Chapter 17
Spatial Patterns of Fertility in Rural Egypt

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Abstract The Getis–Ord G_i^* statistic and the Getis spatial filtering method are shown in this paper to be very useful geospatial tools for uncovering the spatial patterns of human reproduction in a rural governorate in Egypt that had been assumed by many to be a spatially homogeneous area. We apply the G_i^* statistic to dasymetrically mapped data from the 1976, 1986 and 1996 censuses of Egypt to show that there were very distinct spatial patterns in fertility over time in this predominantly rural region of the Nile Delta. The spatial filtering technique allows us to conclude as well that the spatial component became more important over time as a predictor of fertility levels. Improvements in education represent a key feature of the changing rural social environment driving these spatial changes in fertility. There is evidence as well that increases in contraceptive utilization contributed to this change, but we are unable to evaluate its spatial component. Nonetheless, the research illustrates and illuminates the underlying conceptual framework that demographic behavior is a joint function of who people are and where they are.

17.1 Background

Demographic literature is rich in studies that compare rural with urban areas, and in the former women invariably have more children on average than do women in the latter. It is nearly an iron law. One of the problems with this type of comparison, however, is that even if rural places have higher fertility than urban places within the same country, rural fertility may be higher in some countries than in others. We may well find that rural fertility in a richer country is lower than urban fertility in a less-rich country. This points to what might be thought of as the cultural and geographic relativity of the urban–rural dichotomy and, at the same time, the underlying social nature of human reproduction. A second problem is that the dichotomy ignores any variability that might occur within either the rural or the urban areas,

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L. Anselin and S.J. Rey (eds.), *Perspectives on Spatial Data Analysis*, Advances in Spatial Science, DOI 10.1007/978-3-642-01976-0_17,

assuming instead that fertility is uniformly higher in rural than in urban areas. Weeks and his associates have shown that this assumption may be very wrong both in rural areas (Weeks et al., 2000) and in urban areas (Weeks et al., 2004). In Greater Cairo in 1986, for example, the average neighborhood-level total fertility rate (TFR) calculated by indirect methods described below was 3.1 children per woman, whereas in the rural governorate of Menoufia, just to the north of Cairo, the average level per village was 5.8. That clear distinction hides considerable overlap, however. The lowest TFR in Menoufia was 3.2 and only 25% of Cairo neighborhoods had a level that was lower than that. The highest TFR in Cairo was 7.7 and only 1% of Menoufia's villages had a rate higher than that.

Very little attention has been given in the literature to the social causes and consequences of fertility levels at these local levels. There is a vast literature on fertility differentials, to be sure, but attention is paid largely to characteristics of individuals without regard to where they live. Entwisle, Casterline and Sayed (Entwisle et al., 1989) have demonstrated that village contexts can be important influences on contraceptive behavior (and thus on fertility) in rural Egypt, but their analysis was limited spatially to a distinction between villages in upper and lower Egypt. There is also a nearly universal finding that fertility differs by social class (defined by income differences, occupational prestige, educational attainment, and often incorporating some element of race/ethnicity). And, since there is a tendency for there to be a geographic sorting process by social class, the local spatial dimension of fertility is implicitly incorporated into that model. Yet, that is almost never measured by demographers, and little attention has otherwise been given to the demographic and social variability in fertility across space. That is to say, little attention is paid to the ecology of fertility, even among social ecologists. Rather, the emphasis is on examining fertility levels at the individual level, using data from surveys that by and large do not permit more than a very generalized spatial analysis. These studies of necessity focus attention on national comparisons or on regional differences within a country.

From a purely geographic perspective, one could argue that this is simply a scale issue. Variability may exist at any spatial scale and the only issue is whether we have the tools to measure it. But from a broader social science perspective, the scale issue matters because it fits into the human ecological approach that suggests that the behavior of people is influenced by their personal characteristics (who they are) and also by their locational characteristics (where they are). This is the underlying premise of spatial demography (also known as geodemographics), as discussed by Weeks (2004a). If we are to understand the patterns and changes in human fertility, we must take into account all aspects of the social world in which people live. Characteristics such as education, occupation, income, ethnicity and religion all play a role in shaping behavior, but the likelihood that a given person will be at one end or another of the continuum on each variable may well depend upon where they live. This is not to be interpreted as geographic determinism, but rather as an acknowledgement that we are social creatures who are influenced by those around us. If we live in an area where, for whatever reason, education is not valued, then the probability that we will value education is commensurately low and our life will probably turn out very differently than if we live in an area where education is highly valued and sought after. This is the essence of spatial autocorrelation as it applies to human society.

The model that guides our research thus incorporates the assumptions that (a) the social environment influences the social and human capital variables that more directly influence the demand for children; (b) the reproductive behavior of some people within a village may influence the behavior of others, even net of the human capital opportunities that objectively exist in the village; and (c) these influences operate on reproductive levels through the mechanisms of the proximate determinants of fertility, such as age at marriage and the use of contraceptives within marriage, to determine fertility at the local level; but (d) changes in reproductive behavior at the local level may be influenced by changes in, and reciprocally influence changes in, other neighboring regions, resulting in spatial patterns of fertility transition; the consequences of which (e) ultimately determine the overall societal level of reproduction, thus creating the wider phenomenon of a fertility transition.

Our goal in this research is to use this conceptual framework to build upon earlier work that examined the spatial component of fertility in the rural governorate of Menoufia, Egypt. That study (Weeks et al. 2000) examined data from the 1976 and 1986 censuses of Egypt, but was published prior to the release of the 1996 census data. That study concluded by making prognostications for the 1986–1996 period with respect to fertility levels, as follows:

> The period from 1976 to 1986 was a period of overall relative stability in fertility levels in rural Egypt and not until the 1996 census data become available at the village level will we be in a position to track significant changes in fertility over time. However, it is clear that at least by 1976 there were clear spatial patterns to fertility in Menoufia and our analysis suggests that these spatial patterns were even more definitive in 1986 than they had been in 1976. This seems to suggest the existence of some momentum for change, which we hypothesize will be observable when the 1996 data become available. The southern portion of the governorate was more obviously the location of higher than average fertility in 1986 than had been true in 1976 and we would predict that the clustering of lower fertility will have exhibited a southward drift or diffusion by 1996. The results from our spatial filtering procedure suggest that some of this effect will be due solely to where villages are located, regardless of any changes in female education. The analysis also suggests that improving levels of female education will have been the most important human capital influence on fertility between 1986 and 1996 (Weeks et al., 2000, p. 712).

