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Climate change, marriage and health

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Few studies to date have examined the triadic relationship between climate change, marriage dynamics, and health. This review will investigate the speculated causal pathway originating from climate change, influencing marriage rates, and ultimately resulting in adverse health outcomes. We first summarize climate-health links, marriage-health links, then the sparse literature on the climate-marriage link; before offering a conceptual framework for future work. Due to the nascent nature of this research area, there is a lack of a unified perspective on these matters. More research is warranted to explore the public health implications of climate change and increasing singlehood. Furthermore, policy adjustments can be tailored to the research findings. For example, distinct public health policies could be applied to men and women if future studies show a significant sex difference in the proposed causal pathway.

KEYWORDS

climate change, climate, marriage, divorce, heat, temperature, health, Incel

1 Introduction

Recent data indicate a global rise in the number of unmarried individuals. Taking the United States, for instance, the number of marriages during a given year per 1,000 people was 10.6 in 1970 and 5.1 in 2020 (Herre et al., 2020). Similarly, the South Korean marriage rate was 9.2 in 1970, which dropped to 4.2 in 2020 (Herre et al., 2020). Furthermore, the marriage rate in the Netherlands was 9.5 in 1970 and 2.9 in 2020 (Herre et al., 2020). There has also been a steady rise in climate change. The relationship between marriage and climate change has recently become a focus of research interest. It has been proposed that the rise in extreme weather events can exacerbate poverty, potentially leading to an increase in child marriages, as families may see marrying off their daughters as a way to reduce financial burdens (Palmer et al., 2024). Globally, one in five girls (12 million per year) and 3% of boys are married as children (Samuels et al., 2024). Child marriage is related to intimate partner violence, school dropout, poor infant health and a plethora of mental disorders (Samuels et al., 2024). The complex interplay between climate change, marriage and health extends beyond child marriages, necessitating a more comprehensive and broader investigation.

2 Climate change and health

The significance of climate change has been universally acknowledged with many systematic reviews indicating an association between climate change and the deterioration of human health (Rocque et al., 2021). Temperature elevation has been the most frequently studied aspect of climate change, showing a consistent association with infectious, respiratory, cardiovascular and neurological adverse health outcomes. Additionally, extreme heat has been found to be related to diabetes, heat exhaustion, and renal diseases (Rocque et al., 2021).

Climate change's impacts are not limited to physical health, it can also have both short-term and long-term effects on mental health (Hwong et al., 2022). Indeed, many studies have indicated an association between climate change and mental instability. Extreme heat has been linked to impaired sleep quality, increased hospital admissions for mental health conditions, and rising suicide rates (Rocque et al., 2021). Rising temperatures and humidity have been associated with increased emergency department visits for mental disorders (Deng et al., 2022). Furthermore, warmer temperatures and extreme rainfall have been linked to a higher frequency of interpersonal violence and intergroup conflicts in humans (Hsiang et al., 2013). Using data from 156 countries, climate change has been significantly associated with a rise in global intimate partner violence (Mannell et al., 2024). In addition to violence toward others, climate change also increases violence toward oneself, such as self-harm or suicide. Research has shown that a 1 °C increase in average monthly temperature is associated with a 0.68% increase in the monthly suicide rate in the United States and a 2.1% increase in Mexico (Burke et al., 2018).

In recent years, there has been a rise in violent acts associated with the Incel (involuntary celibate) ideology, including mass shootings, homicides and suicides. Incels are often characterized as a high-need group experiencing mental health challenges, united by a fear of loneliness and singleness (Sparks et al., 2022). There are concerns that the escalating severity of climate change and its potential to increase violence, combined with declining marriage rates, could exacerbate Incel-related violence and contribute to social and public health problems.

While debates persist, some research suggests that inherent well-being is correlated with an increased likelihood of marriage and decreased divorce rates (Guner et al., 2018). Given that climate change may negatively impact both physical and mental health (Table 1), potentially escalating violence toward others and oneself, it is plausible that worsening climate conditions could be linked to declining marriage rates.

