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BIRTH SEASONALITY AS A RESPONSE TO A CHANGING RURAL ENVIRONMENT (KAYES REGION, MALI)

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Summary. Birth seasonality responds to a variety of environmental and socio-cultural factors. The present study was carried out to quantify the trends in seasonal variation in birth rate in seven districts in the Kayes region of Mali between 2007 and 2010 and to attempt to link climatic- and agricultural-cycle-dependent factors with birth seasonality. Lagged regression analysis based on time series analysis techniques was used to investigate seasonality of births registered in health facilities and its association with climate, labour migration, agriculture workload, malaria infection and food supply. There was a clear bimodal pattern in month-to-month institutional delivery rate variation, and this seasonal pattern repeated each year over the study period. The data showed that rates of health-facility-attended deliveries were high at the end of the dry season (April–June), fell rapidly in the first half of the rainy season, rose again during the later part of the rainy season (August–October) and fell to their lowest values after the rains. The first peak observed in spring (April–June) corresponded to conception nine months earlier during the rainy season (between July and September), while the second peak observed in the third quarter of the year (August–October) corresponded with conception at the beginning of the dry season right after the harvest period (between November and January). Between these peaks was an abrupt trough in July. The findings support a causal process through which climate change influences conception/birth seasonality in two direct and indirect pathways. On one side climate change influences conception/birth seasonality from the effects on fetal loss (changes in annual rainfall leading to changes in malaria incidence) and on the other side by affecting fecundability (changes in agricultural cycles leading to changes in food production, agricultural workload and socio-cultural events, which in turn influence energy balance and sexual behaviour). Labour migration, which is closely linked with the agricultural cycle, influences sexual intercourse and thus marital fertility. Finally, the model emphasizes an eco-systemic approach to the study of birth seasonality.

Introduction

Many previous studies have found seasonal and annual cyclic patterns in birth outcomes for different populations and geographic zones. Although seasonal distributions of births vary considerably from place to place, the most pronounced seasonal birth patterns are generally observed in developing countries (Condon & Scaglion, 1982; Becker *et al.* 1986; Lam & Miron, 1991a, 1994; Bailey *et al.*, 1992; Bronson, 1995; Leslie & Fry, 1989). Subsistence societies are subject to fluctuations in climate, resources and stressors that intensify seasonal patterns in births (Leslie & Fry, 1989). Subsistence agricultural populations often exhibit a birth seasonality pattern related to the agricultural work cycle and food availability (Panter-Brick, 1996). Birth seasonal pattern reflects seasonal variations in conceptions, which are themselves influenced by seasonal variations in frequency of sexual intercourse and fecundity. Although not all fetal losses (miscarriages and spontaneous abortions) are measurable, particularly during the early stages of pregnancy, they cannot be discounted from the birth seasonal pattern because their effects are indistinguishable from those of variations in conception rates (Becker *et al.*, 1986; Lam *et al.*, 1994). Different environmental and associated behavioural mechanisms have been proposed as explanations for seasonal variations in frequency of sexual intercourse (Lam & Miron, 1991a, 1991b, 1994), fecundity with energy balance (Leslie & Fry, 1989; Bailey *et al.*, 1992; Leslie *et al.*, 1993; Lam & Miron, 1996), and fetal loss following infectious disease (Lam & Miron, 1994; Shulman & Dorman, 2003; Desai *et al.*, 2007). Environmental factors influence fecundity and fetal loss, while behavioural factors, which may also depend on environmental factors, influence coital frequency (Leslie & Fry, 1989; Russell *et al.*, 1993; Panter-Brick, 1996). A model of the direct and indirect pathways by which climate change may affect birth seasonality in subsistence agricultural societies is attempted along these lines (Fig. 1). Climatic factors influence seasonal variations in conceptions/births, both directly and indirectly. Indirect influence refers to climatic factors (rainfall and temperature) that regulate cycles in agricultural activities, which in turn determine workload intensity (influencing frequency of sexual intercourse, energetic ovulation and/or fetal loss), food supply (influencing energy balance and then fecundity and fetal loss), socio-cultural events and economic migration (influencing frequency of sexual intercourse). Climatic factors can also directly influence seasonal variations in conception and birth: hot temperatures may reduce fecundity and malaria infection may result in fetal loss in the heavy rain season. Periods of hot temperatures and heavy rain may also lead to changes in behaviour, which in turn may influence the frequency of sexual intercourse. Seasonality and variability in climatic factors are reflected in seasonality and variability in each link along the causal chain (Leslie & Fry, 1989; Lam & Miron, 1991a; Bailey *et al.*, 1992).

Annual rain onset, duration and levels shape the annual cycle of agricultural activities and determine the timing and amount of planting and crop germination. Periods of heavy workload generally result in a lower frequency of sexual intercourse and in reduced energetic balance, which in turn alter ovarian function in women (Panter-Brick, 1996; Bentley *et al.*, 1998; Ellison *et al.*, 2005). Women who are malnourished are unlikely to conceive (Ferguson, 1987; Leslie & Fry, 1989; Bailey *et al.*, 1992; Ellison, 1994; Ellison *et al.*, 2005) and, conversely, better food supplies are related to higher conception rates (Ferguson, 1987; Bailey *et al.*, 1992). In subsistence populations, the uncertainty of the food supply and its seasonal variability may, in the absence of well-functioning credit or