In order to evaluate the correctness of those forecasts, we first revisit the data sets in order to improve the dasymetric mapping so that the point-pattern spatial analysis, which is based on distances between villages, is optimized. In that process we are able to harmonize the administrative boundary changes that took place between censuses. Furthermore, we have now been able to use the Egypt Demographic and Health Survey data to derive usable estimates of underenumeration in the census, from which we can calculate improved fertility estimates for each village in Menoufia. With these methodological refinements in hand, our research questions become (1) Did fertility decline more between 1986 and 1996 than it had between 1976 and 1986? (2) Did fertility decline more rapidly in the southern part of the governorate than in the northern part? And (3) was the decline due both

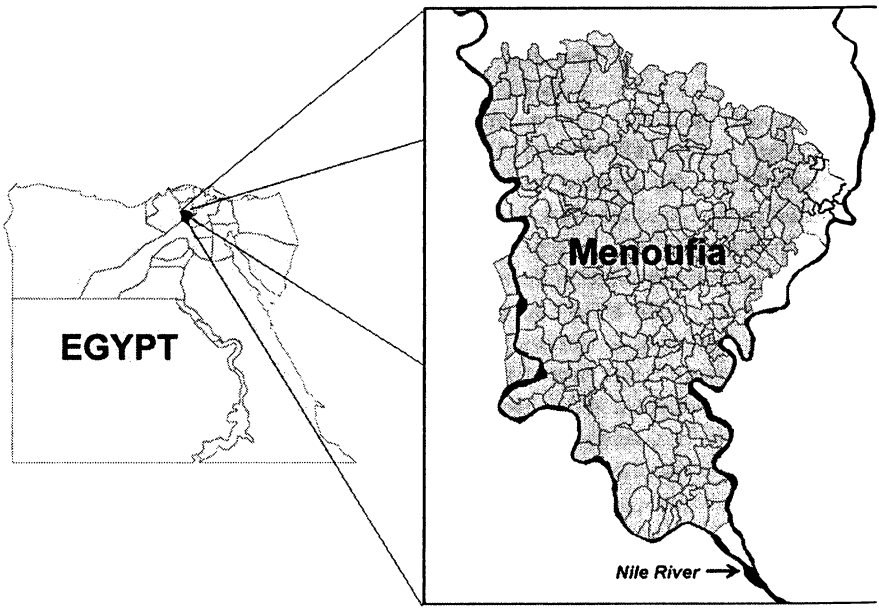

Fig. 17.1 The study site of Menoufia governorate, Egypt

toimprovements in female literacy as well as being conditioned by the geographic location of a village within the governorate?

17.2 The Study Site

The study site is the governorate of Menoufia, in the Nile delta region of Egypt, just to the northwest of Cairo (see Fig. 17.1). Menoufia is one of the 26 governorates that form the administrative regions of Egypt, roughly equivalent to states in the United States or to counties in the United Kingdom. The 1996 Census of Egypt enumerated 2.8 million people in Menoufia, representing about 4% of the total population of Egypt. The officially-defined rural population accounted for 80% of the governorate's population in 1996. The southern region of Menoufia is situated just below (to the north of) the Barrage that controls the flow of water from the Nile as it enters the Delta, which has permitted perennial irrigation in the region since the early nineteenth century. But even for millennia prior to that this was a rich agricultural area with traditions that almost certainly contribute to the maintenance of low levels of education and higher than average levels of fertility.

We chose Menoufia as a study site less for its specific demographic characteristics than for the fact that it has been relatively well studied in nonspatial analyses and thus there are comparative studies by which to judge the spatial analysis produced by our own work (see especially Gadalla, 1978; Weeks et al., 2000). Menoufia does have some advantages for spatial analysis including its essentially flat landscape in the Delta region of the Nile, which means that elevation is not an issue that needs to be dealt with. Partly for this reason, there are more than 300 villages, with an average population per village in 1976 of 6,036, increasing to 7,840 in 1986, and up to 9,349 by 1996. Thus, in 1996 the average village had more than half again as many people living in it as in 1976, a situation that almost certainly was going to induce some changes into village life.

17.3 Data and Methods

17.3.1 The Variables in the Statistical Models

We use census data aggregated at the qurah level. In its most literal translation from Arabic, a "qurah" is a city, but in the Egyptian census definitions it refers to the administrative boundaries of a village, as illustrated in Fig. 17.1. The dependent variable in our analysis is an estimate of the fertility rate derived from age structure data in the census. The independent variables include those that are measured comparably over the three censuses that we are analyzing: (1) marital status as a proxy for the average age at marriage; (2) female education (illiteracy); and (3) two measures of the local neighborhood context, including the sex ratio as a proxy for the impact of the outmigration of males to Cairo or, more likely, to Gulf States for temporary employment, and the size of the village as a proxy for its level of urbanness.

As is true in many less-rich countries, the amount of detailed information collected in the census is limited, and so we employ an indirect measure of the total fertility rate (TFR – the number of children a woman would have in her lifetime if reproduction remained at the current level) as our dependent variable. We derived the TFR from the age structure data in the census, applying the CBR-TFR population analysis spreadsheet developed by the International Programs Center of the US Census Bureau (Arriaga, 1994). This spreadsheet estimates the crude birth rate and total fertility rate using the total population, the female population in childbearing ages by 5-year age groups, general fertility rate, and empirical patterns of age-specific fertility rates included in the program.

Before making these calculations, we dealt with the issue of the accuracy of the age and sex structure as enumerated in the census, since if we are to estimate fertility indirectly from the age structure, we need to be confident in that source of data. We have employed information from Demographic and Health Surveys (DHS) in Egypt as a source of comparative data. The age groups that are of importance for indirectly estimating fertility are the children aged 0–4, which are notoriously the least well enumerated, and women of reproductive age (15–49). In general we assume that the interviewers of the DHS were likely to obtain more accurate information than would have been obtained by enumerators in the census. The sampling error in the DHS is sufficiently low so that any large disparities between the DHS and the census for both girls and boys are likely to be statistically significant beyond the 0.01 level. The 1995 DHS included 548 households from 17 different villages in Menoufia governorate, and from the household listing in the DHS we reconstructed the age and sex structure as reported for each household, representing a sample household population in Menoufia in the 1995 DHS of 3,196 persons. These data were then compared with the 1996 census age distribution for Menoufia to assess potential errors in the census age distribution. We also made the assumption that the 1-year difference between the census and the DHS would not affect our comparison in any meaningful way.

From this comparison we concluded that boys aged 0–4 were underenumerated by 18% in the census, and girls that age were underenumerated by 7%. We thus made an across-the-board adjustment in each village to increase the number of children aged 0–4 by those amounts. We then rejuvenated the population of girls and boys aged 0–4 from the census by dividing by the respective sex-specific survivorship rates. Survivorship rates are calculated from life tables derived from ${}_nM_x$ data compiled by the Cairo Demographic Center (2001), adjusted for likely underregistration of deaths. From these estimates we calculated the number of births over the prior five years, and dividing that by 5 and then dividing by the rejuvenated average number of women of reproductive age produced an estimate of the average single year general fertility rate. This value was combined with data on the female population by 5-year age group, and the total population in each village to estimate the total fertility rate based on empirically derived relationships between the GFR, the female population, the total population, and age-specific fertility rates in the population analysis spreadsheets. Our calculations produced a TFR for Menoufia in 19[illegible] of 3.6 children per woman.

