Mapping out social change in South India

A geographic information system and its applications

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3.1 Graphic representations of the Sabarimala pilgrimage (Kerala)[18]

The pilgrimage to Sabarimala in the inland mountainous south of Kerala is organized around a cult of universalistic design – that of Ayyappa, ambivalent deity born of the marriage of Siva and Vishnu. It represents in the contemporary period one of the most significant phenomena in the reconstruction of the religious in India. As Radhika Sekar (1992) noted, the pilgrimage to Sabarimala presents anthropological and sociological characteristics that clearly distinguish it from other South Indian pilgrimages: a period of ritual initiation (*mala puja*), a basically male pilgrimage in order to preserve the ritual purity of the site (pubescent women are excluded from it), a period of austerity (vegetarianism, piety and chastity) or *vratam*, the promotion of a message of equality and an opening to all social strata as well as to all religious adherences.[19] An observer makes the following comments: "A silent and unnoticed religious fervour has been sweeping the southern states in the last two or three years. In numerous towns and villages, hundreds of boys are joining thousands of their elder menfolk in donning the black garb indicative of the Ayyappa *bhakta*. From street hawkers to auto drivers, bus conductors to salaried employees, skilled artisans to professionals […] irrespective of wealth or riches, the Ayyappa fever seems to have infected everyone" (V. Suresh, 1992: 178). The Ayyappa cult also integrates, although in negligible proportions, Muslims and Christians.

To obtain the *darshan* ("vision" or divine benediction by the sight of the idol) of Ayyappa, which is the main goal of the pilgrimage to Sabarimala, the pilgrims must fulfil a series of austerities during a period of 41-61 days preceding the departure, calling to mind the figure of the ascetic renouncer. Paradoxically, this is hardly apposite as regards the Sabarimala pilgrimage, in view of the mass of pilgrims who make their way to receive a *darshan* responding above all to personal and very concrete preoccupations. The desire for liberation or deliverance (*mukti*) that characterizes the spiritual quest of the ascetic appears here to be secondary, that is, quite different from the actual social reasons of the pilgrimage

[18] Section written by Rémy Delage. The author wishes to thank most particularly the team of a few professors and some dozen students for having participated in the survey (Kamaraj University in Madurai and Tamil Nadu, Sri Venkateshwara University in Tirupati, Andhra Pradesh, and colleges in Erumely, Palakkad and Pondicherry). A survey of such scope could not have taken place without the decisive assistance of an interpreter, P.V. Ashokan (Palakkad).

.[19] Among the many processions which punctuate the course of the pilgrimage, those for which Erumely is well-known (point of departure of the traditional route through the forest) involve a processional activity quite uncommon in India. The pilgrims go for the *darshan* of Ayyappa in a temple, then for that of his Muslim companion Vavar in a mosque, before ending with the *darshan* of Ayyappa in the largest of the two temples. Once the procession and the ritual ablutions have been completed, the pilgrims can begin their journey by foot through the forest, or even by vehicle via road to Pampa.

expressed in the vows made and the thanks given. This pilgrimage thus bears the stamp of devotion (*bhakti*) and for this reason does not diverge from the general movement of uniformization of practices that characterizes modern Hinduism. “Structural factors partly account for the development of reformist ideals, for the standardization of practices and iconography, and for the progressive construction of a common ‘Hinduism’ ” (Tarabout, 1997: 144).

However, without dispensing with the anthropological material necessary for the interpretation of the phenomenon in its totality, we instead stress here the spatial dimensions of the pilgrimage analyzed on different scales, starting from the local or micro-regional level and proceeding to South India as a whole. While in the 1950s-1960s, Sabarimala only attracted groups originating from the Malabar Coast and from the Tamil districts neighbouring Kerala (Madurai, Virudunagar, etc.), the pilgrimage today draws several million devotees coming mostly from the four corners of South India (Kerala, Tamil Nadu, Karnataka and Andhra Pradesh). It is interesting to note in passing that the popular literature in Malayalam and Tamil on the Sabarimala pilgrimage often makes reference to an ideology known as “Dravidian” to (re)construct a discourse of identity around a phenomenon that is above all of social and religious nature.

From these elements a first hypothesis follows, that of the opposition between the Sabarimala pilgrimage, confined to the limits of South India, and the pan-Indian expression of pilgrimage, illustrated for example by Tirupati in Andhra Pradesh, an opposition that has refuelled the debate on the traditional North-South divide of India. The second hypothesis, which we shall partially verify in this contribution, is the geographic hypothesis of the temporary distortion of the map of South India by the itineraries of the pilgrimage that sustain here and there certain historical major routes.

Taking the map as a common thread of this study, but also as an expedient for describing certain structures of the pilgrimage, we shall begin by citing a number of original graphic descriptions of the event from the popular literature. The next stage consists in retracing the major methodological steps in the compilation of a database on the pilgrimage that we have been able to establish by combining the results of a survey by questionnaire with the georeferenced SIFP database. We will then be in a better position to present the initial results of a new cartography of the major routes of religious movement between Kerala and Tamil Nadu. This should, in conclusion, lead us to a redefinition, on the one hand, of certain migratory logics structuring the mobility of pilgrims through an array of preferential itineraries and, on the other hand, to the integration of this study in a historical geography of the flow and the networks of circulation in Tamil Nadu, as well as in South India.

3.1.1 Popular mappings of the Sabarimala pilgrimage

The micro-territory centred on Sabarimala is located at the intersection of four districts and at the confluence of spaces of differing natures. To understand the links existing between this cultural territory and the numerous networks established there, we must take into account the temple villages of Pampa (located 4 or 5 km from the Sabari Hill) and of Sabarimala (Pathanamthitta district), as well as the localities of Pandalam (Pathanamthitta district) and Erumely (Kottayam district). While the village of Erumely constitutes a major junction in the network through which the majority of the pilgrims must pass, it appears that some processions involving the localities of Pandalam[20] (Pathanamthitta district), Alangad[21] (Ernakulam district) and Ambalappuzha (Alappuzha district) go beyond the supposed frontiers of the territory under study.

Even though one never finds very accurate maps, the popular literature on the pilgrimage to Sabarimala (magazines, booklets, reviews and seasonal publications) nevertheless offers a collection of publications in the form of sketches or maps on different scales (see Figure 12), according to the nature of the booklet and the geographic origin of the publisher. They can be obtained in the bookshops of Erumely, Pampa and Sabarimala, but also more or less everywhere in South India if one explores the literature in vernacular language (sometimes in English) on the Ayyappa cult and the Sabarimala pilgrimage. These maps represent valuable research material to the extent that they indicate the main routes to reach the temple, situated in a sparsely populated mountainous region with a high forest density, in the centre of the Periyar Tiger Reserve (PTR). They also make it possible to identify the cult sites marking out the itineraries and structuring the pilgrimage to Sabarimala.

[20] Until the proclamation of the Travancore-Cochin Hindu Religious Institution XVth Act in 1950 and the transfer of authority from the royal family to the Travancore Devaswom Board (TDB), the royal family of Pandalam was in full possession of the temple and its lands, but also in charge of the ritual programme.

[21] Today, the two groups belonging to the neighbouring localities of Alangad and Manjapra today claim the legitimacy of the processional group of Alangad (*Alangad Yogam*).

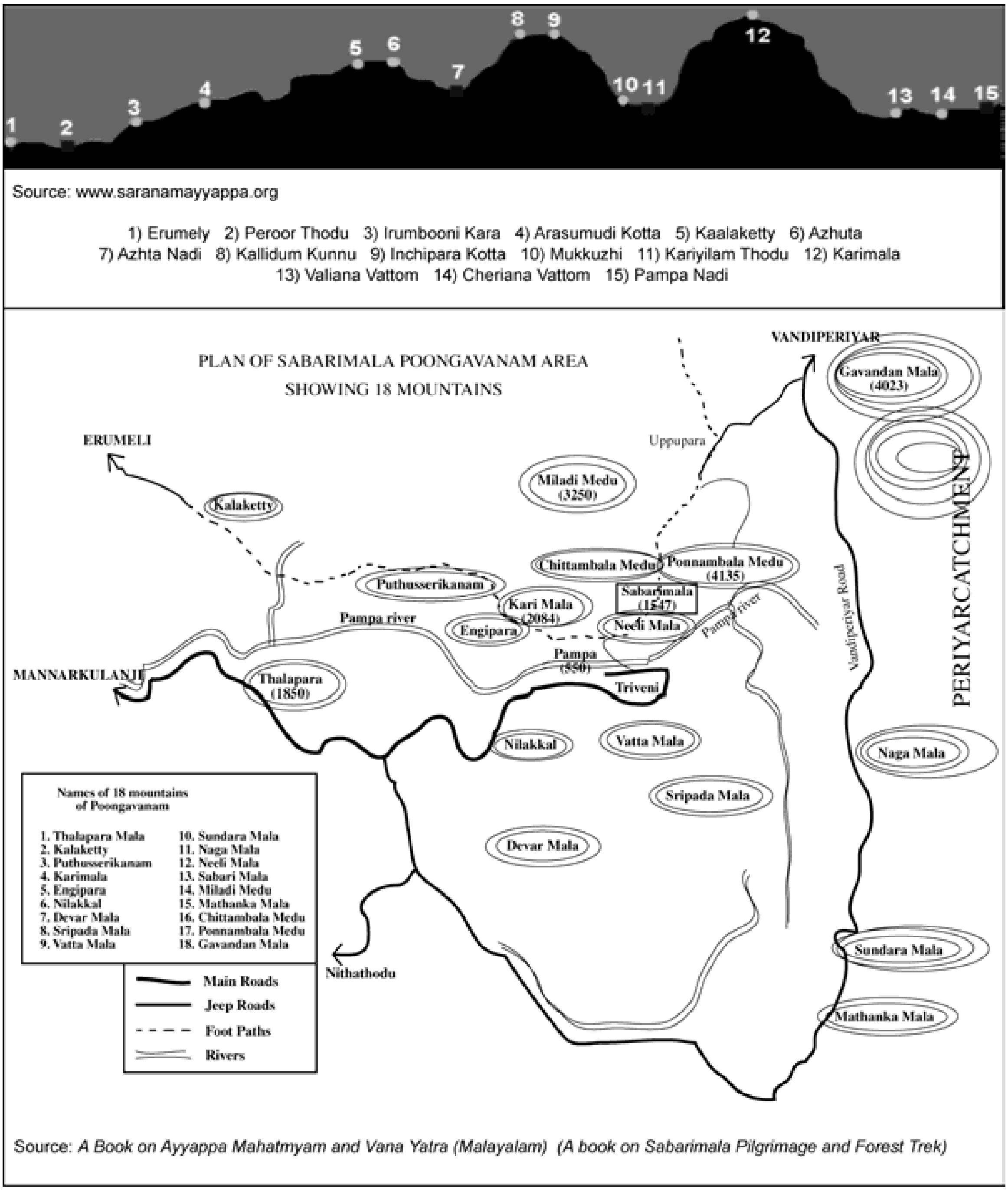

Figure 12 : Topographical cross-section of the forest trek and « Ayyappa's garden » (Poonkavanam)

On the basis of two distinct sources of information (the Internet site of Akhila Bharatha Ayyappa Seva Sangham[22] and a Malayalam booklet entitled "Ayyappa Mahatmyavum Vana Yatrayum"[23]), we have brought together in Figure 12 an approximate

[22] The address of the site is: www.saranamayyappa.org. Dating from 1946, the Akhila Bharatha Ayyappa Seva Sangham (ABASS) association was created under the regime of the Charitable Trusts Act. It carries out the promotion of the Sabarimala pilgrimage and of the figure of Ayyappa, as well as the diffusion of the values of equality and fraternity.
[23] See Bhaskaran Nair (1998).

topographical section of the forest route between Erumely and Pampa (about 75 km) and a flat representation of the “Ayyappa garden” (Poonkavanam), a symbolic territory in the form of an envelope crowning the Sabarimala temple or immediate sphere of influence of the deity (Sabarimala Kshetram). The first allows one to discern the difficulties connected with the physical effort of the march, while the second drawing illustrates the role played by the mountain in the patterning of a geographic imagination of the pilgrimage (the forest route is represented by dotted lines on the sketch, between Erumely and Pampa via Kalaketty and Kari Mala).

It should be added that, on the regional scale, the Western Ghats have long been integrated in the collective imagination as a place of divine sojourn and as playing the role of a major geographic barrier, curbing or preventing interactions of all kinds. Numerous passes (for example, that of Shenkottai), and in particular the Pallakad Gap, have enabled commercial exchanges, tracing itineraries anchored in the cultural representations of space.

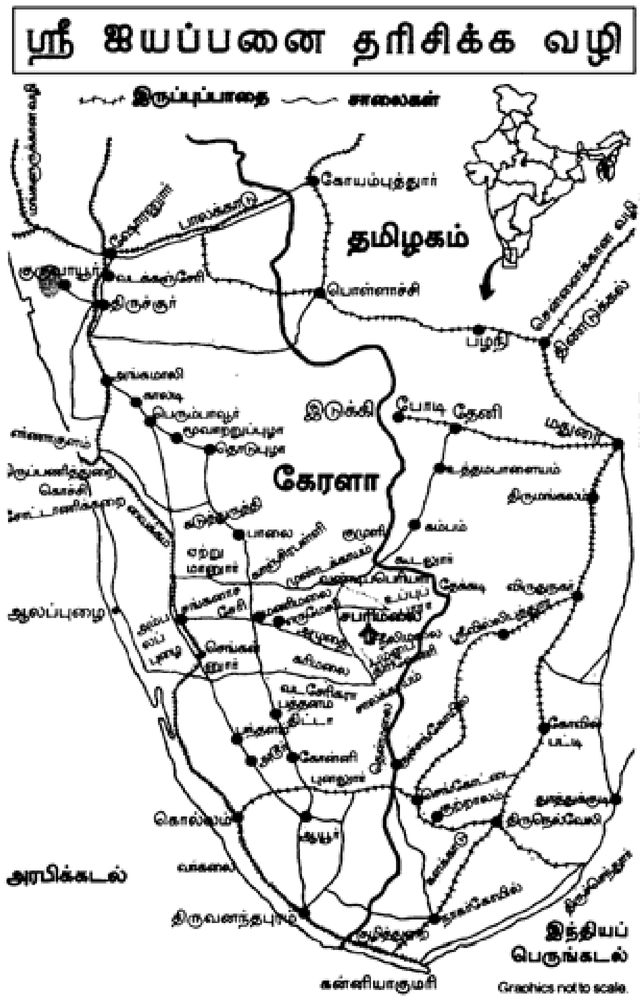

Figure 13 : The road network leading to Sabarimala from Madurai, Tamil Nadu (sources : Dinamalar, 29/10/2000)

In Figure 13, we can identify on the basis of a map in Tamil and its English translation (figure 14), derived from a booklet that appeared in Madurai, the major gateways to Kerala: by way of the Pallakad (Palghat) Gap to the north, the most recent route from Kumily at the level of Madurai, the Shenkottai passes to the south or the long historical route by way of Kaniyakumari at the southernmost point of the Deccan. One will note that the geometrical centre of the map is none other than Sabarimala, representing thus an area demarcated in the north by the town of Coimbatore, in the east by the temple town of Madurai and in the south by the pilgrimage centre of Kaniyakumari, and overshadowing the rest of Tamil Nadu. This obviously does not correspond to the real zone of attraction of the pilgrimage, which merges with the administrative boundaries of South India (north of Karnataka and Andhra Pradesh).

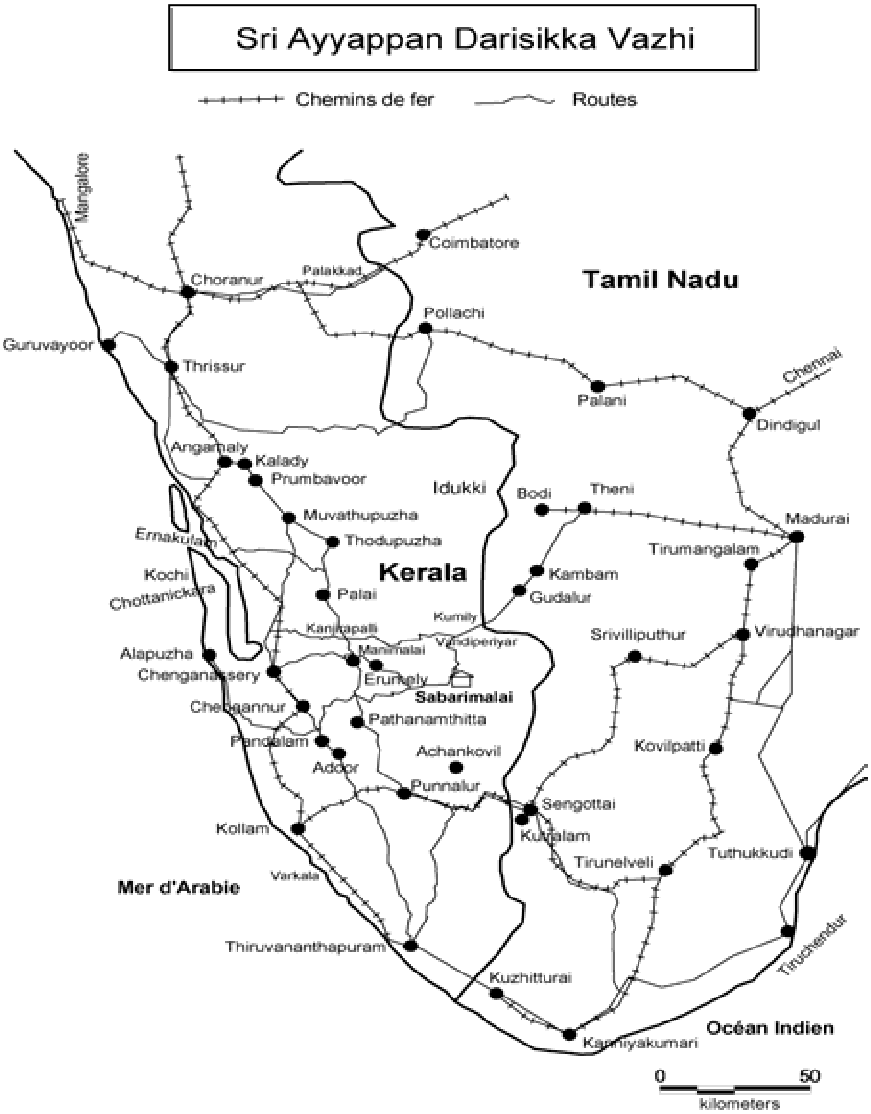

Figure 14 : The road network leading to Sabarimala from Madurai, Tamil Nadu (previous map translated in English)

By matching the geographic information from sources of this type, it would have been possible to draw a map of the infrastructure of both geographic and ritual networks structuring a territory centred on Sabarimala. This will allow us to examine the more complex hypothesis of the regional opening of Kerala through the contradictory play of the increasing concentration of transport networks on its margins, conflicting movements between processional groups and the "deterritorializing" effects of the management of the pilgrimage by the Travancore Devaswom Board,[24] a semi-governmental institution responsible for the temple affairs.

