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Distribution and determinants of early marriage and motherhood: a multilevel and geospatial analysis of 707 districts in India

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Abstract

Background Early marriage and motherhood have long been prevalent in India, with 44.5% of women aged 20–24 reporting marriage before 18 in NFHS 3 (2005–2006), dropping to 26.8% in NFHS 4 (2015–2016). Early motherhood has also seen a significant decline, with first births by age 18 decreasing from 34.3% in NFHS I to 8.2% in NFHS V. Despite these improvements, significant regional disparities persist due to social, normative, and legal factors. This study investigates the spatial heterogeneity of early marriage and motherhood across Indian districts, offering a multilevel analysis that reveals critical local variations often obscured at broader levels. Understanding these patterns is crucial for targeted policy interventions and addressing the root causes of early marriage and motherhood.

Methods Utilizing data from the fifth round of National Family Health Survey, this study employs multilevel logistic regression and geospatial analysis to assess the determinants and spatial distribution of early marriage and early motherhood among ever-married women in India. The analysis incorporates individual, household, and community-level variables, complemented by spatial analysis techniques, including Empirical Bayes Bivariate Moran's I values and LISA cluster maps, to identify regional patterns and hotspots.

Results This study revealed that educational attainment emerged as a critical determinant, with uneducated women significantly more likely to marry early. Socioeconomic factors, such as poverty and limited mass media exposure, also heightened the risk of early marriage and motherhood. Caste and religion were significantly associated with these events, with marginalized groups facing higher prevalence. Spatial analysis revealed significant geographic disparities, with central and eastern regions showing higher concentrations of early marriage and motherhood. District-level characteristics and the influence of neighboring districts were also significant, highlighting the importance of localized interventions.

Conclusions The findings underscore the critical role of education, economic empowerment, and media literacy in mitigating early marriage and motherhood risks. The study calls for multi-sectoral interventions in geographical hotspots to break the cycle of early family formation and promote reproductive health. Policies enhancing educational opportunities, addressing economic disadvantages, and considering district-specific factors are essential. Comprehensive strategies are necessary to empower women, foster reproductive health, and address the multifaceted nature of early marriage and motherhood in India.

Keywords Early marriage, Early motherhood, Multilevel analysis, Geospatial analysis, Districts of India, NFHS-V

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Introduction

Early marriage refers to any formal or informal union between a male and female under the age of 18 worldwide; 21% of women alive in 2020 were married before their 18th birthday, and about 12 million girls under 18 are married each year—this is about 23 girls married as children every minute [1]. Globally, marriage is widely celebrated as a significant milestone in adult life, recognized as a universal social institution by the United Nations since 1990 [2]. This institution typically involves the union of an adult male and an adult female, conferring upon them the social roles of husband and wife [3]. Despite its societal importance, early marriage prevails worldwide, posing numerous challenges, particularly for women when they marry at a young age. This practice, prevalent globally, has severe and harmful consequences for young individuals, especially females, who are compelled to enter matrimony prematurely [4]. Worldwide Sixty million marriages occur before the age of eighteen, reports UNICEF. In addition to violating children's fundamental human rights, the practice of early marriage deprives them of their rights to health, learning, and safeguarding against violence, extortion, and assault [5]. A study conducted in the U.S. found that 25% of women marry before age 23 [6]. According to the U.S. Census Bureau, a significant proportion of young people continue to marry at young ages: 19% of 20–24 years old, including 13% of men and 25% of women have married [7]. Bangladesh has one of the highest rates of child marriage in the world, at 66%, according to UNICEF flagship research [8]. Observational studies from low-income countries indicate that young women who stay in school marry late, while those who skip school early are more likely to marry and become pregnant earlier [9, 10]. Primary school Enrolment has increased significantly in many poor countries in the last decade. Nonetheless, enrolment at the secondary level is much lower than at the primary level in most low-income countries, particularly for girls [11]. A study by Marshan et al. in Indonesia found that Indonesia has a significantly lower rate of early marriage than other emerging nations in Sub-Saharan Africa and South Asia. In addition, Jones and Gubhaju (2008) discovered that, although there has been a noticeable decline in the average age of marriage in Southeast East Asia [12], including Indonesia, the prevalence of marriage is still high compared to other industrialized nations [13].

As India has a long history of early marriage, the issue of early marriage is still a result of a complicated web of cultural practices, social norms, economic considerations, and deeply ingrained prejudices; fifteen years ago, 44.5% of Indian women aged 20–24 who participated in the National Family Health Survey (NFHS) 3 (2005–2006) were married before turning 18 [14]. With 26.8% of Indian women aged 20 to 24 reporting marriage before the age of 18, more recent numbers from NFHS 4 (2015–2016) demonstrate a notable drop in early marriage [15]. furthermore, marriage-related socio-religious practices, women's autonomy, area, and level of urbanization all had a substantial impact on early marriage. Regional differences in early marriage prevalence may be explained by variances in sociocultural norms about marriage, the social value of girls, and familial organization [16]. At the district level, urbanization has some impact on early marriage. These findings compare to country-level research undertaken in developing nations [17].

There are differences in the frequency of early marriage, District-level disparities are probably hidden from view by national and even state-level assessments of these variables [18–22]. States in India differ greatly from one another not only in terms of population, geography, economy, religion, and culture, but also in terms of the scale at which programs aimed at reducing child marriage are typically implemented (International Institute for Population Sciences [23–26]. These localized norms may contribute to the continuation of the practice of child marriage in certain states and communities in India, even as the prevalence of child marriage has declined for the nation as a whole. the sub-national variability of child marriage in India requires an awareness of these relationships between neighbouring states. While the administrative capabilities and legal frameworks of Indian states may vary from one another [27], many state boundaries can be viewed as culturally porous, with members of the same caste or sub-caste communities residing in neighboring states [25]. This is significant in the context of child marriage as, historically, Indian marriages have taken place between members of the same caste or group [28]. Families have been known to purchase brides from other states in places like Rajasthan, where the bulk of the girls are minors, because of the state's male-to-female sex ratio [27, 29]. Although no academic studies have examined the spatial prevalence of this practice to the authors' knowledge, it is possible that these transactions are more widespread throughout border regions. In fact, we uncover evidence of substantial and adverse indirect effects of distance to state borders, showing that child marriage prevalence is often greater in districts whose neighbouring districts are located close to state boundaries. These findings appear to support the hypothesis that state borders are where the illegal practice of child marriage is concentrated, suggesting the need for more targeted prevention initiatives. The prevalence of child marriage was shown to be highly positively correlated with the population density of nearby districts. Spatial heterogeneity analysis revealed that this correlation was

especially strong in regions of West Bengal, Karnataka, Chhattisgarh, and Jharkhand. Geographically specific factors that could affect this association in these locations include low levels of female education and high percentages of marginalised populations.Spatial demographers consider the place an essential determinant of attitudes and behaviour. An apparent reason is that geographic features can inhibit or facilitate behaviours due to commonalities such as structural access to resources (for instance, distance to a health clinic). More importantly, perhaps, place is essential because it is through spatial clustering of socially connected individuals that clustering of social norms typically occurs [30, 31] among a significant portion of women. Furthermore, many women continue to get married around 18 or shortly after. Thus, they can face the same issues as brides who are too young [32].