We repeated the procedure for 1986, comparing data from the 1988 DHS with the 1986 census data for Menoufia. The DHS in 1988 included a sample of 3[illegible] households in 10 villages, with a total household population of 2,449. We did not find that the differences were statistically significant, so no age adjustments were undertaken. We then constructed a life table for Egypt for 1986, building on the 19[illegible] life table, but incorporating higher death rates, especially at the younger ages. [illegible] estimated from DHS data, in order to rejuvenate the population, as described above for the 1996 calculations, in order to complete our indirect estimation procedure. We did not have a comparable fertility survey for the period near the 1976 census and so we assumed that no adjustment was necessary, since that had been true [illegible] 1986. We then rejuvenated the 1976 census data based on the life table for Egypt available from the International Programs Center at the US Census Bureau (http://www.census.gov/ipc/www/idbacc.html).

The predictor variables are limited in number, especially given the need to have comparability across all three census dates. We measure the human capital variable in the village in terms of female education. The data are available only for [illegible] women aged 15 years and older, regardless of specific age or other characteristics. In addition, because of the limited educational attainment of women in Menoufia the educational variable was measured as the percentage of women aged 15 years and older who are illiterate. Our expectation is that lower levels of illiteracy will be associated with lower levels of fertility, and that declines in illiteracy over time will be associated with declining fertility. We also anticipate some interaction between education and marital status. The literature suggests that the early impetus for fertility decline in Arab countries has come from a delay in marriage (occurring in the general absence of any offsetting rise in out-of-wedlock births) (Rashad, 2000). In a society where virtually all women eventually marry, the proportion of women who are currently married should be an index of the relative age at marriage from one place to another. And, since out-of-wedlock births are relatively rare in Muslim countries such as Egypt, we would expect that fertility will be lower where the proportion of married women is lower.

We also take into account that in rural areas there may be migration out of the village and it will disproportionately affect males. As a result, the relative absence [illegible] men could have a dampening influence on fertility. We control for this effect by [illegible]ing the sex ratio of males aged 25–44 years to females aged 20–39 years as a covariate in the analysis. The final covariate introduced into the model is the total population size of the village, serving as a proxy for the relative degree of urbanness of the place.

17.4 Dasymetric Mapping of the Villages

The use of point pattern spatial analysis with data that are aggregated at an administrative level such as the qurah in Menoufia requires that an assumption be made about the point that will best represent the area for which the data are aggregated. The easiest and most common solution is to assume that data are uniformly distributed within the area and that the geographic center (centroid) of that polygon adequately describes the average location of people to whom the data refer. This approach may, however, compromise the accuracy of the spatial analysis. For decades, if not centuries, Menoufia has been one of the most rural and most densely populated rural areas of Egypt (Gadalla, 1978). It has been, and remains, predominantly agricultural, with the population congregated into rural villages from which people go out each day to work in the fields. Because most of the area in each qurah is devoted to agriculture, the assumption of a uniform distribution of the population within each qurah is certainly not accurate, and there is no reason to believe that the geographic center of the area defined as the village is a good representation of where the population actually resides. This is one component of the well-known modifiable areal unit problem (MAUP) Openshaw (1984). "The MAUP concerns the fact that varying the scale of data aggregation, and/or aggregating data using different aggregation boundaries at a single scale, may affect the results of spatial statistical analysis" Mennis (2002).

A dasymetric approach to the data helped to deal with two additional problems that confronted us with the Menoufia data: (1) the administrative boundaries of several qurah actually cut right through the middle of built areas and so we had data for what seemed to be two or more places when in fact the data really only referred single village; and (2) the administrative boundaries had changed slightly betw 1976 and 1996, leading to the need to harmonize the data over time. The dasym approach attempts to improve on the default method (the geographic center of entire administrative area) by more accurately locating the point in each pol based on ancillary information about where the people are located. Our anci data are based on the classification of satellite imagery into those areas that repre a built environment (the villages) or not (the agricultural fields and other non-vi areas). For this purpose we used an Indian Remote Sensing IRS-1C LISS-III m resolution multispectral image covering bands 2, 3, and 4 (green, red, and infra-red) satellite image acquired in 1996. Although the village boundaries have enlarged somewhat between 1976 and 1996, especially as a result of the nificant population growth discussed above, we assume that the geographic cen the built area is the same for all three census dates. The classification methods with the imagery are discussed elsewhere (Weeks et al., 2004, 2005; Weeks, 20 Rashed et al., 2001, 2003, 2005). Once the imagery was processed and the buil identified, we calculated the centroid of the built area and used it to represen data for the village, rather than the geographic center of the entire administrat defined area. If more than one built area existed within the village administr boundaries, the weighted mean center of all built areas was found, using the extent of each built area as its weight.

Especially important in this process was the identification of single villages had been split into multiple administrative units. Figure 17.2 illustrates ho default placement of points could artifactually create spatial autocorrelation data because the hypothetical village shown is administratively divided int parts, for each of which a separate set of census tables will have been created. A ing the geographic center to those data would then produce data allocated to different points. Since the demographic characteristics are likely to be similar f four parts of the village, this situation would appear at first glance to refer to similar villages next to one another – a classic case of spatial clustering. In the data are all associated with different segments of the same built area, a fa we discover only with the use of ancillary data, in this case the satellite im and which is corrected for through the dasymetric approach. This process re the number of points associated with villages from 314 to 286.

17.5 Statistical Analysis

Our approach to answering the research questions posed in this paper is multiple regression techniques, taking into account any observed spatial Assuming that a spatial pattern exists in the data, we next want to know where the clustering occurs. Where are the "hot spots" in which high le fertility are clustered and where are the "cold spots" in which lower levels of ity are clustered? The local spatial statistic we utilize is the $G_i^*(d)$ statistic

