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Key Points:

- Climate change impacts on health affect men and women differently due to underlying socioeconomic, cultural, and physiologic factors
- Climate change threatens to widen existing gender-based health disparities, especially in India and other low- and middle-income countries
- Integration of a gendered perspective into existing climate, development, and disaster-risk reduction policy frameworks can decrease negative health outcomes

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Climate Change and Women's Health: Impacts and Opportunities in India

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Abstract Climate change impacts on health, including increased exposures to heat, poor air quality, extreme weather events, and altered vector-borne disease transmission, reduced water quality, and decreased food security, affect men and women differently due to biologic, socioeconomic, and cultural factors. In India, where rapid environmental changes are taking place, climate change threatens to widen existing gender-based health disparities. Integration of a gendered perspective into existing climate, development, and disaster-risk reduction policy frameworks can decrease negative health outcomes. Modifying climate risks requires multisector coordination, improvement in data acquisition, monitoring of gender specific targets, and equitable stakeholder engagement. Empowering women as agents of social change can improve mitigation and adaptation policy interventions.

1. Introduction

The United Nations Framework Convention on Climate Change notes that women face higher risks and experience a greater burden of climate change impacts. This is notably true for health impacts, making climate change a risk-multiplier for gender-based health disparities. According to the World Health Organization (WHO) and the American College of Obstetricians and Gynecologists (American College of Obstetrics and Gynecologists, 2016), women are at higher risk due to biologic, political, and cultural factors (Chauhan & Kumar, 2016; World Health Organization [WHO], 2014; ACOG policy statement). Compounding women's health vulnerabilities is poverty, which amplifies risk on a regional scale. Globally, a total of 1.3 billion people in low- and middle-income countries live below the poverty line, 70% of whom are female (WHO, 2002).

India is a culturally and geographically diverse country and is in the midst of a period of rapid industrialization and urbanization, with a growing population. Since 2000, technologic and economic progress has resulted in favorable gains in development indices; however, wide gaps in gender-based health disparities remain (Balarajan et al., 2011; Bhalotra & Clots-Figueras, 2014). These economic gains have been coupled with a near doubling of CO₂ emissions per capita, and the benefits of industrialization have been unequally distributed among the population (World Bank Group, 2018a, 2018b). The net result of these changes is that women, especially those in poverty, are at a higher risk of enduring negative health consequences associated with wide-spread impacts from emissions of heat trapping greenhouse gasses (GHGs), now and in the future.

While climate change threatens to widen gender-based health disparities, women's social roles and potential for affecting change afford opportunities for solutions. There exists an imperative for policymakers to move beyond traditional separations of health, gender, and environment and to embrace proactive gender-based solutions to both protect women's health and mobilize their social potential to mitigate, adapt, and respond to climate threats. This manuscript was originated from the discussion of a solution-oriented session on Climate Change and Women's Health at the International Conference on the Environment and Women's Health, held at Amity University in Lucknow, India, 1 December, 2017 (Failey, 2017).

2. Gender and Climate Change Vulnerability in India

Climate change affects health through a multitude of mechanisms, including heat, poor air quality, extreme weather events, as well as through meteorological changes that alter vector-borne disease, reduce water

quality, and decrease food security (Crimmins et al., 2016). In India, climate change is having wide-spread impacts, which are anticipated to worsen under future climate scenarios (Barros et al., 2014). The Government of India has a stated policy of sustaining economic growth rates while simultaneously curbing GHG emissions (Government of India, 2008). However, sustained economic growth rates, as measured by gross domestic product, do not necessarily equate to sustainable human development. Currently, India ranks number 131 on the United Nations Gender Inequality Index (UNDP, Human Development Reports). An economic growth plan that fails to take gender issues into account is likely to widen existing gender inequalities. To achieve inclusive economic growth and simultaneously curb GHG emissions, accurate accounting of the biological, cultural, and socioeconomic factors, which place women at risk for acquiring climate sensitive communicable and noncommunicable diseases, is paramount (see Table 1).

2.1. Heat Impacts

The average annual temperatures in India in 2030, compared to the 1970s, are projected to increase between 1.7 and 2.2 °, with a commensurate increase in the intensity and duration of heatwaves (Barros et al., 2014). Already, the health impacts are manifest, with increases in the number of deaths associated with high temperatures over the past 15 years (Akhtar, 2007; Azhar et al., 2014; McMichael et al., 2008). Although robust surveillance data are lacking, several studies have demonstrated that women, especially older women and pregnant women, suffer a greater burden of heat related health impacts (Kovats & Hajat, 2008; Sarofim et al., 2016; Schifano et al., 2009).

Women differ from men in their physiologic compensation to elevated temperatures, which contributes to their biologic vulnerability. They dissipate less heat by sweating, have a higher working metabolic rate, and have thicker subcutaneous fat which decreases radiative cooling (Duncan, 2006). Cultural vulnerabilities include poor access to healthcare and cooling facilities due to personal safety concerns and a lack of access to personal transportation, culturally prescribed heavy clothing garments that limit evaporative cooling, and a lack of awareness of women's vulnerabilities to heat among local, national, and global decision makers and health care personnel.