Similarly, early motherhood, poses a significant health risk to young women. Because of the numerous health repercussions and socioeconomic ramifications for both the mother and the child, early motherhood is considered a serious global public health concern. 11% of all births globally occur among the estimated 16 million women between the ages of 15 and 19 who give birth yearly [33]. Compared to high-income nations, the average adolescent birth rate is two times higher in middle-income countries and five times higher in low-income countries [33]. Notwithstanding a notable 11.6% reduction in adolescent-specific fertility rates over the previous 20 years worldwide, some 21 million females between the ages of 15 and 19 become pregnant in developing nations [34]. In many developing nations, half and three-quarters of all married women's first births occur in less than two years after the ladies enter their first relationship. Early motherhood is still common in low- and middle-income countries (LMICs), where 18 million teenage girls give birth annually, or 95% of all adolescent births worldwide [35, 36]. Every year, some 7.3 million females under the age of 18 give birth in low- and middle-income nations. Early pregnancy is frequently linked to poverty and school dropout. In low-income countries, maternal complications rank as the fourth most prevalent cause of death for girls between the ages of 15, and 19, and adolescent pregnancies have a higher risk of prematurity and low birth weight, which increases morbidity and mortality [37].

In South Asia, the problem of early motherhood is compounded by the cultural norm to have children soon after marriage. Delaying the age of marriage in South Asian countries will, therefore, also delay when young women first have children; however, the occurrence of early marriage in these countries leads to early motherhood [38]. Furthermore, India has a population of 253 million adolescents aged 10–19 years. The 4th National Family Health Survey estimates indicate that 11.8 million early motherhoods occurred in India [39], the percentage of early motherhood at exact age 15 for the women of current age group 15–19 was 6.8% in NFHS I and 0.1% in NFHS V. For the age group 20–24, in NFHS I, 34.3% women already had their first birth at the age of 18 which is declined to 8.2% in NFHS V with approx. decrement of 76.1% [15]. According to certain research, the economic, social, and educational structures of society can have an impact on pregnancy during adolescence in addition to individual traits moreover behaviors, attitudes, values, and opportunities of the individuals are influenced by the characteristics of the community. These ecological or spatial model components take into account in the context of various ecological systems or habitats in which they reside, including relationship, families, home, community, neighbourhood, schools, and workplaces [40–42]. The foundation of these models is that studying an individual without considering the spatial and geographical systems in which they exist may miss the important aspects of the occurrence of early motherhood. People are organized geographically; thus, behaviours and values can be considered by analyzing the group structure [43–46].

The country as a whole has seen a decrease in early marriage and early motherhood. More recently, social norms have been emphasized in development and public health interventions to address early marriage and motherhood. These interventions emphasize community engagement and social and behaviour change techniques to influence these norms at the community level [47]. According to spatial demographers, location plays a significant role in determining attitudes and behaviours. One obvious explanation is that, due to shared characteristics like structural access to resources, geographic factors can promote or impede certain behaviours (for instance, distance to a health facility). Perhaps more importantly, location matters since social norms are often clustered through the spatial clustering of socially connected persons [30, 31]. Spatial heterogeneity examines how a relationship between certain traits or behaviours typically quantifiable at a single and more aggregate level, like a national-level estimate—may differ depending on the location, such as how the same relationship may appear in various villages, communities, or districts. There are differences in the frequency of early marriage and early motherhood, the social and normative aspects contributing to it, and the laws and programs intended to address it throughout India. Analysis of these characteristics at the national and even state levels probably conceal disparities at the local level [48–51]. States in India differ significantly from one another not only in terms of population, geography, economy, religion, and culture

but also in terms of the scale at which programs aimed at reducing early marriage and early motherhood [26, 52].

This geographic analysis of early marriage and early motherhood is designed to explore sociodemographic variations in the prevalence of these two events and the social and connectivity factors that may influence the prevalence of early marriage and early motherhood in India. The objectives are to assess geographic variations in these two events across Indian districts, identify cold and hot spots, and quantify spatial heterogeneity and spatial dependency in early marriage and motherhood factors. Comprehending how normative social factors influencing early marriage and motherhood concentrate, spread, and interact differently within and between different geographic areas reveals location-specific differences that could potentially improve the focus of social and behavior change prevention initiatives.

Data and method

Data source

Latest round of the National Family Health Survey (NFHS-V), 2019-21, popularly known as Demographic Health Survey (DHS) globally has been used as a data source. This survey collects the data for 707 districts nested within 36 states and union territory, covering 7,24,115 eligible women in the age group 15–49 years. A two-stage stratified sampling design in urban and rural areas was used. Additionally, for the selection of primary sampling units i.e., villages in rural areas and census enumeration blocks in urban areas, the 2011 census served as a sampling frame. The NFHS contains detailed information about age at occurrence of reproductive events like age at menarche, age at first marriage, age at first cohabitation, age at first sex age at first birth, etc. This survey also includes thorough information on demographics, family planning, nutrition, maternal and child health, reproductive outcomes, and other maternal health issues. The present study used the national as well as district-level estimates of early marriage and early motherhood to see their predictors and spatial heterogeneity across 707 districts, provided by NFHS 2019-21.

Variable description

In this study, for early marriage 1,71,199 ever or currently married women aged 20–29 years, whose age at marriage reported, were drawn from the overall sample of 7,24,115 women aged 15–49 years (Table 1). Additionally, for early motherhood 1,36,674 women aged 21–29 years whose age at first birth reported in the survey were taken from the overall sample of 7,24,115 women aged 15–49 years (Table 1). Therefore, if the women in the age group 20–29 years never had married or not reported their marriage date or year of marriage, she was excluded from the study for early marriage. Similarly, in the case of early motherhood, all those women aged 21–29 years who had not given their first childbirth information were excluded from the study (Appendix Figure A1).

Table 1 Distribution of weighted samples of married and motherhood women by background characteristics

Characteristics	First marriage[a]		First motherhood[b]	
	N	Percentage	*N*	Percentage
Regions				
East	32,307	18.9	26,293	19.2
West	16,679	9.7	12,976	9.5
North	32,008	18.7	25,295	18.5
South	25,101	14.7	19,734	14.4
Central	42,690	24.9	33,821	24.8
Northeast	22,414	13.1	18,555	13.6
Place of residence				
Urban	47,235	27.6	36,737	26.9
Rural	1,23,964	72.4	99,937	73.1
Education				
No education	25,435	14.9	22,224	16.3
Primary	19,878	11.6	17,191	12.6
Secondary	95,571	55.8	76,492	56.0
Higher	30,315	17.7	20,767	15.2
Social group				
SC	39,128	24.0	31,216	24.0
ST	16,796	10.3	13,496	10.4
OBC	74,303	45.6	59,209	45.5
Others	32,835	20.1	26202.5	20.1
Religion				
Hindu	1,39,732	81.7	1,11,414	81.6
Muslim	24,541	14.3	19,823	14.5
Christian	3,053	1.8	2,417	1.8
Others	3,812	2.2	2,973	2.2
Wealth				
Poorest	34,572	20.2	28,807	21.1
Poorer	36,998	21.6	30,288	22.2
Middle	35,997	21.0	28,860	21.1
Richer	35,220	20.6	27,669	20.2
Richest	28,412	16.6	21,050	15.4
Mass media				
Low	1,09,531	64.0	90,114	65.9
Moderate	41,202	24.0	32,081	23.5
High	20,466	12.0	14,479	10.6
Relation to husband prior to marriage				
No	1,46,838	85.8	1,17,455	86.1
Yes	24,361	14.2	19,036	14.0
Total	**1,71,199**	**100**	**1,36,674**	**100**

[a] Women aged 20–29 years were taken as eligible sample for first marriage,
[b]women age 21–29 years were taken as eligible sample for first motherhood,
Total sample may or may not add to N due to missing values

Outcome variable

During the survey, there were four questions asked to the respondent to know about the women's age at their first marriage and first birth. The questions are: (1) In what month and year did you get married? (2) When you married your first husband, what was the month and year of that time? (3) How old were you when you first got married? (4) In what month and year child was born? For all births of the respondent. For the early marriage we had used the variable cmc (century month code) (first) to get married to know the exact age of the respondent first got married. The dependent variable was early marriage, categorized dichotomously as yes (married before 18 years) and no (married at 18 years or thereafter), similarly early motherhood, categorized as yes (given their first birth before 21 years) and no (given their first childbirth at 21 years or thereafter).