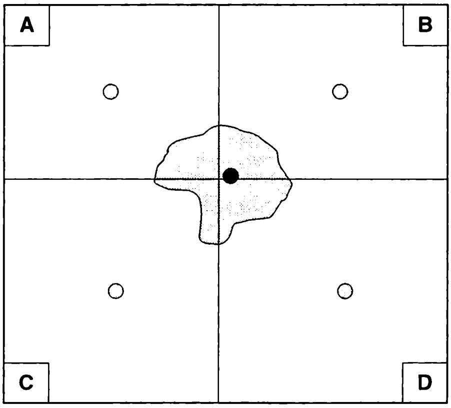

Fig. 17.2 Situations improved by dasymetric mapping

1995b; Ord and Getis, 1995). We then use the results from the clustering statistics to conduct a spatially filtered regression analysis. This is a method that allows us to quantify the role that spatial autocorrelation is playing in the observed variability of the dependent variable (Getis, 1995b; Getis and Griffith, 2002; Weeks et al., 2004). Anselin and Rey (1991) have differentiated between two forms of spatial dependence; that which is a nuisance, and that which represents a substantive spatial process. As a nuisance, it can be controlled with a properly designed weights matrix within a spatially autoregressive model. However, when the spatial dependence is a subject of inquiry, as it is in this research, it is useful to be able to quantify the role that it plays within each of the predictor variables. Two such filtering approaches are currently available – the Getis filtering method (see Getis, 1995b) and the Griffith eigenfunction decomposition method (see Griffith, 2000). Both of these methods are capable of identifying the spatial effects within a regression framework (Getis and Griffith, 2002), but in this research, we employ the Getis method. We thus use the $G_i^*(d)$ statistic as a spatial filter to extract the spatially autocorrelated portion of each of the variables in a regression model. The difference between the original variable x_i and the filtered variable x_i^f becomes a new variable x_i^{sp}, that represents the spatial effects embedded in x_i (Getis, 1995b). These two variables, x_i^f and x_i^{sp} replace the original variable x_i in the regression equation to produce a spatially filtered regression model in which the contribution of the spatial and filtered (non-spatial) components of each factor can be determined by the beta coefficients in the resulting model. These techniques of spatial filtering were developed originally by Getis (1995b) and have been modified into a Fortran program by Scott (1999) in the format that will be used in this project. In this format, the regression model to be tested is as follows:

$$\begin{aligned}\text{TFR} =& \{\text{illiteracy filtered}\} + \{\text{illiteracy spatial}\}\\ &+ \{\text{marital status filtered}\} + \{\text{marital status spatial}\}\\ &+ \{\text{sex ratio of adults filtered}\} + \{\text{sex ratio of adults spatial}\}\\ &+ \{\text{village population filtered}\} + \{\text{village population spatial}\} + \text{error}\end{aligned}$$

By solving the equation with the filtered and spatial components separated, the spatial autocorrelation is removed from the residuals and incorporated into the model as a component helping to predict variation in the dependent variable.

The final model fit has been shown to be comparable whether using spatial filtering or autoregressive models (Getis and Griffith, 2002), but the spatial filtering technique has the advantage of giving us intermediate information about the effect of spatial dependence on the dependent variable that is not available within an autoregressive framework.

17.6 Results

We organize our results around the three research questions posed above, which require that we look at the spatial pattern and regression results for 1976, then 1986, and 1996, and then examine the changes over time.

17.6.1 Did Fertility Decline More Between 1986 and 1996 than Between 1976 and 1986?

Fertility did indeed decline more in Menoufia between the 1986 and 1996 censuses than it had in the previous decade. This pattern was at odds with the country as a whole, which experienced a more rapid decline between 1976 and 1986 than between 1986 and 1996, as can be seen in Table 17.1. In 1976, the TFR for Menoufia was slightly less than for the country as a whole, but Menoufia experienced only a slight decline between then and 1986, as Weeks and associates (2000) have already shown. However, the country was experiencing a rather rapid decline during that time and by 1986 the TFR in Menoufia was nearly one child higher than for the country as a whole. The decline in Egypt was led by the urban areas, which had about a 10-year head start on rural areas in the fertility transition (Weeks et al., 2004). Between 1986 and 1996 Menoufia experienced a very rapid drop in fertility and thus in 1996 it was once again at parity with the nation.

The data in Table17.1 lead us clearly to expect that changes in the educational level of women were playing a role in Menoufias fertility decline. Between 1976 and 1996 there was little overall change in the proportion of women who were married suggesting that there were few observable shifts in the pattern of marriage. However female illiteracy dropped substantially, from 77% down to 52%. At the same time

Table 17.1 Fertility decline in Egypt and Menoufia, 1976–1996

	Egypt		Menoufia					
	TFR	Change in TFR	TFR	Change in TFR	Proportion married	Female illiteracy	Sex ratio at reproductive ages	Village population size
1976	6.05		5.84		0.61	0.77	0.86	6,036
1986	4.51	1.54	5.40	0.44	0.63	0.67	0.88	7,840
1996	3.57	0.94	3.56	1.84	0.63	0.52	0.92	9,349

Sources: Data for Egypt are from the International Database of the International Programs Center of the US Census Bureau; Menoufia data were calculated by the authors from Egyptian census data

the sex ratio at the reproductive ages was increasing, probably due especially in the 1990s to the Gulf War, which forced many Egyptian men back to their villages from the oil fields in Kuwait and Iraq. All other things equal, we would expect this to have created an upward pressure on fertility as men returned to more frequent intercourse with their wives. If age at marriage was not rising, and women were more likely to have their husbands around, the likely explanation for the decline would almost have to be an increase in contraceptive utilization among women, and we will look for that evidence later using data from the Egypt Demographic and Health Survey.

Having now laid out the case for the overall pattern of change in fertility in Menoufia, the remainder of this analysis is devoted to examining at a finer spatial scale what was going on Menoufia to create this fertility transition that was timed differently from the country as a whole, so that we can improve our understanding of the demographic changes in Egypt.

17.6.2 Spatial Patterns of Fertility in Menoufia in 1976

In 1976 the average woman in Menoufia was having children at a rate that would produce nearly six children over the course of her lifetime. Although fertility was quite high in most places throughout the governorate, the distribution of fertility by village was negatively skewed, indicating that there were several places with significantly below average fertility levels. The left panel of Fig. 17.3 shows the spatial pattern of total fertility rates by village. The substantial level of spatial autocorrelation is evidenced by the global Moran's I statistic of 0.35, with $z(I)$ being equal to 9.39.

The right panel of Fig. 17.3 shows the statistically significant clusters with respect to fertility, based on the Getis–Ord G_i^* statistic, as discussed above. There are scattered clusters of low fertility, especially in the center of the governorate around the city of Shbin El Kom, the capital and largest of the governorate's handful of urban areas and home to Menoufia University which was, in fact, founded in 1976. In particular, low fertility is found in the northern area formed by the triangle

