Although there is a substantial overlap in the population served by the Social Security and the Ministry of Health, the later tends to be more important in rural areas and among the poor than the former. The four most popular contraceptive methods are the pill (26%), sterilization (22%), condom (22%) and IUD (12%) (Caja Costarricense de Seguro Social 1994: Table 9.12).

To put things in perspective, it is important to note that a lack of geographic variation in contraceptive practice in Costa Rica reduces the pertinence of some spatial analyses in this article. Costa Rica is a country with a high degree of spatial integration and a good communications network. In addition, public health services, which include family planning, have high coverage, reaching even the most remote areas. For example, 98% of deliveries occur in hospitals. Physical accessibility, therefore, does not seem critical for practicing family planning in this country, which is well-documented in earlier studies (Rodríguez 1978; Hermalin et al. 1988). Moreover, the recent ESR showed that the median reported travel time to public family planning outlets is only 28 minutes, which is very short compared to the median of two hours and 21 minutes reported as spent in the waiting room of public clinics (Caja Costarricense de Seguro Social 1994: Table 10.6. The figures are self reported times by users of resupply methods for the most recent visit to a family planning clinic).

DATA

The chapter uses mostly three geocoded data sets:

1) The Costa Rican Reproductive Health Survey (ESR), conducted in 1992-93 by the Social Security Office with assis-

tance from the US Centers for Disease Control and Prevention (CDC). The ESR's sample is nationally representative of females aged 15 to 49. It includes 3,618 respondents in 188 clusters (Caja Costarricense de Seguro Social 1994). These clusters are a sample of the 1984 census tracts.

2) An inventory of about 300 delivery points of public family planning services. Private facilities—private physicians' offices and pharmacies—are not considered. The only information available for each clinic in this inventory is its size, as measured by an estimate of the number of consultation hours (all purposes and for family planning) provided in 1992. This estimate is based on unpublished data on outpatient consultations from the Department of Biostatistics of the Social Security Office and from the Statistics Department of the Ministry of Health.

3) About 11,000 "segmentos" (census tracts) of the 1984 census. A census tract comprises 50 households on the average, and an area of one or two city blocks or one to ten square kilometers in rural areas. This data set was used to estimate the population densities for survey clusters and the catchment populations for service facilities. The Costa Rican Statistic and Census Directorate provided the original census files.

Geocoding Procedure

The ideal situation for spatial analyses would be to have X, Y earth coordinates for every household and health facility in the country. For practical purposes, however, it is sufficient to take sampling clusters and census tracts as single points and to geocode their centroid. This means obtaining the coordinates for about 100 to 300 points in a typical survey: hardly a daunting task. Geocoding all census tracts is more demanding, but it is not essential for most of the analyses in this article. Given the purpose for which a census tract is defined (convenience of enumeration), its demographic centroid is clearly a more accurate representation of the location of the tract's population than a polygon of its entire area (Bracken 1989).

Three geocoding procedures may be considered:

1) The least expensive procedure consists of matching the survey or census to a data set which already contains X, Y coordinates. For example, in the US one could record the zip code of each sample unit and merge the survey to many commercially available geocoded data sets containing zip codes. In developing countries, however, geocoded data bases with an appropriate geographic detail are rare.

2) An alternative procedure is to locate the sampling points and tracts on appropriate maps and to read the coordinates there. These maps must be accurate, geo-referenced and of a large scale. If, for example, the typical error involved in placing the points on the map and reading the coordinates were of the order of one centimeter, working on maps with a large scale of 1:10,000 would result in a typical error of 100 meters, but on a small scale of 1:1,000,000 the error would be a disappointing 10 km. The costs involved in geocoding from maps are small, but the potential for error is large.

3) A probably more accurate, but also more expensive, alternative is to use "global positioning system" (GPS) devices to obtain the coordinates in the field from satellite signals. The accuracy of these measurements is usually of the order of 30 meters. The costs involved in this procedure come mostly from purchasing GPS devices and visiting every site on the field. The 11,000 census tracts (which include the 188 ESR clusters) were geocoded for this study by reading their centroid's coordinates from maps. Since Costa Rican census maps do not have earth coordinates, a two-stage procedure was devised. College students implemented this procedure. First, we took the earth coordinates of a series of reference points from geo-referenced maps of the National Geographic Institute. The scale of these maps is 1:10,000 in the Central Valley and 1:50,000 in other areas. We

identified one reference point (typically the church, a school, a cemetery, or the "plaza") for each census map. Usually there was one or two census maps per administrative "distrito." Second, we graphically measured X, Y plane coordinates for every tract's demographic centroid on census charts, taking the aforementioned reference point as the cartesian origin of the system. The scale of census charts ranged from 1:800 to 1:20,000. A computer merged the two sets of coordinates and maps' scales to compute projected earth coordinates, using the Lambert Conformal projection (Inter-American Geodetic Survey 1950).

Given that data errors are critical in assembling geographic information systems (GIS), these measures were validated in the field for a sample of 40 tracts, which are also ESR clusters. Field measures were taken from satellite signals with a GPS device. Figure 1 shows the discrepancy between the two estimates, as measured by the Euclidean distance between the two pairs of coordinates. The median discrepancy is about 60 meters. Discrepancies larger than 300 meters occurred in less than one-forth of observations. Considering that GPS-based measurements do have some error margin, one may say that the error in the great majority of our map-based measurements is lower than 200 meters. The probability of having errors larger than 500 meters is nil. Figure 1 also shows that errors tend to increase at smaller map's scales, especially at scales smaller than 1:3,000 (less than 33 cm. per km. in Figure 1).

The data set of health delivery points was geocoded on the aforementioned maps of the National Geographic Institute at scales 1:10,000 and 1:50,000. These data were also GPS validated for a sample of 40 points. No discrepancies larger than 300 meters occurred.

An important characteristic of the ESR is that it recorded the identification of the specific facilities used by women for family planning and other purposes. This information enhances substantially the possibilities of analysis, especially regarding consumer behavior in choosing a family planning outlet. It also permits one to have cartographic measures of the distance to the clinics which respondents use that can be compared to reported travel times.

Visual Display

An obvious use of geocoded data is for survey characteristics and results displaying on maps. Maps are an important, although under-utilized, means for conveying information, especially to statistically unsophisticated audiences. Maps are also a unique means for detecting spatial relations. More than a century ago, John Snow, the father of epidemiology, used maps to understand the spatial dynamics of a cholera epidemic in London (Haggett et al. 1977).

Map 1 displays the location of the 188 ESR sampling clusters in Costa Rica in relation to the distribution of the population. The clusters are heavily concentrated in the Central Valley around the capital city, following the pattern of the general population. But the clusters also appear reasonably spread all over the national territory. This map assures that there is a fair representation of Costa Rican geography in the ESR sample.