The analysis of these popular maps of the pilgrimage makes it possible to formulate the hypothesis of a discrepancy between the geographic imagination, the representation and the reality of the phenomenon. To respond to this hypothesis, it is necessary to compare the first results with those linked to the treatment of a complementary type of geographic information, namely, data recorded directly from the pilgrim population during the main season. The use of the SIFP database is here clearly distinct from its employment in other contributions in the sense that we do not make use of the census data to work on the geographic magnitude of a phenomenon. Rather, the georeferencing of this base is used to locate the places that constitute an itinerary of the pilgrimage, starting from a field survey of a phenomenon having a South Indian purview.

3.1.2 Methodological challenges of mapping pilgrimage data

After the exploration of a territory in the form of networks centred on Sabarimala, the cartography of the itineraries to Sabarimala between Tamil Nadu and Kerala will enable us to discover the gaps between the geographic imagination and the reality of the Sabarimala phenomenon in South India. In fact, the maps presented earlier showed above all the itineraries of the networks on the Kerala scale, or the internal ritual routes between Erumely and Sabarimala. The data collected during a survey by questionnaire now serve to represent in a complementary manner the routes outside this cultural micro-region, that is to say, itineraries on the scale of South India between the place of residence of the pilgrims (point of departure) and the villages of Erumely and Pampa (places of arrival). We have confined ourselves in the framework of this contribution to the routes followed by the population of

[24] Projects include the laying of a railway line between Kottayam and Erumely, of a cable car between Pampa and Sabarimala (a project abandoned because it was contrary to the spirit of the pilgrimage), new forest roads between Pampa and Sabarimala, and the invention of new ritual connections along the processional route by the Alangad group and in numerous temples situated in southern Kerala, in part destructuring the original geographic networks of the pilgrimage.

Tamil origin, as the latter is strongly represented during the main season and during the monthly openings throughout the year.

All stages of the methodological trajectory will be examined, from the conception of the questionnaire and the conditions of the survey to the data entry and processing in the georeferenced database, which makes it possible to accurately map the major pilgrimage routes leading to Sabarimala.

In order to draw up a very precise sociological and geographic profile of the Sabarimala pilgrimage, a vast survey by questionnaire was carried out in the village of Erumely among a sample of around 900 pilgrims during the main season, which extends from mid-November to the end of December in 2001 (*Mandalam* season) and to the end of January in 2002 (*Makara Vilakku* season). The challenge in this undertaking resides more in the size and the form of the sample than in the structure of the questionnaire itself. In fact, we shall not present here the socio-economic data of the pilgrim population derived from the collected information (age, family, level of education, profession, standard of living, etc.), but we shall instead focus our attention on the geographic origin of the pilgrims (state, district, taluk/mandal, village/town) and the trajectories they temporarily delineated. Also, for about three months, Malayalam and Tamil, but also Telugu, Kannada, Hindi and English are spoken in Sabarimala. This very broad linguistic gamut lends the pilgrimage an undeniable touch of originality, but at the same time represents an obvious constraint for the course of research. The original questionnaire was therefore prepared in English and then translated and distributed in six languages (English, the four main languages of the South and Hindi).

A range of possibilities for graphic representation emerges from this operation, resting on a cartography of variable scale centred on the most significant itineraries at the levels of South India and the four states represented, the main places of passage and the practices connected to them, as well as the other pilgrimage centres annually visited by the swamis.[25] Continuing a bit further with the spatial imagination of the pilgrims, we can also map the places they dream of visiting at least once in their lives. Although difficult to realize for technical reasons, a flow-line map with proportionally sized arrows would represent the ultimate possibility of graphic representation and modelling of the Sabarimala pilgrimage by making it possible to visualize the most frequented nodes connecting different flows and perhaps revealing the competing catchment areas of a place.

[25] The pilgrims setting off for Sabarimala call themselves and call each other swami or Ayyappa, out of concern for equality among themselves and before the god. In effect, they elude the rigidity of the social order during the time of the pilgrimage, but nevertheless reinstate their social identity and their status once this geographic ritual has ended.

Beyond the entry of the questionnaire data in a database, the stage that directly follows the empirical process of the field survey (questionnaire design and survey operations) consists of encoding, separating and classifying these chains of geographic places or trajectories.

3.1.3 From survey information to geographic and statistical data

Having collected information on the itineraries of the pilgrimage, which appear in the form of chains of places between the point of departure and Sabarimala (Table 3), two methods are available to us for sorting the data. The first consists in positioning the places manually so as to draw the itineraries, but this considerably limits the subsequent possibilities for working on the same type of thematic applications as the database would fail to be georeferenced.

Map code	Village/Town	X	Y
516100	Madurai U.A ,	78,102130000	9,887601000

Table 3 : Coding of localities and geographic coordinates

Chennai U.A
Villupuram
Tiruchirappalli U.A.
Tiruparangundram
Courtlam Slopes
Achankovil
Kulathupuzha
Erumeli South
Nilackal
Pampa
Sabarimala

Table 4 : Succession of places visited by a pilgrim on the way to Sabarimala

The second method links the raw Sabarimala database and the SIFP database following an empirical process of location and identification of the places one-to-one. We allocate to each of them a set of data consisting of a general identification code, a name, as well as the *x* and *y* coordinates, which are indispensable for a precise plotting of the pilgrims in their migratory movement (Table 3). This method makes it possible to draw complex itineraries in a quasi-automated manner (Table 4).

While some of the places collected on paper are at times difficult to situate because of the bad spelling or writing of the surveyors, a still larger number of these places raise problems for a different reason. This is the case of the geographic origin of the Kerala pilgrims who often identify themselves with hamlets belonging to a much larger geographic entity, the *desam*. As the latter are not administrative entities, they are not listed in the SIFP database. In the case of places of passage such as the temples visited (which do not always correspond to administrative units), it was necessary to refer to tourist maps of the states concerned and then return to the original census maps or search the atlases, popular literature or any other source of information to locate these holy places.[26] When a village can not be located, we replace it with the coordinates of the chief town of the taluk or, failing that, with those of the district capital. Once the missing links have been located, we create new points (code, name, *x, y*) so as to complete the database (Table 4).

The logic of the questionnaire would have it that a single journey there and back corresponds to several individuals from the same group of pilgrims. At this stage in the preparation of the final database, we identify the similar routes and then sort the database in such a way that only the outward journeys remain. We can then classify the itineraries according to the number of places cited or the number of stopovers, from the most to the least informed in terms of geographic information, according to a process of triangulation of the table of data. Starting from a sample of 263 Tamil pilgrims and approximately 70 distinct itineraries, we first aggregate the individuals belonging to the same administrative entity for a map of departure representing the geographic distribution of pilgrims in Tamil Nadu (map with a pattern of points) and the number of individuals according to the district of origin. Then, we choose from among all the itineraries those which appear to us to be the most significant in order to best respect the variety of the routes according to the point of departure and the number of stopovers (selection of some dozen itineraries). Let us note that this type of cartography of pilgrimage routes is not statistically significant because of the unevenness of the geographic information (the number of stopovers mentioned in the questionnaires) collected from the pilgrims.

3.1.4 Between Tamil Nadu and Kerala: the pilgrim's routes to Sabarimala

We have chosen to break down the graphic method of plotting the itineraries of the pilgrimage between Tamil Nadu and Kerala into four stages: a table of geographic origins of the pilgrims by district (Table 5); the geographic distribution of the pilgrims in Tamil Nadu

[26] See the maps indicated in the bibliography.

(Figure 15); two conventional forms of graphic representation of the pilgrimage (Figure 16); a map of the pilgrimage routes of Tamils visiting Sabarimala (Figure 17).

District Village/Town*	**Number**	**District Village/Town***	**Number**	**District Village/Town***	**Number**
Ariyalur (0)		*Kanniyakumari (0)*		*Sivaganga (10)*	
Chennai (11)		*Karaikal (1)*		Karaikudi*	9
Chennai*	11	Karaikal*	1	Tiruppattur*	1
Coimbatore (17)		*Karur (18)*		*Thanjavur (0)*	
Coimbatore*	10	Karur*	18	*The Nilgiris (0)*	
Panappatti	1	*Madurai (58)*		*Theni (21)*	
Sivanmalai	1	Kodangipatti	2	Bodhi Hill North	5
Tiruppur*	5	Madurai*	21	Kambam*	5
Cuddalore (33)		Melur*	4	Myaladumparai	8
Alappakkam	1	Peraiyur*	9	Silamalai	1
Avatti	1	Sholavandan	22	Thevaram	1
Cuddalore*	22	*Nagappattinam (3)*		Uttamapalaiyam	1
Keerapalayam	3	Palakurichi	3	*Tiruchirapalli (0)*	
Padirikuppam	5	*Namakkal (2)*		*Tirunelveli (6)*	
Tanur	1	Neikkarapatti	2	Sankarankovil*	6
Dharmapuri (3)		*Perumbaloor (1)*		*Tiruvallar (1)*	
Gobinathampatti	3	Tittagudi	1	Tiruvallur*	1
Dindigul (22)		*Pondicherry (34)*		*Tiruvanamalai (0)*	
Dindigul*	10	Pondicherry*	34	*Toothukudi (1)*	
Kurumbapatti	9	*Pudukkottai (4)*		Sindalakkarai	1
Palani*	3	Arantangi*	1	*Vellore (4)*	
Erode (1)		Kallakurichi	3	Guduivattam*	4
Kondalam	1	Ramanathapuram (0)		*Villupuram (1)*	
Kancheepuram (1)		*Salem (3)*		Nainarpalayam	1
Salur	1	Mahudanchavadi	3	*Virudhunagar (4)*	
Kanniyakumari (0)				Arupukkottai*	2
				Virudhunagar*	2

Table 5 : District-wise geographical origin of Tamil pilgrims

Table 5 constitutes a necessary stage in the mapping of the geographic distribution of the Tamil pilgrims according to the district of origin, but also town and village (see Figure 15). At first sight, one observes the relative concentration of the individuals in the centre Tamil Nadu, with a majority of pilgrims originating from the Madurai region.[27] Although it is true that the pilgrims coming from the districts neighbouring Kerala maintain privileged links

[27] Ayyappa is supposed to have spent time in Madurai, the seat of the Pandyan Kingdom. This would partly explain the traditional attachment of people from the Madurai region to the Sabarimala pilgrimage. "The folk songs concerning his [Ayyappa's] trip to the Pandyan Kingdom describe his journey [from Pandalam to Madurai] through dense forests and mountains" (Vaidyanathan, 1978).

with Sabarimala, this differential is perhaps to be ascribed to the place where the survey was conducted (Erumely), which is located on the Kumily-Kottayam axis and which is of easier access for them. In addition, we could not test the gravitational constraint according to which the number of pilgrims would be inversely proportional to their distance from Sabarimala or from Kerala. There are certainly effects of distance that play on the motivation of the pilgrim movement, but the sample of the population retained for the survey may not representative from a statistical point of view. It can be representative within each linguistic group (150-250 individuals questioned), but the proportions of each in terms of participation or of number should not be confused with the size of the sample and its representativeness.

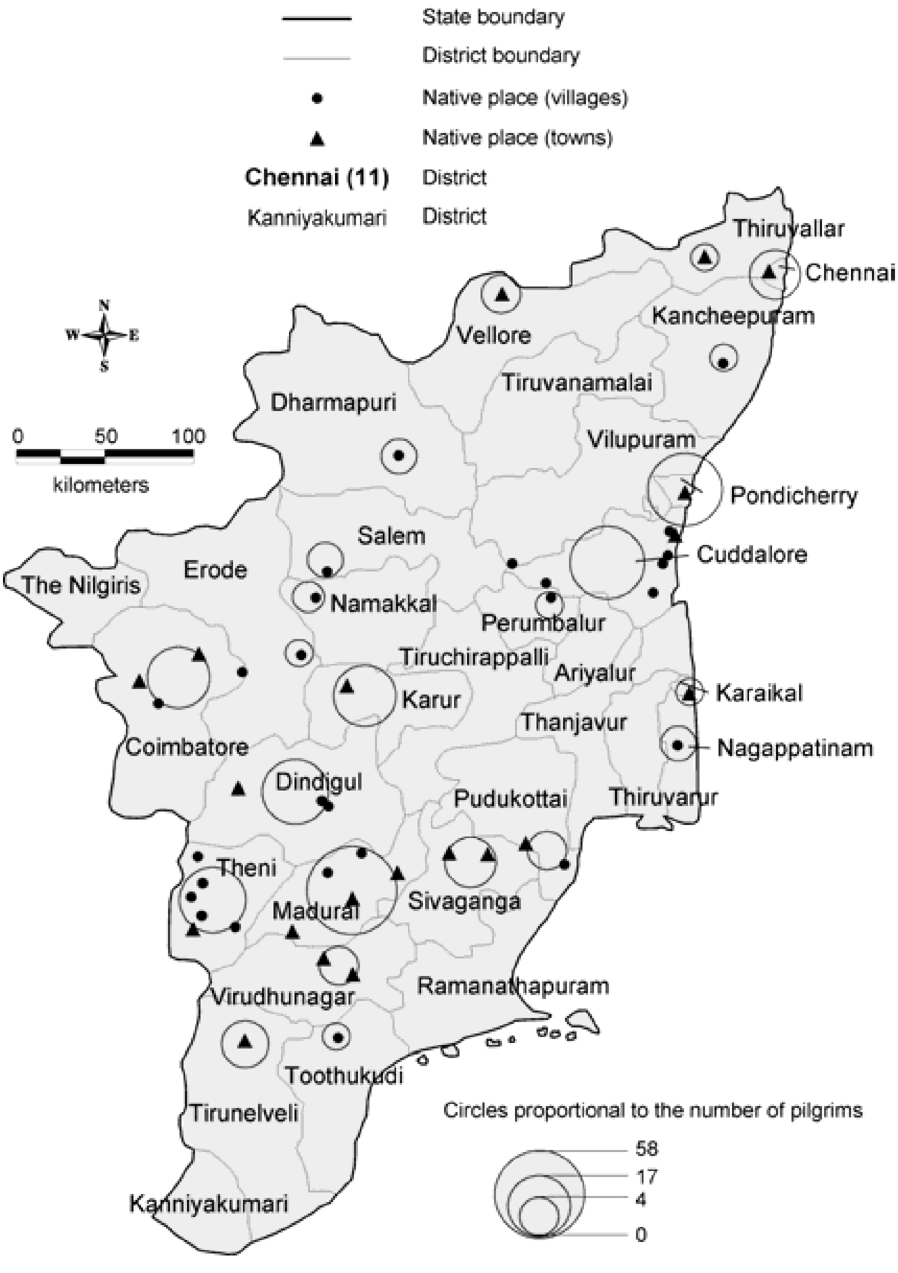

Figure 15 : Geographical origin of Sabarimala pilgrims from Tamil Nadu

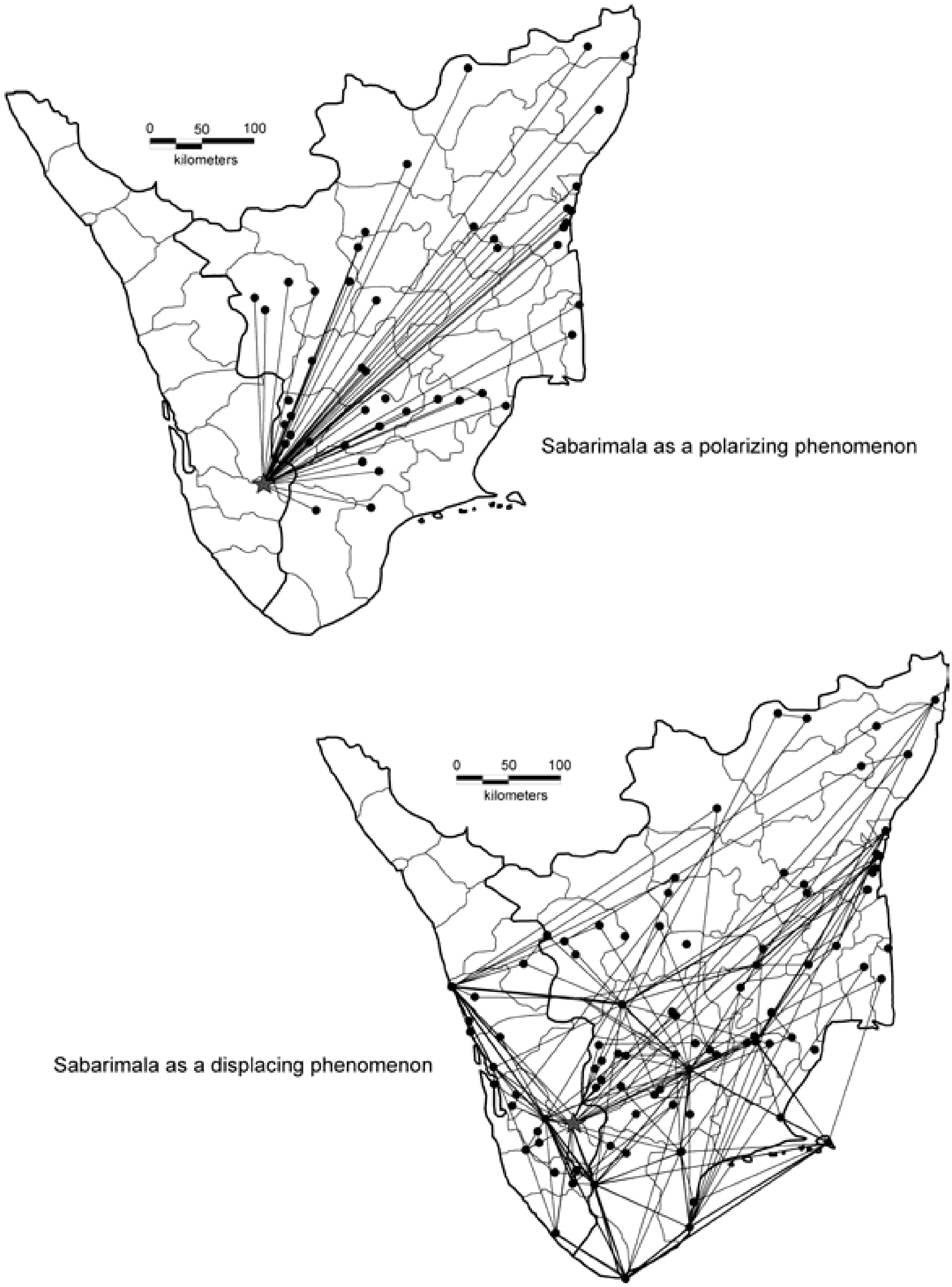

Figure 16 : Two graphical representations of pilgrim flows to Sabarimala

For Figure 16, we have opted for a representation in segments or straight lines between two points so as to visualize, in the first case, the geographic audience of the pilgrimage and, in the second, the diversity and overlapping of the itineraries between Kerala and Tamil Nadu. While the first of the two maps exhibits the polarizing nature of Sabarimala, the second reveals the places frequented by the Tamil pilgrims beyond their borders (crossborder pilgrimage). However, this “aerial” (crow’s flight) representation does not explain the high historical and symbolic charge of the pilgrimage routes in South India. For this reason, we have relied in Figure 17 on the physical networks of communications and transport to draw the pilgrimage itineraries and to elicit meaning from them.