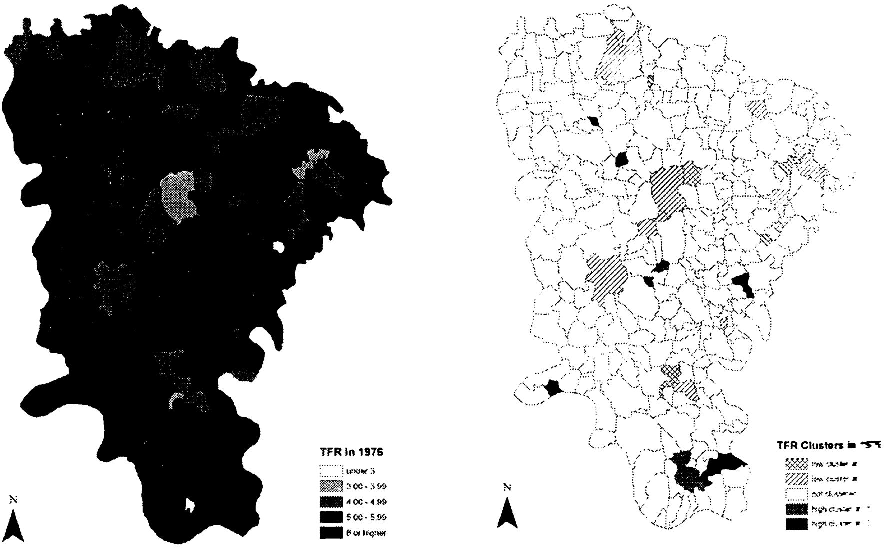

Fig. 17.3 Fertility levels in Menoufia in 1976

between Shibn El Kom, a larger urban center, Tanta, which is just across the administrative boundary in the adjacent northern governorate of Gharbia (not shown in Fig. 17.3), and another urban center, Banha, which is just to the east in the adjacent governorate of Qalyubbia (also not shown). Highways and railroad lines link these three places and form, in essence, the more urban or cosmopolitan corridor in Menoufia. The highest fertility is in the southern part of the governorate nearest to the Nile Delta Barrage. As the crow flies, this area is geographically closer to Cairo, but it is less connected to Cairo by way of transportation networks than is the northern part of the governorate.

Although we have only a limited number of variables available to us, the ordinary least-squares model shown in Table 17.2 reveals that the four predictor variables account for 47% of the village to village variability in fertility levels. Of these, the proportion of women who are married is clearly the most important, and as that proportion goes up, so does the fertility rate. But the other three variables are also statistically significant predictors, with higher illiteracy being associated with higher fertility, a higher sex ratio equating to higher fertility and a larger population size in the village correlating with lower fertility. However, the model has a high level of spatial autocorrelation in the residuals, suggesting that the model needs better specification to account for the spatial component.

The lower panel of Table 17.2 shows the results of the spatially filtered regression, undertaken as described above in the methods section. The spatial and non-spatial components of the proportion married are nearly equally important predictors of fertility, suggesting that both the level itself and being in the neighborhood of similarly situated villages affects the level of the TFR. However, only the non-spatial

Table 17.2 Regression models for fertility in Menoufia, 1976

Predictor variables	Initial OLS model			
	Standardized beta coefficient	t-score	p-value	Moran's $z(I)$
(Constant)		−1.463	0.144	
Proportion married	0.502	8.555	0	3.891
Female adult illiteracy	0.139	2.382	0.018	5.39
Sex ratio at reproductive ages	0.15	3.239	0.001	2.276
Village population	−0.159	−3.412	0.001	1.091
Adjusted $R^2 = 0.47$				
$Z(I)$ for residuals	2.997			
	Spatially filtered model			
(Constant)		−0.245	0.807	
Female illiteracy non-spatial	0.135	2.423	0.016	
Female illiteracy spatial	0.037	0.6	0.549	
Proportion married non-spatial	0.357	6.594	0	
Proportion married spatial	0.412	5.94	0	
Sex ratio non-spatial	0.149	3.193	0.002	
Sex ratio spatial	0.113	2.121	0.035	
Village population	−0.174	−3.706	0	
$R^2 = 0.48$				

Dependent variable is village TFR

component of female illiteracy is statistically significant. We posit that the spatial component is not significant because the high level of illiteracy in 1976 meant that nearly every village was likely to be in the midst of other villages with generally high levels of female illiteracy. The non-spatial component of the sex ratio was somewhat more important than the spatial component, although the latter was statistically significant. The village population size had not exhibited a spatial pattern and so it was not spatially filtered. It remains a statistically significant predictor of fertility. The R^2 is essentially the same for both the initial and the filtered models, but the filtered model has provided additional information about the spatial nature of the predictors of fertility in Menoufia.

17.6.3 Spatial Patterns of Fertility in Menoufia in 1986

As has been anticipated from the earlier study Weeks et al. (2000), the fertility pattern in 1986 is not dramatically different from that in 1976. The left side of Fig. 17.4 reveals a spatial pattern very similar to that in Fig. 17.3, and the Moran's I of 0.37 (with a normalized z-score of 9.85) confirms the visual impression of a non-random distribution of fertility levels around the governorate. The right side of Fig. 17.4 does show, however, that the hot spots of high fertility in the northern part of the governorate were no longer visible in 1986. The implication is that the northern villages in the governorate were the ones most involved in the relatively modest decline in fertility between 1976 and 1986.

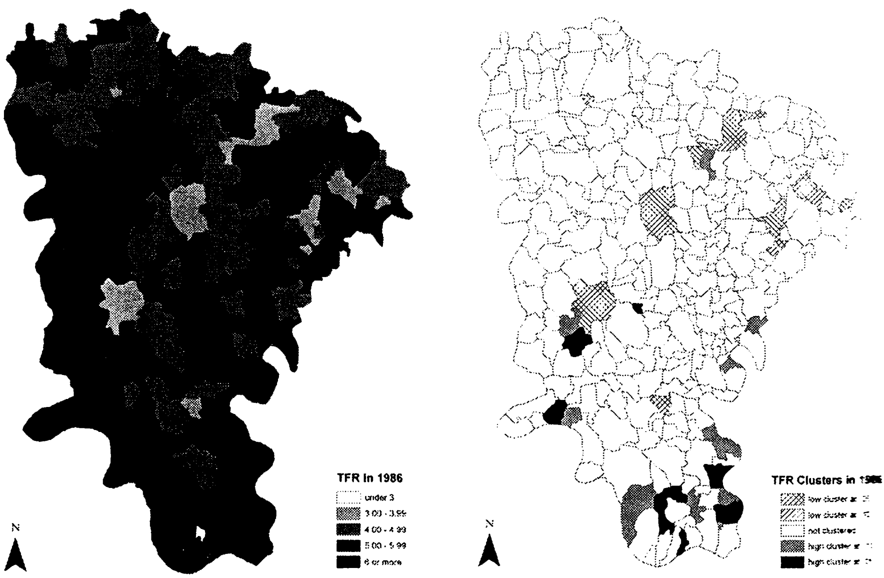

Fig. 17.4 Spatial pattern of fertility in 1986

The regression models for 1986 are shown in Table 17.3. Two things stand out in these results. The first is that female adult illiteracy emerges in 1986 as the most important predictor of the TFR in Menoufia's villages. The second is, that largely as a result of the emergence of education as a key predictor of fertility, the R^2 goes up to 0.59, which is considerably improved over the 1976 results. The sex ratio is again a predictor of fertility levels, but in 1986 the size of the village's population is no longer a factor.

The residuals showed a significant level of spatial autocorrelation, as they had in 1976, and so we applied the spatial filtering process to these data. The non-spatial component of illiteracy was a stronger predictor of fertility than was the spatial component, but both are the top two factors influencing fertility levels in 1986. The spatial component of the proportion married was slightly more important than the non-spatial, whereas the non-spatial component of the sex ratio was more important than the spatial, as had been true in 1976.