3 Marriage and health

3.1 Marriage is generally associated with better health

The importance of marriage deserves elaboration due to its profound impacts on human health. Indeed, romantic relationship quality has been found to be related to general health, anxiety, depression, diet and physical activity (Sailer et al., 2024). A significant body of research has supported the link between high-quality marriage and well-being. In terms of physical well-being, the epidemiologist William Farr suggested the longevity advantage of marriage in French men in 1858 (Gellatly and Störmer, 2017). Additionally, a meta-analysis indicated reduced odds of cardiovascular diseases in married compared to unmarried people (Wong et al., 2018). Another meta-analysis further suggested that compared to never-married people, married individuals had a reduced risk of dementia after considering the confounding effect of education (Sommerlad et al., 2018).

In addition to physical well-being, improved mental health conditions after marriage have been extensively documented (Kravdal et al., 2023; Becker et al., 2019; Stokes and Moorman, 2018; Fu and Noguchi, 2016). Compared to married people, a large-scale, cross-country study indicated an overall higher risk of developing depressive symptoms in unmarried people (Zhai et al., 2024). Another study found that never-married status above the mean first marriage age (32.8 years in men and 30.1 years in women) was associated with suicidality, mental disorders such as agoraphobia, obsessive-compulsive disorder, mood disorder and major depressive disorder in Korea (Lee et al., 2020). Along with marriage itself, marital satisfaction was also linked to depressive symptoms (especially in older people) with most studies reporting small to medium effect sizes (Goldfarb and Trudel, 2019). Moreover, high-quality marriage was found to be associated with better sleep quality (Chen et al., 2015). A meta-analysis also indicated the relationship between higher overall marital quality and lower anxiety (Postler et al., 2022). During the COVID-19 pandemic, married individuals were found to be less likely to experience mental health problems following declines in work-related income (Jace and Makridis, 2021). With increasing age, single people showed a steady rise in the odds ratio for depression compared to married people (Bulloch et al., 2017).

While marriage is often associated with improved physical and mental health, some caveats and mediators such as sex, financial status and geographical regions must be considered. Moreover, despite the documented health benefits of marriage, many individuals remain single voluntarily or involuntarily.

TABLE 1 Physical and mental impacts related to climate change.

Physical impacts related to climate change	Mental impacts related to climate change
• Facilitating transmission of infectious diseases • Exacerbating respiratory diseases • Exacerbating renal diseases • Exacerbating diabetes • Triggering cardiovascular events • Causing dehydration, heat exhaustion or even heat stroke	• Impairing sleep quality • Rising self-harm and suicide rates • Increasing emergency department visits for mental disorders • Increasing frequency of interpersonal violence and conflicts • Rising global intimate partner violence

3.2 Some caveats to be considered

Despite decades of extensive research documenting the associations between marriage and improved health outcomes, certain studies have raised questions regarding the mechanism and long-term consistency of these health facilitation effects (Huntington et al., 2021). Huntington et al., found that although some indicators of mental and physical health improved up until the point of marriage, these indicators then stabilized or began to decline (Huntington et al., 2021). Moreover, when examining the protective effect of marriage on mental health, it is essential to consider that individuals with better health are often more likely to marry (Braithwaite and Holt-Lunstad, 2017).

3.3 Sex as a mediator

Indeed, the association between marriage and wellbeing is complicated as it might be mediated by sex. A recent longitudinal study ($N = 7{,}641$) indicated that men who were continuously married

reported more satisfactory physical wellness, mental wellness, social wellness, and self-rated wellness than their never-married counterparts (Ho et al., 2024). However, this association was not found in women (Ho et al., 2024). In a qualitative study, husbands' frequency of verbal compassion expression toward their wives was largely associated with their own personal distress instead of their spouses' distress. This phenomenon was absent in wives (McNeil and Repetti, 2023). The study also found that women's mental health was more significantly influenced by their spouses' mental health (Behler et al., 2019) whereas men's mental health was more notably affected by their spouses' physical health (Jain and Ma, 2024). Furthermore, another study showed that spousal perceptions of positive marital quality were associated with lower depressive symptoms only for women (Bulanda et al., 2021). Another study showed that the marital protective effect on mental health was found against anxiety, depression, fear, and bipolar disorders for both sexes and against substance abuse/dependence and conduct disorder only for women (Feder et al., 2019). Researchers also found that compared to men, women experienced more mental health decline after marriage (Huntington et al., 2021). Consequently, the sex factor should be considered when interpreting existing research results or designing future studies regarding marriage, climate change, and health.