Explanatory variables

Socioeconomic and demographic covariates included in the study were categorized as follows Place of residence was taken as rural and urban as provided in the survey. Religion was recorded as Hindu, Muslim, Christian, and Others. Ethnicity (Caste) was recorded as SC, ST, OBC, and others. Wealth Index was coded as Poorest, Poorer, Middle, Richer, and Richest. Educational status of respondents was recorded as No education, Primary, Secondary, and Higher. Mass Media exposure was coded as Low, Moderate, and High for the questions (i) Do you read a newspaper or magazine almost every day, at least once a week, less than once a week, or not at all? (ii) Do you listen to the radio almost every day, at least once a week, less than once a week, or not at all? (iii) Do you watch television almost every day, at least once a week, less than once a week, or not at all? (iv) Do you usually go to a cinema hall or theatre to see a movie at least once a month? Regions of India were coded as East, West, North, South, Central, and Northeast. Relation to husband before marriage was coded as yes and no. However, district-level educational attainment, socioeconomic status, and marginalized population are included as community-level variables in the study. These variables capture important attributes of the broader community context and are essential for accurately modelling and understanding the geographical variations within communities. In case of geospatial regression analysis meso scale correlates refers to the factors or variables that operates at an intermediate geographical scale typically between the macro-scale (regional i.e. district level).

Statistical analysis

Descriptive statistics like frequency and percentage distribution of respondents by various socio-demographic characteristics were computed. Bivariate analysis was used to inspect the association between predicted and predictor variables.

To investigate the clustering effect of the variables of early marriage and motherhood, multilevel multivariable logistic regression analysis was used. Four-level random intercept logistic models were specified to dissect the variation in the prevalence of early marriage and motherhood, for the probability of an individual 'i' in PSU 'j', district 'k', and state 'l' to have an early marriage and motherhood (Yijkl = 1, if an event occurs) as

$$\mathbf{Logit}(\pi_{ijkl}) = \boldsymbol{\beta}_0 + \boldsymbol{\beta}\mathbf{X'_{ijkl}} + (\mathbf{f_{01}} + \mathbf{V_{0kl}} + \mathbf{u_{0jkl}})$$

This model calculated the log-odds (π_{ijkl}) adjusted for a vector ($\mathbf{X}'_{ijkl}$) of the aforementioned independent variables measured at the individual level. The parameter β0 denoted the log-odds of having early marriage and motherhood for women belonging to the categorical variables' reference category. The random effect inside the brackets was interpreted as a residual differential for the state l (f_{0l}), district k (v_{0kl}) and PSU j (u_0jkl). All three residuals were assumed to be independent and normally distributed with mean 0 and variance $\sigma^2 f_0$, $\sigma^2 v_0$, and $\sigma^2 u_0$. This variance was quantified between states ($\sigma^2 f_0$), district ($\sigma^2 v_0$), and between PSU ($\sigma^2 u_0$), respectively, in the log-odds of women with early marriage and motherhood for all background characteristics. For binary outcome, the variance at the individual level (lowest level) could not be obtained directly from the model instead it is assumed to follow a logistic distribution with a fixed variance of $\pi^2/3$ or 3.29 [53]. We then computed the variance partitioning coefficient (VPC using the latent variable approach) to assess the significance of each geographical unit (z) using the following formula, $\boldsymbol{VPCz = \sigma^2_z / (u_0 + v_0 + f_0 + 3.29)}$ [54].

We fitted four models with relevant variables. Model 1 (the empty model) was the first one to be fitted, and it determined whether or not the outcome variable (early marriage and early motherhood) varied across different levels. The second model (Model 2) was created to investigate the relationship between individual-level characteristics with early marriage and motherhood. The third model (Model 3) was created to investigate the links between household and individual characteristics with early marriage and motherhood. The complete model (Model 4) included both components at the individual/household and community levels. Both

fixed effects and random effects were included in the multilevel logistic regression analysis [55, 56]. Using adjusted odds ratios with a 95% confidence interval, the fixed effects (measures of association) looked at associations between explanatory factors and outcome variables, while the random effect measured variation in outcome among clusters and was expressed using intraclass correlation (ICC) and variance partitioning coefficient (VPC) [56]. The Akaike information criterion (AIC) was used to assess the model's fit, and the Likelihood Ratio (LR) was utilized to determine whether the model was adequate. Each additional model's AIC value was compared, and the model with the lowest AIC value was deemed to be the best-fit model [57]. The entire model best fits the data since it has the minimum AIC value among the models taken into consideration.

To comprehend the spatial dependence and clustering of early marriage and motherhood, univariate and bivariate Moran's I statistics, local indicators of spatial association (LISA Map), and significant maps were used. A univariate LISA map was used to show the geographic clustering of the study's variables, and a bivariate LISA map was utilized to assess the correlation between the predicted and weighted average of the predictor variables in a given district. Moran's I generally use numbers between 1 and +1, with positive numbers denoting spatial clustering of values that are similar and negative numbers denoting spatial clustering of values that are dissimilar. Zero values signify random geographical patterns without any spatial autocorrelation.

To understand the significant predictors of early marriage and early motherhood at the district level, a set of regression models was used to give the best fit of the data. At first, we used the Ordinary Least Square (OLS) regression with each of the outcome variables and estimated the extent of spatial autocorrelation in the error term and the corresponding Moran's I statistic. Since the OLS confirmed spatial autocorrelation in its error term for the outcome variable, we further estimated the Spatial lag model (SLM) and Spatial Error Model (SEM). Further, among these two models (SLM and SEM), the model with a lower AIC value was considered the best spatial fit model.

For descriptive statistics, bivariate and multilevel analysis STATA 16.0 were used. Further, to visualize the district-level prevalence of early marriage and motherhood and for preparing the shape file, Geographical Information System (ArcGIS version 10.4) software was used. Further, to check the spatial dependence, GeoDa software was also used as a statistical tool.

Ethical consideration

Because our research is based on previously collected survey data, in which any identifying information about a specific person has been deleted. Before taking part in the survey, all participants gave their informed consent, and all data was collected confidentially. The Measure DHS International Program gave written permission to use the data, and the dataset was made public. As a result, no permission is required to utilize the dataset.