17.6.4 Spatial Patterns of Fertility in Menoufia in 1996

By 1996 the spatial pattern of fertility in Menoufia was clearly altered from previous years, as shown in Fig. 17.5. Dramatically lower fertility levels are nearly the norm throughout the governorate, so much so that there are very few clusters of low fertility. The distribution of TFR by village is now positively skewed and the more unusual villages are now those that persist in their high fertility. These places are most noticeably in the southern part of the governorate.

Table 17.3 Regression models for fertility in Menoufia, 1986

Predictor variables	Initial OLS model			
	Standardized beta coefficient	t-score	p-value	Moran's $z(I)$
(Constant)		−3.679	0	
Proportion married	0.244	5.297	0	5.294
Female adult illiteracy	0.589	12.587	0	5.223
Sex ratio at reproductive ages	0.11	2.813	0.005	4.907
Village population	0.019	0.464	0.643	1.735
Adjusted $R^2 = 0.594$				
$Z(I)$ for residuals	2.559			
	Spatially Filtered Model			
(Constant)		−2.168	0.031	
Female illiteracy non-spatial	0.48	10.83	0	
Female illiteracy spatial	0.347	6.361	0	
Proportion married non-spatial	0.167	4.005	0	
Proportion married spatial	0.263	4.339	0	
Sex ratio non-spatial	0.101	2.588	0.01	
Sex ratio spatial	0.042	0.907	0.365	
Village population	0.01	0.249	0.804	
$R^2 = 0.605$				

Dependent variable is village TFR

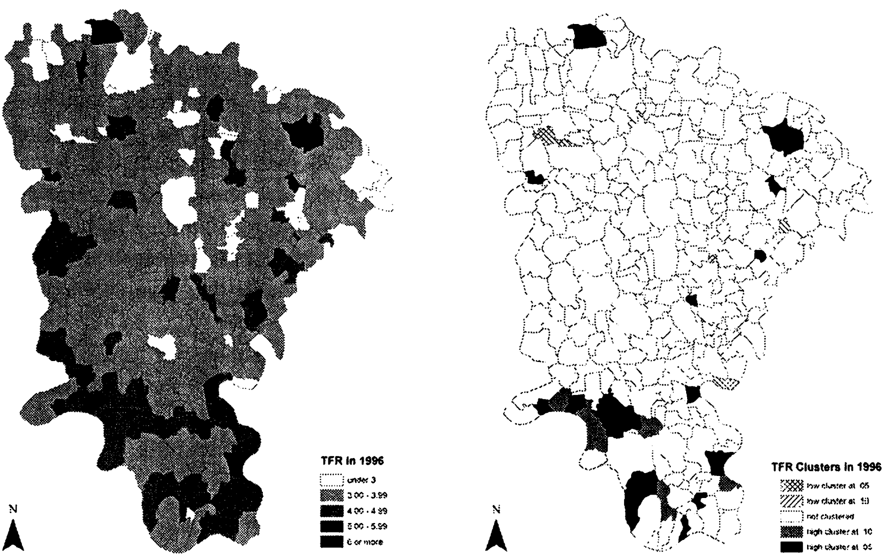

Fig. 17.5 Spatial pattern of fertility in 1996

Table 17.4 Regression models for fertility in Menoufia, 1996

Predictor variables	Initial OLS model			
	Standardized beta coefficient	t-score	p-value	Moran's $z(I)$
(Constant)		−4.509	0	
Proportion married	0.331	6.419	0	7.09
Female adult illiteracy	0.393	7.712	0	6.234
Sex ratio at reproductive ages	0.197	4.26	0	9.229
Village population	−0.014	−0.299	0.765	1.825
Adjusted $R^2 = 0.45$				
$z(I)$ for residuals	2.544			
	Spatially filtered model			
(Constant)		−3.34	0.001	
Female illiteracy non-spatial	0.296	6.246	0	
Female illiteracy spatial	0.291	5.046	0	
Proportion married non-spatial	0.248	5.241	0	
Proportion married spatial	0.214	3.605	0	
Sex ratio non-spatial	0.179	3.849	0	
Sex ratio spatial	0.118	2.435	0.016	
Village population	−0.014	−0.297	0.767	
$R^2 = 0.45$				

Dependent variable is village TFR

In 1996 female illiteracy was the most important predictor of fertility, as it had been in 1986, although the proportion married was nearly as important, as seen in Table 17.4. The sex ratio continued to be a significant factor, whereas population size was not. Again, the spatial autocorrelation in the residuals led us to engage in spatial filtering and the results suggest that the non-spatial component of female illiteracy was slightly more important than the spatial component, and this was true as well for the proportion married, and also for the sex ratio. In all cases, however, both the spatial and non-spatial components of those variables were statistically significant. Overall, the predictor variables in 1996 were able to explain 45% of the intervillage variability in the TFR in Menoufia.

Comparisons of the three different census dates suggests that over time illiteracy became an ever-more important predictor of village-level fertility rates and that the spatial component emerged out of the shadows between 1976 and 1986 to assume greater importance in understanding fertility patterns within Menoufia.

17.6.5 Did Fertility Decline More in the South than in the North?

We examined the overall change in fertility between 1976 and 1996 to see if there was a spatial pattern to the change. As can be seen in Fig. 17.6 there is a pattern to the change, and the z-normalized value of Moran's I is 5.03. But the decline in fertility

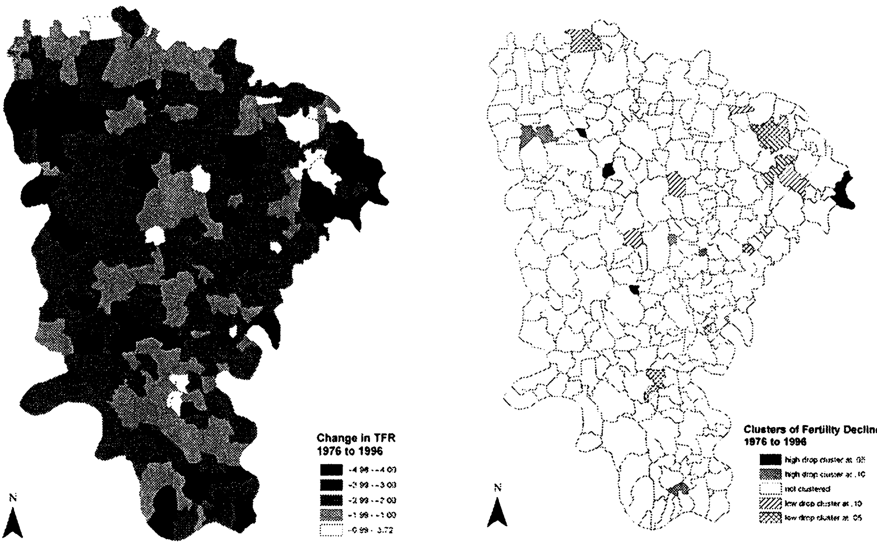

Fig. 17.6 Spatial pattern of fertility change between 1976 and 1996

was generally greater in the north than in south, contrary to what we had anticipated. The data are shown in terms of absolute decline, regardless of the starting point, so this would have privileged the villages in the south, where the starting level of fertility was highest. Yet, even given this advantage to the south, the absolute decline was higher in the north. The right-hand panel of Fig. 17.5 shows the clusters of fertility change. Although the clusters are scattered about the governorate, there are more "high decline" clusters in the north than in the south.