Pregnancy also contributes to vulnerability. Prolonged exposure to high temperatures are associated with still birth, congenital birth defects, and preterm delivery—regardless of maternal ethnicity or age, with younger mothers having an even higher risk of negative outcomes (Balbus & Malina, 2009; Basu et al., 2016; Ha et al., 2017; Strand et al., 2011; Van Zutphen et al., 2012). High ambient temperatures are also linked to pregnancy complications, such as gestational hypertension, preeclampsia (Makhseed et al., 1999), and poor neonatal outcomes (Kakkad et al., 2014). Heat is teratogenic at crucial stages of development (Van Zutphen et al., 2012). It also increases production of vasoactive substances, increases blood viscosity, and affects endothelial cell function, which may alter placental blood flow and increase propensity for hypertensive crises and stillbirth (Ha et al., 2017).

2.2. Air Quality

Increasing atmospheric CO₂, increasing temperatures and changes in precipitation patterns contribute to poor outdoor air quality, which in turn negatively impacts human cardiopulmonary health (Fann et al., 2016). Physiologically, ozone and PM_{2.5} inflame airways and enter the bloodstream where they cause endothelial cell dysfunction and oxidative injury, aggravating cardiopulmonary disease, and contributing to premature death (Beggs & Bambrick, 2006; Bell et al., 2004; Brown & Bowman, 2013). Several experimental studies have shown that pulmonary deposition of inhaled particles differs between men and women, with women demonstrating higher burdens (Chen et al., 2005). Additionally, women are at higher risk of cardiovascular complications, as demonstrated in a recent study where intima media thickness of arteries in women was significantly correlated with ambient levels of PM_{2.5}, whereas in men it was not (Künzli et al., 2005). Furthermore, women may be more hematologically sensitive to toxicologic influences of airborne pollution than males because they have higher rates of anemia (Sørensen et al., 2003).

In India, the mean PM_{2.5} increased from 60 µg/m³ in 1990 to 76 µg/m³ in 2015, accompanied by an increase in mean ambient ozone exposure from 62 to 76 ppb and a 150% rise in air pollution related deaths (Health Effects Institute, 2017). Compounding the direct health burden, poor air quality is also associated with increased healthcare utilization. In Delhi in November of 2017, PM_{2.5} concentrations were greater than

Table 1

Examples of Health-Related Climate Change Projections or Impacts in India, Resultant Health Impacts on Women, Cultural and Socioeconomic Vulnerabilities, and Examples of Gender-Based Solutions

Exposure pathway	Climate change projections and impacts in India	Women's health vulnerabilities	Cultural and socioeconomic vulnerabilities	Gender-based solutions
Increasing frequency of extreme heat events and rising average seasonal temperatures	<ul style="list-style-type: none"> Annual temperatures in India in 2030, compared to 1970, are projected to increase between 1.7 and 2.2 °C (Barros et al., 2014) resulting in more individuals exposed to extreme temperatures. 	<ul style="list-style-type: none"> Increased morbidity and mortality Adverse reproductive outcomes including preterm delivery (Kuehn & McCormick, 2017), congenital defects (Van Zutphen et al., 2012), gestational hypertension, and preeclampsia (Makhseed et al., 1999) 	<ul style="list-style-type: none"> Poor access to healthcare and cooling facilities due to personal safety concerns and lack of access to personal transportation. Lack of communication and awareness of women's vulnerabilities to heat among local, national and even global decision makers and health care personnel Death of gender disaggregated heat-related health data, unknown critical exposure windows Culturally prescribed heavy clothing garments 	<ul style="list-style-type: none"> Provide air conditioning in maternal wards (shown to decrease intensive care need in neonatal period; Kakkad et al., 2014) Increase access to prenatal care in heat vulnerable geographic areas Implement heat early warning systems with educational messages targeted at women Collect and disseminate gender disaggregated public health data Consideration of the detrimental effects of urban heat islands, especially in regions with poor access
Poor air quality from combustion of fossil fuels; increased ground-level O ₃ from elevated temperatures	<p>In India, there has been a 150% rise in air pollution related deaths over the past 20 years (Health Effects Institute, 2017). Without concerted efforts to reduce GHG emissions and other sources of air pollution, safe levels of ambient pollutants will not be achieved by 2030 (Dholakia et al., 2013).</p>	<ul style="list-style-type: none"> Respiratory and cardiovascular disease (Beggs & Bambrick, 2006) Adverse reproductive outcomes (Glinianaia et al., 2004; Pope et al., 2010; Šrám et al., 2005) Women experience greater deposition of inhaled particles in their lungs (Beggs & Bambrick, 2006) Secondary to higher prevalence of anemia women are more sensitive to toxicological exposure (Chen et al., 2005) 	<ul style="list-style-type: none"> Traditional indoor stoves for cooking and heating utilize biomass, which produces carbon monoxide, hydrocarbons and particulate matter and accounts for nearly 24% of ambient air pollution from PM_{2.5} (Health Effects Institute, 2018). Women spend more time in the home and thus are disproportionately affected. 	<ul style="list-style-type: none"> Improve access to clean burning cook stoves - shown to reduce exposure to carbon monoxide, hydrocarbons and particulate matter and decrease health risks (Wilkinson et al., 2009) Consider women's transportation needs during urban planning Consider the impacts of poor air quality on fetal and maternal health and strive to reach PM_{2.5} targets in rural and urban environments (Kuehn & McCormick, 2017)
Increasing frequency of climate-related disasters, including hurricanes, flooding and wildfires (Watts et al., 2017)	<p>Projected increased intensity of tropical cyclones along coastal regions of India, affecting highly vulnerable districts with poor infrastructure and high population density (Barros et al., 2014)</p>	<ul style="list-style-type: none"> Women suffer disproportionate mortality and decreased life expectancy after during disasters (Kuehn & McCormick, 2017; Van Zutphen et al., 2012) Women and girls are at high risk of physical and sexual violence, especially those belonging to marginalized sectors of society (International Federation of the Red Cross and Red Crescent, 2007) 	<ul style="list-style-type: none"> Women have unequal access to basic social goods and mortality is worsened when women have a lower socioeconomic status (Moosa & Tuana, 2014; WHO, 2014) Women are often homebound caring for children and elderly while waiting for relatives to return prior to evacuation 	<ul style="list-style-type: none"> Provide gender sensitive emergency shelters that proactively safeguard women Provide emergency obstetric and gynecologic care very early in the course of disasters