3.4 Money as a mediator

In addition to sex, money plays a crucial role in the interaction between marriage and health. A study revealed that married individuals exhibited better physical capabilities, such as grip strength and walking speed, compared to their unmarried counterparts, with much of this advantage attributed to the greater wealth of married individuals (Wood et al., 2019). Furthermore, research indicated a U-shaped relationship between a wife's relative income and a husband's psychological distress, with the husband's stress reaching a minimum point when the wife contributes 40% of the total household income (Syrda, 2020).

3.5 Geographical region as a mediator

The interaction between marriage and health can vary significantly due to sociocultural differences across different countries. Compared to married people, a large-scale cross-country study found that unmarried individuals, particularly highly educated men in Western countries, such as the United States, United Kingdom, and Ireland, had a higher risk of developing depressive symptoms (Zhai et al., 2024). This phenomenon was not prominent in Eastern countries. Presumably, this difference was attributed to the higher tolerance for emotional distress in Eastern cultures. The increased risk of depressive symptoms among unmarried individuals was significantly influenced by alcohol consumption and smoking in China, Korea, and Mexico, but not in the United States, United Kingdom, and Ireland (Zhai et al., 2024). Another study revealed that the protective effect of marriage on mental health was more pronounced in the older generation than in the younger generation in China and Japan, but not in Korea (Fu and Noguchi, 2016).

Apart from sociocultural regional differences, genetic diversity may also contribute to variations between countries. A study found that individuals with the CC genotype (compared to AC/AA) of the oxytocin pathway CD38 gene, rs3796863 reported higher levels of gratitude, trust, and forgiveness, leading to more satisfying marriages (Makhanova et al., 2021). Consequently, the geographical difference in marriage rates may be related to the potentially different distribution of this CD38 gene in various regions.

3.6 Marriage paradox

Despite the health benefits associated with marriage, the decision to marry remains a complex choice. In recent years, the global marriage rate has been gradually declining (Herre et al., 2020). Various factors have been identified as driving forces behind changes in the marriage market, including women gaining more control over their fertility with the advent of birth control pills, shifts in the modern wage structure with a reduced gender wage gap, and the illusion of endless choices facilitated by the Internet as a new matching technology (Stevenson and Wolfers, 2007). Additionally, marriage can be unstable, with approximately one out of three married individuals experiencing discord in their relationships, and 40–50% of first marriages ending in separation or divorce in the United States (Whisman et al., 2025). Infidelity in romantic relationships is also on the rise, with the rate of sexual infidelity among Chinese individuals increasing from 8% in 2000 to over 24% in 2015 (Luo and Yu, 2022).

The "marriage paradox" refers to the phenomenon where the institution of marriage is receiving less cultural and demographic support even though its objective value remains high (Wilcox and Hawkins, 2024). Despite the documented health benefits of marriage (Wilcox and Hawkins, 2024), the US marriage rate declined by 19% for men and 17% for women from 2008 to 2021 (Pepin and Cohen, 2024). People in the United States are also getting married at increasingly older ages (Bloome and Ang, 2020). Study also showed declining optimism toward marriage among US 12th graders (Pepin and Cohen, 2024). It has been found that college-educated, religious, and conservative Asian Americans are more likely to choose marriage (Wilcox and Hawkins, 2024) while black people with low incomes are less likely to be married (Bloome and Ang, 2020).

In conclusion, the interaction between marriage and health is complex, with mediators such as sex, financial status, and geographical regions playing significant roles. Furthermore, some health benefits associated with marriage may be temporary. Despite the numerous health advantages linked to high-quality marriages, an increasing number of individuals are opting not to marry or are choosing to end their existing marriages.

4 Climate change, marriage and health

To date, there are only three peer-reviewed scientific articles directly addressing the relationship between climate change and marriage (Huang and Ma, 2024; Ventura et al., 2021; Jennings and Gray, 2017; Table 2). To my knowledge, no study has directly assessed the interconnectedness between climate change, marriage and health. Despite the limited availability of existing literature, discussions of the current published studies will facilitate the design of future research endeavors.