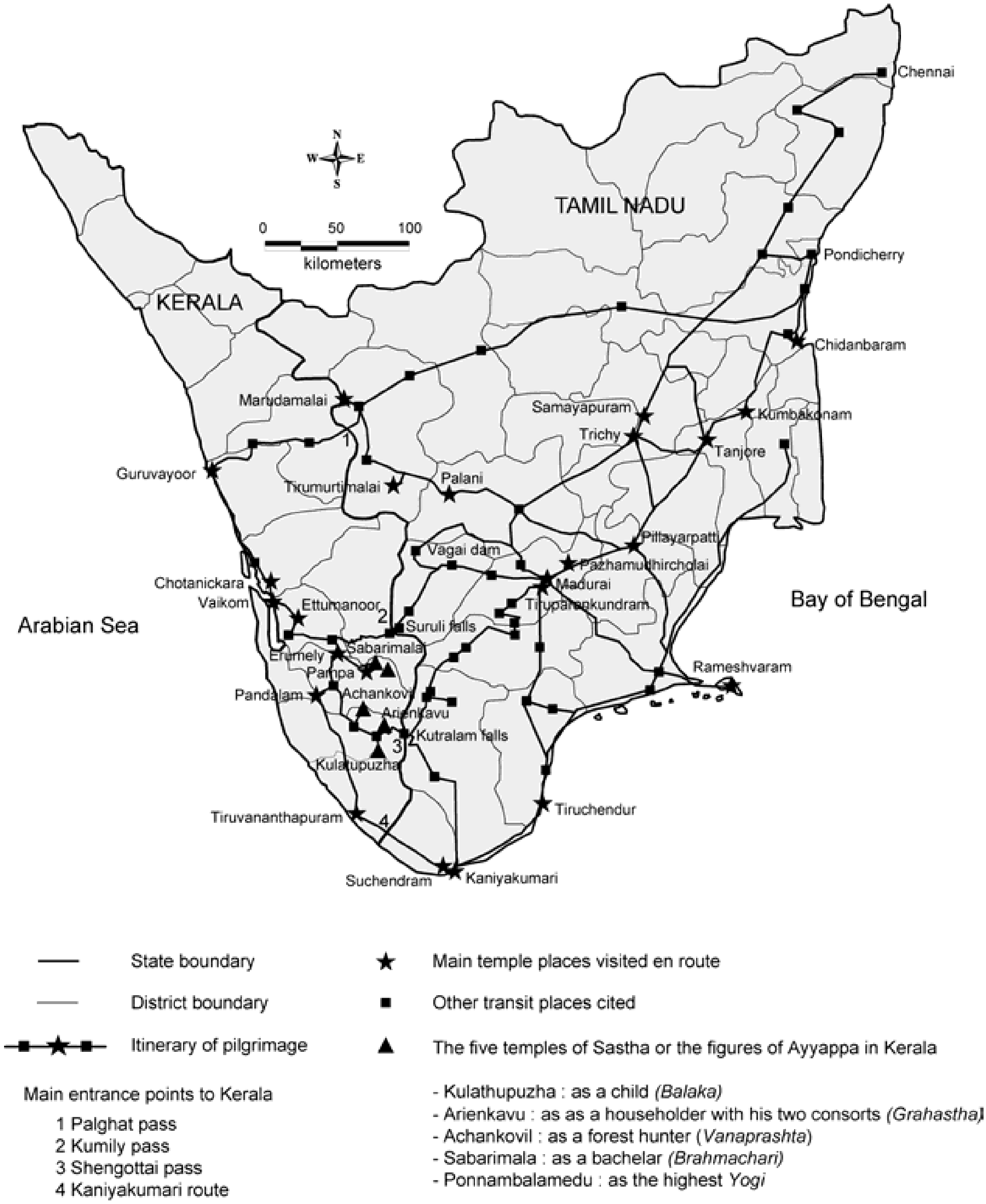

Figure 17 : Main routes leading to Sabarimala

3.1.5 Conclusions and discussion: pilgrimage and circulation in South India

On the basis of this attempt to graphically represent the pilgrimage itineraries between Tamil Nadu and Kerala, we can draw initial conclusions and put forward new working hypotheses to measure the magnitude of the Sabarimala phenomenon in South India.

First of all, it appears that the reticular geographic formation of pilgrimage obeys logics of original mobility beyond the most common logics governing regional migratory exchanges with Kerala.[28] On the other hand, the transport infrastructure plays a crucial role, as is known in the case of the train: "The first method of mass land transportation to be introduced in South Asia began operation in 1853 and quickly affected pilgrims and the temporal and spatial flows of pilgrim traffic" (Kerr, 2001: 326). The increased rapidity of movement, itself linked to the general improvement in the material transport conditions (notably the railways), certainly explains the standardization of the pilgrimage and the opening of Kerala in the contemporary period. It is, on the other hand, only an indirect cause of the renewal of attendance in the pilgrimage today; the grounds of the pilgrim logic are still, in our opinion, to be sought in a complex tangle of reasons and social and religious determinations.

Turning now to the final map of the pilgrimage itineraries (Figure 17), one notes first a historical continuity of certain routes leading to Sabarimala. The inland north-south axis of Tirupati-Tiruvanamalai-Madurai-Rameshwaram is greatly frequented by Tamil pilgrims before ascending to Sabarimala, either by way of Kaniyakumari in the south, or via the Shenkottai Pass to enter Kerala. The inland Tirupati-Rameshwaram axis belongs to an old pilgrimage route, that between Kashi and Rameshwaram, a historical continuity that is reinforced by a dense and solid network of rest-houses for pilgrims in Tamil Nadu (Deloche, 1993: 165). Other transversal axes of circulation, crossing the Western Ghats in the north by way of Palakkad (Madras-Coimbatore-Calicut), in the centre via Kumily (formerly through the forest) and in the south via the Shenkottai and Aramboli Passes, continue to structure the system of pilgrimage routes to Sabarimala.

Moreover, these routes or chains of places are significant from the moment certain of the links define the zones of attraction of the Tamil pilgrim population. These major nodes are for the most part temple towns such as Tiruvannamalai (Siva), Madurai (Meenakshi), Palani (Murugan), Rameshwaram (Siva), or Kaniyakumari (Devi Bhagavathi). On the outward as

[28] For example, the logic of pilgrim mobility does not at all depend on the international emigration for work in the Gulf countries or the flows of tourists to Kerala, and the migratory networks of Tamil workers in Kerala (cf. tea plantations) remain confined to the adjoining districts.

well as the return journey, the preferred pilgrimage itineraries of the Tamil population very often include the segments Madurai-Rameshwaram-Tiruchendur-Kaniyakumari-Suchendram-Kutralam Falls (before entering Kerala), or by way of the north, the Madurai-Palani-Marudamalai axis. In Kerala, the Tamil pilgrims visit almost exclusively the temples of Guruvayoor (Krishna), Chottanickara (Rajarajeshwari), Ettumanoor (Siva), as well as two temples of Sastha-Ayyappa, namely, Kulatupuzha and Arienkavu, in which the deity is represented in the former in his youthful form and in the latter as a householder.

In conclusion, the comparison of a local, regional (popular literature) and “scientific” production of maps on the pilgrimage is relevant in redefining the major axes of religious circulation between Kerala and Tamil Nadu. The analysis of popular maps reveals a clear gap between the representation and the reality of the Sabarimala phenomenon. For example, Figure 13 depicts a space oriented toward Kerala, the centre of which is Sabari Hill, while Figure 16 clearly shows a zone of attraction of the Tamil population that has shifted to the east. Finally, from Figure 17 emerges still more complete information, revealing, on the one hand, the historical axes of circulation (previously identified by Jean Deloche, *ibid*) and, on the other, more original itineraries traversing new places with a recreational role, for example, the Tekkady tourist park and the waterfalls at Suruli not far from Kumily, or again the dam on the Vaigai river near Theni in the district of the same name.

Moreover, a historical perspective shows us the importance of these routes. As was observed in a recent work, “the totality of circulations occurring in a given society and their outcomes could be viewed as defining a ‘circulatory regime’ (…) [which] in its turn tends to shape society” (Markovits *et al.*, 2003: 3). The circulation occasioned by the pilgrimage and its intensification in the contemporary period without question exhibits effects of the uniformization of Hinduism, revising the religious field through social change. Gilles Tarabout has clearly pointed out the importance of these changes by referring to recent modes of mass communication that play the role of diffusion channels of a “general attitude of piety” (*ibid*: 141-144).

Situating in this way the analysis at the intersection of an ethnocentric mapping and a more Cartesian cartography, with its geometric forms and representations of space, our approach is meant to contribute to the discussion on the mutual effects of pilgrim circulation and social change in India, while promoting the production of geographic discourse on South India.

3.2 The geography of irrigation in South India[29]

The SIFP database also provides non-demographic information on village infrastructures and land use. We shall give an initial illustration of their utility by presenting a general cartographic analysis of irrigation in South India. It should be pointed out that the data concerning irrigation are rarely adequate from either a statistical or geographic point of view. In the first place, they are not the object of a systematic collection or publication in India. If they exist at the district level according to statistics by state, they are not at the same time available for all of India. The ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) collects agricultural information district-wise, but does not avail of data for all the states. The CMIE (Centre for Monitoring the Indian Economy) also occasionally publishes irrigation data according to district, but series available are usually incomplete even at the district level.

On a smaller scale, the regional statistics offices often have information for taluks/tahsils or for development blocks (see, for example, Rawal, 2001). But the collection is seldom systematic and it is not possible to compile data for several states. For this reason, the data gathered on the occasion of the census prove to be of great value, for they provide not only exhaustive information, which in itself is very rare, but moreover at a maximum level of disaggregation. The village irrigation data are, in fact, nowhere else collected, and for this reason the map presented in Figure 18 has an entirely original character. We have plotted here the percentage of irrigated lands in the cultivated area of the villages.[30] This analysis rests on the 10-km clusters for South India, using the same procedure as described before: clustering, kriging interpolation, and final contouring.

[29] This section was written by Christophe Z. Guilmoto. For a more systematic treatment, see notably Guilmoto (2002).
[30] Olivia Aubriot, who drew the maps of the modes of irrigation in Tamil Nadu, made in 2000 the first analyses on the basis of the village database.

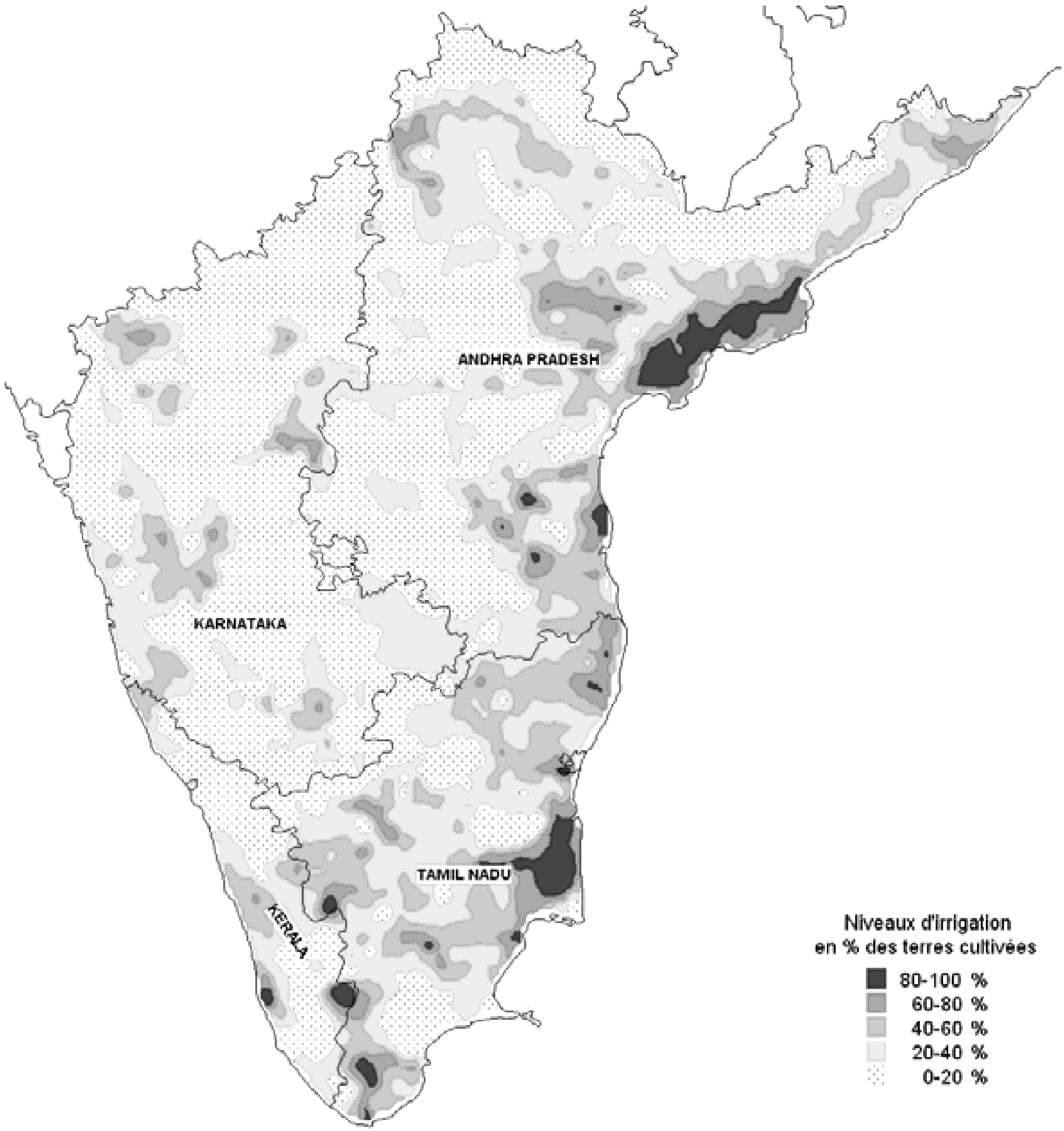

Figure 18 : Irrigated land as percentage of cultivated areas in South India, 1991

We are not going to analyze here the determinants of irrigation in South India. A systematic interpretation would require in particular a detailed comparison with the maps of hydrography, relief and soils, which is beyond the scope of this brief presentation. But the map that is shown here makes it possible to describe the contours of irrigation in South India with an uncommon precision. One recognizes the very high concentration by sub-regions and the geostatistical analysis (see below) shows, furthermore, the strong geographic homogeneity of irrigation over a short distance. The first dimension that shows through is the west-east gradient of irrigation, closely linked to the slope running from the southern Ghats to the coast: irrigation, notably in the large deltas, is oriented toward the eastern littoral. One will also observe, in the more arid regions of the Deccan Plateau (in the central zones of the states of

Karnataka and Andhra Pradesh), the effect of large hydro-agricultural developments that have enabled of the establishment of large irrigated pockets, as for example around the Tungabhadra in central Karnataka. One also finds, in the middle of a plateau characterized by a semi-arid climate and a primarily rain-fed agriculture, small zones where irrigation can involve more than half the lands under cultivation, which represents an extremely high figure.

The highest values of degree of irrigation, at levels close to fully irrigated (more than 80%), are observed mainly in the rice-growing deltas of the Bay of Bengal, that is, at the mouths of the Kaveri, Krishna and Godavari Rivers, the sources of which are in the Ghats. One can also recognize several inland river basins, such as those of the Palar to the west of Chennai, or the mid-valleys of the Vaigai around Madurai in Tamil Nadu, or again, of the Godavari on the border between Andhra Pradesh and Maharashtra, owing to the Nizam Sagar.