Map 2 illustrates for the Valley of "San Isidro del General" (window marked in Map 1) the service availability environment and the use of resupply family planning outlets by women in the sample. Outlets are connected to sampling units by black lines with thickness proportional to the number of users in the survey. The number labeling each line is the average travel time in minutes as reported by the respondents. The map also contains national roads and provincial borders. The map confirms a well known fact: the Health Posts of the Ministry of Health do not provide family planning. For example, women in cluster E conveniently have a health post nearby but they must travel several miles to obtain family planning from Health Centers in Buenos Aires or San Isidro. A Health Post is a tiny, rural facility (often built by the community) staffed with one or two "health workers" who are not allowed to prescribe contraceptives. Once a month or so, a physician may come to the Post to provide outpatient consultations, but he or she is too busy during these visits to take family planning consultations.

Health posts aside, the map shows that, as it is usually assumed, most women go to the nearest outlet. There are, however, important deviations from this norm. Women in cluster C, for example, skip the neighboring Clinic of Palmares and go further away to the health center in the city of San Isidro. Three explanations for this behavior may be (1) the clinic of Palmares (also known as Daniel Flores) was established too recently (1988) and some users don't know about its services while others are not ready to switch to this new facility; (2) that services provided in this small clinic do not fulfill users' needs; and (3) users do multipurpose shopping trips to the city of San Isidro, which is the most important urban center in the zone. Models of consumer spatial behavior (and the contemporary success of massive shopping malls) show that for single-purpose shopping trips (one good one trip) consumers indeed go to the nearest store supplying the good; however, for multiple-purpose trips consumers go to a center supplying the whole range of goods (Bacon 1984).

Map 2 also suggests a reasonable correspondence between the Euclidean distance to the outlet and reported travel times. Moreover, some travel times that appear excessive for the distance involved, become reasonable when one considers the lack of connecting roads. This is the case for the times between G and Buenos Aires (148 minutes for 10 miles) and between D and Pejibaye (90 minutes for 3 miles).

A different pattern of outlet use was observed on a map for sterilized women (not shown). Long distance trips, especially to hospitals in the capital city, are more frequent among these women –a behavior that makes sense for a method that requires somewhat sophisticated surgery facilities.

Spatial Trends and Small-Area Estimates

Sample surveys do not give stable estimates for small or medium-size geographic areas, in spite of the high demand for this information among managers. At the most, a typical survey can provide estimates for a few large regions. However, if one is prepared to accept that the variable in question (say, the CPR) varies smoothly across the space (or, at least, in a geographic neighborhood), geocoded surveys can provide improved estimates for any specific location as defined by its coordinates X and Y. These estimates are based on trend surfaces implicit in the data.

There are several techniques for identifying trend surfaces, which are broadly used in disciplines such as geology, topography, and meteorology. Those ubiquitous weather maps are an example of trend-surface estimates derived from a handful of sampling points. Trend surface analyses aims at isolating the underlying "signal" or systematic component in spatial data from the "noise" or random component. A simple technique for estimating trend surfaces (which was used in this article) is by fitting a polynomial on the X and Y coordinates with a degree to be chosen according to statistical criteria. An alternative to polynomials are nonparametric local regression models—a kind of two dimensional spline that assumes a smooth surface in the neighborhood of each observation. In a GIS framework, it is also possible to spatially smooth the data using such techniques as a roving window to compute weighted averages with neighboring observations.

This article estimates trend surface polynomials for: (1) the contraceptive prevalence rate and (2) the choice of IUD among contraceptive users. Maps 3 and 3b show the resulting surfaces. These maps do not show the estimates as shaded areas or contour lines deliberately, to avoid extrapolations to uninhabited lands. The maps show results only for meaningful human settlements.

The surface for the contraceptive prevalence rate confirms that this rate is high all over the territory. The few centers with less than 60% of couples practicing contraception are located in a northern region bordering Nicaragua and in a southeastern region (Sixaola) bordering Panama, which also is the region with the largest concentration of indigenous population. This figure is strikingly similar to a map about the fertility transition in Costa Rica published elsewhere (Rosero-Bixby and Casterline 1994).

In contrast with the diminishing gradient out from the center observed for contraceptive prevalence, the surface for IUD choice (proportion of contraceptive users who chose this method) shows a diminishing gradient from east to west. IUD is less popular in north-western regions. Since this pattern probably mirrors the preferences and skills of providers, program managers may consider whether retraining practitioners in IUD insertion in north-western regions may be needed.

Are the patterns unveiled by these surfaces statistically significant? Do these surfaces improve significantly conventional survey estimates? Table 1 shows the improvement in the Log-Likelihood ratio for the logistic models involved in these estimates. As it is customary, the improvement is measured with reference to the null model, which is equivalent to assume that all clusters are identical to the national average. Table 1 also shows, as a contrast, the fitness of a logistic model on the probability of being in a consensual union, a behavior that is known for being strongly differentiated across spatial boundaries in Costa Rica (Glaser 1994). Note that third degree polynomials best fitted the surfaces for contraceptive use and consensual unions and a second degree polynomial fitted IUD choice. Of course, second-degree polynomials imply 5 parameters (X, Y, XY, X^2, and Y^2) and third degree polynomials imply 9 parameters. All the Chi-square statistics in the table are significant at 1%. The Chi-square values of comparing the estimated surface with the null model suggest that there is, indeed, a significant improvement over simply applying national estimates to every location. The surfaces are also a significant improvement over specific estimates for the 6 health regions of Costa Rica. The improvements in the estimates for contraceptive use and IUD choice are not, however, as large as those for the prevalence of consensual unions.

Measuring the Service Supply Environment

In measuring physical accessibility to family planning services, there are several issues poorly addressed by the literature (Chayovan et al. 1984; Hermalin et al. 1988). Some of these issues may be better addressed with geocoded data. An important concern is the internal validity of subjective assessments about distances or travel times to family planning outlets made by survey respondents or "knowledgeable" informants. A DHS comparative study of the availability of family planning and health services points out several limitations derived from the subjective nature of the data (Wilkinson et al. 1993). Accessibility indicators based on objective cartographic measures may represent an improvement in internal validity over subjective assessments. Moreover, cartographic based indicators may allow to validate the information on reported travel time to facilities and to cast some light on the issues of whether to use actual vs. perceived access indicators or micro- vs. macro-level measurements (Entwisle et al. 1984).

Figure 2 plots the reported travel time against the Euclidean distance between a respondent's residence and the family planning outlet reported as used by this respondent. A "heaping" tendency in reported travel times is evident; i. e. responses clearly cluster at 5, 10, 15, 10, 30, 45 and 60 minutes. Correspondence between the two measures is moderately high in the logarithms (correlation coefficient of 0.67). A "power" model, estimated with Poisson Regression on the logarithm of the explanatory variable (McCullagh and Nedler 1989), indicates an expected travel time of about 15 minutes for the first kilometer and time increments of 0.5% for each one-percent increase in distance. For example, the expected travel time is 36 minutes for 5 km. and it is 52 minutes for 10 km. The estimated parameters seem to be a reasonable estimate of a conversion factor from distance to travel time and a fair representation of what people usually do, which is to take a faster means of transportation for traveling longer distances.