Results

Table 1 illustrates the weighted distribution of women who have married and experienced their first motherhood based on various background characteristics. The study included a total of 171,199 women aged 20–29 years with recorded age at first marriage and 136,674 women aged 21–29 years with recorded their age at first motherhood. Among the women in the first marriage sample, approximately 24.9% were from the central region, while 18.9% were from the east region. The majority of respondents (72.4%) resided in rural areas, and around 14.9% had no formal education. Additionally, about 45% of the women belonged to the Other Backward Classes (OBC). The majority (81.7%) of the respondents identified as Hindu, with 20.2% falling into the poorest socioeconomic group and 16.6% in the richest group. Most respondents (81.7%) had limited exposure to mass media, and 85.8% had no previous relationship with their husbands. In the recorded first motherhood samples, 24.8% of respondents were from the central region, followed by 19.2% from the east region. Similarly, the majority of respondents were from rural areas and identified as Hindu (81.6%). About 16.3% of women were illiterate, and 45.5% belonged to the OBC category, with 24.0% belonging to the Scheduled Caste (SC). More than one-fifth (22.2%) of women were classified as being in the poorer category, and 65.9% of respondents had limited exposure to mass media. Furthermore, 86.1% had no exposure to mass media.

Table 2 displays the bivariate distribution of early marriage and early motherhood across various background characteristics. Among the total sampled women, 63,169 women (36.9%) experienced early marriage, while 77,691 women (56.8%) had their first child at an early age. In terms of regional distribution, nearly 47% of women in the eastern region entered into early marriages, followed by the northeast and central regions with 34.8% and 34.4%, respectively. Similarly, 66.5% of women in the eastern region gave birth to their first child at an early age, followed by the northeast and central regions of the country. The data also reveals that approximately 4 out of 10 women in rural areas were married before the age of 18, while 6 out of 10 women

Table 2 Bivariate analysis showing the distribution of early marriage, early motherhood by background characteristics

Characteristics	Early marriage (Yes): *N* (%)	Chi square (*P*-value)	Early motherhood (Yes): *N* (%)	Chi square (*P*-value)
Regions				
East	15,314 (47.4)	0.000	17,485 (66.5)	0.000
West	5575 (33.43)		6997 (53.9)	
North	8685 (27.13)		11,719 (46.3)	
South	7878 (31.39)		10,771 (54.6)	
Central	14,684 (34.4)		17,801 (52.6)	
Northeast	7818 (34.88)		11,002 (59.3)	
Place of residence				
Urban	13,368 (28.3)	0.000	18,183 (49.5)	0.000
Rural	49,801 (40.2)		59,508 (59.6)	
Education				
No education	14,547 (57.2)	0.000	15,672 (70.5)	0.000
Primary	10,639 (53.5)		12,113 (70.5)	
Secondary	35,294 (36.9)		45,300 (59.2)	
Higher	2689 (8.9)		4606 (22.2)	
Social group				
SC	15,618 (39.9)	0.000	18,594 (59.6)	0.000
ST	6708 (39.9)		8221 (60.9)	
OBC	26,622 (35.8)		32,633 (55.1)	
Others	10,406 (31.7)		13,723 (52.4)	
Religion				
Hindu	51,564 (36.9)	0.000	62,592 (56.2)	0.000
Muslim	9822 (40)		12,424 (62.7)	
Christian	847 (27.7)		1234 (51.1)	
Others	910 (23.9)		1410 (47.4)	
Wealth				
Poorest	18,393 (53.2)	0.000	20,110 (69.8)	0.000
Poorer	16,828 (45.5)		19,329 (63.8)	
Middle	13,357 (37.1)		16,855 (58.4)	
Richer	9989 (28.4)		13,836 (50)	
Richest	4602 (16.2)		7560 (35.9)	
Mass media				
Low	46,965 (42.9)	0.000	55,755 (61.9)	0.000
Moderate	11,736 (28.5)		15,733 (49)	
High	4468 (21.8)		6202 (42.8)	
Relation to husband prior to marriage				
No	53,730 (36.6)	0.000	65,989 (56.2)	0.000
Yes	9439 (38.8)		11,600 (60.9)	
Total	**63,169 (36.9)**		**77,691 (56.8)**	

had their first child before the age of 21. Furthermore, a significant portion of uneducated women (57.2% for early marriage and 70.5% for early motherhood) experienced early marriage and early motherhood. The prevalence of early marriage and early motherhood was highest among Muslim women, followed by Hindu women. Additionally, women in the poorest socioeconomic category and those with limited exposure to mass media had a higher likelihood of experiencing early marriage and early motherhood in India.

The results presented in Table 3 showcase a classical multilevel logistic regression analysis examining the factors associated with early marriage in India at both individual/household and community levels. These results highlight significant variations at the state, district, and PSU (Primary Sampling Unit) levels regarding early marriage, with Model 4 being the best-fitted model, as evidenced by its lowest values of AIC, BIC, and log-likelihood among all models. In Model 1 (the Null Model), it is observed that there is significant variance at the state, district, and PSU levels, with values of 0.45, 0.24, and 0.28, respectively. These variances indicate heterogeneity in early marriage prevalence at different levels. Since both the variance and the ICC (Appendix Table A1) are greater than zero, it suggests that multilevel analysis is an appropriate approach for further investigation. Model 2 considers individual-level factors such as age, education, mass media exposure, and prior relationship with the husband, all of which are significantly associated with early marriage. Importantly, these factors remain significant even after controlling for household-level factors in Model 3 and household/community-level factors in Model 4. In Model 4, the analysis demonstrates that as the respondent's level of education increases, the likelihood of early marriage decreases significantly. For instance, women with primary education (AOR: 0.93; CI: 0.89–0.97), secondary education (AOR: 0.53; CI: 0.51–0.54), and higher education (AOR: 0.12; CI: 0.11–0.12) all have lower odds of early marriage compared to those with no formal education. Women who had a prior relationship with their husbands were 1.2 times more likely to experience early marriage. Additionally, Muslim and Christian women had 17% and 16% lower chances of early marriage, respectively, compared to Hindu women. Women belonging to the Other Backward Classes (OBC) had 1.26 times higher odds of early marriage compared to Scheduled Tribe (ST) women. The odds of early marriage decreased significantly with increasing wealth among women. The analysis also reveals that the variation in early marriage is attributed to differences between districts, with Model 1 showing 13% variation (ICC: 0.13; CI: 0.1–0.18), which is reduced to 7% in the full Model 4 (ICC: 0.07; CI: 0.05–0.08). This suggests that clustering at the district level may be responsible for the variations in the likelihood of early marriage. Similarly, for the state level, the variation ranges from 9% in Model 1 to 3% in Model 4.