This cartographic exercise is, however, also meaningful on a local scale, as for example in a given district: it highlights the fine differences to appear that exist between micro-regions, which are at times extremely pronounced because of physical constraints. The village data are not necessarily of exemplary quality, and this is all the more the case as we only avail here of the extent of irrigated lands, without knowing the real farming intensity enabled by the access to water, that is to say, the number of harvests per year. It is therefore often useful to aggregate the data to obtain a more reliable picture of the differentials between villages or groups of villages. This preliminary work would facilitate a subsequent analysis of irrigation according to each technique employed, for example, distinguishing the recourse to groundwater from that to river water, or showing the singular geography of the system of tanks that are scattered over South India and that are often the first source of irrigation in the driest regions deprived of accessible groundwater tables. Irrigation can also be related either statistically or cartographically to other data, in particular of a socio-economic nature, to study the potential impact of irrigation on the rural world (development of infrastructures, human development, composition of the population, etc.).

There are thus numerous paths to approach at the micro-level a phenomenon that is not known except through local monographic studies or aggregated analyses at the state level or for the country as a whole. Furthermore, one will have observed that the zones of irrigation appearing on the map of South India do not match the administrative boundaries, including those of districts that represent the smallest scale for which these statistics are sometimes published in India. This once again indicates that a spatial analysis of this kind judiciously reveals geographic units, at times sheer watersheds, which the official administrative division has a tendency to gloss over.

3.3 Measuring sexual discrimination in rural South India[31]

We wish to briefly describe how a study devoted to sexual discrimination can rely on a GIS. Discrimination against girls is seen to be more or less pronounced in India according to region or caste and religion, and the geographic dimension of the phenomenon is far from random. This discrimination can be broken up into numerous elements: educational, with clearly lower literacy rates for girls; residential, when forms of reclusion of women are encountered in certain regions of the North; economic or demographic in the case of negligence of girls in comparison to boys as regards allocated resources (health care, food, child development), etc. The aspect with which we are concerned in this study represents two of the extreme components of this discrimination: the selective abortion of female embryos and infanticide of girls. These forms of discrimination are currently expressed in India by the lower number of girls compared to boys (today 927 girls for 1000 boys of less than 7 years), with pronounced variations between regions and social groups.

The study of these forms of discrimination was based in particular on the resources of the SIFP database. In effect, to approach all the aspects of this problematic, the field work[32] was combined with a statistical and cartographic approach, for which work on the spatialized database was seen to be indispensable. From this database, numerous variables were employed, but most particularly sex ratio calculations: the general sex ratio of the population and, above all, the child sex ratio as defined below.

In this section, we shall show how a database derived from the census, having been spatialized in a GIS, makes it possible to analyze the phenomena of discrimination on several levels. We shall first examine the variable employed, the child sex ratio, and its significance in population geography and shall then interpret a number of maps that describe the spatial dimensions of sexual discrimination in South India and Tamil Nadu.

3.3.1 From population geography to child sex ratio

Population geography attempts to provide a spatial view of the facts of population; it is concerned with the spatial distribution of populations and that of their structures, general

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[31] This section, written by Stéphanie Vella, lies in the framework of a doctoral work entitled “Spatialization of sexual discrimination in Tamil Nadu” conducted at Bordeaux University under the supervision of Professor Singaravélou.

[32] This study is based in part on a field work of six months in which surveys were conducted in a rural area in a group of hamlets comprising several castes in the state of Tamil Nadu. The objective of the questionnaires addressed to the villagers was to make a general appraisal of sexual discrimination on a day-to-day basis, from conception to adult age.

characteristics and evolutions. Thus, should one be concerned with the structure of a population according to a strictly demographic criterion, the distribution by sex is most often studied in association with the distribution by age (age pyramids). Although the sex distribution is of interest in itself, it is an aspect that is generally little studied by population geography in comparison to studies devoted to population numbers, fertility, migrations or mortality. Among the data currently employed to quantify sexual discrimination, the sex ratio is a good reflection of the status of the woman in a society. The sex ratio is, in fact, a crucial variable in the determination of a possible inequality between men and women according to the groups considered (population by age, urban, literacy, etc.). An imbalance in this ratio can express recent or past events (war, epidemic, etc.), as we shall see in the case of our study of sexual discrimination. Following normal practice, the sex ratio will be calculated for the Indian data as the number of women for 1000 men, and this choice facilitates the analysis of the deficits of women observed in India. On a smaller spatial scale, the sex ratio of the population can reveal certain socio-spatial practices. Distribution by sex is, moreover, one of the factors that in its turn influences demographic behaviours, for the imbalance of the sexes is nearly always expressed by a lower birth rate.

Composition by sex depends on the sex ratio at birth and on the sex differentials in mortality and migration. The migration factor, above all of an economic character, is responsible for a significant part of the observed variations in the sex ratio: for example, the preponderance of males among migrants to urban areas results n skewed sex ratios being observed in most Indian cities. On the other hand, the main factor used in this presentation, the child sex ratio (CSR),[33] is not susceptible to migratory mechanisms, which are very limited in these age classes, and consequently represent a valuable indicator of the situation of girls. It directly influences the total sex ratio, which has been extensively studied in India because of its imbalances (Visaria, 1999).

In 2001, the total sex ratio in India reached 107 men for 100 women. In most developing countries, one observes a slight numerical dominance of the male sex: the ratio is 109 men for 100 women in Melanesia, 107 in South Asia, 104 in China, 103 in the Middle East and 101 in North Africa and in Central America. But it is less than 100, and thus in favour of women, in South-East Asia and in Central and East Africa. In the developed countries, the women are more numerous. In Europe, the total sex ratio ranges from between 95 and 98 men for 100 women (Noin, 1996).

[33] The CSR is here computed as the number of girls for 1000 boys aged 0-6 years.

3.2.2 Indirect data for a sensitive topic

The SIFP database makes it possible to multiply the points of view for approaching a "sensitive topic" (Lee, 1993) so that the survey work would not be the only support and so as to be able to draw up a spatial model on different scales. These scales correspond to India, its states, South India, but also to districts, taluks and villages. Two types of geographic population targets were therefore utilized, the second being included in the first: the total population of which a census was taken and the sample population in the villages studied. In fact, a difficulty in approaching a sensitive topic, concerning illegal practices such as foeticide or infanticide, is to elaborate methods for assessing the frequency of events that are hidden and go unreported. The official statistics under-estimate or ignore them. The problem is therefore to have an idea of the volume of concealed phenomena. Thus, to come to know even approximate figures pertaining to infanticides and abortions, as well as the utilization of new technologies of reproduction, proves to be nearly impossible in the field. Even the attempt to obtain (government) hospital data poses problems, for these figures are taboo. In addition, the cases of infanticide remain practically unreported by the police because very few complaints are registered; judicial statistics alone are therefore of little help. When the raw figures exist at the civil registration, they are very much lower than in reality.[34] In fact, village nurses can record infanticides as deaths due to "social causes", but their superiors frequently prefer to report them as "natural death". To conclude, let us point out that the number of many abortions, practised in private clinics or by traditional practitioners, is also unknown.

The computation of sex ratios at birth or the antenatal or post-natal mortality figures provide indirect indications as to the intensity of phenomena of discrimination. Similarly, in our case, the child sex ratio will serve as reference to indirectly quantify these two forms of discrimination. The figures from the census are therefore invaluable; they are calculated on the basis of distribution by sex available for all villages (and larger units) since the 1991 census.[35] The SIFP database has the additional advantage of being computerized and spatialized and thus enables a systematic utilization. We can thus search the correlations between the degree of development of the villages and sexual discrimination. Moreover, we can draw maps and establish a model of this spatialization, first statistically and then

[34] The study of the statistics of the civil registration would warrant a separate examination that will not be developed here.
[35] The census figures for 2001 are not yet available for the village level. Other figures exist for districts or taluks since 1871.

cartographically, alternating between a global perspective that brings out the regional contrasts and village variations.

3.3.3 *Variations in the child sex ratio*

The imbalance of the child sex ratio, as well as the mortality sex ratio[36] and the sex ratio at birth, have in fact revealed for numerous years specific discriminatory socio-cultural practices anchored in the context of the Indian patriarchy, namely, the infanticide of girls and the selective abortion of female embryos.[37] The sex ratio of the Indian population has been diminishing with near regularity since 1901, as well as the ratio of the child population, notably in certain regions (the Punjab, Haryana, Rajasthan, and Tamil Nadu). These behaviours were statistically registered, but were difficult to show at the time of the first censuses; the excess in the number of men was often initially explained by the under-registration of women as compared to men. The government and a number of researchers continue to put forward the under-registration of girls at the time of censuses to explain their lower number, but these cases of under-declaration cannot explain the magnitude of such deficits. They can, on the other hand, entail differing results between surveys such as the NFHS and the census (IIPS, 1995; Guillot, 2002).

The child sex ratio has been regularly decreasing for several decades and the provisional results of the last census of 2002 show (Table 6) an almost general decline of ratios in the major states, except in Kerala. The Punjab and Haryana, in the north-west, are the two states having the lowest sex ratios and the most pronounced decline. Concerning this considerable fall in the CSR in 2001, the census office observed for the first time that it could be attributed to the recent use of sex determination tests, infanticide being in fact seldom mentioned by the government.

This research is conducted in South India for various reasons: sex discrimination is there less studied than in the North and the relative homogeneity of the states in the South seems to confirm the traditional North-South dichotomy. However, one can now show that heterogeneities, on smaller scales, exist between the four states and that Tamil Nadu presents specificities as regards sexual discrimination. The objective of this research is to provide

[36] The index is computed as the ratio of female to male mortality. It can be calculated on child mortality (number of deaths of children below one year on the number of births in the same year).
[37] Through the bias of the female child ratio, on the other hand, it is difficult to differentiate between infanticide and sex-selective abortion. One can say that until the years 1975 in the North and 1985 in the South, the child sex ratio did not depend of sex-selective abortion, but after these dates, both have an influence, with selective abortion gradually taking precedence over the infanticide of girls and excess female mortality during childhood.

preliminary elements to explain the mechanisms of sexual discrimination in specific regions of South India.

States	Sex ratio below 7 1991	Sex ratio below 7 2001	Change in %
India	945	927	-1,9
Punjab	875	793	-9,4
Haryana	879	820	-6,7
Rajasthan	916	909	-0,8
Uttar Pradesh	927	916	-1,2
Gujarat	928	878	-5,4
Madhya Pradesh	941	929	-1,3
Maharashtra	946	917	-3,1
Tamil Nadu	948	939	-0,9
Himachal Pradesh	951	897	-5,4
Kerala	958	963	+0,5
Karnataka	960	949	-1,1
Andhra Pradesh	975	964	-1,1

Source: Census of India (1991, 2001)

Table 6 : Sex ratio below 7 in several States, 1991-2001.

To analyze the demographic data, spatial analysis is thus seen to be relevant for presenting the results, making possible both an easy inter-state comparison and a study of variations in the child sex ratio on a more reduced scale within the states. The maps drawn by the Indian government are limited to the district scale,[38] while the GIS of the SIFP allows the very necessary mapping of the data at the village level. The maps thus prepared are on a much more reduced scale and more precise than what a map by district or taluk can offer, which can be verified by comparing a map of taluks (Figure 19) with that of villages (Figure 21).

[38] It should however be noted that the serious worsening of the child sex ratio in 2001 in the Punjab and in Haryana recently led the Census of India to publish separately a very unusual series of maps of the sex ratio: maps of Indian districts, of the taluks in the Punjab, and even a map of villages in the district of Firozpur (maps published in mid-2003).

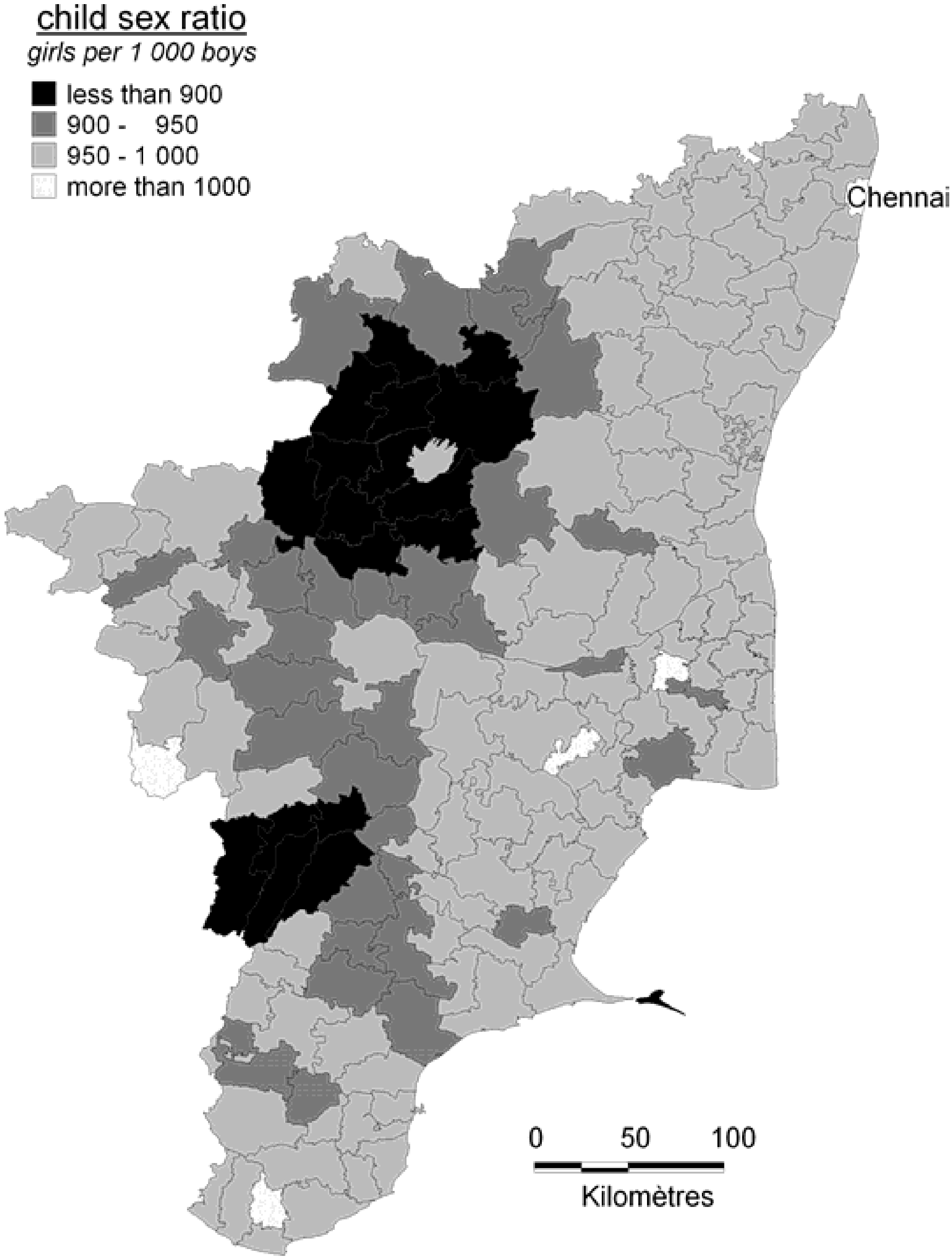

Figure 19 : Child sex ratio (below 7), Tamil Nadu taluks (rural data), 1991

3.3.4 Child sex ratio in South India, 1991

The map in Figure 20 represents the child sex ratio in rural South India, in 1991. Before entering into an interpretation, we will point out that it was prepared according to the method described earlier: the villages are aggregated by clusters of 10 km so as to offer a regular grid with units that are sufficiently populated for a significant calculation of the child sex ratio. A spatial interpolation was done with the CSR data brought together by means of ordinary kriging (Chou, 1997). Then, the contouring of the homogeneous statistical regions was done. The value 900 was retained as threshold of abnormality of the CSR, so as to favour the clarity of the map, whereas some authors place it at 930 or 950 girls for 1000 boys.