Table 1 (continued)

Exposure pathway	Climate change projections and impacts in India	Women's health vulnerabilities	Cultural and socioeconomic vulnerabilities	Gender-based solutions
		<ul style="list-style-type: none"> • Women giving birth in the time period following disasters have an increased risk of complications including preeclampsia, bleeding and low birthweight infants (Tong et al., 2011) 	<ul style="list-style-type: none"> • Poor, single, elderly women, adolescent girls, and women with disabilities are often at greatest risk for abuse because they have fewer personal, family, economic, and educational resources from which to draw protection, assistance and support • Women suffer disproportionate job loss and stagnant personal economic recovery following disasters (Tobin-Gurley et al., 2010) • Poor access to obstetric care during and after disasters 	<ul style="list-style-type: none"> • Increase availability of gender-disaggregated disaster-related health data • Increase gender specific public health messaging before, during, and after disasters • Provide gender sensitive psychologic services in the aftermath of disasters • Create economic recovery plans that provide vocational training for the female workforce
Shifting rainfall and temperature patterns impair crop, livestock and fishery yields, contributing to food insecurity	India is projected to experience increases in extreme precipitation as well as decreases in seasonal rainfall resulting in extended periods of drought (Barros et al., 2014)	<ul style="list-style-type: none"> • Women suffer higher rates of macro and micro nutrient deficiencies • Women are inherently sensitive to the effects of food insecurity and resulting nutritional deficiencies due to increased needs during menstruation, pregnancy and nursing. • Malnutrition leads to poor neonatal outcomes including intrauterine growth restriction and perinatal mortality (FAO, 2013) 	<ul style="list-style-type: none"> • Nutritional scarcity can be intensified by cultural practices that prioritize food provision to children and adult males. • In low-income countries, women produce between 60–80% of all food-livelihoods, as well as nutritional status are threatened when climatic conditions negatively impact agricultural yields (FAO, 2013) • Less than 10% of female farmers are landowners, and barely 2% have proper paperwork for their land (GDI, 2017) • Therefore, women suffer on account of their relative lack of control over farmlands and nutritional security 	<ul style="list-style-type: none"> • Empowerment through women-centered climate resilient farming models that encourage and assist women to gain cultivation rights and simultaneously provide skills and training to implement resilience building practices. • Community-based reintroduction of nutrient-dense, locally available wild edibles into the regular diets • Strengthen nutritional interventions in reproductive-aged women
Water insecurity and increased risk of waterborne disease	Based on 2015 estimates, only 62% of urban communities and 28% of rural communities in India have access to improved sanitation. (World Bank Group, 2018a) Future impacts of heavy precipitation and drought (Barros et al., 2014) may worsen these conditions.	<ul style="list-style-type: none"> • Water scarcity forces provision from sources that may be biologically and toxicologically contaminated, resulting in bacterial, viral and protozoan infections as well as toxin exposure (Duncan, 2006) • Traveling long distances to procure water increases 	<ul style="list-style-type: none"> • Traditionally, women have the household role of providing water for the family. Water scarcity equates to more time spent harvesting water and less time spent on other activities of livelihood such as economic gain • In some regions carrying water may use up to 85% 	<ul style="list-style-type: none"> • Increase accessibility to affordable home water filters • Increase public investment in water infrastructure in