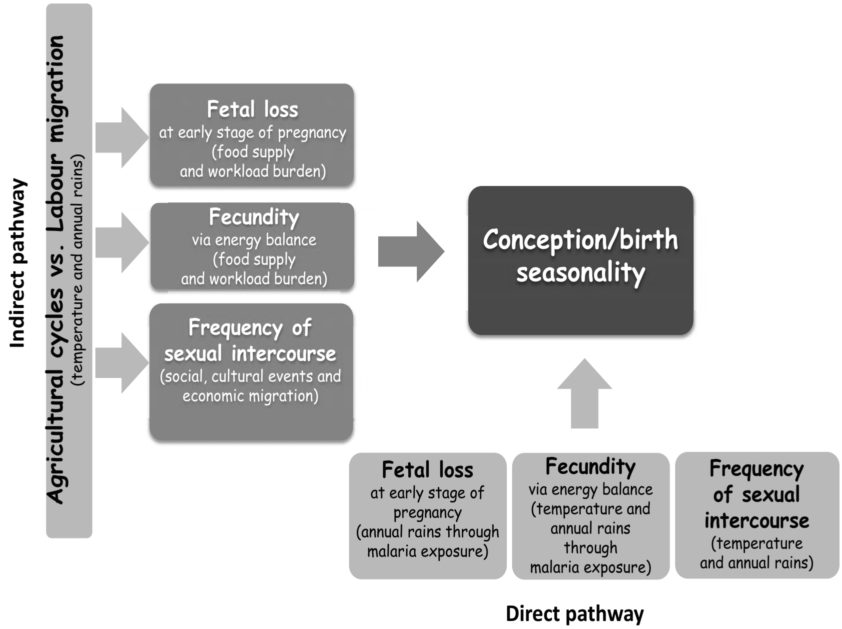

Fig. 1. Scheme of a tentative chain effect of birth seasonality in subsistence rural populations in the Kayes region (Mali).

an efficient food provision system, put households at risk for food insecurity and malnutrition across seasons. Thus, seasonal birth patterns are likely to be more pronounced in agricultural subsistence populations than in other populations (Bailey *et al.*, 1992; Ellison, 1994; Bronson, 1995). Outside of the crop-growing season, many rural dwellers are impelled toward migration by economic opportunities, setbacks and imbalances (Agadjanian *et al.*, 2011). Seasonal economic migration in subsistence agricultural societies is recognized as a phenomenon that affects marital fecundity, as it often separates families for prolonged periods (Omondi & Ayiemba, 2003; Agadjanian *et al.*, 2011). Although marital fecundity decreases outside the crop-growing season, which is also the period of economic migration, it is likely that a high frequency of intercourse in the period immediately following men's return increases conception rate.

Patterns of social behaviour affecting the frequency of sexual intercourse are often invoked to explain observations in birth seasonality. Seasonal ceremonials, festivals and wedding events, many of which are related to the agricultural cycle, have been identified as possible contributing factors to seasonality in birth (Russell *et al.*, 1993). Seasonality in marriages affects the number of women susceptible to conception, which in turn would result in a seasonal change in births (Demoliates & Katsouyiannopoulos, 1995; Stolwijk *et al.*, 1996). In traditional populations, the probability of conception depends more on cultural events or religion observances than it does in modern societies, where conception depends more on choice of time of pregnancy (Bobak & Gjonca, 2001). Although not related to natural seasonality, Ramadan may also have an effect on conception rate, since during the holy month of Ramadan sexual intercourse is limited to night time and weddings do not occur (Condon & Scaglion, 1982).

During the wettest seasons of the year, spontaneous abortions due to infection and disease are more likely, and women are often unaware of these miscarriages or are not reported. In regions where malaria is endemic, its transmission leads to miscarriage, especially when there is parasitization of the placenta. Pregnant women affected by malaria during the first trimester of pregnancy are more likely to abort than are other women (Menendez, 1995; Steketee *et al.*, 2001). A decreased conception rate has also been attributed to high temperature at hottest periods owing to a decrease in spermatogenesis, as high scrotal temperature depresses sperm counts (Levine *et al.*, 1988; Russell *et al.*, 1993; Thonneau *et al.*, 1998; Gyllenborg *et al.*, 1999), and/or to a decrease in sexual activity at this time of the year. The rainy season may generally be a precarious time period for conception, as it is marked by the concurrence of peaks of disease (malaria infection), food shortage during the pre-harvest period and high energetic demand for agricultural work activities. The confluence of these multiple linkages around October in Mali make this an especially difficult time, particularly for rural populations depending on subsistence agriculture.

The present paper aims to provide contemporary evidence of a seasonal pattern of birth deliveries in the rural region of Kayes (Mali) using monthly retrospective data from health centres between 2007 and 2010. The seasonal agricultural system of this region provides a unique setting to study the local conditions that influence birth rates, which allow for testing the hypothesis that birth seasonality responds to a variety of environmental and socio-cultural factors. An ecosystemic approach was adopted, which takes into consideration annual rains, temperature and malaria transmission, as well as annual variations in agricultural workload, food supply, economic migration and cultural events. The Kayes region is divided into seven health districts whose geoclimatic and migration characteristics vary, providing an opportunity to investigate whether these resulted in differences in patterns in birth seasonality.

As it remains difficult to evaluate home delivery births in Mali (Ferguson, 1987; Bantje, 1988; Tembon, 1990), information on birth seasonality was limited to registered deliveries attended in primary health centres (Enabudoso *et al.*, 2011). Although availability and accessibility of health care services did not fall within the main scope of the present study, rain-dependent travel time to health centres was taken into account in the seasonal pattern of deliveries. Distance and long travel times to health centres are known to be key barriers to access in low-income rural communities (Ronsmans *et al.*, 2003; Guagliardo, 2004; Babinard & Roberts, 2006; Fournier *et al.*, 2009; Moïsi *et al.*, 2010; Pirkle *et al.*, 2011; Schoeps *et al.*, 2011). During the rainy season, flooding and impassable roads may exacerbate the distance barrier, particularly for communities where a seasonal road is the main means of access, thereby reducing the rate of institutional deliveries because many women are unable to overcome the geographical obstacles to get to health centres (Babinard & Roberts, 2006; Schoeps *et al.*, 2011).