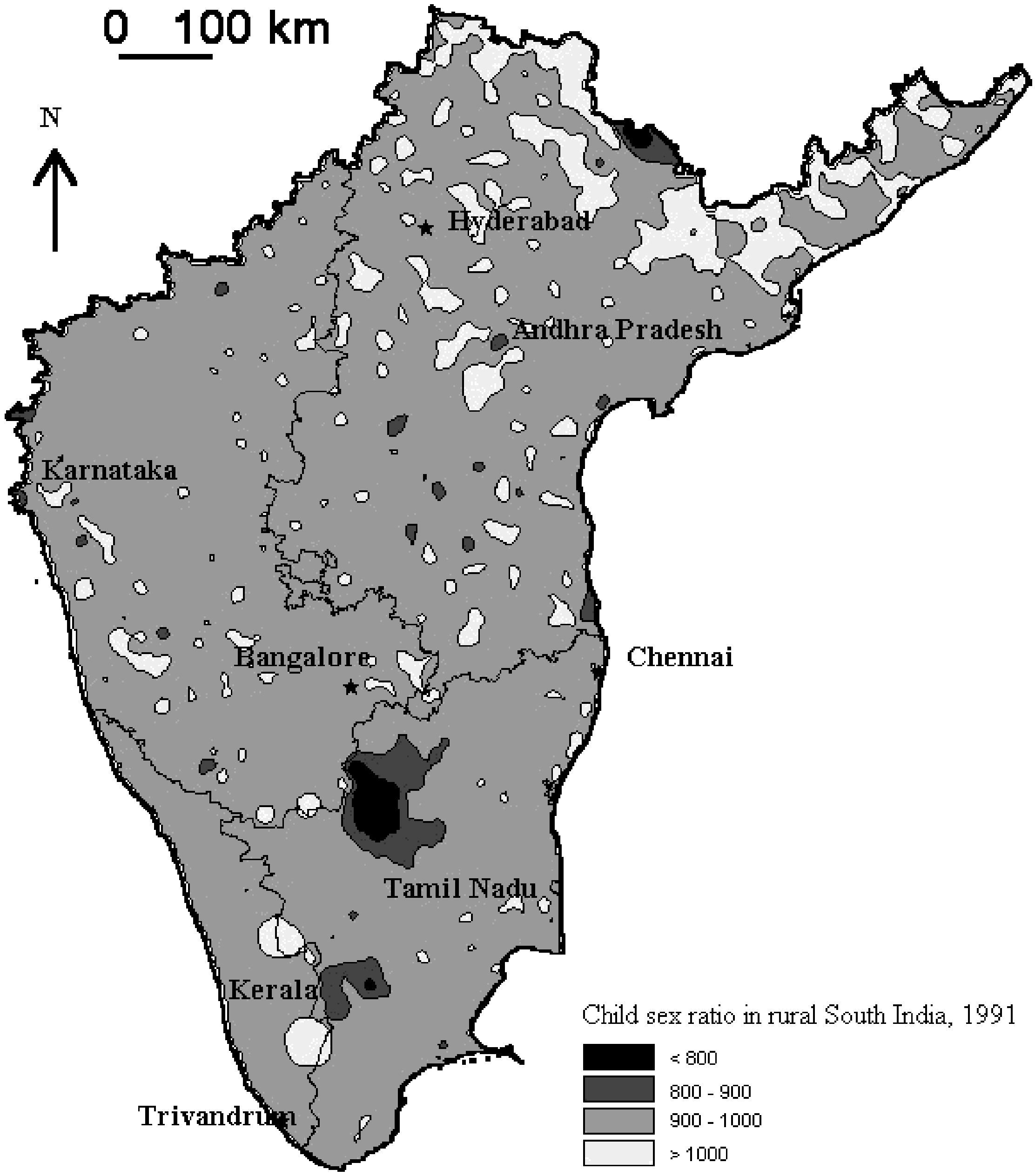

Figure 20 : Child sex ratio (below 7) in rural South India, 1991

The map makes it possible to disaggregate large regional units and to reveal with greater precision the micro-regional contours. Here, it measures the intensity of sexual discrimination in rural South India. Globally, the rural CSR lies between 900 and 1000, but appreciable geographic variations appear upon reading this map. One will note first that few regions have a CSR above 1000. Among these regions, we may identify several tribal tracts bordering northern Andhra Pradesh, but also of isolated pockets along the western and eastern

Ghats. In Andhra Pradesh, a few micro-regions with ratios disadvantageous for girls stand out, one of which is a zone in the north. In Karnataka, apart from the frontier zone adjacent to the region of Salem in Tamil Nadu, the zones with low CSRs are very isolated. In Kerala, it appears that the rural CSR values follow an average level, with two zones very advantageous to girls in two districts along Tamil Nadu.

This cartography brings out above all the particularism of Tamil Nadu, for it is there that two regions of sexual discrimination, of significant size, are identified in the most pronounced manner. Apparently, the gender imbalance is locally significant in Tamil Nadu and follows a precise geographic contour, which we shall now examine in greater detail.

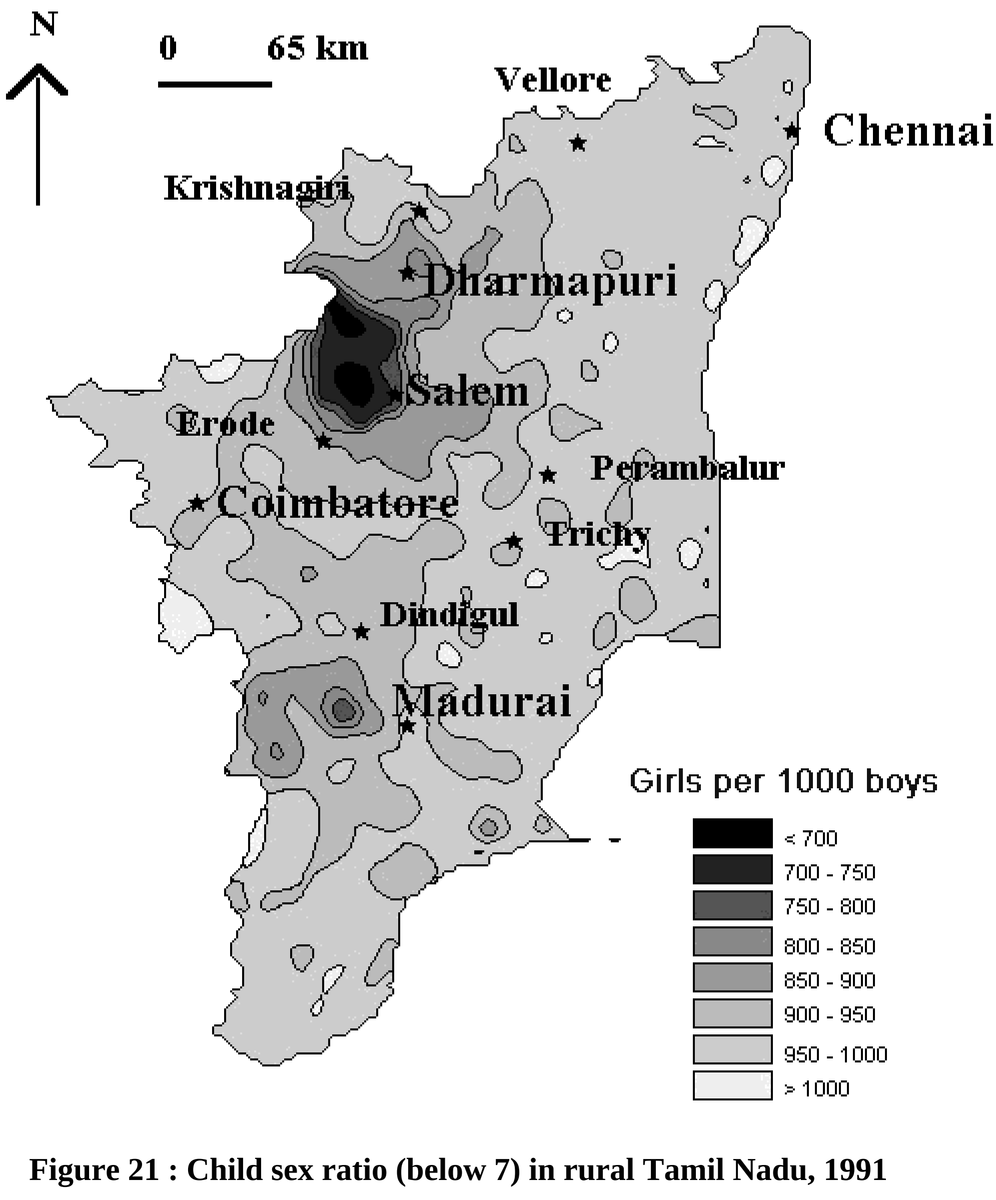

Figure 21 : Child sex ratio (below 7) in rural Tamil Nadu, 1991

The spatial modelling of the child sex ratios at the level of Tamil Nadu in 1991 (Figure 21) reveals the large disparities within the state. In most of the state, the CSR is above

950 and thus corresponds to the normal values of mortality according to sex. But the situation presents itself quite differently in certain seemingly isolated pockets, where the CSR is very much lower than elsewhere. This is the case to the west of Madurai and in the pocket of Salem-Dharmapuri. One again notes the high spatial compactness of the phenomenon, which is not the result of the geostatistical smoothing carried out on the basis of spatial data on a small scale. The proportion of girls is the lowest in the north-west and the highest in the south and north-east of Tamil Nadu. Thus, the thirteen taluks having extremely low CSR values in 1991 belong to the then districts of Salem, Dharmapuri and Madurai.

Finally, one will notice that the magnitude of girl-boy imbalance is in several areas considerable, for values beneath 660 are observed in the Salem area. These are regions where there appears to be a deficit of one girl in three in 1991. At a more local level in this zone, there are numerous villages with more than 2000 inhabitants where the CSR is two boys for one girl. We have here without doubt the absolute peak in India of discrimination against young girls. Furthermore, the block that records the lowest CSR in Tamil Nadu (614) is a rural block in the district of Salem. The as yet incomplete results from 2001 do not contradict our observations, for one observes in the rural parts of the taluk of Omalur (Salem district) a CSR of 549 girls for 1000 boys. Even though very isolated, this value is much lower than those observed in all the tahsils in the Punjab or in Haryana.

The variations are very pronounced in the Kongu Nadu region that encompasses the districts of Coimbatore, Erode and Salem, whereas this area presents a certain economic and cultural homogeneity: agriculture is closely linked to industry and it is a rather prosperous region. The birth rates can be very low there, the town-country links are close in relation to the rest of the state and the intensity of irrigation there is also very high. Thus, following the major Coimbatore-Bangalore road that traverses this zone from south to north, one begins in Coimbatore, a very prosperous region where the CSR is at a normal level (950-1000). The road crosses the plateau of Kongu Nadu and the ratio remains within the average values (900-1000). But before crossing the Kaveri, a sudden change intervenes and the CSR declines strongly, moving from 950 to less than 830. Very quickly the absolute minimum of 614 is reached: in less than 50 km, the CSR has decreased by 50%. After the city of Salem, the CSR increases noticeably to return to 800 in Dharmapuri, then 950 in Krishnagiri more to the north and again attains to median values approaching Karnataka. It is difficult to think that this is actually a homogeneous zone, in particular as regards population, in view of the appearance of extreme variations in behaviour concerning sexual discrimination.

While the Salem zone is the most highly pronounced in terms of the deficit of girls, reinforced by that in Dharmapuri, this deficit appears to be much less extensive and of much lower intensity in the more southern region centred on Usilampatti (Madurai district). It seems to be connected to the preceding by zones in which the CSR lies between 900 and 950. Since the 1991 census, the phenomenon has progressed, an expansion to additional taluks has taken place and some authors spoke, in 1996, of a "belt" to spatialize the discrimination of girls (Athreya and Chunkath, 1998).

Thus the zoning of infanticide[39] begins in the western half of the district of Madurai and extends across the districts of Dindigul, Karur, Salem and Dharmapuri to the west of Vellore district. Salem and Usilampatti seem to function as secondary independent loci, after Madurai. In fact, even though Salem, Dharmapuri and Madurai are always cited as regards infanticide, on a smaller scale, the geographic distribution becomes thinner; one observes that at least twice as many of the districts are implicated in infanticides. On the other hand, the districts in the south, east and in the Kaveri delta seem to be spared from this phenomenon and no anomaly was discerned in these zones, if not, in 1999, in such districts as Perambalur and Tiruchirappalli that are somewhat peripheral to the Madurai-Salem axis. Another major exception concerns Coimbatore district; although it is in the west on the edge of the Usilampatti-Salem corridor, it is not at all affected by infanticide, according to the presently available data.

These maps therefore make it possible to bring to light very precise zones of sexual discrimination. We have presented only the maps of 1991, but the exploitation of the aggregated results from 2001 will enable us to conduct a more diachronic analysis and to study the spatial progression of child sex ratios from 1991 to 2001. These maps on the scale of South India and Tamil Nadu should confirm the socio-spatial diffusion of sexual discrimination. A parallel analysis is also being done on the scale of the whole of India, where the propagation of techniques for the detection of the sex of the foetus has caused an increase in sex-selective abortions.

[39] We speak of infanticide because the practice is old and goes back some fifty years in Tamil Nadu. In 1991, selective abortion was still infrequent in this state.

3.4 Spatial distribution of medical infrastructure in Andhra Pradesh[40]

Devoted to maternal care in rural India, this research work began with the analysis of health care structures in the region of Rayalaseema, the southern part of Andhra Pradesh, through the information contained in the SIFP database and preceded an intensive survey in a specific subregion along the limits between Andhra Pradesh and Karnataka (Chasles 2001). The intended objective of this section is however more global: we will try to give here a regional representation of rural health facilities in Andhra Pradesh. To this purpose, cartography and geomatics (geographic information system) as well as statistics (principal component analysis, PCA) were called upon. As we shall see, the complementarity of these methods will allow us to shed light upon a health care gradient within the state, in addition to, and this is certainly the most important, providing elements for an understanding of the spatial logic of the distribution of health services.

3.4.1 Data and scale of analysis

The processing of data was carried out on the scale of the *mandal*. This administrative unit corresponds by and large to that of the *taluks* or *tahsils* of the other states, even though, as has been previously observed, the mandals are comparatively of a much smaller size. The 1099 mandals encompass the 26,686 villages of Andhra Pradesh and offer the advantage of being of relatively homogeneous size, in distinction to villages, whose population may vary in a ratio from 1 to 100. The use of clusters is thus not indispensable here.

By means of a principal component analysis, we have examined the near-totality of variables relating to the available medical infrastructures in the census of 1991. We examine here the proportion of villages in each mandal possessing the following health facilities: hospital, maternal and child welfare centre, maternity home, child welfare centre, primary health centre, health centre, primary health sub-centre, dispensary, family planning centre, nursing home, community health workers, registered private practitioner and other medical practitioner. Should no infrastructure be present, the distance to the closest infrastructure has been included. Only two variables (other medical centres, tuberculosis clinic) had to be removed because of their rather dubious quality.

Principal component analysis is a mathematical procedure that transforms a number of correlated variables into a smaller number of uncorrelated variables (called principal

[40] This section was written by Virginie Chasles in the framework of a doctoral research under the supervision of Alain Vaguet of the University of Rouen. See also Chasles (2002).

components). This technique “allows [one] to extract from a dataset the largest amount of information in a simple and coherent format and helps to identify the interrelationships between variables and the gaps between geographical units under study” (Sanders, 1990: 17). In our analysis, the objective is to reduce the number of variables related to medical infrastructure that are found in the SIFP dataset. The first principal component accounts for as much of the variability in the data as possible: it serves therefore as a global indicator of the quality (quantity and diversity) of medical facilities found in villages of each taluk.[41] Hence, it is positively correlated with all variables listed above. This indicator mainly concerns the structures relating to the public sector. Different levels of the health hierarchy are here coincident, for one finds both centres having a range of relatively wide and elaborate services and, conversely, local centres delivering more preventive than curative care. From this plurality of listed centres there obviously result zones with diverse services, each of which is globally proportional to its “technical plateau”. Thus, by way of example, a community health centre (CHC) corresponds theoretically to a population of one lakh, while the coverage for a sub-centre (which depends on a primary health centre) involves no more than 5000 persons (and less in tribal zones).

3.4.2 Medical infrastructure in Andhra Pradesh

The principal component analysis (PCA) makes it possible to measure the medical service on the mandal level and to show certain characteristics of the location of medical structures. The variables have not been retained in a random manner, but because of their correlation to the first principal component. The result, and notably the first factor resulting of the PCA, is assessed by its eigenvalue that measures the quality of this factorization. In our analysis, the first factor that accounts for the quality of the medical infrastructure is endowed with a quite high eigenvalue as it amounts to 3.3 (the value of other eigenvalues is less than 1.4).

This result was then compared with the average population of the villages. One observed a strong relation between the population size of the villages and the distribution of the health care infrastructures. This result is expressed by the scatter of points represented in Figure 22. The presence of the provision of health care facilities tends to slowly increase when the villages have less than 1000 inhabitants, to then rapidly increase and reach a new plateau near 10,000 inhabitants. It can be said generally that the number of health care centres

[41] Sébastien Oliveau uses a similar procedure to compute a “modernization index ” for Tamil villages (see below).

is proportional to the average size of the population of the villages. In greater detail, one recognizes a log-linear curve that moves between the minimum level (no infrastructure) and the maximum level (all infrastructures), characteristic of mechanisms of diffusion.

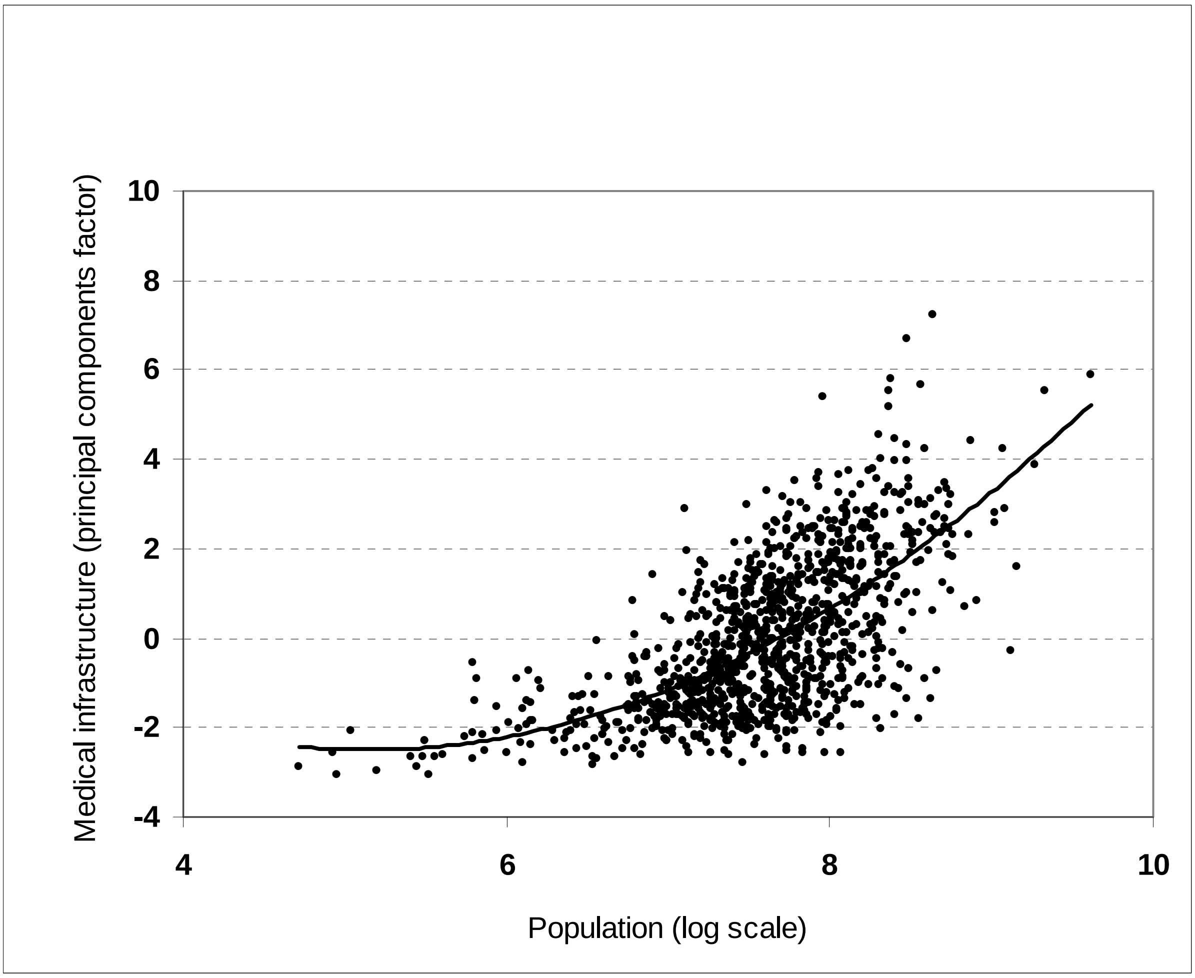

Figure 22 : Medical infrastructure and population size in Andhra Pradesh, 1991

Mapping the first factor resulting of this PCA, one obtains in Figure 23 the map of the mandals classified according to the quality of their health infrastructure. This correlation sheds light on the different entities that make up Andhra Pradesh. More precisely, it can be noted that the health framework follows quite exactly the economic landscape of this state. In other words, the provision of health care is distributed according to a gradient proportional to the level of development and, in this case, to the population densities.