The lack of a perfect correspondence between cartographic distances and travel times may arise from errors in the perceptions of travel times, from the use of different means of transportation, and, as noted in Map 2, from the lack of direct roads connecting two points. This article did not refine the cartographic measure based on straight lines, although such improvement is feasible in a GIS that includes roads and transportation networks. However, to take into account this shortcoming in further analyses, an indicator of the relative travel time was computed for each cluster, as the ratio of the observed times to the model-estimated (the expected) times.

A preliminary analysis of the scatterplot in Figure 2 showed a handful of outliers with reported travel times of five or ten minutes and cartographic distances in the order of 100 kilometers. These outliers came from errors made in the field and in the office identifying the outlet actually used by respondents. The cartographic information thus served to isolate and clean up this error.

There has been some debate about whether to use aggregated or individual measures of access to family planning outlets (Tsui et al.1981; Chen et al. 1983; Entwisle et al. 1984). A limitation of individual-level indicators is that information is often not available (or it is unreliable) for respondents who do not use family planning outlets (Chayovan et al. 1984). To overcome this limitation, this article computed an aggregated indicator (the average) of reported travel time for each sampling cluster, which later may be applied to every individual in the cluster. The comparison of these cluster averages with cartographic distances resulted in a nicer looking plot (non shown) than that in Figure 2. However, the estimated parameters of the corresponding model were essentially the same as in Figure 2.

It is important to note that the mean travel time to family planning outlets is not a pure supply measure. It is in part determined by consumer behavior, since not everybody in a cluster chooses the same or the closest outlet. Moreover, the perception of travel times may be biased as a function of family planning behavior (those who are more inclined to use contraception may perceive shorter travel times to the outlets), which would result in a spurious association between these two variables. Given these caveats, other accessibility indicators must be explored, for which geocoded information is especially useful.

Traditional access measures are usually based on the distance to the nearest outlet or the presence of outlets in the community or within the boundaries of administrative areas. Using services in other communities, skipping the nearest outlet, overlapping catchment areas, redundant services in a community, and competition with other potential users are issues not properly addressed by these traditional accessibility measures. Having geocoded data permitted us to compute two more refined indicators of the service supply environment: total and per capita density of services within a radius. Density indicators are not new (DaVanzo 1988). The novelty is in the flexibility for defining these indicators with geocoded data. First, there is not the constraint of using arbitrary geographic units (Makuk et al. 1991). Second, there is the freedom for defining areas of any shape and size and addressing the "modifiable areal unit problem" (Wrigley 1995). Third, it is possible to introduce distance-decay effects. Fourth, there is the flexibility for incorporating in access measures qualitative and quantitative characteristics of outlets and considering the presence of competing users (Rosero Bixby 1993).

This article relies on distance-dependent calculations of potential access and potential population—concepts widely used by geographers—to determine the density of services as an indicator of accessibility. The concept of potential is as follows: the potential number of elements (clinics, people, and so forth) at a point i is the sum of the elements existing in all locations j weighted by the inverse of the distance between i and j. The calculation is usually limited to locations within radius r from i.

The formula used for computing the total density of family planning services A_i is:

$$A_i = \sum_j^r \frac{H_j}{d_{ji}^b}$$

A_i = density of services (hours provided) for location i;
H_j = family planning hours provided by clinic j;
d_{ji} = distance between locations j and i;
b = distance decay exponent,
r = radius from i for the maximum distance to consider in the sum.

This formula has been used to measure accessibility to workplaces (Duncan 1964) and to health practitioners (Thouez et al. 1988). It has, however, the limitation that it does not consider the size of the population served, i.e. the competition among clients for a service. To correct this deficiency, Joseph and Bantock (1982) propose to compute per capita density considering the size of served populations C_j in clinics' catchment areas:

$$B_i = \sum_j^r \frac{H_j / C_j}{d_{ji}^b} \qquad C_j = \sum_h^r \frac{P_h}{d_{jh}^b}$$

B_i = per capita density of services (yearly hours per women) for location i;

C_j = population (women in reproductive age) served in the catchment area of radius r by clinic j; as estimated by the population potential for location j,

P_h = population (women in reproductive age) in all places h within the catchment area of clinic j.

This article experimented with combinations of radii ranging from 5 to 20 km. and distance-decay exponents of 0 and 1. For radii larger than about 10 km, results were not sensitive to changes in the radius nor in the decay exponent. The second panel in Table 2 shows correlation coefficients larger than 95% between total densities computed for radii of 10 and 15 km. and distance-decay exponents of 0 and 1. Similar correlation's occurred (not shown) for per capita densities. Thus, the calibration or selection of these parameters (radius and distance-decay) does not seem critical for computing the density measures introduced here.

The first panel in Table 2 compares the two density measures and two traditional measures of accessibility: the mean travel time reported by women in each cluster (a datum from the survey questionnaire) and the straight line distance between the cluster and its nearest family planning outlet (a cartographic measure that requires geocoded data). Correlation coefficients between the three cartographic measures are moderately high (65% to 70%) and with the right sign, indicating that there are both some degree of overlapping and some degree of orthogonality. In contrast, there are only modest correlation coefficients between the reported travel time and the three cartographic measures. Reported travel time and service density thus appear as two distinct dimensions of accessibility in this data set. Since substantially different pictures may correspond to different indicators, careful attention must be given to the choice of indicators of service environment. An earlier study comparing several accessibility measures in Thailand also found that results are sensitive to the choice of indicator (Chayovan et al. 1984).

An important use of accessibility indicators is for guiding decision makers in the selection of sites for new clinics and in the expansion of services in exiting clinics. Map 4 depicts the service supply environment on the Costa Rican territory as measured by the per capita service density. Note that this density measure was not computed just for the survey clusters but for every meaningful population center in the country, using the geocoded data from the inventory of facilities and census tracts. Note also the metrics of the density indicator. For example, a figure of 0.05 indicates the availability of about one service-hour per year for every 20 women in reproductive age. Managers need to understand these metrics for setting minimum standards or goals for the provision of services. Taking, for example, a minimum acceptable density of 0.05 hour-women, Map 4 shows that no town in the Central Valley is below this minimum. It also shows that priority for expanding services should be given to Southern and North-Western regions, where there are about 40 towns below the minimum.

Contextual Indicators in Multilevel Models

Multilevel models on adoption of family planning, fertility preferences and other behaviors often include as contextual factors aggregate indicators for the community or the administrative unit where the individual lives. These levels of aggregation, however, may be inappropriate if contamination across communities occur, or if the administrative boundaries are arbitrary, or if the aggregate area is too small or too large (Makuk et al. 1991). Moreover, the concept of "community" or "locality" has proved to be troublesome, especially in comparative studies (Wilkinson et al. 1993: 6). Geocoded data give flexibility in the choice of aggregate units and permit one to define units that are comparable across countries. It is, for example, possible to define a circle with a determined radius, which will be free of the constraints of arbitrary borders and will be internationally comparable.

Models of spatial diffusion and social interaction also deal with aggregate indicators for both the index community and for neighboring communities. For example, in explaining adoption of family planning, diffusion models may include as contextual explanatory factors the level of contraceptive use in the community in question and in other relevant areas for capturing the influence of neighbors (Rosero-Bixby and Casterline 1994). Once again, geocoded data give flexibility for constructing indicators about the influence of neighbors.