Table 1 (continued)

Exposure pathway	Climate change projections and impacts in India	Women's health vulnerabilities	Cultural and socioeconomic vulnerabilities	Gender-based solutions
Changes in temperature, precipitation and ecology are altering the geographic distribution of vector-borne diseases	<ul style="list-style-type: none"> In India, several climate-sensitive VBDs are endemic, including Malaria, Dengue, Chikungunya and Japanese Encephalitis. Projected changes in climatic conditions are likely to alter the distribution and prevalence of these diseases (GOI, 2008) 	<ul style="list-style-type: none"> exposure to heat (Shiva & Jalees, 2005) Lack of access to water and sanitation creates unsafe conditions for women, especially during reproductive times (Birch et al., 2012) Infection during pregnancy can result in anemia and diminished trans-placental nutrient transport resulting in intrauterine growth restriction and increased vulnerability of the mother to hemorrhagic complications of delivery¹ Pregnant women have a risk of severe malaria that is three times as high as that of nonpregnant women (Steketee et al., 1996) Dengue virus is associated with increased risk of cesarean delivery, eclampsia and growth restriction (Pouliot et al., 2010) 	<ul style="list-style-type: none"> of a woman's daily energy intake (Duncan, 2006) Traveling long distances to collect water places women at risk for physical abuse and harm Women spend more time around the house performing domestic tasks, which places them in close proximity to domestic standing water and mosquito breeding sites Lack of access to prenatal obstetric care and assisted deliveries places women with infections at risk of postpartum hemorrhage and poor maternal outcomes, including death 	<ul style="list-style-type: none"> high risk areas such as urban slums. Engage local female leaders and female heads of household in local, regional, and national sanitation projects to promote culturally acceptable infrastructure development that ensures women have safe and private access to hygienic facilities and clean water Promote water-saving practices that take into account the different uses of water for women Collection of gender disaggregated health data Vector-borne surveillance systems and early warning systems can permit effective and efficient prepositioning of resources including bed-nets and insecticides. Child care facilities can support women's care giving role while transformation of gender norms takes place

Note. FAO, Food and Agriculture Organization; GDI, German Development Institute; GHG, greenhouse gas; GOI, Government of India; VBD, vector-borne disease.

1,200 $\mu\text{g}/\text{m}^3$, more than 40 times WHO established upper limit of 25 $\mu\text{g}/\text{m}^3$ (WHO, 2018a), resulting in a 30% increase in all-cause hospital admissions (Doshi, 2017).

The use of biomass for household cooking and heating also contributes significantly to human exposure to ambient air pollution (Chafe et al., 2014), accounting for nearly 24% of ambient air pollution from PM_{2.5} in India (Health Effects Institute, 2018). Around a quarter of the 1.6 billion people of the world that live with no access to electricity live in India and a further 300 million people in India live with “very, very limited access to electricity” (World Bank Energy database, 2018). This results in individuals turning to inefficient energy sources such as biomass in rural areas and waste plastics in cities. In general, women spend more time in the home and therefore are disproportionately exposed. Additionally, there is some evidence to support that women may be more susceptible to deposition of inhaled particles in lung tissue and therefore to systemic hypoxia from lung disease-related anemia (Chen et al., 2005). In India, over 50% of pregnant women suffer from anemia (World Bank Group, 2018a). Furthermore, ambient air pollution has been linked to congenital birth defects, still births, and intrauterine growth restriction (Glinianaia et al., 2004; Ritz et al., 2002; Šrám et al., 2005). This effect may be due to placental hypoxia or to the toxic effects of air pollutants.

2.3. Disaster-Related Impacts

According to a recent Lancet report, the frequency of weather-related disasters—including hurricanes, flooding, and wildfires—increased by 46% from 2007 to 2016 (Watts et al., 2017). For India, the Intergovernmental

Panel on Climate Change projects future increases in extreme precipitation events during the monsoon coupled with a decrease in nonmonsoon season rainfall (Barros et al., 2014). This pattern places many populated regions at high risk for both floods during the monsoon season and drought in the dry season (Asokan & Dutta, 2008; Barros et al., 2014). Flooding poses health risks due to trauma, drowning, and exposure to pathogens and toxic compounds in contaminated flood waters. Additionally, the Intergovernmental Panel on Climate Change projects that the frequency of cyclones in India is likely to decrease, but that the intensity of those that do arise will likely increase (Barros et al., 2014). Along coastal regions of India, there are urban clusters with poor infrastructure and high population density that are extremely vulnerable (Barros et al., 2014).