The most populated state in South India, Andhra Pradesh is characterized by real regional contrasts. Broadly speaking, the state includes two semi-arid climatic entities and a coastal area. Telengana extends to the north-east, while Rayalaseema includes the four districts in the south of this region. Finally, coastal Andhra corresponds to the deltaic region composed in particular of the Krishna and Godavari Rivers. On this map, two regions acquire distinctly individual characteristics through a high density of infrastructures compared to the rest of the state. The first region concerned is organized along the seafront and is characterized mainly by an exacerbated polarity around the main rivers mentioned above and corresponds overall to coastal Andhra and to the richest deltas of Andhra Pradesh, such as that of the Godavari. This sub-region took advantage of its geographic location through an optimal utilization of its territory. In particular, due to the efforts made to extend the percentage of irrigated lands, this region has ensured itself a relatively prosperous development in both the agricultural and industrial sectors. This has naturally entailed higher population densities than elsewhere and a real demand for medical care facilities. We are not examining whether these needs are completely met, but it appears that in this region the health care provision is the densest and probably the best.

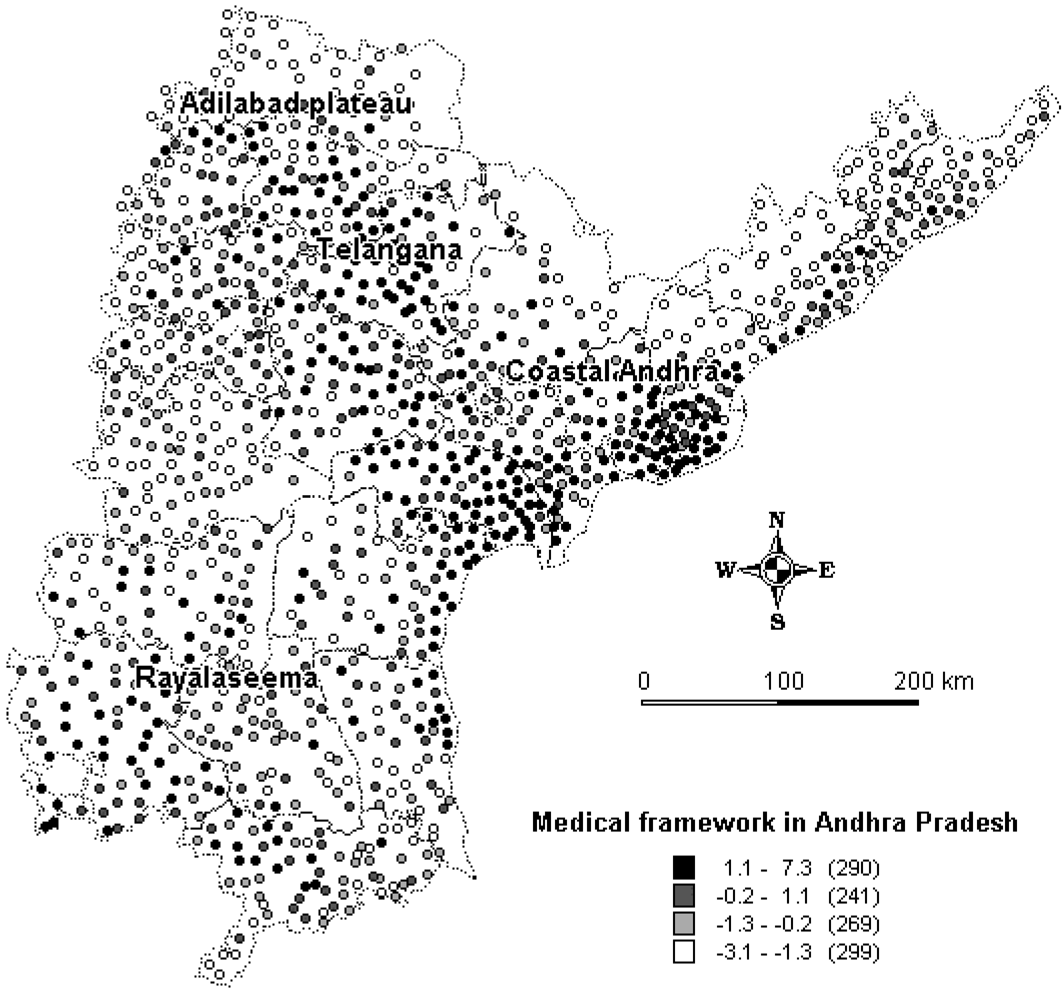

Figure 23 : Medical infrastructure in Andhra Pradesh mandals, 1991

To this first sub-set can be compared the region of Telengana, in which the state capital, Hyderabad, is located. In spite of a health system that seems less dense, the region is also looked on as being fortunate and distinguishes itself in this state. It behaves somewhat as a coastal extension, and this is above all attributable to the underlying dynamics of the two rivers flowing through it. Located on the Deccan Plateau, Telengana has an old urban and economic tradition. This explains why it is characterized by a relatively large provision of health facilities in comparison to the neighbouring regions. However, there are marked contrasts within Telengana itself. Thus, two somewhat marginalized zones are demarcated by their lack of infrastructures: the Adilabad Plateau in the north-west that is characterized by a severe economic backwardness, and south-west Telengana that suffers for its part from the aridity of its physical environment.

Rayalaseema is in a position that could be qualified as residual or even as intermediary. It should be said that it is characterized by the conjunction of several major handicaps: marked above all by a rainfall deficit, with an annual average of 691 mm, as opposed to 929 in Telengana and 1024 in coastal Andhra, this region is also characterized by very limited natural resources and a slow economic development. Hence, the weakness of its infrastructures, notably in the domain of health, would appear to be inevitable. But the regions that appear on this map as being the most underprivileged in Andhra Pradesh coincide with several mountainous and forest tribal zones in the north and centre of the country, where the population densities are very low and which avail of only minimal infrastructures.

3.4.3 Conclusion

The results obtained here unquestionably conform to the numerous theories pertaining to the location of services, in particular to those concerning local services, to which belong health care centres. Globally¸ since the 1960s (Merenne-Schoumaker, 1996: 39), a general dependence between the number and the nature of services and the size of the population has been shown. However, as regards this assertion, it has been pointed out that this relation is, more precisely, not continuous and that it thereby underscores the population thresholds: above, the infrastructure exists, below, it is absent. The infrastructures are organized along hierarchical lines, according to the size of the population necessary for their existence, and hence are established, in theory, according to the correspondence supply/demand, or supply/need. Let us also add that their distribution is also influenced by the socio-economic characteristics of the prospective users, in other words, by their solvency, which for us lies within the wider question of the economic dynamics of the regions studied. It must be observed that the health care framework in Andhra Pradesh is in line with these models, for, as we have been able to see, it is organized according to the size of the population that is itself, generally speaking, dependent on the level of economic development of the different spatial units studied. To conclude, let us note that one should not misunderstand the results presented here. They have revealed the main factors accounting for the distribution of health care facilities. They do not signify that the health care needs of the populations are really satisfied.

3.5 Urban spread and rural continuity. A quantitative approach[42]

The problem of modernization in a country like India constitutes a preferred domain of research in the social sciences. Our section intends to view modernization in its geographic dimension in order to go beyond the approach that consists in viewing development in distinct manners for town and country, and to establish a continuous framework of the space of development. We take here the example of Tamil Nadu.

3.5.1 A new approach to rural-urban linkages

The study of town-country relations is an old one in geography and represents a frequently used entry for the study of a region. This dual approach is characteristic of geography, and while it is found in other disciplines (in particular demography and economy), it is not utilized in such a systematic manner.

This approach has evolved and the simplistic dichotomy that it suggests has been emphatically called into question. Supplanting studies that would oppose towns to the surrounding countryside are studies that take the different rural spaces into account in a more precise manner. More than the milieu (rural or urban), it is now the space that is here considered in a more global dimension. The evolution of the vocabulary describing the different types of space according to their more or less urban or rural characteristics and their position in relation to the urban centre clearly reflects the general change of geographic approach. One now systematically distinguishes the town, its suburb and its peri-urban fringe from rural spaces. Countries such as France have refined the description of rural space by distinguishing different categories of spaces within the countryside: rural under weak urban influence, rural poles, periphery of the rural poles and finally the isolated rurality (Hilal and Schmitt, 1997). One can see in this evolution the necessity of adapting analysis to a space that has become more complex. Thus, the proportion of farmers, a traditional characteristic in the definition of rural space,[43] has regressed to such an extent in Western societies that it no longer allows the distinction between town and country.

This increasingly precise division reminds us of an essential element in the study of the relations between town and country: the dichotomy is artificial, the demarcation is never

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[42] This section was written by Sébastien Oliveau. This work is part of a doctoral research under the supervision of Prof. D. Pumain: “Village modernisation and distance to town in South India”.

[43] This is still the case in India, as the census employs three characteristics to divide administrative units: the population, the density and the proportion of working males employed in agriculture.

clear, and there exists a continuum from the rural to the urban. For this reason, some have decided to abandon this classification for a continuum analysis of rural space according to urban impact. Thus Kundu *et al*. (2002) have published a study showing the role played by the distance to town on different socio-economic variables. Their analysis, based on the statistics of a survey undertaken by the NCAER (National Council for Applied Economic Research), demonstrates quite clearly the interest of such an approach.

The authors show there how different economic (such as the per capita income or the size of landholding) and social (morbidity, literacy) variables decrease as they become more distant from urban centres. The method used consists in ordering the villages according to their distance from town, on the basis of the data provided by the census, then in examining how the value of the variables considered evolves.

The method is interesting, but the data employed bear a strong bias. The database of the NCAER is of good quality on the aggregated level of India, but using this base of 33,230 households spread over 1765 villages poses a considerable geographic problem: how to include in the same analysis Tamil villages, which are less than 30 km away from the closest town and which are well served by transport and communication, with villages in Rajasthan, which may be sometimes lost in the midst of the desert? The complete disregard of the regional dimension in this type of study is disturbing and creates a very significant bias. Thus, villages that are more than 30 km from a town will be less developed than the others, not because they are isolated, but because they belong to a less developed state. It should also be noted that the quality of the census concerning the distance to town, as we shall see, varies greatly.

To mitigate the limitations of this approach by sampling, the simplest method is the use of an exhaustive database and the systematic study of the different urban centres. This is what we have done by relying on the SIFP database, as presented in the first section of this paper.[44]

We thus wanted to study the urban influence on the countryside in Tamil Nadu, using the entire rural database for the state. To this purpose, a series of calculations was made using a GIS software in order to obtain the distance as the crow flies of each village from the nearest town. This enabled us to calculate the coefficients of correlation between the distance to the town and different variables, as Kundu *et al*. have done. The major results of these

[44] The database for Tamil Nadu is available in the form of a CD-ROM, see Guilmoto *et al*. (2000).

correlations are presented in Table 7. The role of the distance to town on the level is seen. Our findings broadly confirm the results of Kundu *et al*.

Density	Household size	Literacy	Workers in the agricultural sector	Workers in the service sector	Workers in household industry	Workers in non-household industry
0.4616	0.164	0.2805	-0.4486	0.4391	-0.1806	0.1327

Sources: S.Oliveau, based on SIFP database

Table 7 : Correlation between city size (logarithm) and various sociodemographic indicators

Nevertheless, a comparison of the correlations between the distance to town and one of the variables common to our work shows slightly different results (see Table 8). The relation between literacy and distance is negative in all cases: the villages closest to towns have average levels of education that are considerably higher than the other villages.

	Census estimate	Census estimate	GIS-computed
Correlation between literacy size and distance to he nearest town.	-0,1789	-0,1545	-0,2883
Correlation between household size and distance to the nearest town.	-0,1141	Not significant	0,0762
Sources	*Kundu et al. (2002)*	*Oliveau*	

Table 8 : Coefficients of correlation between distance to town and literacy and household size. Comparison of different findings

The differences in the two series of results are no doubt connected, on the one hand, with the differences between the sources and the regions concerned, but also with the use of the distance calculated with our GIS. One will also note that our results for Tamil Nadu appear clearly more significant when the distance geometrically computed by the software is used,[45] rather than the information from the census. This suggests that the census figures could be of rather poor quality.

3.5.2 Large-scale analysis

The following procedure, which consists in studying separately the effect of the distance to town on different indices, had, however, a detrimental effect: the synthesizing

[45] It is generally assumed that the distance as the crow flies usually provides a good approximation of the real distance on the scale of our study (see Berroir, 1998).

view provided by the study of distance is dissipated in the study of multiple indices. It is therefore preferable to construct a global index collecting the census data, and we have taken recourse to a factor analysis (principal component analysis) to construct an index of modernization, as Virginie Chasles has done regarding the medical infrastructure in Andhra Pradesh. The calculations carried out (not reproduced here) show that one obtains a composite index that is correlated to very numerous socio-economic characteristics. This modernization index corresponds to villages in which literacy is good and fertility is low. It is also correlated with a pronounced presence of industrial activities, but still more with tertiary activities, at the expense of the primary sector. In addition, the proportion of working population, characteristic of an agricultural setting, is low. The agricultural sector is there characterized by a weak presence of cultivators, which is connected with a more intensive irrigated agriculture and with a high demand for labourers.[46] These villages are rather well provided with educational, medical and transport infrastructures.

We then carried out a regression of our index according to the distance to town. The results are, as one can expect, significant, for more than 11% of the variance is thereby explained. The connection is highly negative between the level of modernization of the village and the distance to the nearest town. This underscores the pertinence of the distinction between different rural sub-spaces according to their distance to town.

To complete this result, we calculated the value of our index for each distance (measured here in kilometres) and these values are plotted on Figure 24. They show a decrease in the level of modernization of the villages according to their distance from towns. The first conclusion is that already proffered by Kundu *et al*: “the spatial distribution of the indicators […] does not decline smoothly, as we move from the city/town periphery to distant areas”. Thus, the decline of the index is first rapid, following an exponential curve, before stabilizing, following a more linear decline.

One can also measure the spatial impact of towns. For this, the point where the curve breaks off is considered as marking the end of the direct urban influence. According to our graph, it is situated at around 4 to 5 km (Figure 24). Another model consists in defining the limits of urban influence at the point where the average value of the index goes below the mean of the index for the entire set of villages (which is 0.014). The urban impact is thus of the order of 9 km. But the absence of a plateau at the end of the curve or of an upward turn of

[46] In Tamil Nadu, intensive crops such as rice require a large labour force and are generally characterized by a high rate of agricultural labourers in comparison to that of cultivators. Conversely, the strong presence of cultivators is usually a sign of less intensive and thus generally poorer agriculture.

the latter leads us to consider that the urban influence, although diminishing with distance, has an impact on all villages, even the most distant.

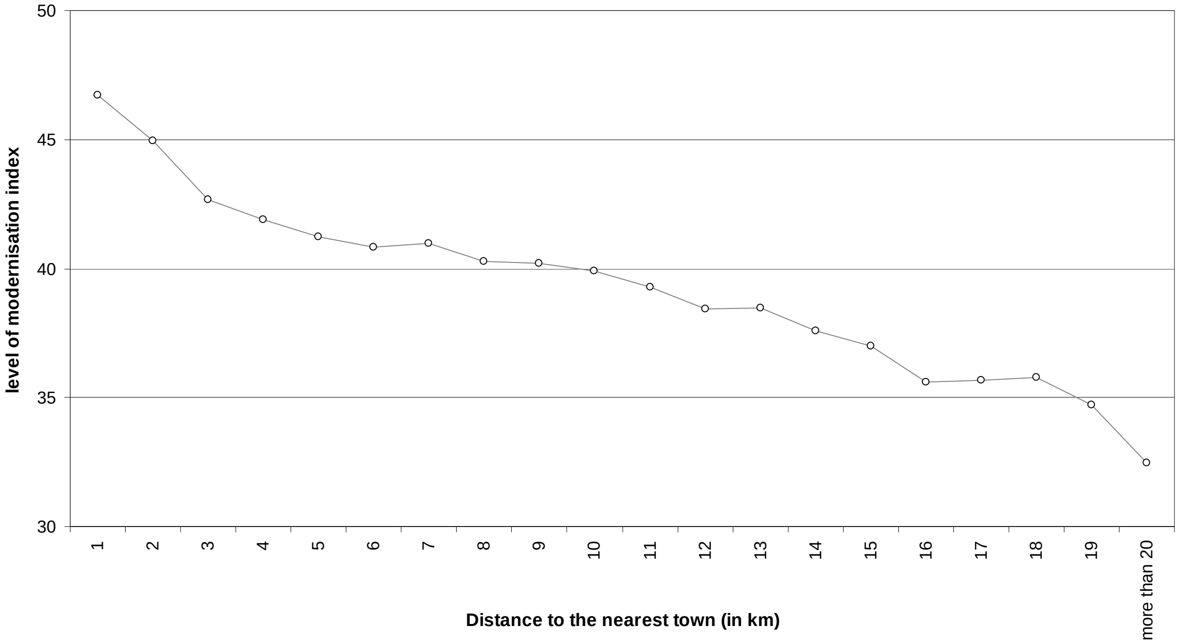

Figure 24 : Modernisation index and distance to the nearest town

This global approach can then be completed by global analyses that distinguish the towns among themselves. The first general criterion retained to classify the towns among themselves is their demographic weight. In fact, the size of the population of a town generally summarizes very well its socio-economic characteristics (Moriconi-Ebrard, 1994). The calculation of the correlation between certain indicators and the logarithms of the population of towns in Tamil Nadu confirms this (see Table 7). We therefore decided to separate the towns according to their size by following the usual Indian classification (see Ramachandran, 1989). One will distinguish here towns of class I (more than 100,000 inhabitants), class II (50,000 to 100,000 inhabitants), class III (20,000 to 50,000 inhabitants) and the set of classes IV, V and VI (less than 20,000 inhabitants). For each class of town (see their characteristics on table 9), we have recomputed the effect of the distance on the degree of modernization of the villages. Different curves are obtained, each corresponding to the effect of the towns classified according to their population; the results are shown in Figure 25.