To illustrate these uses of geocoded data, Table 3 shows the results from two multilevel logistic regression models, on the probability of using contraceptives (conditional on being in a union) and of choosing the IUD (conditional on using contraceptives). The estimates in Table 3 are in no way intended as a full scale analysis. Both model specification and its statistical estimation may improve in a full scale analysis. The two models include as contextual regressors three indicators computed with geocoded data: (1) the percent use of contraceptives/IUD by women in a 10 km. radius computed as population potential with a distance decay correction (the index woman was excluded when computing these proportions), (2) the cluster's relative difficulty for traveling, and (3) the per woman density of family planning services in a 10 km. radius as defined before.

The propensity of other women in the area to use contraceptives or to choose the IUD shows significant effects on the adoption odds of individuals. The odds of using contraceptives increase 11% with a 10-point increase in the contextual contraceptive prevalence rate. The odds of choosing the IUD increase by 26% with a 10-point increase in the contextual percentage of IUD users. These associations may be genuine manifestations of person-to-person diffusion, but may also be just a reflection of omitted variables in the models, the effects of which have been picked up by areal prevalence. Purging the possibility of spurious effects with, for example, instrumental variables is beyond the scope of this article.

The cluster's relative travel time does not show any significant relation with adoption of contraception or IUD choice. This result suggests that using travel distances instead of Euclidean distances for computing access indicators will have little consequence for impact analyses.

Service density does not show a significant effect on contraceptive use. Although the effect of service density on IUD choice also is not significant, it is so by just a narrow margin (the z value of 1.5 is significant at 13% level). An increase in one hour per woman density of family planning services (which is a huge increase) would double the odds of choosing the IUD according to the model.

The lower panel in Table 3 shows a sensitivity analysis of using alternative access indicators in the logistic equation. For the model on contraceptive use, all cartography-based indicators do not show significant effects. The reported travel time (averaged for the cluster), in contrast, shows a significant effect: one extra hour of travel reduces by 38% the odds of using contraception. Given that there may be some endogeneity in reported travel times, this result is inconclusive.

For the model on IUD choice, no indicator outperforms the effect of per capita density of family planning services.

Clinic's Choice

Contrasting with the rich literature on health service utilization, consumer behavior in choosing a family planning outlet in developing countries has seldom been studied. Geocoded survey data make such study possible, specially if the survey recorded the identification of the outlet used by respondents and if it was complemented with a geocoded inventory of facilities.

Visual analyses such as that for Map 2 are a first step for understanding service utilization.

Statistical models are a more rigorous approach. As an illustration, this article estimated a model on the odds (O_{ij}) that a user i of resupply methods chooses the family planning outlet j. The ESR contains information for about 550 users of resupply methods from public outlets, who combined with about 300 relevant outlets result in a data set with about 165,000 observations, one for each user-outlet pair. To avoid such a big file, a matched case-control design was adopted instead. Nine "controls" (non used outlets) were randomly selected for each user, which resulted in about 5,500 observations. As required in matched case-control designs (or in discrete-choice econometric models) conditional logistic regression was used to estimate the model (Breslow and Day 1980; Greene 1990). Table 4 shows the results.

Only five explanatory variables were available for this analysis: the size of the clinic as measured by the number of weekly hours of family planning (h_j), the Euclidean distance between user's residence and clinic (d_{ij}), the clinics' catchment population potential (c_j), the proportion of outpatient consultations for family planning purposes (f_j), and whether the clinic pertains to the Social Security Office. Natural logarithms of the first three variables were entered in the model. The regression coefficients of these three variables thus measure elasticities on the odds of choosing an outlet. Moreover, the regression coefficient for the log-distance variable is an estimate of the aforementioned distance-decay effect. The model also tested selected statistical interactions of these five variables with individual and contextual characteristics. Only one interaction (between the contraceptive method adopted and clinic's size) deserved some further consideration. The estimated model in Table 4 implies the following relations:

IUD users: $$O_{ij} = k\frac{h_j^{1.3}c_j^{0.1}}{d_{ij}^3}(4.1)^{f_j}(1.9)^{s_j}$$

Other users: $$O_{ij} = k\frac{h_j^{0.4}c_j^{0.1}}{d_{ij}^3}(4.1)^{f_j}(1.9)^{s_j}$$

where k is an unknown constant and all other symbols stand for the previously defined variables.

The size of the clinic and the distance to it emerged as strong predictors of clinic's choice in this model. A one-percent increase in the weekly hours of family planning of a given clinic increases in 1.3% the odds of choosing it among IUD users and 0.4% among users of other methods. In turn, a one-percent increase in the inverse of the distance to a clinic increases by 3% the odds of choosing that clinic. The distance decay exponent for spatial analyses of accessibility and use of family planning in Costa Rica is thus 3. The size of the population served by the clinic does not appear as an influential factor in the decision of using the clinic. The relative importance of family planning in a clinic, as measured by the proportion of consultations with this purpose, is positively related to the decision of using the clinic. Going from zero to 100% family planning consultations would increase the odds of adopting the clinic four times, correspondingly, increasing that proportion by 20 percentage points will increase the odds of choosing the clinic by 33% ($[4.1]^{0.2} = 1.33$). Social security clinics are preferred over those of the Ministry of Health. The odds of choosing the former are 87% higher. This effect, as well as that of the proportion of family planning consultations, is not, however, significant at the customary 5%, but being significant at 10% justifies some attention to them.

Overall results of the choice model resemble the classic gravity formula of Newtonian physics (Haynes and Fotheringham 1984) in which the attraction between two bodies (two planets, earth and the apocryphal apple) is proportional to their masses and the distance between them. Perhaps if data on a clinic's characteristics (such as those available from situation analyses) were available in Costa Rica, elements of quality of care would explain in part the choice of a clinic beyond this simple gravity model.

CONCLUSION

This article has illustrated the feasibility of geocoding a DHS-type survey and has shown some of the payoffs of this data collection strategy. The cost of adding geo-references to a survey in Costa Rica was nil in comparison to its benefits, particularly for better understanding the family planning service supply environment. The gains from geocoding a survey increase when it is accompanied by an inventory of geo-referenced facilities and when the survey keeps track of the specific facilities used by respondents. DHS-type surveys should consider geocoding their sampling units as a routine procedure. A geocoded survey, in combination with an inventory of facilities that includes some qualitative information about clinics, seems an attractive alternative to the "Service Availability Module" currently used in the DHS program.

The article has also shown that displaying survey results on maps is an effective way for conveying information on the spatial dimensions of family planning and for understanding the service supply environment. Trend surface analyses of some results of the Reproductive Health Survey conducted in Costa Rica in 1992-93 improved survey's estimates for small areas and pinpointed important spatial differences in contraceptive prevalence and IUD choice. Measuring the service supply environment, i.e. the accessibility to family planning services, was sensitive to the indicator used. Different measures give substantially different pictures of family planning availability. Cartographic based measures, however, have an edge in objectivity and comparability. A concrete result that can contribute to improve accessibility measures in Costa Rica was the calibration of a distance decay exponent of 3 per kilometer and an elasticity of distance to travel time of 0.53. Improved measures of contextual variables were used in multilevel models on contraceptive use and IUD choice. The results regarding the impact of service density were mixed in these multilevel models. In turn, diffusion from neighbors appeared as a significant factor for the use of contraceptives and IUD choice. A model for the choice of family planning outlet arrived at a classic gravity formulation in which larger and closer clinics are more likely to be chosen. These results did not come from full scale analyses but from quick exercises devised to illustrate the use of geocoded information.