Women are more likely to die in cyclones and floods (WHO, 2014). In 1991 when cyclones in Bangladesh killed 140,000 people, 90% of the victims were women (Aguilar, 2004) and in 2008 when cyclone Nargis hit Myanmar, 61% of the 130,000 deaths were likewise women (WHO, 2014). The combination of social inequalities in terms of access to basic social goods, culturally prescribed roles, and biologic vulnerabilities may explain this disparity (Moosa & Tuana, 2014). The gender difference in mortality has been found to be larger when women are from a lower socioeconomic status in a particular region (WHO, 2014). Other research suggests that cultural factors contribute to vulnerability when women are homebound caring for children and elderly while waiting for relatives to return from a disaster-related evacuation. Underlying poor literacy and education may also play a role. If public warnings do not take into account women's access to information and the possibility that homebound women in remote areas only speak a minority language, women will be unable to appropriately take steps to safeguard their lives (United Nations Division for the Advancement of Women [UNDAW], 2001).

Physically, women of all ages are more calorie-deficient than men leading to poor physical health and vulnerability to resource shortages ensuing from catastrophes (Rahman, 2013). Additionally, poor baseline nutritional status and physical health may prevent escape and survival in the acute phase of a disaster (Cannon et al., 2003; Chowdhury et al., 1993; Dankelman, 2008). Pregnant women are a particularly vulnerable population and those giving birth in the time period following disasters have been found to have an increased risk of complications including preeclampsia, uterine bleeding, and low birthweight infants (Tong et al., 2011).

In the aftermath of climate driven disasters, women and girls—especially the elderly or those living in lower socioeconomic circumstances—are at higher risk of physical, sexual, and domestic violence (International Federation of the Red Cross and Red Crescent, 2007; UNDAW, 2001). Women may be separated from family, friends, and other support systems and may avoid using shelters for fear of abuse. Furthermore, poor, single, elderly women, adolescent girls, and women with disabilities are often at greatest risk because they have fewer personal, family, economic, and educational resources from which to draw protection, assistance, and support. Additionally, these same risk factors correlate with a comparatively higher risk for mood disorders, such as depression and anxiety (Norris et al., 2002). Adequate provision of mental healthcare challenges health-care systems globally, but especially in India, where the government allocations per capita for health average 5 USD/year (World Bank Group, 2018a). Women also suffer disproportionate job loss and stagnant personal economic recovery following disasters as often the best, and only jobs available are in construction and rebuilding efforts, which are traditionally male-dominated fields (Tobin-Gurley et al., 2010). According to the World Bank, 84% of Indian women are currently deemed to have *vulnerable employment* at baseline (World Bank Group, 2018a).

2.4. Food Insecurity and Malnutrition

Under changing climatic conditions, India is experiencing both increases in extreme precipitation as well as decreases in seasonal rainfall, with the net result being extended periods of drought (Barros et al., 2014). Variable precipitation combined with rising seasonal temperatures can have profound implications for crop, livestock, and fishery yields and result in food insecurity and economic instability. Already, many regions of India are water-stressed secondary to unsustainable consumption of groundwater for irrigation and industrial uses, especially in the states of Rajasthan, Punjab, and Harayana (Rodell et al., 2009). The projected country-wide loss in agriculture due to drought in 2030 is estimated at over \$7 billion, which is projected to severely affect the income of 10% of the Indian population (Barros et al., 2014). For example, the Indo-Gangetic plains currently produce 14–15% of the world's wheat, feeding around 200 million people of the region (Ortiz et al., 2008). These yields are expected to decrease by 51% due to heat stress and drought by 2030. Additionally,

sorghum grain yield is projected to decline by 2–14% by 2020 and continue to decline sharply throughout the century (Srivastava et al., 2010).

Women are inherently sensitive to the effects of food insecurity and resulting nutritional deficiencies due to increased needs during menstruation, pregnancy, and nursing. Furthermore, nutritional scarcity can be intensified by cultural practices that prioritize food provision to children and adult males. Poor nutritional status with resulting anemia is highly prevalent among women and children in India (World Bank Group, 2018a). Micronutrient deficiencies are associated with cognitive impairments, including poor attention span, diminished working memory, emotional and behavioral issues, and impaired sensory perception, which lead to poor educational outcomes (Jáuregui-Lobera, 2014). Maternal undernutrition has profound effects on neonatal development and is associated with intrauterine growth restriction, pregnancy complications, and perinatal mortality (Food and Agriculture Organization [FAO], 2013). According to the Food and Agriculture Organization (FAO), in places where iron-deficiency anemia is prevalent, the risk of women dying during childbirth is increased by as much as 20% (FAO, 2013).

Additionally, in developing regions, women are the primary agricultural producers, responsible for the provision of 60–80% of all food (German Development Institute, 2017). Thus, their livelihoods, as well as their nutritional status, are threatened when changing climatic conditions prevent successful agricultural yields. Prevalent cultural norms compound these hazards to the wellbeing of women. Despite the fact that they produce most food, less than 10% of female farmers are landowners, and barely 2% of owners have proper paperwork for their land (German Development Institute, 2017). Therefore, women suffer on account of their relative lack of control over farmlands, as well as their lack of access to crop insurance to overcome the losses incurred by environmental change.