	Class 1	Class 2	Class 3	Class 4-6
Number of towns in this class	31	39	64	91
Average number of inhabitants	441 800	70 000	31 100	12 400
Number of villages, by size class of their nearest town	2839	3413	4910	4660
Average level of modernization of villages, by size class of their nearest town	0.52	-0.18	-0.22	0

Sources: S. Oliveau, based on SIFP database

Table 9 : Characteristics of towns and their hinterland according to their size class

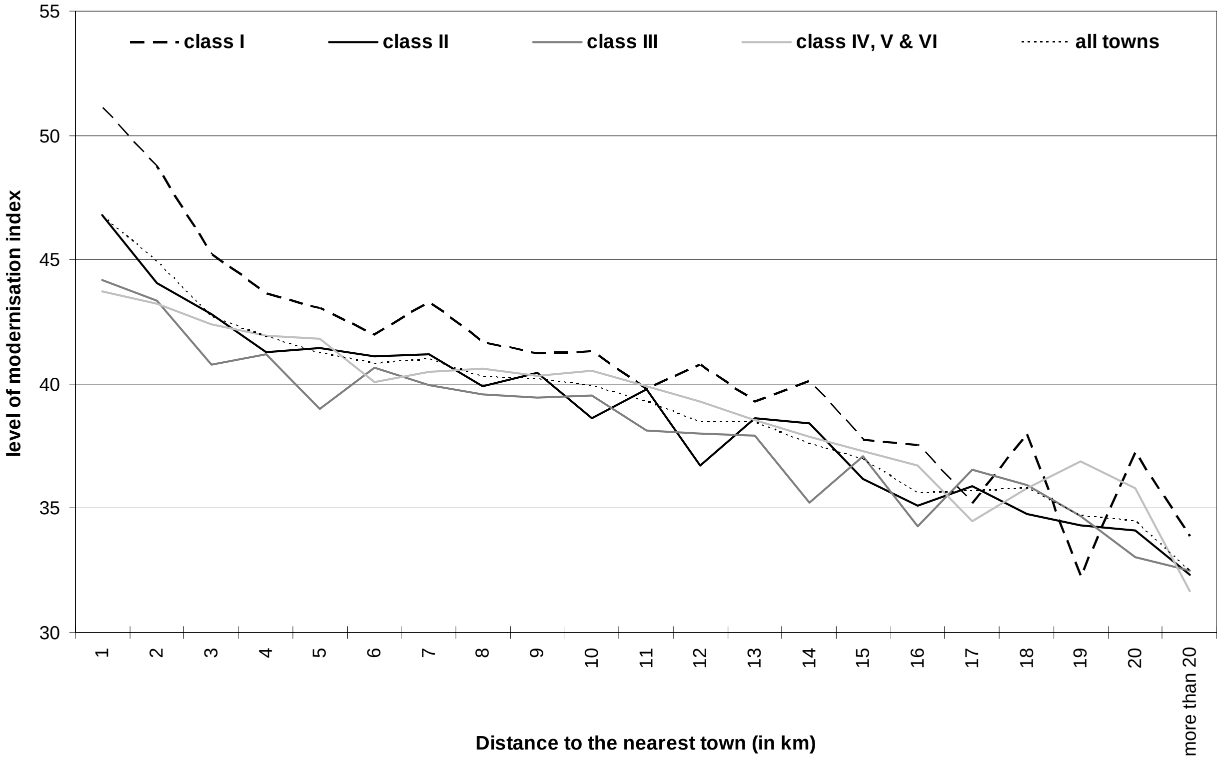

Figure 25 : Modernisation index and distance to the nearest town classified by town class

The results are particularly clear as concerns villages near towns of class I: the effect of urban proximity is much greater than for the other towns and this is perceptible up to approximately a distance of 15 km. This means that the impact of the largest towns goes far beyond that of smaller towns. The interpretation of the curve relating to villages close to towns of classes II, III and above all IV, V and VI is more ambiguous. The effect of urban hierarchy is, in fact, hardly discernable among these classes, the respective curves of which distinguish themselves but little. In our hypothesis, the town would have an influence proportional to its size on the level of modernization of the villages. It appears that the smallest towns actually have as much influence as the medium-sized towns. This can result from our mode of calculation that takes into account the nearest town, even if a (larger) town is also close. It is also possible that the differential effect of the size of the towns is only perceptible as of a certain demographic threshold, which in our case study on Tamil Nadu would be around 100,000 inhabitants, confirming what Kundu observed in the 1980s (Kundu, 1992).

We shall now test the effect of the administrative status of these towns in order to see if the same differences are found. Three large categories of towns are distinguished in India: urban agglomerations, municipalities and town panchayats. This classification is interesting in that it takes into account the size of the towns, but also their local importance. Urban agglomerations (UA) are defined by the census as a continuum of several towns or a town of class I and its, or their, outgrowths. Municipalities are urban spaces having their own management system, whereas town panchayats (TP) are urban units which, according to the census, are without municipal status. There is quite logically a gradation of size from the UA (which may include municipalities and TPs) to the TP. Thus, in Tamil Nadu, the UAs have on the average 387,000 inhabitants, as opposed to 64,000 inhabitants for municipalities and 17,000 for town panchayats.

The influence of towns on villages according to their status is much clearer (Figure 26). The UAs have a greater and more extensive influence and are in this respect very comparable to towns with more than one lakh examined previously. The municipalities function as do the medium-sized towns. As for town panchayats, their impact is much less strong and much less extensive. If one takes into consideration the wide-spread idea according to which the administrative status would be arbitrary, this result can be surprising. But if, on the contrary, one considers that the arbitrariness of these divisions hinges in fact on a less mechanical evaluation in which the human assessments of the role of each town serve to relativize the socio-demographic statistics, one then sees that this division corresponds better to reality.

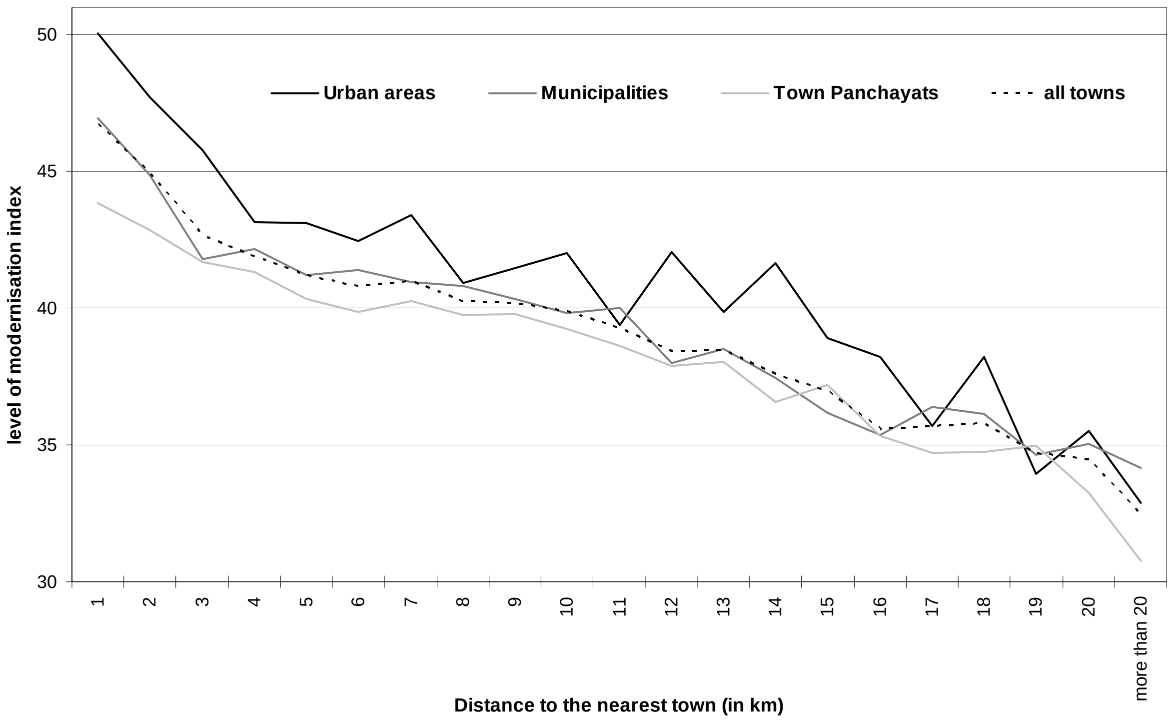

Figure 26 : Modernisation index and distance to the nearest town classified by town status

In conclusion, we will call to mind that the use of Euclidean distance does not fail to raise problems, already profusely observed in geographic literature, as this measurement is but an approximation of the actual distance between localities. Thus, an approach based on the distance by road, as Sharma observes (1980: 226), would certainly be very enriching for the analysis. Better still, to view the time involved in going from one place to another, rather than the distance, would without doubt be a great step forward. Unfortunately, the distance given by the census is not reliable as the errors are too frequent and difficult to rectify. In addition, the automatic measurements of distance by GIS are not yet practicable for Tamil Nadu. However, this work has made it possible to establish a solid framework for the spatial analysis of the countryside in India and for the role played by urban proximity. A further step will consist in making this a viable decision support tool.

3.6 The geostatistical analysis of fertility in South India[47]

To conclude this paper, we shall provide another example of the application of our database to spatial analysis, this time not concerned with cartography or ordinary statistics. We shall return to one of the points of departure of the study conducted by the South India Fertility Project on fertility decline: What are the reasons for the very high degree of spatial compactness of fertility such as is observed in India at the district level, but also for South India? Is it a mere cartographic idiosyncrasy, or must one read therein the trace of structuring forces that consistently determine the fertility variations among the Indian regions? It would be difficult to briefly respond to the latter question, which prompted somehow our research programme (the SIFP), but it can be observed that, in the first place, the spatial configuration of fertility is far from being a matter of chance. It proves to be, furthermore, relatively invariant, discernible from one census to the next since the beginning of the fertility decline on a large scale in the 1960s.[48] But how far can we trust the maps about this? And furthermore, is cartographical inspection enough when we want to compare the way different social features appear on the map of South India?

3.6.1 Why geostatistics?

The analysis of maps rests on visual scrutiny by the reader and for this reason depends closely on their quality, but also on the initial cartographic choices. Maps are seldom unequivocal and the data can lend themselves to numerous manipulations (Monmonier, 1991). And, although data that are mapped can be compared with each other more efficiently with basic statistical analyses (such as regressions), the analysis of the polarization of a given phenomenon on one and the same map is much more empirical, if not approximate. We shall now make use of more powerful geostatistical tools to measure this spatial correlation, starting with fertility measurements.

We have used for this a common measurement, namely, spatial autocorrelation calculated with the Moran index.[49] Moran's *I* index, the definition of which is given below,

[47] This section was written by Christophe Z. Guilmoto. This work benefited from the support of the EMIS project.

[48] Various maps published in Guilmoto (2000) and Guilmoto and Rajan (2001, 2002) easily confirm this strong geographic patterning.

[49] Regarding the Moran coefficient, see for example Bailey and Gatrell (1995). A simpler measurement of Moran's *I* consists in computing the index only for localities that are adjacent, and not by distance class as is done here.

makes it possible to measure the statistical correlation *I(h)* between *n* pairs of localized observations (the values z_i or z_j), classified according to the distance *d* separating them.

$$I(d) = \frac{m \sum_{i,j} (z_i - \bar{z})(z_j - \bar{z})}{n \sum_{i} (z_i - \bar{z})^2}$$

The numerator of the index is the covariance between the observations separated by a given distance and the denominator is the total variance of the sample with *m* size: one compares the variations between distant observations with variations among all observations. By analogy with the measurement of the usual correlation between two variables (r^2), this index takes a value near to 1 when the spatial autocorrelation is maximal between pairs of observations, which may be the case when the localities are very close. It takes a value of zero when there is no statistical relation between the observations, and more rarely a value of –1 when the observed values are, on the contrary, opposed to each other.

The spatial correlation of social characteristics is seldom zero for close observations, but its intensity is highly variable: there can be strong variations on the micro-scale or, on the contrary, a great homogeneity and the visual examination of the maps scarcely make it possible to discern them. The Moran coefficient allows a systematic analysis of the effects of proximity and consequently of the spatial cohesion of the phenomena. In the case of spatial autocorrelation, the correlation between the observed values, here of fertility, is supposed to be very strong when the localities are close to each other. When the localities are distant, the correlation between the values will be zero, for the observed fertility values will have no relation to each other.

The results presented come from 2151 clusters of 10 km in rural South India. Having a similar area and a uniform distribution, these clusters are thus devoid of spatial or administrative bias. In addition, the average population of the clusters (approximately 65,000 inhabitants) is large enough to provide very robust values of child-woman ratios. Finally, their number makes it possible to carry out the necessary geostatistical computations. We must in fact examine the clusters, not individually, but by groups of two by measuring for each pair of clusters the distance separating them. With clusters of 10 km, one counts not less than 2.3 million pairs of localities, which still lies inside the limits of computation. A similar analysis based on 10,000 localities would be probably much more complex in computational terms.

3.6.2 *The comparison of autocorrelation coefficients*

The distribution of distances, measured between centres of clusters, is plotted on Figure 27. Distances have been classified by 20-km lags. Thus, the first lag includes localities (here clusters) that are distant by less than 20 km, while the second lag includes those that are distant by 20 to 40 km, and so on. As the figure shows, the number of pairs of observations rapidly increases with distance. For the first lag, we have less than 4000 pairs, but this is more than enough to compute Moran's *I* statistic. The maximum number of pairs (37,000) is reached for localities that are distant by about 400 km. The number of pairs then regularly decreases and the largest distance between South Indian localities (1450 km) is observed between Kaniyakumari and north-east Andhra Pradesh.

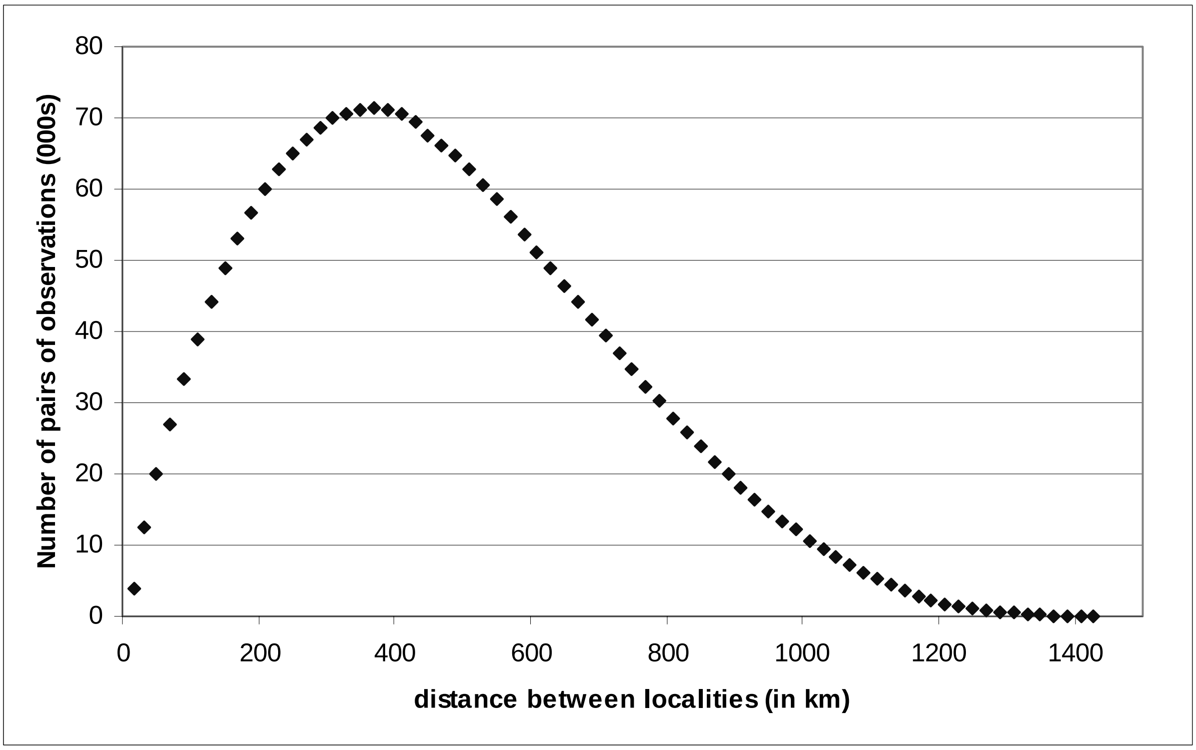

Figure 27 : Distribution of distances between localities, 10-km clusters, South India

We have chosen in our examination to limit ourselves to distances of less than 400 km, representing around one third of the maximum distance between clusters and somewhat less than the global average distance between clusters. The autocorrelation measurement for distances of more than 400 km is generally zero, or negative, for the observations no longer bear any relationship to each other, and it is for this reason that we are more interested in short distances. We will show here a selection of results corresponding to certain variables of the database, paralleling presentations provided earlier in this book.