Table 4 presents the findings from a classical multilevel logistic regression analysis that explores the factors associated with early motherhood in India, considering

Table 3 Classical multilevel logistic regression analysis of individual/household and community level factors associated with early marriage in India

Background Variables	Model 1	Model 2	Model 3	Model 4
Individual-level Factors	**AOR [95% CI]**	**AOR [95% CI]**	**AOR [95% CI]**	**AOR [95% CI]**
Age (Ref: 20–24)				
25–29		0.98 [0.96,1.00]	1.00 [0.99,1.03]	1.01 [0.99,1.03]
Education (Ref: No education)				
Primary		0.91*** [0.88,0.95]	0.93*** [0.89,0.97]	0.93*** [0.89,0.97]
Secondary		0.48*** [0.46,0.49]	0.52*** [0.50,0.54]	0.53*** [0.51,0.54]
Higher		0.09*** [0.09,0.10]	0.11*** [0.11,0.12]	0.12*** [0.11,0.12]
Mass Media (Ref: Low)				
Moderate		0.87*** [0.84,0.89]	0.93*** [0.90,0.96]	0.93*** [0.90,0.96]
High		0.77*** [0.74,0.81]	0.84*** [0.80,0.88]	0.84*** [0.81,0.88]
Relation to husband prior to marriage (Ref: No)				
Yes		1.12*** [1.09,1.16]	1.15*** [1.11,1.19]	1.15*** [1.11,1.19]
Household-level factors				
Place of residence (Ref: Urban)				
Rural			0.96* [0.93,1.00]	0.96* [0.92,1.00]
Social group (Ref: ST)				
SC			1.26*** [1.21,1.30]	1.19*** [1.15,1.24]
OBC			1.37*** [1.32,1.42]	1.26*** [1.21,1.31]
Others			1.24** [1.19,1.29]	1.16*** [1.10,1.21]
Religion (Ref: Hindu)				
Muslim			0.84*** [0.80,0.87]	0.83*** [0.79,0.87]
Christian			0.83*** [0.76,0.90]	0.84*** [0.77,0.91]
Others			0.81*** [0.75,0.88]	0.82*** [0.75,0.89]
Wealth (Ref: Poorest)				
Poorer			0.91*** [0.88,0.94]	0.91*** [0.88,0.94]
Middle			0.79*** [0.76,0.82]	0.79*** [0.76,0.82]
Richer			0.67*** [0.64,0.70]	0.67*** [0.64,0.70]
Richest			0.49*** [0.46,0.52]	0.49*** [0.46,0.52]
Community (district) level factors				
Percentage of below primary education				1.02*** [1.01,1.01]
Concentration of marginalized population(% ST)				0.99** [0.99,1.00]
Percentage poverty				1.01* [1.00,1.02]
Random effect result				
Variance for state	0.45 [0.27, 0.75]	0.23 [0.14, 0.39]	0.17 [0.10, 0.29]	0.13 [0.07, 0.21]
VPC for state	0.11 [0.07, 0.16]	0.06 [0.04, 0.10]	0.05 [0.03, 0.07]	0.04 [0.02, 0.05]
Variance for districts	0.24 [0.21, 0.27]	0.14 [0.12, 0.16]	0.13 [0.11, 0.15]	0.12 [0.10, 0.14]
VPC for district	0.06 [0.05, 0.06]	0.04 [0.03, 0.04]	0.03 [0.03, 0.04]	0.03 [0.03, 0.04]
Variance for PSU	0.28 [0.25, 0.31]	0.17 [0.15, 0.18]	0.16 [0.14, 0.18]	0.16 [0.14, 0.18]
VPC for PSU	0.07 [0.06, 0.07]	0.04 [0.04, 0.05]	0.04 [0.04, 0.05]	0.04 [0.04, 0.05]
Model fitness				
Log-likelihood	**-104695.77**	**-98231.87**	**-92873.33**	**-92847.36**
AIC	**209401.50**	**196485.70**	**185788.70**	**185742.70**
BIC	**209451.80**	**196596.30**	**185998.70**	**185982.80**

VPC Variance Partitioning Coefficient, *AIC* Akaike information criterion, *BIC* Bayesian information criterion, *PSU* Primary sampling unit, *AOR* Adjusted odds ratio, *CI* Confidence Interval. *$p < 0.05$*; **$p < 0.01$; ***$p < 0.001$

Table 4 Classical multilevel logistic regression analysis of individual/household and community level factors associated with early motherhood in India

Background Variables	Model 1	Model 2	Model 3	Model 4
Individual-level factors	**AOR [95% CI]**	**AOR [95% CI]**	**AOR [95% CI]**	**AOR [95% CI]**
Age (Ref: 21–24)				
25–29		0.55*** [0.53,0.56]	0.56*** [0.55,0.58]	0.56*** [0.55,0.58]
Education (Ref: No education)				
Primary		1.00 [0.96,1.05]	1.02 [0.98,1.07]	1.03 [0.98,1.07]
Secondary		0.59*** [0.57,0.61]	0.63*** [0.61,0.66]	0.64*** [0.61,0.66]
Higher		0.13*** [0.12,0.14]	0.15*** [0.15,0.16]	0.16*** [0.15,0.16]
Mass Media (Ref: Low)				
Moderate		0.91*** [0.88,0.94]	0.96** [0.93,0.99]	0.96** [0.93,0.99]
High		0.83*** [0.79,0.86]	0.88*** [0.84,0.92]	0.88*** [0.84,0.93]
Relation to husband prior to marriage (Ref: No)				
Yes		1.16*** [1.12,1.21]	1.17*** [1.13,1.21]	1.17*** [1.12,1.21]
Household-level Factors				
Place of residence (Ref: Urban)				
Rural			0.96* [0.92,0.99]	0.95* [0.92,0.99]
Social Group (Ref: ST)				
SC			1.12*** [1.08,1.17]	1.13*** [1.08,1.17]
OBC			1.16*** [1.12,1.21]	1.15*** [1.10,1.20]
Others			1.12*** [1.07,1.17]	1.12*** [1.06,1.17]
Religion (Ref: Hindu)				
Muslim			1.00 [0.96,1.05]	0.99 [0.95,1.05]
Christian			0.84*** [0.77,0.92]	0.85*** [0.77,0.92]
Others			0.94 [0.86,1.02]	0.94 [0.86,1.02]
Wealth (Ref: Poorest)				
Poorer			0.95** [0.91,0.98]	0.95** [0.91,0.98]
Middle			0.86*** [0.83,0.90]	0.87*** [0.83,0.90]
Richer			0.76*** [0.72,0.79]	0.76*** [0.73,0.80]
Richest			0.62*** [0.59,0.66]	0.62*** [0.59,0.66]
Community (district) level factors				
Percentage of below primary education				1.01*** [1.00,1.01]
Concentration of marginalized population(ST)				1 [1.00,1.00]
Percentage poverty				1 [1.00,1.00]
Random effect result				
Variance for state	0.26 [0.16, 0.44]	0.13 [0.08, 0.21]	0.10 [0.06, 0.16]	0.09 [0.06, 0.16]
VPC for state	0.07 [0.04, 0.11]	0.04 [0.02, 0.06]	0.03 [0.02, 0.04]	0.03 [0.02, 0.04]
Variance for districts	0.15 [0.13, 0.18]	0.08 [0.07, 0.09]	0.08 [0.07, 0.09]	0.08 [0.06, 0.09]
VPC for district	0.04 [0.03, 0.04]	0.02 [0.02, 0.03]	0.02 [0.02, 0.03,	0.02 [0.02, 0.02]
Variance for PSU	0.18 [0.16, 0.21]	0.10 [0.08, 0.12]	0.09 [0.07, 0.11]	0.09 [0.07 0.11]
VPC for PSU	0.05 [0.04, 0.05]	0.03 [0.03, 0.04]	0.03 [0.02, 0.04]	0.03 [0.02, 0.03]
Model fitness				
Log-Likelihood	**-90543.83**	**-84440.11**	**-80459.43**	**-80447.23**
AIC	**181097.70**	**168902.20**	**160960.90**	**160942.50**
BIC	**181146.80**	**169010.30**	**161166.10**	**161177.00**