2.5. Water Scarcity and Water-Borne Disease

Globally, there is an uneven distribution of fresh water, with the highest scarcity in the most populated areas. Shifting rainfall patterns, increased rates of evaporation, and population growth are projected to result in an additional 1–4 billion individuals exposed to drought by the end of the century (Watts et al., 2017). The current burden of water-borne disease in India is enormous, although difficult to accurately quantify due to lack of reporting, poor surveillance, and decentralized data infrastructure (Bush et al., 2011). Based on 2015 estimates, only 62% of urban communities and 28% of rural communities in India have access to improved sanitation (World Bank Group, 2018a).

Water scarcity forces people to drink from sources that may be biologically and toxicologically contaminated. Traditionally, women have the household role of providing water for the family and there is an increased risk of contracting water borne diseases among primary water handlers (Birch et al., 2012; Duncan, 2006). Water scarcity also equates to more time spent harvesting water and less time spent on other activities of livelihood. It is estimated that during the dry season in India, in water stressed areas, 30% or more of a woman's daily energy expenditure is spent harvesting water (WHO, 2014). Additionally, the manual labor involved in water harvesting places women and female children at risk for cumulative damage to the spine and neck leading to chronic skeletal pain. Traveling long distances for water also increases exposure to heat stress and heat stroke and threatens women's personal safety by increasing their risk of violent crime (Jalees, 2005). A lack of clean water and proper sanitation infrastructure also poses serious health challenges to women, especially during menstruation and pregnancy when more frequent hygiene may be sought (Birch et al., 2012).

Poverty exacerbates the health impacts of water scarcity on women. In urban areas, due to a lack of ownership of water pipes, poorer people often have to pay higher prices for water. In such areas, a lack of access to water has been linked to higher mortality rates for women (Sandys, 2005).

2.6. Vector-Borne Diseases

As a result of alterations in temperature and precipitation, the geographic range and abundance of disease vectors is changing, exposing more people to tick borne and mosquito-borne illnesses (Beard et al., 2016; Monaghan et al., 2018; Ortiz et al., 2017; Pachauri et al., 2014). In India, several important vector-borne diseases (VBDs) are endemic, including Malaria, Dengue, Chikungunya, and Japanese Encephalitis. Although public health and meteorological surveillance data are frequently lacking, several regional studies have found correlations between the prevalence of these diseases and climatic variables (Khan et al., 1996; Laneri et al., 2010; Murty et al., 2010). Although the prevalence of VBDs is strongly influenced by climate, behavioral and

physiologic factors determine disease burden on a local level. For example, the recent increase of Dengue in certain regions of India is likely due to permissive ecologic conditions, which favor mosquito development coupled with population expansion, unplanned urbanization, deteriorating basic sanitary conditions, and inadequate water supply and waste management systems on a local level (Gupta & Reddy, 2013).

Men and women have a different risk of acquiring VBDs because they occupy different environments throughout the day and have different biologic risks. Pregnant women are a notably vulnerable population. They are at heightened risk for contact with vectors due to increased time spent around the home near domestic standing water. Additionally, physiologic changes during pregnancy increase vulnerability. Higher CO₂ production, a chemoattractant for mosquitos, and increased peripheral blood flow and skin temperature together increase biting risk. Furthermore, hormonally induced changes in immunologic function may suppress host defenses resulting in higher intensity of viremia and parasitemia (Kourtis et al., 2014; Lindsay et al., 2000; Mbonye et al., 2005). Henceforth, studies have found that pregnant women have a risk of severe malaria that is 3 times as high as that of non-pregnant women (Rijken et al., 2012). Malaria infection during pregnancy results in anemia and diminished transplacental nutrient transport from placental parasite sequestration, resulting in intrauterine growth restriction and increased vulnerability of the mother to hemorrhagic complications of delivery (Steketee et al., 1996). In a recent study of three districts in India, 23% or more of maternal deaths between 2004 and 2006 were attributable to malaria, making it the most common cause of maternal death during pregnancy (Kourtis et al., 2014).

Other VBDs carry different pregnancy complications. Dengue virus, which has been increasing in severity and distribution in India over the past decade (Mutheni et al., 2017), is associated with increased risk of cesarean delivery, preeclampsia and intrauterine growth restriction (Pouliot et al., 2010). Zika virus, also transmitted by the aedes mosquito, is an emergent climate-linked infectious disease with devastating fetal impacts including microcephaly, central nervous system malformations, and impaired cognitive development (Petersen et al., 2016).

3. International Policy Frameworks

Climate change, poverty, and gender inequality are increasingly recognized as global problems; however, achieving the integration of policies, surveillance, and program creation and implementation necessary to make progress in solving these inter-related issues has proven challenging at local, national, and international levels. Mindfully developing policies that engage and support women at all levels of society are cornerstones of both enhancing health resilience and also finding viable solutions to sustainability challenges.