Methods

Study sites

The Kayes region is located in the western part of Mali and is bordered by the Koulikoro region to the east, Senegal to the west, Mauritania to the north and Guinea Conakry to the south. It consists of seven health districts: Kayes, Bafoulabé, Diéma,

Fig. 2. Map of the seven districts in the studied Kayes region (Mali, West Africa).

Kéniéba, Kita, Nioro and Yélimané (see Fig. 2). It has over 1.6 million inhabitants and covers a surface area of 120,750 km^2, corresponding to 10% of the national territory. Population density is about thirteen inhabitants per square kilometre, and dispersal rates vary from nine inhabitants per square kilometre in the districts of Bafoulabé and Kita to 21 inhabitants per square kilometre in Yélimané. The ecozones range from arid Sahel in the north (Sahelian domain) to the semi-tropical south (Sudanese domain). It is classified as a semi-arid area, with annual rain ranging from 475–724 mm in dry areas (Nioro, Yélimané, Kayes and Diéma) to 725–974 and 975–1424 mm in moderate (Bafoulabé) and wet areas (Kita and Kéniéba), respectively. The Kayes region is predominantly rural and has a seasonal agricultural system that revolves around a rainy season from June to October and a dry season from November to May. The rainy season starts in June and peaks in August, ending late in October. The crop-growing season varies between 120 and 210 days in moderate and wet areas, and lasts from 60 to 90 days in dry areas (up to 150 in Kayes). Depending on the ecozone, sowing starts in May or June and may continue until July. The main crop-harvesting period extends from the end of August or early September until December. The Sahelian districts of Nioro and Yélimané enjoy a second growing season, which is a flood-recession growing season spanning December to March. The main staple crops in the Kayes region are sorghum, millet, maize and, to a lesser extent, rice and fonio (*Digitaria exilis*). Market gardening of off-season crops is increasingly undertaken by women as a livelihood strategy and generally occurs from February to May, except in drier areas, where it can start in early December.

As in most sub-Saharan countries, migration is an increasing phenomenon in Mali (de Haan *et al.*, 2002). Recognized as an alternative coping strategy, it represents a shelter against risks of crop income shocks in agricultural subsistence areas (Schrieder & Knerr, 2000; Gubert, 2010). In the Kayes region, there is a strong tradition of economic migration in Nioro and Yélimané. While for the most part migrants remain internal, there is a significant and growing phenomenon of international, quasi-permanent migration to France and, to a lesser extent, to Senegal and Ivory Coast (Gubert, 2010). In the Kayes region, internal migrants leave to work elsewhere outside the crop-growing season, returning for the crop-growing season or when times improve. It is especially the men who leave to earn money, but a substantial number of women migrate as well. The flourishing gold mines in Kéniéba, which has two of the region's four industrial gold mines, attract many male economic migrants and some women as well.

The population is a naturally reproducing population. The fertility rate in Kayes is 6.7 children per woman, which is close to the national rate of 6.6 (CPS/DNSI, 2006). Assisted deliveries represented 50% and 57% of total estimated deliveries in the Kayes region in 2007 and 2008, respectively (DRS, 2008). Regional statistics (DRS, 2008) showed that the mean percentages in 2007–2008 varied among the seven districts. The drier districts of Kayes (74%), Yélimané (60%), Diéma (56%) and Nioro (54%) showed the highest values. The wet districts of Bafoulabé (48%) and Kita (46%) exhibited lower values, and Kéniéba's was lowest at 24% (DRS, 2008).

Environmental factors

Rainfall. Rainfall data are routinely collected at the rainfall stations in each health district's capital city and compiled at the meteorological head office in Bamako. Rainfall is typical of the monsoon pattern of the Sahel, peaking in August and with little or no rain between November and early June. As rainfall is indirectly associated with malaria incidence and indirectly with economic migration/crop-growing season, rainfall data were excluded from the lagged regression analyses.

Food supply. Monthly food supply was assessed from each health district's food supply estimate during the crop-growing season. District monthly food supply estimates were based on the combination of crop production data in the reports of the Malian Early Warning System (*Système d'Alerte Précoce* or SAP), information at the district's head office of agriculture, and from consumption crop storage data at the regional Malian Office of Agricultural Products (*Office des Produits Agricoles du Mali* or OPAM) in Kayes. Food supply was an ordinal variable with three increasing levels (low, moderate, high). The monthly reported price of cereals from the OMA (*Observatoire du Marché Agricole*) was used as a second food supply estimator in each health district and was considered a continuous variable within the statistical analyses.

Economic migration and workload during the agricultural cycle. Labour migration and burden of workload during the crop-growing season variables were built by combining data from SAP crop production reports with general information collected at each district's local head offices of agriculture. Both variables were ordered on a scale from 1 to 4 (low, medium, medium–high, high) and were considered categorical variables within the statistical analyses.

Geographical data

Distance to health facilities measured as continuous travel time. Measures of geographic access vary in complexity and specificity; here, geographic access was proxied by measurements of time-weighted mean travel distance in the dry and rainy season, as previously done in the similar study by Pirkle *et al.* (2010).