VPC Variance Partitioning Coefficient, *AIC* Akaike information criterion, *BIC* Bayesian information criterion, *PSU* Primary sampling unit, *AOR* Adjusted odds ratio, *CI* Confidence Interval. *$p < 0.05$ * ; **$p < 0.01$; ***$p < 0.001$

both individual/household and community-level factors. Similar to the case of early marriage, the results indicate significant variations in early motherhood at the state, district level, and PSU level, with Model 4 being the most suitable model due to its lowest AIC and log-likelihood values among all models. In Model 1 (the Null Model), there is observable variance at the state, district, and PSU levels, with values of 0.26, 0.15, and 0.18, respectively. These variances indicate differences in early motherhood prevalence at different levels. The presence of variance and ICC values greater than zero suggests that multilevel analysis is an appropriate approach for further investigation. In Models 2, 3, and 4, individual-level factors such as age, education, mass media exposure, and prior relationship with the husband are found to be significantly associated with early motherhood, even after controlling for household and community-level factors. Model 4 demonstrates that as women's education levels increase, the odds of experiencing early motherhood decrease. For instance, women with primary education (AOR: 1.03; CI: 0.98–1.07) have slightly higher odds of early motherhood, although this difference is not statistically significant, while women with higher education (AOR: 0.16; CI: 0.15–0.16) have significantly lower odds of early motherhood compared to those with no formal education. Women who had a prior relationship with their husbands were 1.2 times more likely to have early motherhood. Similarly, as with early marriage, Muslims tend to have lower odds of early motherhood, but these estimates do not reach statistical significance, and women belonging to the Other Backward Classes (OBC) have higher odds of early motherhood. Furthermore, the odds of experiencing early motherhood decrease as women's wealth increases. The analysis also indicates that the variation in early motherhood is attributable to differences between PSUs, with Model 1 showing 13% variation (ICC: 0.13; CI: 0.1–0.16), which is reduced to 7% in the full Model 4 (ICC: 0.07; CI: 0.06–0.09). At the district level, the variation starts at 9% in the Null Model and is reduced to 5% in Model 4 (Appendix Table A1). These findings suggest that clustering at the PSU and district levels may contribute to variations in the likelihood of early motherhood.

Figure A2 demonstrates the prevalence of early marriage/cohabitation and motherhood in the district of India 2019-21. The figure illustrates that there were 218 districts where the prevalence of early marriage ranged from 25 to 36.9%, with the majority of these districts located in the northern region. Additionally, there were 177 districts with a prevalence of early marriage ranging from 37 to 48.9%. Notably, the district with the lowest prevalence of early marriage was Thrissur (3.1%), while the highest prevalence was observed in Murshidabad district (65.1%). Regarding early motherhood, there were 255 districts with a prevalence ranging from 45 to 57%, and 226 districts with a prevalence ranging from 58 to 72%. In contrast, 40 districts had a prevalence of early motherhood ranging from 17 to 31%, with the lowest prevalence occurring in Kangra district (17.6%). Additionally, 48 districts had a prevalence greater than 73% but less than 86%, with the highest prevalence of early motherhood found in the Purba Medinipur district (85.8%).

Appendix Table A2 presents the univariate and bivariate Moran's I statistics, indicating the spatial dependence for district-level prevalence of Meso scale variables associated with early marriage in India from 2019 to 2021. The univariate Moran's I value for early marriage is 0.511 (Z value: 19.68), signifying a high level of spatial autocorrelation in early marriage across Indian districts. Furthermore, the empirical Bayes Bivariate Moran's I values range from 0.076 for rural areas to 0.467 for women with no prior relationship. Among all the meso scale variables, the highest positive spatial autocorrelation with early marriage is observed for women with no prior relationship (Moran's I: 0.467, Z-value: 18.32), followed by low mass media exposure (Moran's I: 0.399, Z-value: 15.67). These findings indicate that there is a significant spatial clustering or pattern in early marriage prevalence, particularly related to women's prior relationships and their exposure to mass media.

Appendix Table A3 displays the univariate and bivariate Moran's I statistics, which illustrate the spatial dependencies for the prevalence of Meso scale variables associated with early motherhood at the district level in India from 2019 to 2021. The univariate Moran's I value for early motherhood is 0.481 (Z value: 19.07), indicating a substantial level of spatial autocorrelation in early motherhood prevalence across Indian districts. Additionally, the empirical Bayes Bivariate Moran's I values range from 0.080 for rural areas to 0.425 for women with no prior relationship. Among all the meso scale variables, women with no prior relationship (Moran's I: 0.425, Z-value: 16.76) exhibit the highest positive spatial autocorrelation with early motherhood, followed by women with no education (Moran's I: 0.380, Z-value: 14.66), and low mass media exposure (Moran's I: 0.363, Z-value: 14.45). These findings indicate that there are significant spatial patterns and clustering in early motherhood prevalence, particularly associated with women's prior relationship status, educational background, and exposure to mass media.

Figure 1 illustrates Empirical Bayes Bivariate LISA cluster maps of India, showcasing the spatial clustering (hotspots and cold spots) of various demographic indicators related to marriage and motherhood in Indian districts during 2019-21. In Map A1 and A2, it is evident that in rural India, a mere 4 out of 708 districts exhibited