The spatial analyses in this article confirmed that accessibility to family planning services is not a likely factor in the use of contraception currently in Costa Rica. It may, however, influence the contraceptive method mix. In turn, accessibility to a clinic seems crucial in the decision to use its services. This is a somewhat trivial result. It is very unlikely that a user will travel 100 km. for a family planning consultation if she can get it from a neighboring clinic. What is not trivial is the calibration of this distance decay effect.

Understanding consumer behavior for choosing a family planning outlet seems an important and promising study field, especially in countries like Costa Rica with a high contraceptive prevalence rate. It will help in fine tuning service supply, to improve the indicators of accessibility, and to assess the impacts of quality of care. Spatial analyses are essential in such studies, as is geocoded information about users and clinics.

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Table 1. Logistic models for trend surfaces on the conditional probabilities of using contraceptives, choosing the IUD,and unmarried cohabitation

Indicators	Using contraceptives	IUD choice	Unmarried cohabitation
Conditional to be:	In a union	Using contraceptives	In a union
N women/clusters	1957/185	1484/185	1957/185
Polynomial degree/ parameters	3/9	2/5	3/9
LL null model	-1082.3	-528.2	-973.2
LL polynomial surface	-1068.3	-519.3	-895.5
Chi2 surface	28.0	17.8	155.4
LL 6-region model	-1077.7	-522.8	-920.5
LL region & surface	-1064.8	-512.5	-887.1
Chi2 surface	25.8	20.6	66.8

LL = Log Likelihood ratio

Table 2. Correlation coefficients among selected measures of family planning supply

Measures	Travel time	Distance to nearest	Density 10 km Total	Density 10 km Per woman
Mean reported travel time	100	43	-28	-28
Distance to nearest		100	-65	-70
Density 10 km. radius:				
Total			100	66
Per woman				100

For total density, distance decay and radius	Decay = 0, 10 km	Decay = 1, 10 km	Decay = 1, 15 km
Decay = 0, 10 km	100	96	95
Decay = 1, 10 km		100	98
Decay = 1, 15 km			100

N = 185 sampling clusters.
All measures are cartographic, except the mean reported travel time

Table 3. Multiple logistic regressions on the conditional probabilities of contraceptive use and IUD choice

Explanatory variables	Contraceptive use		IUD choice	
	Odds Ratio	(z)	Odds Ratio	(z)
Individual level				
Age in 5-year groups	1.13	(3.03)	0.86	(-2.34)
Reproductive goals				
Want child now	1.00	Reference	–	
Want no more children	5.80	(11.70)	1.00	Reference
Want to defer	6.84	(10.98)	1.19	(0.93)
Education in 5-year levels	1.38	(4.03)	1.43	(3.20)
Secularization index (1 to 4)	1.07	(1.38)	1.14	(1.88)
Contextual level				
Users* within 10 km.	1.11	(1.91)	1.26	(2.41)
Relative travel time	1.00	(0.01)	0.96	(-0.18)
FP hour-year/woman, 10 km	1.08	(0.20)	2.02	(1.50)
Pseudo R2 (Chi2)	0.09	(191.14)	0.04	(38.21)
N observations	1,927		1,460	
Sensitivity, access indicator				
FP hour-year/woman, 10 km	1.08	(0.20)	2.02	(1.50)
Same, no distance decay	1.30	(0.79)	1.20	(0.37)
Same, total FP hour-week	1.00	(0.07)	1.05	(1.47)
Distance nearest outlet (5 km)	0.89	(-1.12)	0.88	(-0.74)
Hours reported travel time	0.62	(-2.46)	0.75	(-0.84)

* OR for 10-point increase in the contextual percentage of users.

Table 4. Conditional logistic regression on the choice of clinic by women using resupply methods in public facilities

Explanatory variable	Coefficient	Odds ratio	z value	P>|z|
Log distance in km.:	-3.02	...	-13.90	0.00
Log weekly FP hours				
IUD users	1.27	...	3.16	0.00
Other users	0.44	...	3.94	0.00
Log catchment population	0.13	...	1.11	0.27
Proportion FP consultations	1.41	4.09	1.69	0.09
Social Security's clinic	0.63	1.87	1.67	0.09

N = 5,510. Pseudo R2 = 0.90.
Matched case-control design (9 controls per case)

Figure 1. Distance between map's and field's measurments of tracts centroids by the scale of census maps