Health data (assisted deliveries and malaria cases). Health policy in Mali is developed by the Ministry of Health and implemented by the National Health Directorate. The medical system in Mali consists of three operational levels. The dataset used for the present study in the Kayes region compiled registered data from the first operational level, which is made up of Community Health Centres (CSCOM). Data from some private clinics (corresponding to CSCOM level) in the city of Kayes were incorporated into those of the Kayes health district. In each health district of the region there is one CSREF (reference centre) that exerts a supervisory role over the CSCOMs. Every trimester the CSREF collects monthly data on registered assisted deliveries and malaria cases in all CSCOMs of the health district. These records have been collected since 2007. Due to this study's interest in identifying periods of birth conception, all deliveries were considered for sampling. Number of deliveries and malaria cases were retrospectively compiled from the records of all CSCOMs in the seven districts, and from private clinics as well in the city of Kayes. Because records collected directly by the CSREF health facilities (for deliveries in those facilities) were quarterly records, these were excluded from the database. The monthly delivery rate was calculated as the ratio of total number of deliveries in that month to the expected number of deliveries, multiplied by 100. The expected number of deliveries was assessed by the authorities as 5% of the monthly population. To contend with missing values in monthly data encountered in several CSCOMs over the four-year study, a data imputation strategy at the CSCOM level was implemented based on a decision tree sequence.

Statistical analyses

Time series were based on retrospective data ARIMA (Auto-Regressive Integrated Moving Average) models. The ARIMA procedure was divided into three stages: identification, estimation and explanation. The first stage was aimed at identifying which model was most appropriate for the data. A common assumption in many time series techniques is that the data are stationary. Non-stationary data, as a rule, are unpredictable and cannot be modelled or forecasted. The identification stage determines whether the time series is stationary and whether there is any significant seasonality that needs to be modelled. Stationarity was assessed by visual inspection from a run sequence plot and also from an autocorrelation function (ACF) and a partial autocorrelation function (PACF). Stationarity was also assessed by white noise tests (cumulative periodogram white noise test, Bartlett's (B) statistics and Portmanteau test) and unit root tests (Augmented Dickey–Fuller and Phillips–Perron tests). Seasonality was first visually detected by a sequence plot, a seasonal subseries plot, ACF and PACF, and then by a periodogram (sample spectral density function and sample distribution density function) for assessing the cyclic nature of univariate time series in the frequency domain.

The augmented sroot and Hegy procedures tested seasonal unit root. Finally, random walk with drift tests were performed to see whether the seasonal pattern exhibited a random walk without trend or drift.

At the model identification stage, candidate ARIMA models that best fitted the time series were identified. The ARIMA model is a family of models characterized by three parameters (p, d and q) that describe the basic properties of a specific time series model. The first parameter, p, represents the order of the autoregressive component of the model. The autoregressive component assumes that each datum can be predicted by the weighted sum of the preceding data, to which is added a random error term. The second parameter, d, refers to the order of differencing, which assumes each datum has a constant difference with the preceding data. Finally, q denotes the order of the moving average component of the model, which assumes that each datum is a function of errors affecting the preceding data plus its own error. If seasonality exists, the goal is to identify the order for the seasonal autoregressive and seasonal moving averages. In the latter case, the model is called seasonal ARIMA (P, D, Q, lag for seasonality). The ACF and PACF plots were used to identify potential candidates for the components p, d and q.

The aim of the estimation stage was to determine which p, d and q best modelled the time series. Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) tests were used to compare performance of maximum likelihood among the different models.

In the present study, a series of ARIMAs were also tested with the factors of interest as covariates for explaining variations in delivery rates. To investigate factors influencing seasonality in conceptions, some nine-month lagged regressions were applied on delivery rates to shed light on possible relationships. All models were adjusted with time-weighted mean travel distance in the dry and rainy seasons.

Results

The month-by-month delivery rates based on merged data from the seven districts are presented in Fig. 3. The seasonal trend in attended deliveries was investigated by fitting an appropriate time series model over the studied period.

Identification stage

Non-stationarity was confirmed by visual inspection from the run sequence plot (Fig. 3) and both autocorrelation function plots ACF and PACF. The run sequence plot and ACF and PACF plots showed that, for all districts merged together, the time series of the delivery rate data displayed periodic fluctuations or cycles (ACF in Fig. 4). Visual inspection of the cumulative periodogram of white noise and Bartlett's and Portmanteau test outputs concluded that the process was different from white noise, thus supporting the conclusion that the time series was not stationary. Finally, Dickey–Fuller and Phillips–Perron tests validated unit root in the time series and showed there was no drift in the time series. Similar statistical outputs were observed in every separate health district.