4.1 First assumption: climate change leads to resource shortages followed by unstable marriages

In the first study, researchers posited that climate change could lead to food shortages and an unfavorable environment for reproduction (Ventura et al., 2021). Following breeding failure, individuals may seek better partners as an adaptive strategy, subsequently increasing the divorce rate (Ventura et al., 2021). Social monogamy is a common mating system in birds, similar to humans, and is prevent across bird species (Ventura et al., 2021). Unlike human monogamy, animal monogamy is often driven by habitat limitations rather than cultural, regional or social norms in humans (Kvarnemo, 2018). While many species of birds are only seasonally monogamous, albatrosses exhibit life-long bonding with single partners, similar to humans. Moreover, divorce and extra-pair copulation are occasionally observed in albatrosses.

In this study, the divorce rate was calculated using capture-mark-recapture and GPS-tracking data of black-browed albatrosses (*Thalassarche melanophris*) on New Island, Falklands. Sea surface temperature data was obtained from the National Oceanic and Atmospheric Administration website. Wind speed was calculated from the meridional and zonal components reanalysis data downloaded from the European Center for Medium-Range Weather Forecasts ERA-5 database. A quasi-binomial general linear model revealed a significant and positive correlation between rising sea surface temperature and an increasing divorce rate ($\chi^2 = 6.8$, $p = 0.009$). However, no significant correlation was found with wind speed analyses. The researchers found a significant and positive correlation between rising sea surface temperature and increasing divorce rate, suggesting that increasing temperatures could exacerbate resource scarcity, leading individuals to seek more capable partners, potentially increasing the divorce rate.

4.2 Second assumption: climate change leads to income reduction followed by increased marriage rate

A recent article published in *Nature* predicted a permanent income reduction of 19% on average globally as a result of climate change (Kotz et al., 2024). In the second study, researchers hypothesized that climate change may reduce income and worsen financial conditions, leading to an increase in the marriage rate as individuals seek financial support (Jennings and Gray, 2017).

Researchers obtained historical data (1871 to 1937) from the Historical Sample of the Netherlands (HSN) and the Royal Netherlands Meteorological Institute. By the mid-late nineteenth century, industrialization, urbanization and economic growth had begun in the Netherlands (Jennings and Gray, 2017). However, flooding and drought were also common occurrences in the Netherlands during 1871 to 1937. The Netherlands experienced more droughts over the past 100 years (Jennings and Gray, 2017). Correspondingly, climate change has increased the odds of worsening drought in many areas of the world today. Using a series of multivariate discrete-time event history models and controlling for many variables such as sex ratio, age structure, place of birth, religion, occupations and urbanization, it was concluded that the marriage rate increased with cold temperatures, riverine flooding and high rye prices. No significant results were documented with other climate indicators (number of hot days, number of cold days, average rainfall, and coastal flooding), suggesting a complex relationship between climate change and marriage dynamics.

4.3 Third assumption: climate change leads to mental instability followed by unstable marriages

In the third study, researchers postulated that climate change could lead to mental instability, aggression, and interpersonal conflicts, ultimately resulting in a higher divorce rate (Huang and Ma, 2024). To test this hypothesis, historical data from multiple countries spanning from 1960 to 2018 were gathered from the World Development Indicators Database, International Disasters Database, and ourworldindata.org website. The researchers utilized a panel fixed effects model incorporating fixed effects for both country and year, along with several control variables, such as the consumer price index, trade, foreign direct investment, and population density. The findings indicated that an increase in flooding and temperature was associated with a rise in the divorce rate, while no significant relationship was observed between the severity of drought and the divorce rate.

4.4 Geographical region as a mediator

The three assumptions fail to account for the influence of geographical region when analyzing the relationship between climate change and marriage. In contrast to the declining marriage rate in

TABLE 2 Three studies addressing the relationship between climate change and marriage.