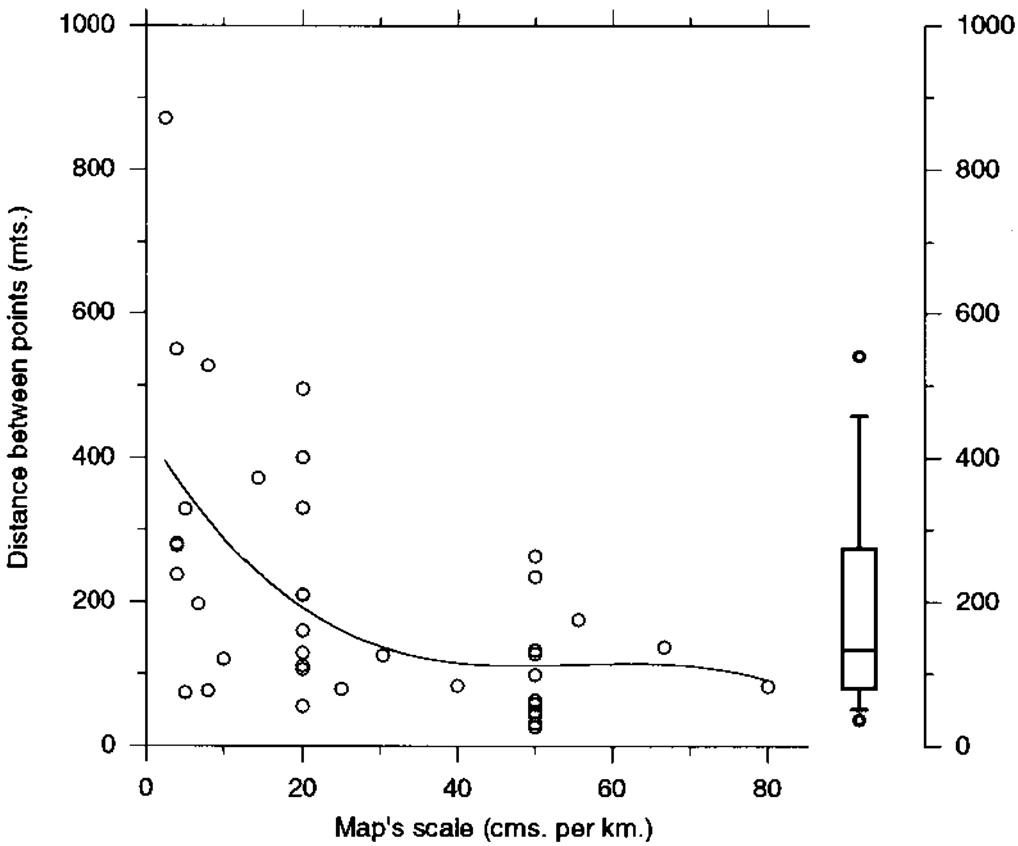
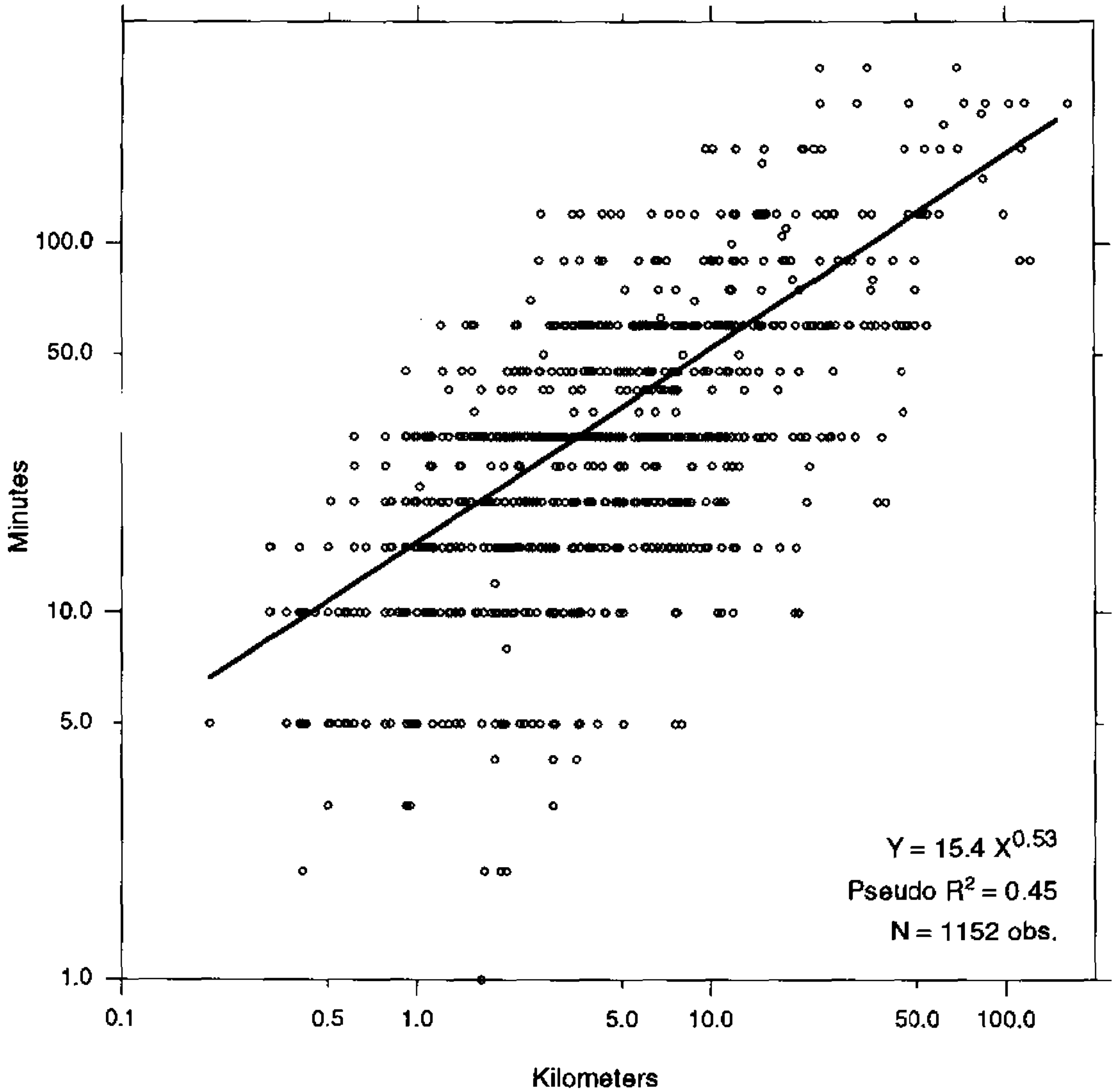
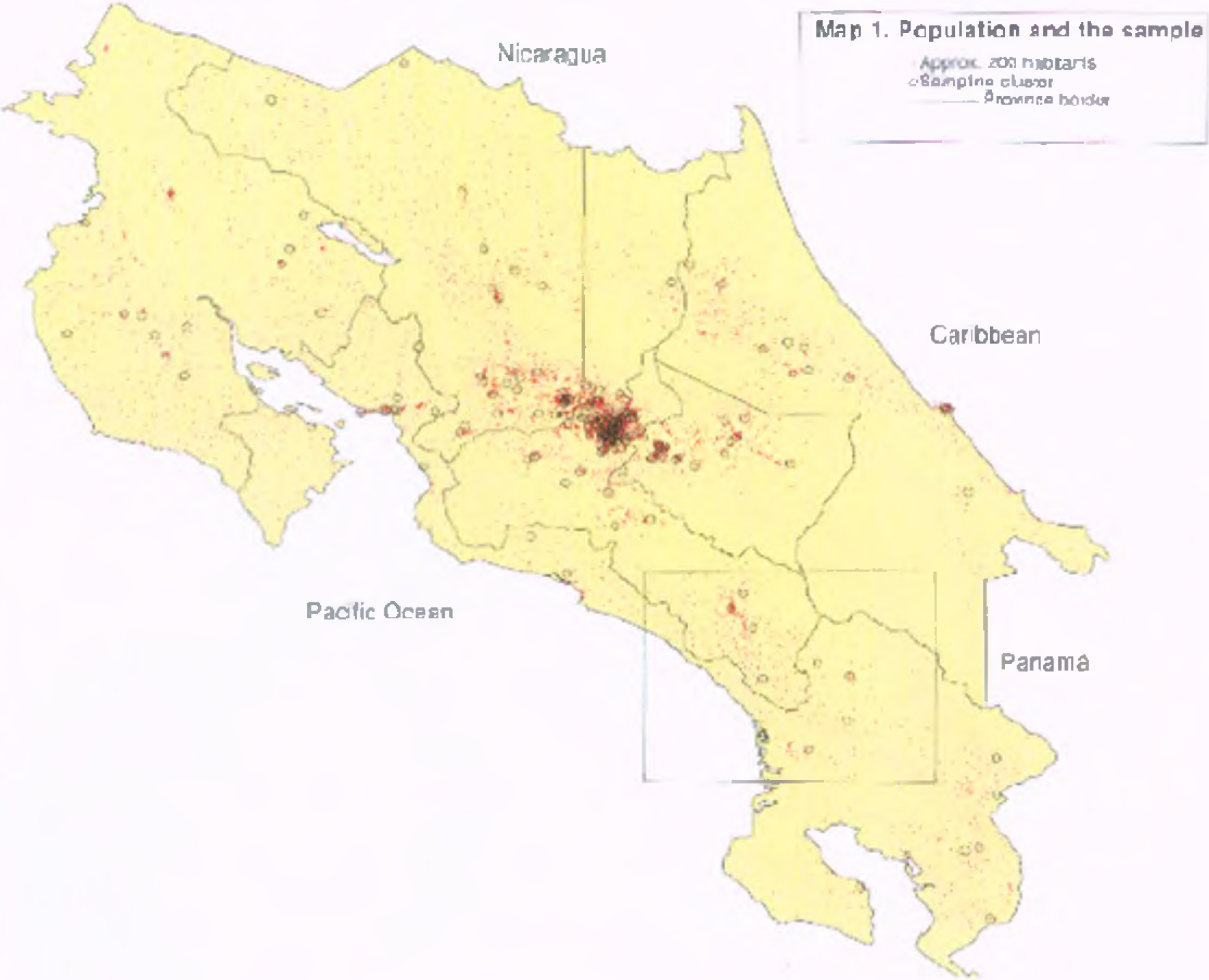