We will naturally begin with fertility (measured by the child-woman ratio) in Figure 28, which we compare with a common demographic index, that of rural density (in inhabitants per kilometre). The spatial autocorrelation for each of these two variables is manifest, because for each of them the correlation between the observations is very pronounced for short distances and then proceeds to diminish when the distance increases. The nearest localities thus have very similar values. Fertility is, however, characterized by an extremely high Moran index for the shortest distances and reaches, in fact, 0.85 (85% of the total covariance). This suggests that the fertility measurements between adjacent clusters are practically identical. This similarity appears also for clusters that are less close. The fertility levels in the localities situated at 100 km distance remain in effect much correlated, with coefficients of around 0.5: approximately half the covariance between these localities would thus be explainable solely with the spatial modelling according to the distance separating them.

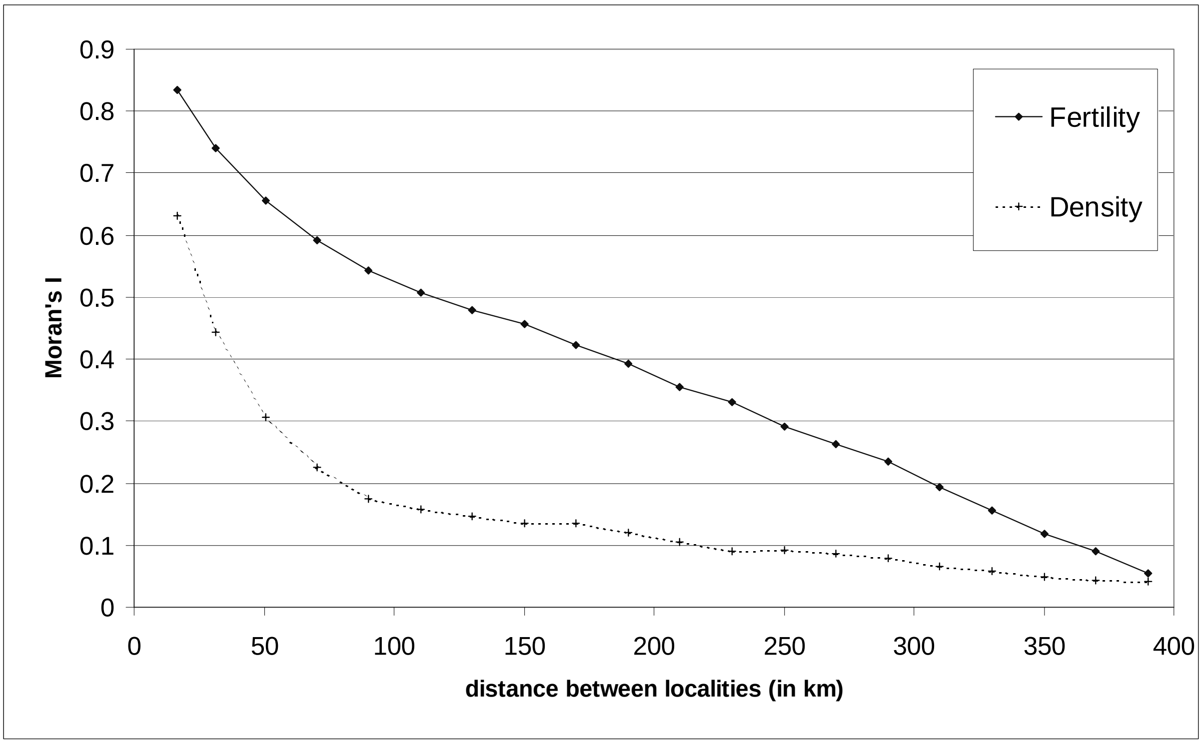

Figure 28 : Moran's I for fertility and density, 10-km clusters, South India, 1991

A more detailed analysis according to orientation would show that the variations in fertility are stronger along the north-south or northwest-southwest axis than in the other directions. This pattern is broadly compatible with the pattern of the social geography of India as a whole, such as was conceived of some twenty years ago (Dyson and More, 1983).

The difference between density and fertility in Figure 28 is striking, for the degree of spatial autocorrelation for the former is much lower despite the well-known strong geographic groupings of the population: very high density in Kerala and in the delta regions, low density on the whole of the Deccan Plateau, etc. One thus notes that the correlation between the density values observed is indeed strong at short distance, but then abruptly decreases to become almost negligible when the localities are at a distance of 100 km. The local variability of the density is therefore high. One can assume that the rural density is linked to highly varied phenomena (such as hydrography, altitude, the presence of a city, etc.) that only have a very limited spatial impact and that, consequently, the spatial homogeneity of the density is only discernable over quite reduced spaces.

Figure 29 that follows takes up the spatial autocorrelation measurement of fertility, comparing it to that of female literacy. As is seen, the spatial correlation of female literacy (population of 7 years and above) is also at a very high level, comparable at first reading to that of fertility. A more detailed examination shows that the spatial correlation of fertility values is somewhat better than in the case of literacy values for the set of distances at less than 300 km. Beyond that, the curves appear to reverse, but the Moran index is then low and without real significance.

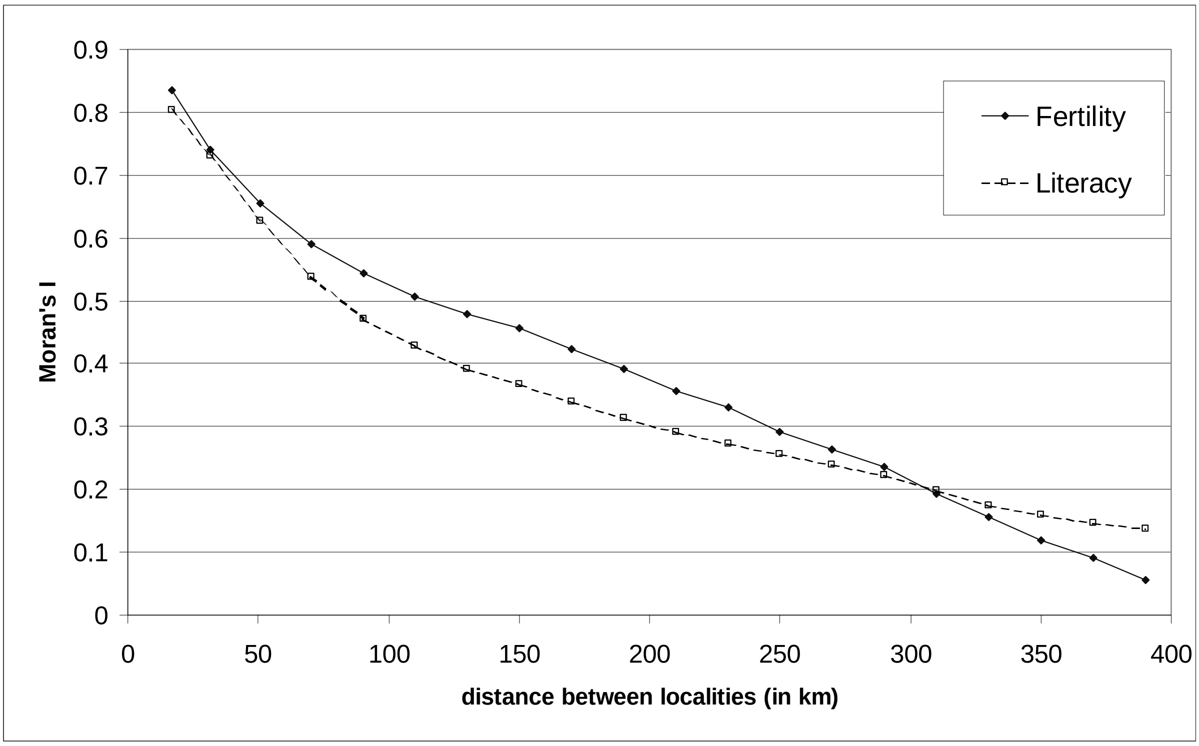

Figure 29 : Moran's I for fertility and literacy, 10-km clusters, South India, 1991

The comparison of education and fertility is far from being purely formal. It is in fact known that of all the fertility correlates in the developing world, female literacy usually appears first (Jejeebhoy, 1995). The education of women, along with urbanization, is the variable that best explains the differences in fertility observed between countries, or within countries between the regions or between social groups. It has been therefore suggested that the strong spatial autocorrelation of fertility would thus only be the by-product of that of literacy.[50] Our comparison shows that this reasoning is not entirely valid, for the spatial correlation for fertility values is here also strong, and even slightly stronger than that for education. Not only does the spatial concentration of fertility appear to be higher, but there are obvious differences between the distribution of values that could be detected without difficulty on maps of the South Indian atlas: fertility may for instance be very low in areas where literacy is not especially high as in Kongu Nadu. This means that spatial pattern of fertility has a spatial signature of its own, characterized by both very high concentration and specific geographic contours. It is also possible that fertility decline by itself tends to reinforce the spatial patterns of fertility, especially if diffusion mechanisms are at play. This question, of course, requires a more detailed examination, one that would, however, exceed the framework of this short section (see Guilmoto, forthcoming).

Figure 30, the last, is devoted to a general comparison of several variables. As is seen, fertility is the most correlated variable of all. As a matter of fact, we have not as yet identified any variable that would display a higher degree of autocorrelation than fertility. As minimum value, we have calculated the Moran index for the building sector, measured here by the percentage of the labour force working in this sector. The correlation is one of the lowest to be observed among the SIFP database variables and becomes practically zero for distances of 50 km or more. One no doubt observes the polarizations of this activity on the South Indian scale, for example, in Kerala because of the expenditures of migrants returning from the Gulf, in rapidly developing peri-urban zones, or even in regions where quarrying is done. But the intensity of this sector of activity in a given locality generally has but little relation to that noted in nearby communities, for the observed variations, which are quite minor, are very weakly determined by location. Beyond a certain distance, there is absolutely no link between the localities and the geographic distribution of the building sector seems to be nearly random. In fact, the needs in this sector are quite well distributed in the rural milieu and the concentrations that may exist are of a very localized character.

The other variables indicate clearly higher levels of autocorrelation that are located at between 40% and 75% of the maximum possible correlation. In particular, irrigation is spatially very strongly correlated, but this features tends to fade away very rapidly with

[50] I thank Patrice Vimard for drawing mortality attention to this issue.

distance: the homogeneity observed among irrigation levels may be true firstly within small geographic units such as watersheds or irrigation systems (for example, by canals). At a distance of more than 100 km, the regional tendency becomes very weak. One can imagine that rainfall, which in large part determines the success of non-irrigated agriculture, will, on the contrary, be strongly correlated and on more extensive spaces. The density of reserved forests (not represented on the graph) is still less spatially autocorrelated, as forested areas usually correspond to isolated zones, the only concentrations of which are found to the mountainous parts of the Ghats.

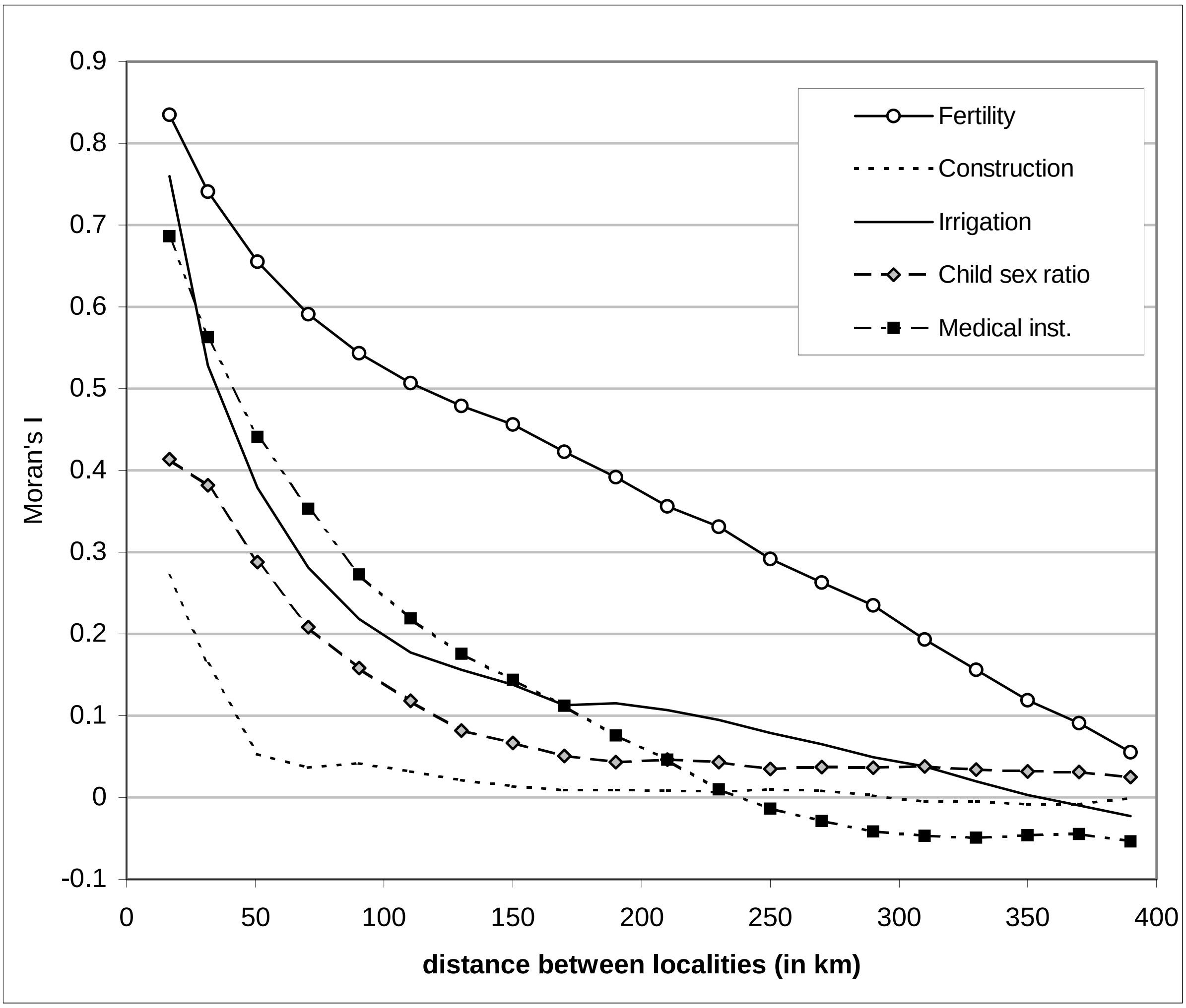

Figure 30 : Moran's I for fertility and other indicators, 10-km clusters, South India, 1991

The state of health care infrastructures, measured by the proportion of villages in the cluster endowed with a medical institution (census definition), displays a very strong spatial coherence and the favoured regions tend to be contiguous. One recognizes here the features illustrated in the study on the scale of Andhra Pradesh conducted by Virginie Chasles.

On the other hand, the child sex ratio on the scale of South India is seen to be very weakly correlated spatially, which requires additional explanation. Stéphanie Vella previously shows that sexual discrimination, far from being randomly distributed, is particularly acute in certain pockets of Tamil Nadu, especially concentrated in the regions of Salem and Usilampatti. According to the calculation of the Moran index, the spatial homogeneity of this phenomenon appears to be moderate (around 40% at short distance) and vanishes beyond 100 km. What this results indicates is, in fact, that the spatial distribution of the child sex ratio in most South India is nearly random: the variations are small from one locality to the next and the observed values are unconnected statistically. It is only in regions where the differences are more pronounced, as in Tamil Nadu, that the regional clustering is more significant. In fact, if the analysis were limited to the 466 clusters of Tamil Nadu, the results would be different: at short distance, the Moran index amounts to 60% and thus approaches that of the other indices. One will note, however, that the autocorrelation on this scale is still below that of fertility. This suggests that a significant part of the heterogeneity between the child sex ratio values cannot be attributable only to strictly speaking socio-spatial phenomena, but is a matter of non-spatialized variables or of an almost random distribution, as is often the case for the sex ratio levels at birth.

3.6.3 An interim conclusion

As an interim conclusion to an exploration that is in its inception, we will note that geostatistical formalization, while common in archaeology or in the environmental sciences, is new and very seldom undertaken in the social domain.[51] The results obtained here are therefore exploratory and must be interpreted above all as comparative: the differences in the calculated levels of spatial autocorrelation should be analyzed, rather than the raw values themselves, which often depend on the levels of scale of analysis as well as the spatial characteristics of the phenomena studied.

The level of clusters (10 km) retained for this exercise is seen to be quite efficient, for it makes it possible to avail of a sample that is neither too large (problem of time involved in calculation) nor too small (problem of non-representative small samples). Furthermore, the scale of aggregation has also made it possible to do away with clusters that are too small, such as in aggregates smaller than 2 and 5 kilometres, the inevitable effect of which is to impoverish the statistical calculations. This problem is frequently a source of difficulty in the calculation of the child-woman ratio because the numbers of children and women are sometimes very imbalanced in the small populations and the geostatistical calculations, which

[51] See however the efforts deployed by the Center for Spatially Integrated Social Sciences (www.csiss.org).

ascribe the same weight to all clusters independently of their demographic size, are particularly vulnerable.

As concerns fertility, there is no doubt that the estimated levels of spatial autocorrelation are extremely high and greater than most of the other variables tested, also on other scales of analysis (Guilmoto and Rajan, 2001). Geostatistical modelling thus goes far beyond the perceptions provided by cartography to point to a dimension that is crucial in the understanding of demographic change in India. It now remains necessary to link this spatial homogeneity of reproductive behaviours to their own logic of evolution within the social institutions that govern them (the couple, the family, the social group, the state, etc.). We are now far from geostatistical formalization, but we hope to have shown that the insights derived from a formal analysis, such as that based on the indices of spatial autocorrelation, compel us to directly approach the spatial question in the analysis of the fertility decline, in a manner parallel to the previously developed examination of the imbalances in the distribution of the sexes.