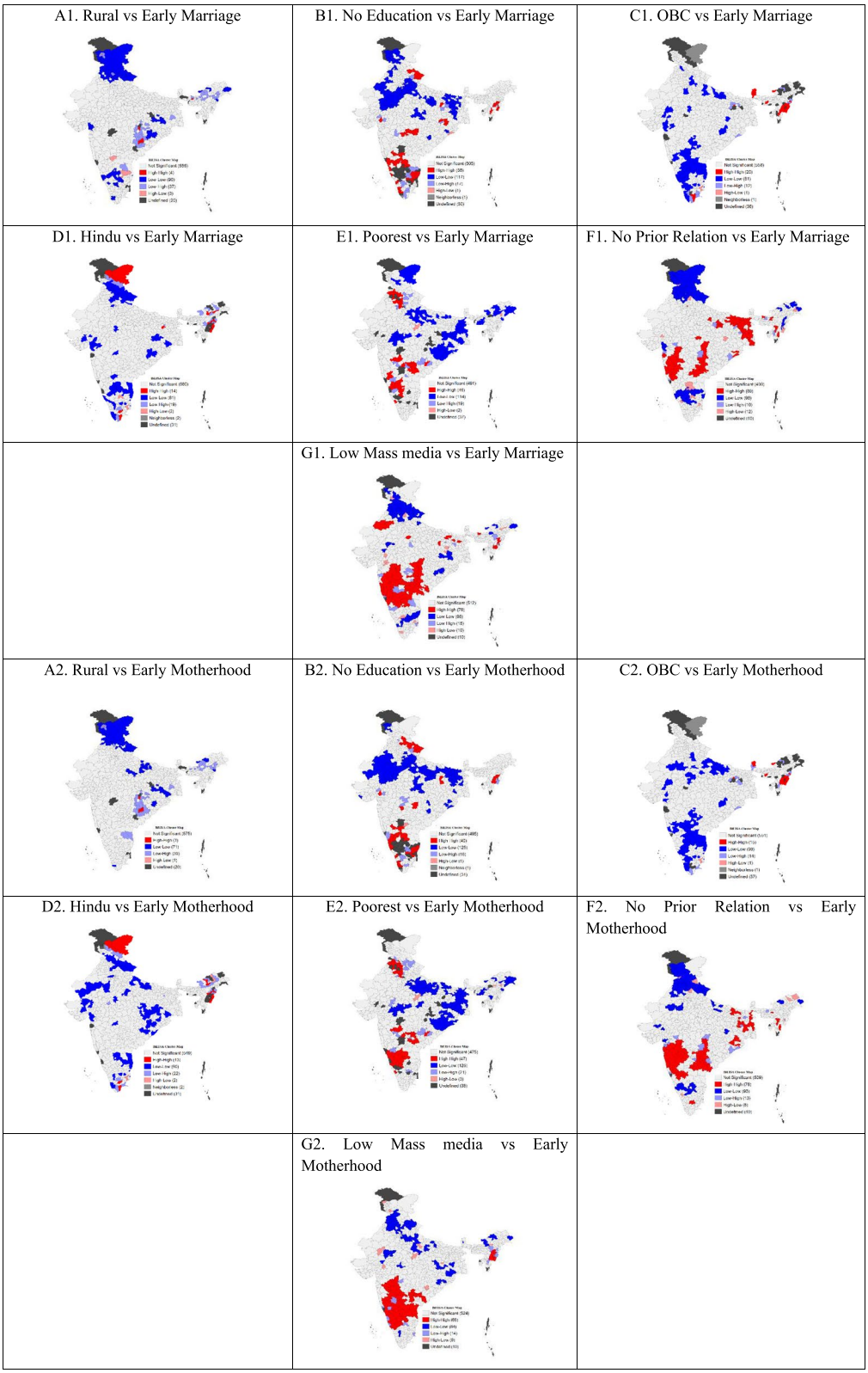

Fig. 1 Emp. Bayes Bivariate LISA cluster maps of India showing the geographic clustering (hotspots & cold spots) of early marriage and motherhood in Indian districts, 2019-21

the highest clustering (high-high) of early marriage, and 3 districts showed similar clustering for early motherhood. This indicates that these areas had a particularly high prevalence of both early marriage and early motherhood. Moving on to Map B1 and B2, we observe that 38 districts, approximately 6% of all districts in India, displayed high-high clustering of early marriage among women with no education, while 40 districts exhibited a similar clustering for early motherhood in this group. Among the poorest women, as depicted in Map E1 and E2, 46 districts were identified as high-high clustering areas for early marriage and 47 districts for early motherhood. This indicates a significant regional concentration of these demographic characteristics among economically disadvantaged populations.

Appendix Table A4, displays the adjusted coefficients of the factors associated with early marriage and early motherhood in India from 2019 to 2021. Initially, without accounting for the spatial structure of the data, an OLS regression analysis was conducted to examine the relationships between early marriage, early motherhood, and the meso-scale correlates at the district level. In OLS regression, a positive coefficient indicates that an increase in the independent variable is associated with an increase in the mean of the dependent variable, while a negative coefficient suggests that an increase in the independent variable is linked to a decrease in the mean of the dependent variable. The results in this table indicate that lack of education (no education) is significantly associated with both early marriage and early motherhood, with coefficients of 0.475 and 0.265, respectively. Furthermore, being in the poorest category and having low exposure to mass media are also significantly associated with early marriage and early motherhood, as indicated by their positive coefficients. This means that an increase in poverty or a lack of exposure to mass media is linked to higher rates of early marriage and early motherhood.

The results obtained now suggested that the prevalence of early marriage and early motherhood was not distributed uniformly across the districts of India and clustered in some particular districts. As a result, we found that there is a positive spatial autocorrelation in the prevalence of early marriage and early motherhood in the districts of India, and we estimated spatial autoregressive models to account for autocorrelation. Among the spatial autoregressive models (SEM: Table 5, SLM: Appendix Table A5), the SEM was the best-fitted regression model as AIC and Log Likelihood value was the least. Table 5, shows the adjusted coefficients of correlates for early marriage and early motherhood in India. When the OLS confirmed spatial autocorrelation in error terms for the outcome variables, we estimated the SEM. The SEM is used to consider the effect of those variables that are not present in the regression model but have an effect on the outcome variable. From this table, it can be seen that no education is significantly associated with early marriage and early motherhood having a coefficient of 0.398 and 0.253 respectively, and for low mass media it is 0.205 for early marriage and 0.192 for early motherhood that is with increase in low maa = ss media exposure early marriage and early motherhood also increased.

The current findings indicate that the prevalence of early marriage and early motherhood in India is not evenly distributed across its districts; instead, it tends to cluster in specific districts. Consequently, our analysis has revealed a positive spatial autocorrelation in the

Table 5 Result of regression analysis (SEM) showing the adjusted coefficients of the correlates for early marriage and early motherhood in India, 2019-21

District-level meso scale correlates	Early marriage		Early motherhood	
	Coef. (SE)	*P* value	Coef. (SE)	*P* value
Rural	0.002 [0.02]	0.929	0.032 [0.02]	0.120
No education	0.398 [0.048]	0.000	0.253 [0.048]	0.000
OBC	0.029 [0.022]	0.180	-0.006 [0.023]	0.799
Hindu	0.056 [0.017]	0.000	0.025 [0.017]	0.151
Poorest	0.081 [0.032]	0.011	0.08 [0.033]	0.017
No prior relationship	-0.05 [0.041]	0.215	-0.119 [0.043]	0.006
Low mass media	0.205 [0.031]	0.000	0.192 [0.032]	0.000
Lambda value (Lag coefficient)	**0.520**		**0.548**	
AIC value	**5129.94**		**5187.770**	
Log likelihood	**-2556.97**		**-2585.883**	
Pseudo R square	**0.594**		**0.530**	
No of district	**707**		**707**	

occurrence of early marriage and early motherhood within these districts. To account for this autocorrelation, we employed spatial autoregressive models, including the SEM. Among the various spatial autoregressive models tested (SEM: Table 5, SLM: Appendix Table A5), the SEM emerged as the best-fitting regression model, as evidenced by the lower values of AIC and Log Likelihood. In Table 5, we present the adjusted coefficients of factors associated with early marriage and early motherhood in India. Notably, the absence of education is significantly linked to both early marriage (with a coefficient of 0.398) and early motherhood (with a coefficient of 0.253). Moreover, for individuals with low exposure to mass media, the coefficients indicate a positive association with early marriage (0.205) and early motherhood (0.192), suggesting that as low mass media exposure increases, so does the likelihood of early marriage and early motherhood.

Appendix Table A5 presents the findings from a SLM regression analysis, highlighting the adjusted coefficients for factors related to early marriage and early motherhood in India between 2019 and 2021. The fundamental assumption underlying this model is that the outcomes of the dependent variable are influenced by the characteristics of neighbouring areas. The table reveals significant associations between early marriage and early motherhood and factors such as lack of education, economic disadvantage, and limited exposure to mass media among women.