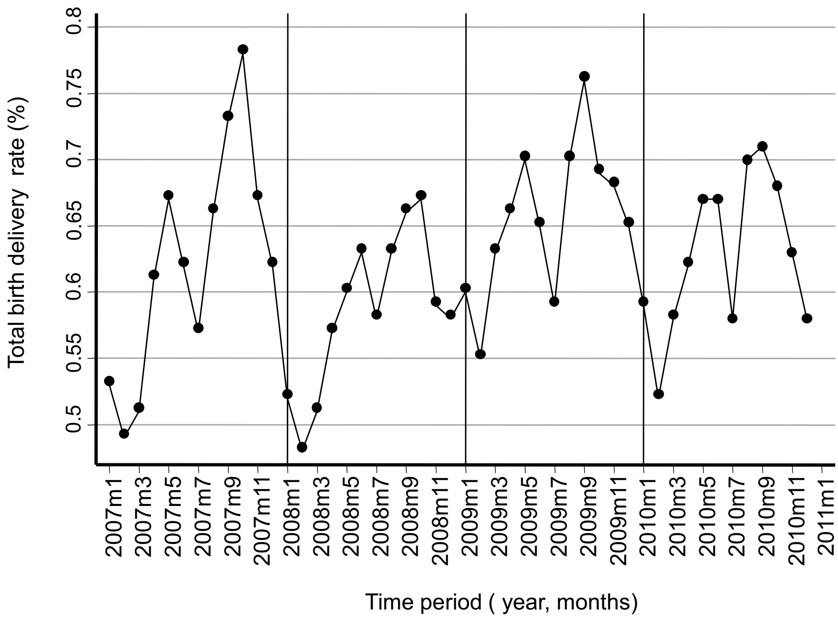

Fig. 3. Sequence plot of total delivery rates from 2007 to 2010, all districts merged.

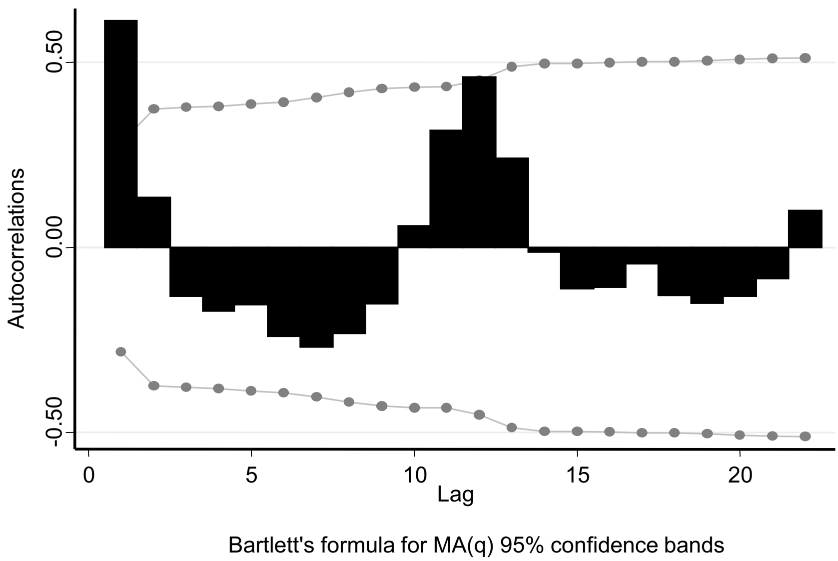

Fig. 4. Autocorrelation function plot. Distribution of autocorrelations with increasing lags between data.

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Seasonal pattern was visually investigated by the run sequence plot, ACF, and the plot of combined monthly delivery rates (Figs 3 and 4, respectively), and then confirmed by the periodogram of sample spectral density function and sample distribution density function in the frequency domain (not shown here). The augmented sroot and Hegy procedures invalidated a seasonal unit root. Finally, the data followed a seasonal pattern that exhibited a random walk without trend or drift. The same was found for every health district. Spectral analysis on merged data revealed a seasonal pattern with peak correlation coefficients of 12-month intervals. There was a weaker but consistent pattern of 6-month intervals. With only small internal yearly variations, the same seasonal pattern repeated every year. Although most districts taken separately exhibited two periodic cycles of 6 and 12 months, Kéniéba showed one 4-month cycle and, to a lesser extent, one 12-month cycle, and Kayes showed only one 12-month cycle. The non-stationarity and the seasonal month-to-month pattern of the birth rate time series every year suggested the use of ARIMA models. The ACF and PACF plots were used to help decide the best appropriate ARIMA model. Various permutations were computed of the orders of correlation, integration and moving average. The optimal combination of parameters was chosen using AIC and BIC values. The ARIMA-based model that best fitted the monthly merged data included one integrative term in ARIMA and one integrative term and one autoregressive term in SARIMA and two terms of moving average in ARIMA and SARIMA (lag 12).

Visual examination of trends

After all health districts were merged and all calendar months combined, a bimodal monthly distribution of delivery rates was clear (Fig. 5). There was an apparent intra-annual seasonal pattern, alternating between lower values extending from December to March and higher values extending from April to late November, but interrupted by an abrupt trough in July. Means of delivery rate varied between 0.39% and 0.45% in low-value periods and were above 0.5% in high-value periods (maximum of 0.53% in September). The delivery rate pattern displayed two peaks: one major peak in the second half of the rainy season in September–October corresponding with a high conception rate in the previous December–January, and a secondary peak in May–June (dry season) reflecting a high conception rate in the previous August–September. There was a 5.5% to 6.5% excess of delivery rates over the annual monthly data during the major peak, while excess ranged only from 1.5% to 3.5% during the secondary peak. The peak of seasonal excess rose to a maximum of 66% in October 2007. The two peaks were interrupted by an abrupt and deep trough in July (values 4% lower than the baseline). The peak-to-trough difference in monthly delivery rates was greater than the peak-to-trough difference between annual deliveries rates in a typical month.