Summary	1st Study	2nd Study	3rd Study
Assumption	Climate change leads to resource shortages followed by unstable marriages	Climate change leads to income reduction followed by increased marriage rate	Climate change leads to mental instability followed by unstable marriages
Publication year	2021	2017	2024
Location	New Islands, Falklands	Netherlands	Worldwide
Methods	Using a longitudinal dataset on the albatross as a model organism	Using a longitudinal data from a historical sample (1871 to 1937)	Using data from multiple open sources (1960 to 2018)
Results	Increasing divorce rate was found with warm sea surface temperature anomalies.	Increasing marriage rate was found following cold temperatures.	Extreme temperature was associated with increased divorce rate.

developed countries, there is a surging incidence of child marriages in Sub-Saharan Africa and South Asia. Child marriage is defined as a formal marriage or informal union between a child under the age of 18 and an adult or another child (Asare and Forkuor, 2024). Climate change-related loss of income with displacement superimposed on social norms and culture have been suspected as the drivers of child marriages in these areas. In times of instability and financial hardship, disadvantaged families might resort to marrying their daughters in exchange for money (Pope et al., 2022). Studies revealed that the practice of child marriage was a risk-coping mechanism adopted by households in the face of shared vulnerability to climate change in Bangladesh (Asadullah et al., 2020) and Ghana (Asare and Forkuor, 2024). Child marriage has been related to intimate partner violence, school dropout, loss of autonomy, reduced employment prospects, poor infant and child health outcomes, depression, anxiety and even suicidal ideation (Samuels et al., 2024). Nevertheless, child marriage is rare in most developed Western countries. Indeed, the relationship between climate change and marriage may differ between countries.

Moreover, in addition to different social adaptations, divergent climate change may also be experienced in different geographical regions. Take temperature elevation as an example, although there is a nearly universal trend of warming in the United States, significantly rising temperatures were not seen in some southeast states such as Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, and Tennessee (Gil-Alana et al., 2022). Accentuating regional disparities, climate change manifests in distinct, location-specific patterns across the globe. Consequently, the relationship between climate change, marriage, and health may also differ between places.

4.5 Divergent types of climate change as a mediator

Different climate change scenarios, as explored in the three assumption studies, could exert varying influences on marriages. For example, the third assumption study indicated that the increase in flooding and temperature brought about the rise of the divorce rate whereas no significant association was found between the severity of drought and the divorce rate.

4.6 Summary of the limitations of these three assumptions

Only a small portion of the variance was explained by the statistical model in each assumption (35% in the first assumption, 4.8 and 16.5% in the third assumption).

Furthermore, in the first assumption, the researchers conducted an animal study, potentially overlooking the complexities inherent in humans (Ventura et al., 2021). In the second assumption, the researchers employed 24 complex models but failed to specify the percentage of variance explained by each model. In the third assumption, there was an absence of any mental health indicator in the study. Consequently, a causal pathway between climate change, health and marriage could not be inferred from the study results (Huang and Ma, 2024). Presumably, the researchers could conduct Structural Equation Modeling (SEM) to investigate the potential causal relationship (Jennings and Gray, 2017).

While these three studies investigated the association between climate change and marriage, none of the employed models examined potential mediating pathways, such as health impacts, income fluctuations or emotional stress levels. Furthermore, individual-level marriage data was not incorporated in the analyses, limiting the ability to assess the direct effects of climate change on marital outcomes. Future study is warranted to assess the interconnectedness between climate change, marriage and health.

5 Suggestions for future research

5.1 Impractical to fit a single regression model: generalizability problem

Based on the limited findings of existing studies, there is no strong evidence to support a significant association between climate change, marriage and health (Huang and Ma, 2024; Ventura et al., 2021; Jennings and Gray, 2017). Certainly, the decision to marry is a complex process influenced by various factors such as income, career planning, mental stability, relationship stability, religion, social norms, and social media-related infidelity. Attempting to incorporate all these factors into a single regression model to examine the relationship between climate change and marriage rate may be impractical. Indeed, the models used in previous studies did not adequately explain a significant portion of the variance (Huang and Ma, 2024; Ventura et al., 2021; Jennings and Gray, 2017).

Instead of pursuing a universal regression model, a more feasible approach could involve investigating the Pearson correlation between climate change and marriage. If a significant correlation between climate change and marriage is identified, a longitudinal study could be conducted with a group of participants from a specific geographical area. This study could collect quantitative data on climate change, marital status and incomes, as well as qualitative data on romantic relationship quality, attitudes toward marriage, and climate change. A longitudinal study, unlike a cross-sectional design, can better support causal inference (Toh and Hernán, 2008), allowing for the exploration of potential causal relationships between health, climate change, and marriage.