17.6.6 Was the Fertility Decline Due Both to Improvements in Female Literacy and to Location Within Menoufia?

The data show that fertility underwent a dramatic decline in this governorate between 1986 and 1996, a result that had been foreshadowed by the changes taking place between 1976 and 1986, especially the improving level of education among women, which was part of a nationwide program pushed by the government in Egypt (Fargues, 1997). Between 1976 and 1986 the percent of adult women who were illiterate dropped from 81% to 67%, even though there was little change in fertility. It seemed unlikely that a shift of that size in female education would not lead eventually to a decline in fertility and, indeed, that drop did occur between 1986 and 1996, as the level of education of women continued to climb, and as women began to catch up with men in terms of educational attainment. On the other hand, there was little change in the percent married, suggesting little change in the average age at marriage, and the sex ratio in the adult ages increased, which we would posit should encourage, rather than discourage fertility.

The regression models of fertility change between 1976 and 1996 quantify these changes, as shown in Table 17.5. We included the fertility level in 1976 as an endogenous variable in the model, because we wanted to see how the other predictors behaved after controlling for the fact that the 1976 fertility level might influence the subsequent fertility decline. As we expected, the change in the proportion married did not predict a change in fertility, largely because there was not much change in the proportion married. The largest standardized beta coefficient, other than the initial fertility level, was the change in levels of illiteracy. The unstandardized coefficients (not shown in the table) suggest that a 10 percentage point drop in illiteracy is associated with a decline of one child in the total fertility rate. The sex ratio was also significantly related to a drop in fertility, with a decline in the sex ratio (indicating fewer men per woman) being associated with a decline in fertility. Change in population size of villages was not associated with a change in fertility.

It was noted above that fertility dropped more in the north than in the south, and that is also where educational levels were changing most rapidly for women. Figure 17.7 shows that in 1976 in nearly all villages at least 50% of adult women

Table 17.5 Regression models of fertility change between 1976 and 1996

Predictor variables	Initial OLS model			
	Standardized beta coefficient	t-score	p-value	Moran's $z(I)$
(Constant)		7.597	0	
Change in proportion married	0.053	1.164	0.245	11.91
Change in female adult illiteracy	0.134	3.341	0.001	3.06
Change in sex ratio at reproductive ages	0.097	2.421	0.016	7.52
Change in village population	0.009	0.226	0.821	2.21
TFR in 1976	−0.69	−16.601	0	9.39
Adjusted $R^2 = 0.62$				
$z(I)$ for residuals = 3.98				
	Spatially filtered model			
(Constant)		−0.336	0.737	
Change in female illiteracy non-spatial	0.12	2.92	0.004	
Change in female illiteracy spatial	0.113	1.741	0.083	
Change in proportion married non-spatial	0.039	0.91	0.364	
Change in proportion married spatial	0.073	1.16	0.247	
Change in village population non-spatial	−0.013	−0.358	0.721	
Change in village population spatial	0.09	2.346	0.02	
Change in sex ratio non-spatial	0.085	2.202	0.028	
Change in sex ratio spatial	−0.02	−0.353	0.724	
TFR in 1976 non-spatial	−0.659	−15.838	0	
TFR in 1976 spatial	−0.338	−5.639	0	
Adjusted $R^2 = 0.64$				

Dependent variable is change in village TFR

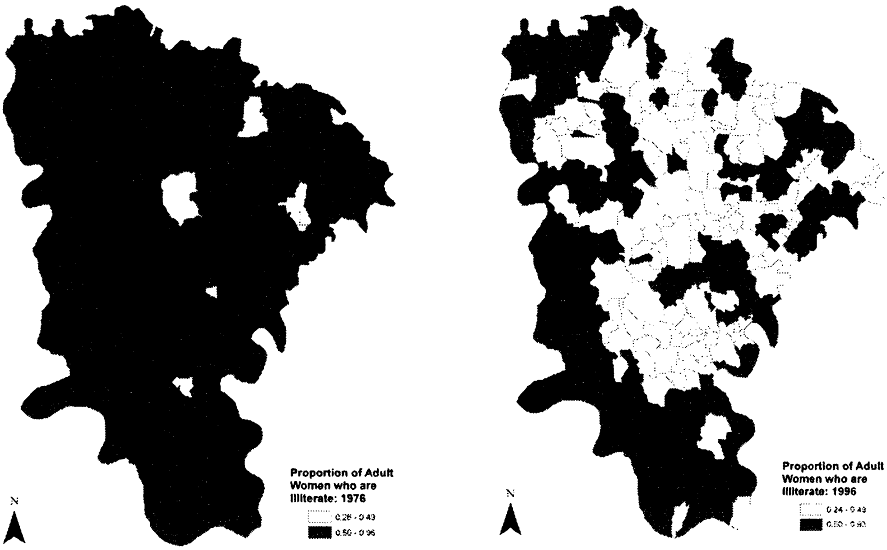

Fig. 17.7 Spatial pattern of illiteracy change between 1976 and 1996

were illiterate. The exceptions to this rule were in some, but not all, of the more urban parts of the governorate, especially Shbin El Kom, in the central northern part of the governorate. By 1996 there had been a huge swath of villages that had dropped below 50% illiteracy and they were heavily concentrated in the northern part of the governorate. This pattern was sufficiently widespread so that only the non-spatial component of illiteracy was statistically significant in the spatially filtered regression (bottom panel of Table 17.5). It is likely that the spatial component of illiteracy was subsumed under the spatial pattern of the TFR in 1976, given the overall relationship between education and reproduction.

17.7 Discussion and Conclusion

We have used a better measure of fertility and a more spatially precise dasymetric mapping approach to confirm that between 1976 and 1986 there was little change in fertility in the rural governorate of Menoufia, Egypt, but there was considerable spatial variability in both of those years. As Weeks et al. (2000) had predicted, we found that in 1986 the governorate was poised for a rapid drop in fertility because of the rapid rise in female literacy that had not yet, in 1986, produced any clear decline in the average number of children being born to women. Our results show that the central and northern parts of the governorate were the sites of the most dramatic declines in fertility, rather than the southern part, as had been anticipated. This is due in large part, we assume, because the decline in illiteracy was more dramatic in those parts of the governorate, and the results do confirm the expectation that education was a key predictor of changing fertility.