Figure 6 shows that, for health districts with a long crop-growing season (Bafoulabé, Kita, Kéniéba) and those whose growing season was followed by flood-recession cropping (Nioro and Yélimané), the high delivery rate period started generally one month earlier (April–May) and ended one month later (December) than in the other two health districts of Kayes and Diéma. Although Kéniéba had a long crop-growing season area, it showed a low birth rate period lasting from November to April. There was no substantial difference between the two annual peaks of delivery rates, even

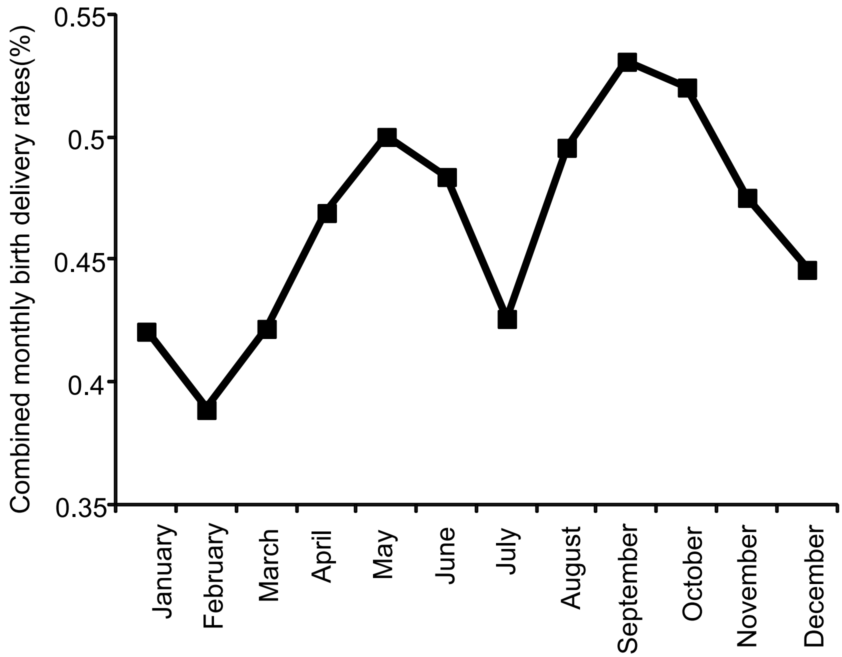

Fig. 5. Distribution of combined monthly delivery rates from 2007 to 2010, for merged districts.

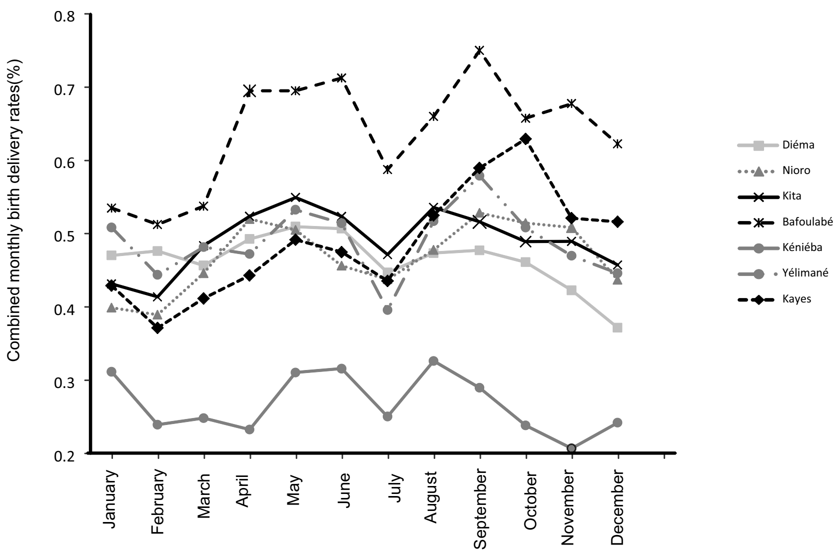

Fig. 6. Distribution of combined monthly delivery rates from 2007 to 2010, for each district taken separately.

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though the peaks of September–October in the Sahelian districts (Nioro and Yélimané) and in the dry district of Kayes were higher than the first one. In each health district, the period of low delivery rate corresponded nine months earlier to a period of conception outside of the crop-growing season. All districts showed a deep and abrupt trough in delivery rate in July interrupting the high delivery rate period. The seasonal pattern of birth rates remained generally unchanged with regular peaks and troughs from year to year.

In summary, the compilation of calendar months shows the delivery rate was high at the end of the dry season, fell rapidly during the first half of the rainy season in July and rose again toward the end of the rainy season. The first period of high delivery rates between April and June corresponded nine months earlier to elevated conception rates during the end of sowing and early harvesting time from July to September, while the second period between August and November–December corresponded nine months earlier to the time of post-harvesting, winnowing and threshing that extended from November to March. December–January was also the period of ceremonials and marriages in all the regions, which can be conducive to rises in conception.

Forecasting birth rates from environmental and social factors

The time series lagged regression models showed that birth rate was negatively related to labour migration, workload intensity and number of malaria cases but positively related to food supply level (Table 1). The 9-month lagged regression on merged data showed that each of the four factors contributed a significant and independent, although complementary, percentage of explanation for delivery rate. Similar results were found in every health district, even if some factors failed to reach significance. For health districts taken separately, annual labour migration was shown to be significant in four out of seven districts. Food supply and malaria infection were significant in four and six health districts, respectively, while workload intensity was retained in four health districts. Although malaria significantly influenced delivery rate in dry zones of the Kayes region only (Yélimané, Diéma, Kayes), the effect of food supply was not related to any particular ecozone. In each district, the annual trough of delivery rate observed in July was highly related to the peak of malaria cases nine months earlier (highest value in October). The effect of workload disappeared when the rainfall factor was included in the models, and vice versa. The two attributes of food supply were highly correlated but the categorical variable showed the highest performances within the models. In the current context, the data did not confirm that there was any effect of temperature or of Ramadan. The accessibility of health care was not significant in the models except for Kéniéba. This suggests that accessibility of health care was not restricted by rainfall in most districts.