Discussion

This study provides a comprehensive overview of the distribution of first marriage and first motherhood among women in India, with a focus on various background characteristics, emphasizing the significance of local factors that may be obscured by estimates at the national, state, or even district level, firstly The multilevel logistic regression analyses used in this study presented valuable insights into the factors associated with early marriage and early motherhood in India, considering individual/household and community-level variables. From the multilevel analysis it was found that educational attainment emerges as a key determinant, uneducated women were more likely to marry early compared to those relatively educated. The reason behind this could be that education modifies people's ideas about the optimal age for a first marriage and raises awareness of the detrimental health effects of early marriage and pregnancy, including fistula and a higher risk of maternal morbidity and death [58]. Girls can be empowered and given other opportunities for the future through education [59]. In this study, it has been also found that caste and religion also exhibit associations with early marriage and motherhood, with women from marginalized groups facing a higher likelihood of experiencing these events, in this study it was highlighted that women belonging to the OBC category had higher chances of early marriage and early motherhood also women belonging to Christian religion had lower chances of early marriage and early motherhood which is also mentioned in research done by Forbes highlighting the modernity in the life style of Christian and Hindu religion people [60]. The impact of socioeconomic factors is evident in our study, with women in the poorest category and those with limited exposure to mass media facing a higher risk of early marriage and motherhood, these findings has been supported by some studies given the poorest women and women having low exposure to mass media exhibit the risk of early marriage and early motherhood [61–63]. The findings in this study underscore the importance of economic empowerment and media literacy in mitigating the risk of early family formation. This study found the contextual nature of early marriage, particularly the social and normative elements that determine age at marriage, is highlighted by the statistically significant interplay among district characteristics [64]. A study done by Upadhyay and Karasek found that the features of the district itself as well as those of the surrounding districts have an impact on this relationship [65].

In our study, the spatial distribution of early marriage and early motherhood was significantly varied within the country. The significant hotspot areas of early marriage and early motherhood were detected in the central and eastern regions, with a notable proportion of women experiencing these events early in their lives which was also found in previous studies done by many researchers [66–68]. Some studies found that the trafficking of minor girls across the India-Pakistan border is a problem that also affects the neighbouring states of Jharkhand, West Bengal, Bihar, and Uttar Pradesh, serving as a risk factor for early marriage due to families marrying their minor daughters out of fear of sexual violence [69, 70]. This study found that the district with the lowest prevalence of early marriage was Thrissur while the highest prevalence was observed in Murshidabad district. This result is consistent with past research from many nations that highlighted the notable regional differences in early marriage. and early motherhood [25, 27, 71–73]. Early marriage and early motherhood fluctuate geographically throughout the states in the region; this diversity may be related to women's educational attainment as well as sociocultural perspectives on these topics. Our research revealed regional variations in women's educational status in India. Of all Indian districts, 6% showed high-high clustering of early marriage among women without any education, while 40 districts showed a similar clustering for early motherhood in this group. Some researchers

have also noted this clustering of early marriage and early motherhood prevalence [74]. Indeed, women with less education are indeed less likely to actively participate in various knowledge-enhancing activities, such as peer talks, service promotions, and reading materials, which raise awareness of the detrimental impacts of early childbirth and marriage It is widely believed in society and culture that being a virgin before marriage is highly treasured, and single girls who are older than 14 are typically ostracised. As a result their girls are compelled to marry before turning 14 [75]. Additionally, in some regions in India, Young women are undervalued, lack authority over resources, and have little influence over decisions made about their personal lives as well as those made at home and in the community. Due to this strict culture and marital custom, young women are compelled to marry at a young age) [76].

The Empirical Bayes Bivariate Moran's I value in this study provides additional insights into the specific mesoscale variables associated with spatial autocorrelation. This study found that for early marriage, the highest positive spatial autocorrelation is observed for women with no prior relationship with their husband. This suggests that the prevalence of early marriage is not randomly distributed but exhibits spatial patterns related to women's relationship history Similarly, for early motherhood, spatial autocorrelation is highest for women with no prior relationship. The Empirical Bayes Bivariate LISA cluster maps offer a comprehensive spatial analysis of the clustering patterns of key demographic indicators related to marriage and motherhood in Indian districts. These maps provide valuable insights into the regional concentrations of early marriage and early motherhood, shedding light on areas with particularly high prevalence and potential areas of concern [77]. The study complements the spatial analysis by providing adjusted coefficients from OLS regression, allowing for a deeper understanding of the associations between demographic factors and early marriage, and early motherhood at the district level from this study it was found that positive coefficients for low exposure to mass media confirm their significant associations with both early marriage and early motherhood which has also been underscore by numerous studies [78–80]. the findings in this study reinforce the associations observed in the SEM, earlier studies also mentioned that the SLM confirms the importance of considering the characteristics of neighbouring areas when assessing the factors contributing to early marriage and early motherhood [81].

In summary, the research findings underscore the spatial clustering of early marriage and early motherhood in Indian districts, emphasizing the need for targeted interventions. In this study, women's education, mass media exposure, prior relation to husband, caste religion, and region were significantly associated with early marriage and early motherhood. Similar to many previous studies [82–86]. Henceforth this study has several strengths. It uses comprehensive data from the fifth round of the National Family Health Survey (NFHS), providing nationally representative insights. The use of multilevel logistic regression allows for a nuanced understanding of early marriage and motherhood determinants, considering individual, household, and community-level variables. Advanced spatial analysis techniques highlight regional patterns and hotspots, facilitating targeted interventions. The study identifies educational attainment as a critical determinant, offering actionable insights for policymakers. It also examines socioeconomic factors, caste, and religion, providing a holistic view of the drivers behind early marriage and motherhood, and emphasizes the need for localized interventions.

However, the study has limitations. Self-reported data could be subject to recall or social desirability bias. While regional hotspots are identified, micro-level variations within districts might be overlooked. The cross-sectional design limits the ability to infer causality. Some potential determinants, like health infrastructure and legal enforcement, might not be fully accounted for. Implementing multi-sectoral and localized interventions uniformly across diverse regions can be challenging. Additionally, addressing deeply ingrained cultural practices requires culturally sensitive approaches, which might not be fully addressed by the study's recommendations.

Conclusion

In conclusion, reduction in early marriage and early motherhood requires comprehensive strategies that encompass sexual and reproductive health education, access to services, and multi-sectoral approaches. The intricate interplay of individual, household, and community-level factors necessitates a holistic approach to addressing these issues. By investing in adolescent health and well-being, we can not only improve individual lives but also have a significant economic impact, particularly in low-income nations. The findings emphasize the need for contextually sensitive interventions, including education initiatives, media campaigns, socio-economic empowerment, and targeted policies that acknowledge the diverse landscape of the country. Implementation of existing policies must be accelerated to ensure wider availability and utilization of reproductive health services for adolescents. Multi-sectoral strategies are crucial, addressing factors such as girls' education and poverty reduction. Continued research and evidence-based interventions are essential to better understand the underlying

factors and develop effective interventions to reduce early marriage and early motherhood.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-20038-2.

Supplementary Material 1.

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Authors' contributions
MS and CS contributed in conceptualizing the study. MS is responsible for the analysis. MS, JG and CS were contributed to the interpretation of the data, and critically revised all versions of the manuscript and approved the final version.

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Availability of data and materials
NFHS data is a nationally representative data set which is available freely in the public domain.

Declarations

Ethics approval and consent to participate
The data is freely available in the public domain and survey agencies that conducted the field survey for the data collection have collected prior consent from the respondent. It also guaranteed that the participants' privacy was protected and that informed consent was obtained from respondents during the survey. Therefore, prior ethical approval for using the datasets was not required.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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