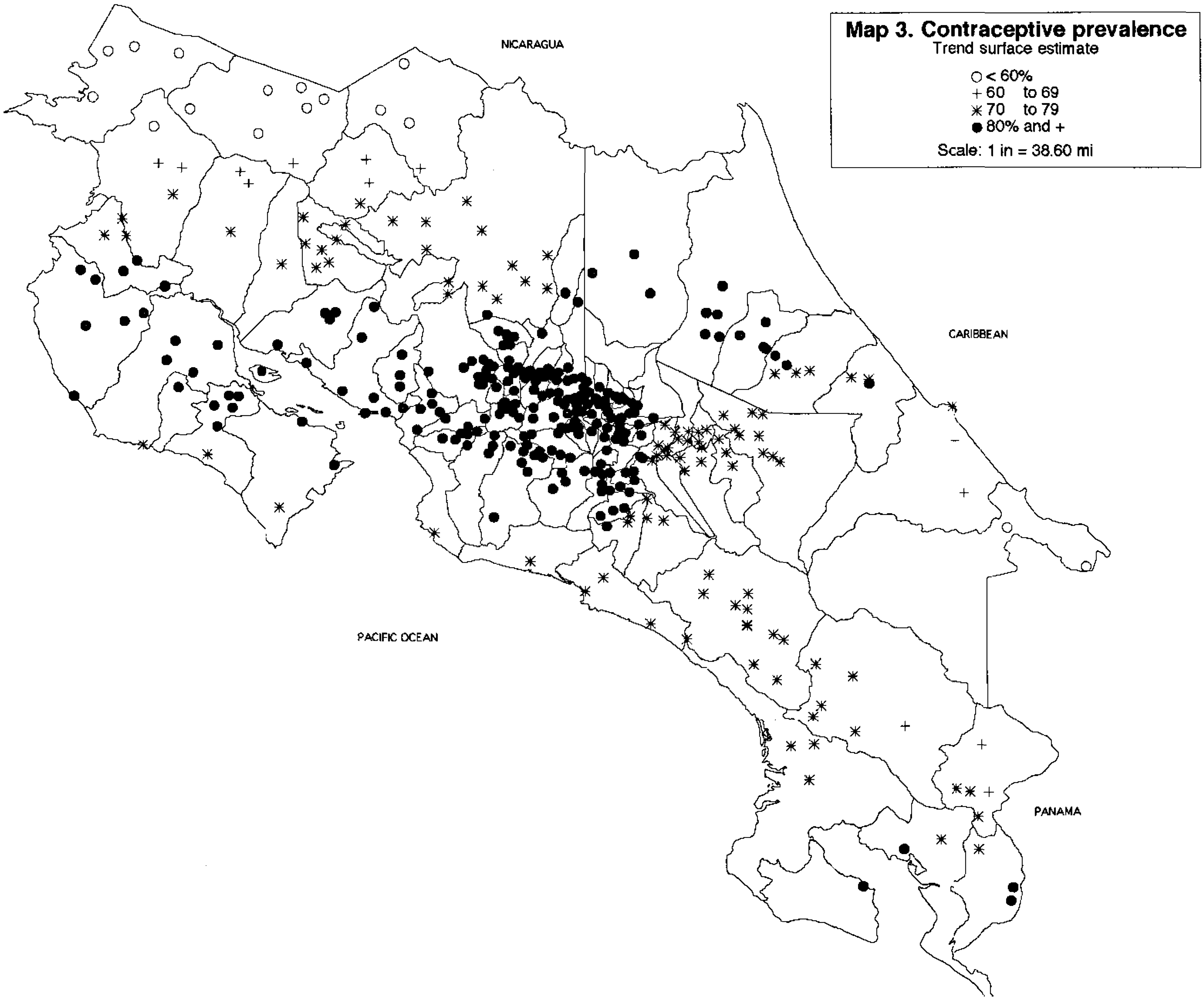
Figure 2. Reported travel time against cartographic distance to family planning outlets