Discussion

The bimodal seasonal pattern in delivery rate was repeated in every district and remained unchanged between 2007 and 2010. Month-to-month variations in the number of deliveries displayed a seasonal regularity with a peak in April–May–June and a second peak in August–September–October. Results from the nine-month lagged regressions

Table 1. Results of the nine-month lagged ARIMA regression models when labour migration, agricultural workload intensity, reliability of food supply and number of malaria cases are used as simultaneously predictive factors of delivery rate

	ARIMA/SARIMA models (p, d, q) (P, D, Q, lag for seasonality)	Log-pseudo likelihood	Labour migration (p-value)	Agricultural workload intensity (p-value)	Reliability of food supply (p-value)	Malaria infection (p-value)
All merged health districts	(0,1,1) (0,2,0,4)	39.85	<0.001	<0.001	<0.001	<0.001
Kayes	(0,1,0) (1,2,0,9)	27.72	<0.001	<0.001	0.02	0.01
Diéma	(0,1,0) (0,1,0,4)	41.42	NS	NS	NS	0.01
Nioro	(0,1,0) (0,1,0,4)	42.24	<0.001	0.03	NS	NS
Yélimané	(0,1,0) (0,1,0,9)	9.32	NS	0.05	0.04	<0.001
Bafoulabé	(1,1,0) (0,1,0,9)	24.01	NS	NS	NS	0.03
Kita	(0,2,0) (0,1,0,6)	20.86	0.01	NS	<0.001	<0.001
Kéniéba	(0,1,0) (0,1,0,6)	37.06	<0.001	<0.001	<0.001	0.05

The pseudo likelihood ratio Chi-squared test is under the null hypothesis (rho = 0). All tests were highly significant ($p<0.05$).
NS, non-significant.

confirm the expectation that malaria infection, labour migration and agricultural workload exert a negative effect on conception rate and thus on delivery rate, while reliability of food supply exerts a positive effect. There are good reasons to attribute these results to climatic factors. Rain influences not only malaria exposure but also the annual agricultural cycle, which in turn influences agricultural workload, labour migration and reliability of food supply.

The first annual peak of delivery rates in April–May–June may be related to a higher frequency of sexual intercourse due to low labour migration and relatively high fecundability with moderate workload and moderate food supply (from mid-August) at the conception time nine months earlier in July–August–September. Rainy season months (June to October) are also known to be months of high conception rates since spouses travel less and stay home (Bentley *et al.*, 1998). The sudden drop in delivery rates in July supports the assumption that the malaria transmission peak in the previous October is a contributing factor (Bentley *et al.*, 1998). The present data cannot tell us whether decreased fecundity or pregnancy losses after malaria infection are contributing factors to a lower incidence of conceptions in October. Except for Nioro, which experiences low malaria exposure, malaria transmission was highly significant in all the models. Since October is part of the harvesting time, intense workload linked with moderate food supply may contribute to the reduced conception rates in October and thus to the low delivery rates in July. The second annual peak of delivery rates in August–October may be related to the combination of low malaria transmission, low workload with high food supply (high fecundability), low labour migration, and high concentration of ceremonials (increase in sexual intercourse) at the time of conception nine months earlier between November and January. The following low delivery rate period (December to March) reflects a low period of conception nine months earlier (March to June) that corresponds with high labour migration and thus reduced cohabitation between marital spouses. The findings suggest that, in the present context, annual male labour migration, which generally occurs outside the crop-growing season, has a depressing effect on monthly fertility (Hampshire & Randall, 2000; Omondi & Ayiemba, 2003; Chattopadhyay *et al.*, 2006; Armah *et al.*, 2010). In Kéniéba, temporary labour migration is extensively practised, as it involves lucrative gold mining activities. There, labour migration often lasts from January to June, such that these workers miss the beginning and the very end of the agricultural season. Independent of seasonality, the lower birth rates (less than 50%) observed in Kéniéba as compared with the other districts may reflect lower fertility, which has already been observed to be a result of the migration phenomenon (Yadava & Yadava, 1990; Omondi & Ayiemba, 2003; Chattopadhyay *et al.*, 2006). In Yélimané, traditional long-term labour migration (in the order of years) may explain the non-significance of seasonal labour migration in explaining delivery rates. Access to health care seems not to be associated with the rainy period, except for Kéniéba, which is a mountainous region with lot of impassable roads.

The findings support a model of birth seasonality that relates climatic variables to variation in fertility through causal chains that link rainfall, on the one hand, to agricultural cycles that influence workload and food supply, and ultimately energy balance, ovarian function and fecundity, and on the other hand, to ecological cycles that influence exposure to malarial infection, leading to fetal loss and lower rates of conception. The findings are consistent with worldwide patterns in rural natural