The WHO has recently placed the “health impacts of climate and environmental change” as one of four top health priorities for the next 5 years and called for placing the well-being of women, children, and adolescents at the centre of global health and development (World Health Organization, 2017) Such ambitious goals theoretically may begin to address policy gaps; however, major restructuring of the organization to support such statements has not occurred.

The Sustainable Development Goals (SDGs) contain separate targets for poverty (SDG 1), gender equality (SDG 5), sustainability (SDG 11), and climate action (SDG 13). Opportunities to interconnect these separate targets through subtargets and indicators that bridge sectors were largely lost during the development of the SDGs. Thus, while there are energy-related indicators in the health goal (related to household use of biomass fuels), there are no health-related indicators in the energy or climate goals. Disaggregation and failure to explicitly link health with these other goal areas lead to discordant efforts, inefficiencies, and communication barriers between involved agencies tasked with solving these multisectoral problems.

Similarly, some advances have been made within the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations International Strategy for Disaster Reduction (UNISDR). UNFCCC decision 21/CP.22 (2017) calls for a *gender action plan* to incorporate a gendered perspective in all elements of mitigation, adaptation, capacity, technology, and finance. Although this framework sets the stage for action, systematic integrative procedures are lacking, as are indicators to monitor progress.

The 2015–2030 Sendai Framework—an international covenant to establish common goals and standards for disaster risk reduction—formalizes climate change as a disaster-risk multiplier to women (UNISDR, 2015).

Furthermore, it calls on adopters to “prepare, review and periodically update preparedness policies, plans and programs with the involvement of all relevant institutions, and to facilitate the participation of all sectors and stakeholders (UNISDR, 2015).” Importantly, it calls attention to women as important stakeholders in risk reduction who, when empowered, can serve as key agents in response, recovery, rehabilitation, and reconstruction. The Framework contains 38 indicators to track progress in implementing the seven targets, which aim to reduce disaster mortality and damage to critical infrastructure and economy through increased multi-hazard early warning systems, improved national and local mitigation strategies, and enhanced international cooperation. The framework also incorporates the related dimensions of SDGs related to poverty, sustainability, and climate action.

Although significant progress has been made within international policy arenas, there are implementation challenges for all policy frameworks. Systematic procedures to integrate policies are lacking both within and between organizations and regional infrastructure to support such targets is often absent as is robust participation of national governments whose constituents might benefit from such policies.

4. Case Studies of Local Solutions

Although national and international policy frameworks are needed to support large-scale action, local action is the foundation of any meaningful intervention. Women occupy many important spaces throughout society, including but not limited to primary food producers; guardians of natural resources; water harvesters, educators, and raisers of children; caregivers for elderly; community leaders; technical and professional leaders; and political leaders. The following series of case studies highlight lessons learned from planning and implementing climate-resilient health solutions in India on local and regional levels.

4.1. Water and Sanitation Improvement in Nanded, Maharashtra

In 2014, the Clean India initiative was launched to eliminate open defecation in the country by building 120 million toilets in rural areas (GOI, 2014). To raise revenue for this program, a tax was levied in the 2015 budget and corporate social responsibility funds were sought. In the past, nearly all sanitation programs had failed, likely due to cultural taboos, residents not wanting a toilet near the kitchen or in the house, water shortage, and lack of accountability for maintenance of toilets in public spaces. A structured policy program was created to distribute funds to state governments. Within the Nanded district of Maharashtra, a unique approach was adopted. State officials traveled in person to communicate directly with community level elected leaders, focusing especially on the female-headed panchayats (local councils). They were made active stakeholders in the entire process and they in turn reached out to the village population seeking input and support. The result was an expansion of the initial project using local funds to address local residents’ needs.

1. The package was enhanced by R2000/toilet to include a bathing area alongside the household toilet, with labor contribution provided by the individual beneficiary. Toilets were built inside the house on a totally on voluntary basis.
2. Sewage holding pits were built outside of houses to hold effluent from toilets and household wastewater. Funds from MNREGA (Mahatma Gandhi National Rural Employment Guarantee Act) were used to construct these pits.
3. The village council (Gram Panchayats) advocated for the building of reverse osmosis drinking water plants from the funds it received from the government. Safe and clean drinking water became available at very low cost to citizens (20 L/5 rupees). This became hugely popular as women were saved the chore of fetching water from open sources.

Engaging local leaders and female heads of household as stakeholders in this project promoted a culture of ownership and innovation. Since women primarily oversee personal hygiene and sanitation practices in the home, engaging them at the stakeholder level was key to designing solutions that were both culturally acceptable and addressed a real need.

Additionally, community activism led to ingenious solutions to pool resources and simultaneously solved other long-standing health issues, such as persistent standing water, poor access to clean drinking water and lack of access to private bathing. By 2016, all 1,309 villages in the district were converted and there was a marked reduction of mosquito breeding sites due to vanishing open gutters and kitchen

wastewater. Notably, during this time there was a marked decline in dengue, malaria, and other vector-borne diseases in the district. The most important lesson learnt is that there has to be ownership and participation (both financially and intellectually) of beneficiaries in creating any new health asset.