By itself, of course, education cannot directly determine fertility levels. Education is a distal, not a proximate determinant of fertility, which include especially age at marriage (which in Muslim countries is almost always the same as the age at first intercourse), contraception, and abortion (which is only available under very restricted circumstances in Egypt). It is noteworthy that the proportion married did not emerge as a variable helping to explain the decline in fertility in Menoufia, because we noted above that a change in the age at marriage has been posited as an important element of the Arab fertility transition. In 1976, 1986, and 1996 it helped to explain the spatial variability in fertility in the governorate, but it was not a change in marriage behavior that seems to have accounted for the decline in fertility between 1986 and 1996. In fact, there was practically no change in the percent married in most villages during that 10-year interval. The obvious implication is that fertility was accomplished by means of contraceptive utilization, rather than delayed marriage.

The census data themselves provide no clues about the possible role of family planning, but we can gain some insights using data from the Egypt Demographic and Health Surveys (http://www.measuredhs.com). In 1988, there were 345 married women of reproductive age included in the DHS in Menoufia sampled from 10 different villages, and in 1995 the sample included 507 women from 17 different villages. Between 1985 and 1995 there was a slight increase in the average age at marriage among women in the sampled villages, but most noticeably the percentage of women who had ever-used a modern method of contraception increased from 62% to 75% (see Table 17.6). The increase was especially noticeable among younger women. For example, women aged 20–24 increased their ever-use of modern contraceptives from 40% to 62%. Although the sample sizes are fairly small, that difference is large enough to be statistically significant. The current use of modern contraception increased from 39% in 1988 to 49% in 1995, and again it was the younger woman among whom the increase was most notable, increasing from 24% to 47% among women aged 20–24.

This rise seems plausible given the high percentage of women (three-fourths at both dates) who indicated that their husband approved of birth control. The data in Table 17.6 also show the likely source of the increase in the use of contraception, namely "family planning effort." Married women in Menoufia were switching from the pharmacy as a source of contraception to a hospital or clinic. This was part of a government effort to promote an increase in the use of contraception in order to lower the birth rate. The decline in mortality was fairly substantial during this time in Egypt. The US Census Bureau's International Programs Center estimates that the infant mortality rate (deaths during the first year per 1,000 live births) was 132 in 1976, 89 in 1986, and 49 in 1996 (US Census Bureau International Programs Center, n.d.). Furthermore, in 1976 childhood mortality rates were consistently higher for females than for males (Makinson, 1986) but that pattern had abated by 1986.

As the death rate goes down among children without a commensurate drop in fertility, the result is that an increasing fraction of children survive to adulthood.

Table 17.6 Results for Menoufia from the 1988 and 1995 Egyptian demographic and health surveys

	1988	1995
Age at marriage	17.7	18.8
Age at first birth	19.5	20.3
Percent ever having used a method of birth control	62	75
Percent aged 20–24 ever having used a method of birth control	40	62
Percent currently using a modern method of contraception	39	49
Percent aged 20–24 currently using a modern method of contraception	24	47
Percent whose husband approves of family planning	76	76
N of living children at first use	3.16	2.76
Source of last method = pharmacy	43	14
Source of last method = private physician	24	24
Source of last method = hospital or clinic	29	60
Percent of women with more than primary education-DHS	17	33
Percent of husbands with more than primary education-DHS	24	49
Percent of women with more than primary education-Census	7	17
Percent married-census	63	63

forcing families and the villages in which they live to adjust to ever larger numbers of young people who need to be clothed, fed, housed, and provided with a job. In 1976, the combination of fertility and mortality in Menoufia meant that the average women could expect to have 4.03 children survive to adulthood. By 1986 this had risen to 4.52 because death rates had dropped dramatically, but birth rates had not. Recognizing this, the Egyptian government implemented a family planning program in many governorates, including Menoufia, to promote the use of contraception. As we have seen, the birth rate did then drop dramatically, but even so a woman in Menoufia in 1996 could expect to have 4.24 children survive to adulthood – a greater number than 20 years earlier, despite the drop in fertility.

Was the drop in fertility between 1986 and 1996 due to this government-sponsored push to encourage the use of contraception, or was it due to the government-sponsored push to improve literacy among the rural villagers, in order to improve their economic productivity? Almost certainly both of those factors were at work, but we do not have the data to decompose their relative contributions. In general, more educated women are more likely to be contraceptors, so we can anticipate that type of interaction. We also know that there is a spatial clustering of villages where illiteracy dropped between 1986 and 1996 and fertility also dropped in those parts of the governorate. We can infer a cause and effect relationship, but we cannot confirm it. Importantly, though, we know that no matter how widespread both government programs might have been, villagers in different parts of the governorate responded differently. There are clusters of high fertility and low fertility, clusters of rapid change and clusters of slow or no change and our spatially filtered regression results suggest that some portion of the spatial pattern is a product of being in the neighborhood of villages where these phenomena are occurring, whether or not your own village may be very similar to those other villages. We have thus shown that at this geographic scale it is important to know where a village is, not just what its demographic characteristics might be, if we are to understand the level of reproduction of women living in that place.

We end by noting that the story of fertility in Menoufia is not yet completely told. We know that fertility changed very little between the 1976 and 1986 censuses, but the data presented here show clearly that a rather dramatic fertility decline was occurring between 1986 and 1996. Keep in mind that our fertility data refer to behavior that was occurring on average 2.5 years prior to the census, so from a calendar perspective, we can say more accurately that there was little evidence of change in fertility between the 1970s and the early 1980s, but there was evidence of substantial change between the early 1980s and the early 1990s. Interestingly enough, the 1996 census seems to have captured the point at which fertility had at least temporarily leveled off. Our calculations from the 1995 DHS for Menoufia show that there is virtually no difference in the TFR as calculated from births in the year preceding the survey compared to the five years preceding the survey, suggesting no trend in reproductive behavior. By contrast, the 1988 DHS data showed that the TFR based on the year prior to that survey was lower than that based on the five years preceding the survey, implying that there was a downward trend over time to the data. Consistent with this idea is the finding from the Egyptian DHS for 2000 that fertility levels were not much different in 2000 in Menoufia than they had been in 1995 (El-Zanaty and Way, 2001). In fact, our analysis of the data for Menoufia (not shown) suggests, if anything, an upward trend in fertility based on births in the year preceding the 2000 DHS compared to the five years preceding the survey. The 2006 census of Egypt has not been completed as of this writing, but when those data become available we will be able to determine whether, for example, fertility stopped declining in villages where illiteracy had not decline as rapidly as in other villages. From such a fact we may infer that the village's fertility decline had been due to the government's family planning program (which was later substantially reduced in funding as a result of changing United States foreign assistance priorities), rather than to a more systemic change in the education of women.