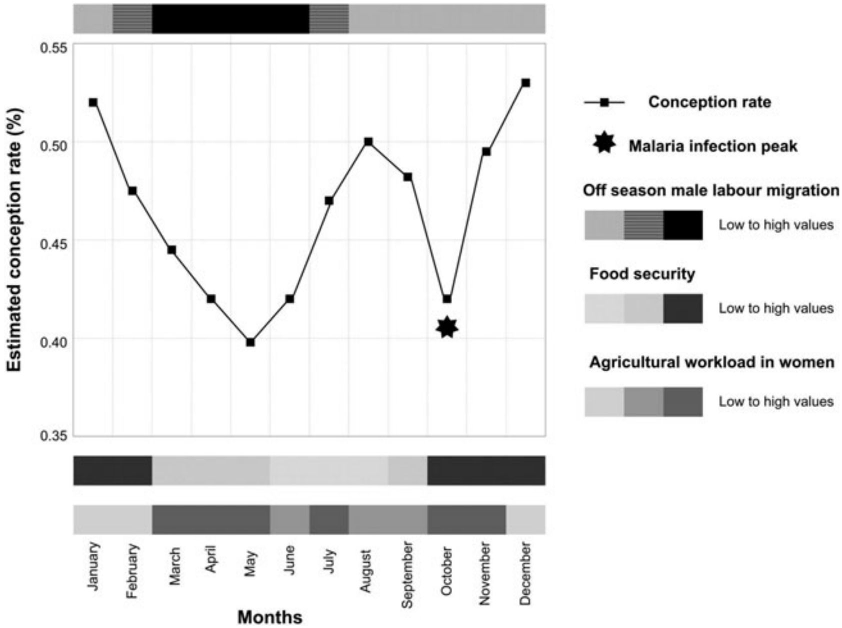

Fig. 7. Ecosystemic scheme of birth seasonality that integrates climatic factors, such as malaria infection season, as well as multiple agricultural-cycle-dependent factors, such as labour migration, food security and farming workload.

fertility populations whose subsistence is based on agriculture and who are vulnerable to changes in food availability and periodic food shortages. With increased climatic uncertainty and irregularities in rainfall, greater variation in seasonal pattern may be expected as an effect of the growing unreliability of food supply (Bentley *et al.*, 1998). It could have been hypothesized that food supply reliability would be more correlated with birth seasonality during years of severe hunger. Labour migration is an opportunity to compensate for failures and uncertainties in subsistence agriculture by offering supplementary food, jobs and income (Armah *et al.*, 2010). Seasonal migration in sub-Saharan countries, which is mainly rural-to-urban migration, is a significant component of the economic life of rural dwellers, who are most dependent on rain-fed subsistence agriculture (Hampshire & Randall, 2000; Armah *et al.*, 2010). Climate uncertainty has made it increasingly difficult to predict fluctuations in crop yield and seasonal variability and many people have chosen to diversify their livelihoods both occupationally and geographically rather than invest in sustainable agriculture (Armah *et al.*, 2010).

This study may suffer from a selection bias, since only institutional deliveries in primary health centres (about 60%) were captured. Nevertheless, data collection in all the primary health centres of the seven districts was exhaustive. Moreover, as the delivery data were controlled by the weighted travel time to health facilities over the year, it is unlikely that the seasonal pattern of deliveries was influenced by access barriers during the rainy season. The fact that the CSREFs' quarterly records of births and malaria cases could not be used in the monthly database meant that the study was oriented even more toward rural dwellers than semi-urban dwellers. Given that most health centres have only recently begun systematically registering deliveries, the analysis of such data is still in the exploratory phase, and no previous studies are available for comparison. The hypothesis of food supply reliability being an underlying factor in birth seasonality would have been more appropriately explored at the community level to test nutrition status. Nevertheless our tentative attempt to link food supply and conception rates showed significant relationships in the models. Since seasonal patterns are not perfectly stable, peaks and troughs shift slightly backward and forward in response to small irregularities in local rainfall, which regulate the crop-growing season and labour out-migration. As a whole, the monthly rainfall pattern did not vary over the years, which explains why the birth seasonality pattern is recurrent from year to year. While conclusive evidence of causality of the relationships cannot be obtained, the good performance of the models and the similar bimodal patterns in birth seasonality among the districts studied support the findings. The pattern and the magnitude of year-to-year delivery rates remain similar in each health district.

The models presented here emphasize an ecosystemic approach to the study of birth seasonality that integrates climatic factors, such as malaria infection season, as well as multiple agricultural-cycle-dependent factors, such as economic migration, food security and farming workload (see Fig. 7). Some transition patterns are observed from dry to wet areas, which are associated with a longer crop-growing season. A longer agricultural activity period is associated with a shorter male labour migration period, and thus, a longer period of high birth rate over the year. An exception to this is Kéniéba, where men passed up working in the fields for part of the crop-growing season, preferring to work at gold mining locations. Seasonal pattern of male out-migration translates into significant changes in birth rates.

Conclusions

The findings clearly show an influence of agricultural cycle and labour migration on month-to-month birth seasonality in the Kayes region in Mali and support a multiple causality for birth seasonality. They indicate a spring trough in conception (March–June) that is probably associated with behavioural factors, such as male out-migration, while the rainy season trough in conception (October) is consistent with biological factors that depress fecundity (mainly malaria infection). The peak of conception during the pre-harvest season (July–September) results from behavioural factors (return of men and cohabitation), and the peak during the post-harvest period in winter results from biological (good food supply and low agricultural workload) and behavioural factors (concentration of marriages and various cultural events). These findings support a model of conception/birth seasonality relating climatic variables to variation in fertility through a series of causal chains linking, on the one hand, annual rains to malaria transmission and fetal loss, and on the other, annual rains to agricultural cycles and thus to food production, agricultural workload and socio-cultural events, which in turn are linked to energy balance (ovarian function or spermatogenesis) and/or sexual intercourse. Labour migration, which is again closely linked with the agricultural cycle, influences sexual intercourse and then marital fertility. The model emphasizes an ecosystemic approach to the study of birth seasonality. Planning strategies are needed that take into account the effects of climate uncertainty, such as the unpredictability of food crop production and increasing male labour out-migration. Understanding the environmental and the socio-cultural drivers of birth seasonality provides new insights to inform strategies for managing assisted deliveries in health centres.

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