5.2 Climate change indicators

Selecting specific climate change indicators for a study can be challenging. For example, researchers have utilized various indicators to assess heat exposure. Some have focused on maximum daily temperature, while others have considered humidity and used the heat index (Bell et al., 2024). Due to a limited understanding of the mechanisms linking climate change and health, choosing appropriate climate change indicators can be difficult. Previous studies have shown that researchers often select a wide range of climate change indicators without robust hypotheses, making it challenging to identify meaningful associations between climate change, marriage, and health (Huang and Ma, 2024; Ventura et al., 2021; Jennings and Gray, 2017).

Research on the interaction between climate change and health has been increasing. To date, most indicators for the health implications of climate change have been developed as independent metrics. However, this approach may overlook the interconnected

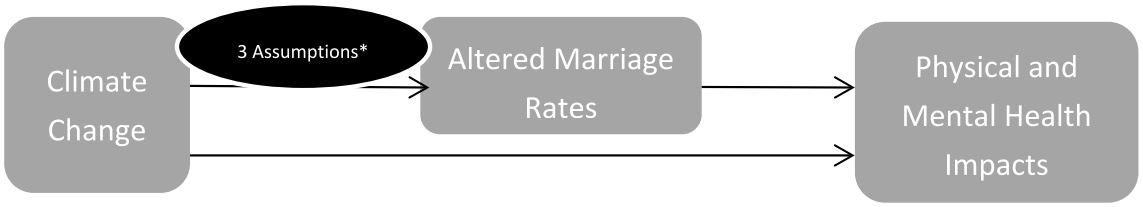

FIGURE 1
Summary of the evidence.

nature of exposure-outcome pathways involving multiple climate change indicators. Some researchers have suggested reframing climate change and health indicators as part of a linked system (Liu et al., 2021). Presumably, an integrated system of climate change indicators could be applied to future research (Liu et al., 2021).

6 Conclusion

6.1 What's known so far

As depicted in Figure 1, climate change could impact marriage rates through different channels such as resource scarcity, income reduction and heightened mental instability (three assumptions). Both climate change and marriage significantly impact on mental and physical health. Furthermore, climate change and shifts in marriage rates are projected to exert multifaceted influence on population health.

6.2 Knowledge gaps

However, the proposed causal pathway (Figure 1) contains unexplored knowledge gaps. For instance, the mediating effects of different geographical regions (regional variation), sex differences, and various climate change indicators have not been thoroughly investigated. Moreover, some health benefits associated with marriage may be temporary and not long-lasting. Indeed, the underlying mechanisms through which marriage impacts health are not fully understood. More empirical data and meta-analysis are needed to validate these assumptions.

A revised research design should be adopted. For example, a longitudinal study could explore the interaction of local climate, marital status, marital satisfaction, household income, physical and mental health indicators using both quantitative and qualitative data. At the population level, specific attention should be paid to child marriage and violence associated with involuntary celibacy (Incel).

6.3 Public health policy recommendations

In regions where marriages are declining, such as the United States, federal policymakers have already recognized the importance of healthy marriages in shaping adult outcomes and enhancing the well-being of low-income populations (Karney and Bradbury, 2005). Indeed, policy adjustments, such as financial incentives, like monetary rewards, could be implemented to promote marriages. Additionally, increased access to physical and mental health check-ups should be provided to single individuals to support their well-being. Correspondingly, in regions experiencing a rise in child marriage rates, such as Sub-Saharan Africa and South Asia, governments and international organizations should prioritize policies that protect girls' rights, promote their education, and provide financial assistance to vulnerable families.

Should future studies validate a significant association between climate change, marriage and health, adaptive policies listed above should prioritize support for communities most susceptible to climatic impacts. Furthermore, policy adjustments can be tailored to the research findings. For example, distinct policies could be applied to men and women if studies show a significant sex difference in the proposed causal pathway (Figure 1).

Author contributions

J-YC: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JC: Supervision, Writing – original draft, Writing – review & editing.

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