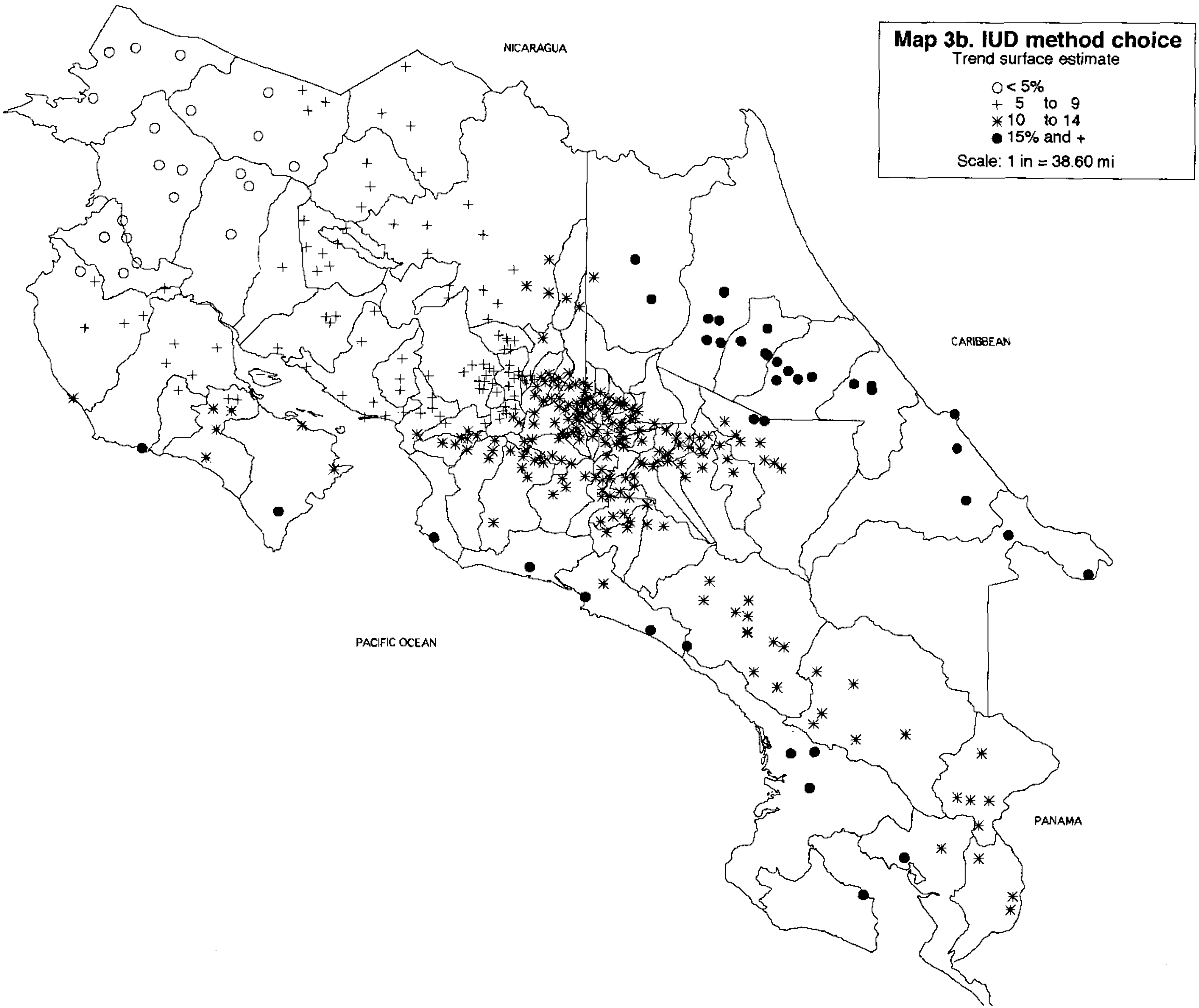




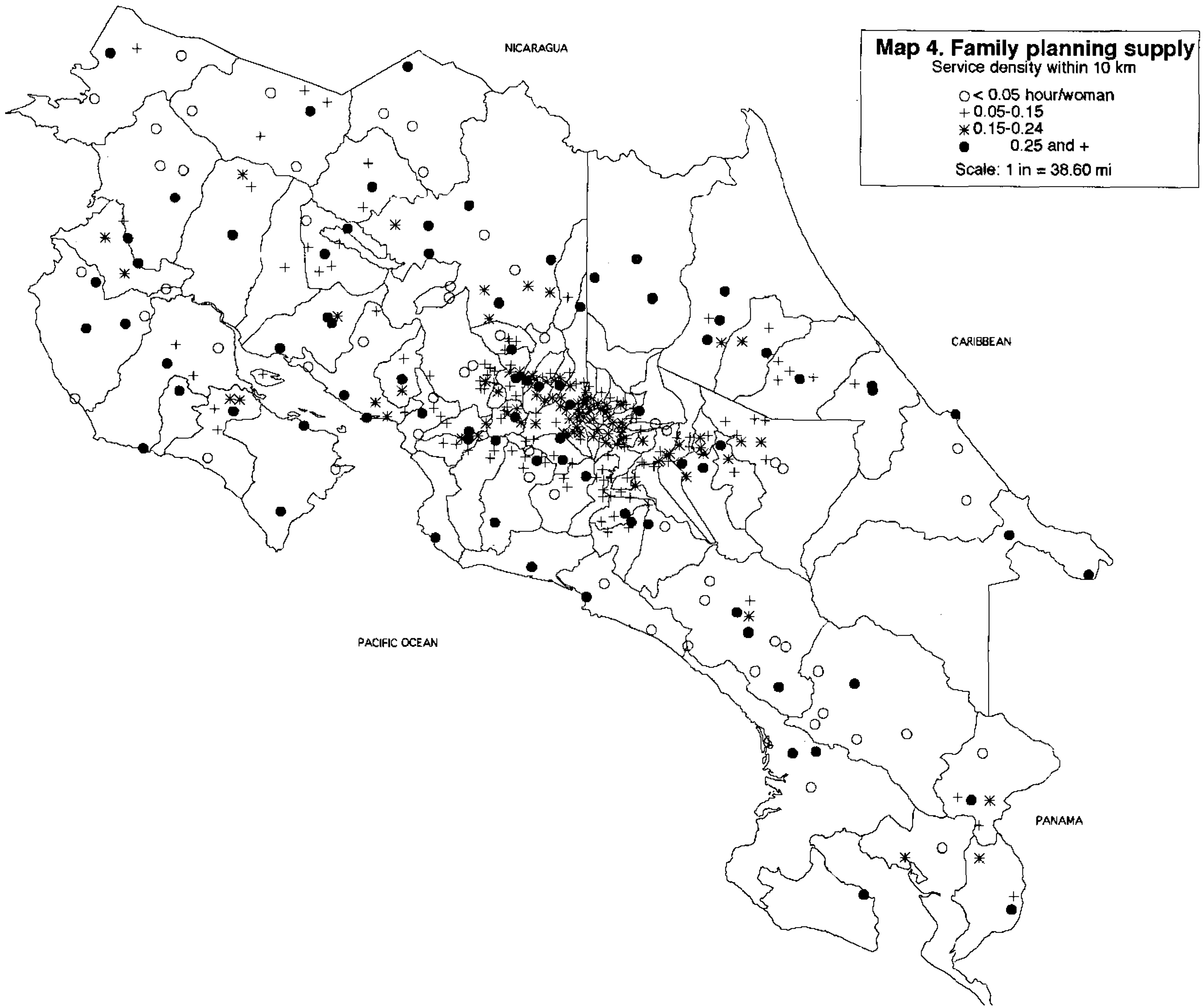
Map 1. Population and the sample

Map 2. FP services use
Sample cluster
Health Center
Health Post
5-9 users
National road
Province border
A
B
C
D
E
F
G
H
33
31
28
67
60
90
47
148
San Isidro
Palmares
Pejibaye
Buenos Aires
Cortes
Palmar Sur
PACIFIC OCEAN
0
5
10
Miles


Map 3. Contraceptive prevalence
Trend surface estimate
○ < 60%
+ 60 to 69
✳ 70 to 79
● 80% and +
Scale: 1 in = 38.60 mi
NICARAGUA
CARIBBEAN
PACIFIC OCEAN
PANAMA



Map 3b. IUD method choice
Trend surface estimate
○ < 5%
+ 5 to 9
✳ 10 to 14
● 15% and +
Scale: 1 in = 38.60 mi
NICARAGUA
CARIBBEAN
PACIFIC OCEAN
PANAMA



NICARAGUA
CARIBBEAN
PACIFIC OCEAN
PANAMA
Map 4. Family planning supply
Service density within 10 km
< 0.05 hour/woman
0.05-0.15
0.15-0.24
0.25 and +
Scale: 1 in = 38.60 mi