4.2. Building Nutritional Security in Palghar, Maharashtra

In the Palghar district of Maharashtra, nearly 30% of women are underweight (body mass index $< 18.5 \text{ kg/m}^2$) and nearly 50% of children age 6–59 months are anemic ($< 11 \text{ g/dl}$) (GOI, 2015). The Energy Research Institute (TERI), an Indian nonprofit organization, has initiated a number of interventions to address chronic malnutrition and anemia related to food insecurity by utilizing the area's abundant natural resources and biodiversity (Parasnis, 2018). The program focuses on reintroducing nutrient-dense, locally available wild edibles into the regular diet of tribal communities. Through community focus groups led by trained local health workers and the introduction of nutrition programs in local schools, social acceptance of these food sources is growing.

Additionally, the local government partners with TERI to sustain these initiatives. At the village level, child development centers are engaged in establishing nutrigardens in public spaces. Nutrigardens exemplify the cultivation of nutrient dense, locally adapted food sources and are also used to improve nutrition in the schools. Simultaneously, local partner organizations support educational classes to train and empower women to take control of their food security by cultivating, procuring and preparing nutrient-rich foods.

Teaching women to understand dietary causes of disease and training them in the procurement of diverse, abundant, and locally adapted food sources promotes food security and independence, while simultaneously acts as a climate mitigation and adaptation exercise. Cultivation of local food reduces the need to use fossil fuel energy for transportation and eliminates the industrial inputs commonly used in large-scale food production. Additionally, cultivation of local foods promotes climate resilience by encouraging biodiversity, preserving the local environment and fostering the use of naturally occurring food sources that do not need large quantities of water or external inputs to grow.

4.3. Climate Resilient Farming in Marathwada, Maharashtra

The district of Marathwada is an agriculturally rich region that is highly susceptible to droughts. According to a study by the Indian Institute of Tropical Meteorology, between 1870 and 2015 the region faced 22 droughts, of which there were five instances of two consecutive droughts, the most recent of which were in 2014–2015 and 2015–2016 (Kulkarni et al., 2016; Seetharaman, 2017). Successive droughts can lead to multiple cascading health issues, impairing not only the agricultural economy but also affecting the health of the communities, where there are high rates of anemia and malnutrition (GOI, 2015).

Through focus groups with the local female farmers, led by Swayam Shikshan Prayog (SSP)—an organization that works for women's empowerment, it was discovered that although women are extensively involved in farming, decisions related to crop selection, cultivation, and consumption rest exclusively with the male counterparts. Women expressed concerns that male counterparts were committed to growing single-strain cash crops like soya, cotton, and sugarcane, which come with expensive chemical inputs. Women shared that they felt stressed and suffered from health ailments because of the increased burden of providing food for the family and high consumption of chemical contaminated food which they believed contributes to poor health (Gopalan, 2016).

Given the regions' propensity for drought and food insecurity and understanding that climate change may worsen this pattern, SSP initiated a women-centered climate resilient farming model (Katakam, 2018). This approach repositions women as decision makers and bearers of knowledge, enabling them to make informed decisions related to what to grow, what to consume, and how much to sell. This model encourages women to gain cultivation rights by starting with a small section of family land, initially ranging to one-half to one acre. Women are then given multiple trainings and participate in groups centered around cultivating food crops, including cereals, pulses, oil seeds, vegetables, and animal fodder. The trainings focus on resilience-building practices including use of bio fertilizers, preservation and exchange of local seeds, increasing crop diversity, increasing number of crop cycles, choice of drought-resistance and water efficient crops, water conserving irrigation techniques, and tree plantation. Adoption of the model has resulted in improved food and nutrition security of the households, reduced the cost of cultivation, increased productivity, and rendered other social, economic, and environmental benefits (Katakam, 2018).

4.4. Affordable Clean Cooking Solutions

The use of biomass fuels for cooking and heating produces carbon monoxide, hydrocarbons, and particulate matter, which are inhaled by those within the closed home space. The release of these toxic pollutants contributes to a range of health impacts including cardiovascular and respiratory disease, lung cancer, and early childhood pneumonia (Kankaria et al., 2014). Additionally, harvesting and burning biomass release about one billion tons of CO₂ each year and contributes to 40–50% of black carbon emissions (Ramanathan et al., 2017). In India, it is estimated that 64% of the total population relies on biomass fuels, which leads to more than 1.2 million deaths each year (World Health Organization, 2018b). Women (and children) spend the maximum amount of time in the home and are thus disproportionately impacted. Moreover, the reliance on biomass fuels results in women and children spending many hours per day collecting fuels, instead of attending to other activities of livelihood, such as education.

Improved cookstoves have been developed and deployed in India with a dual objective of reducing health and environmental risks associated with biomass combustion. However, despite clear scientific evidence of the efficacy and health benefits of these innovations, their widespread dissemination and use has been slow. For a variety of behavioral, cultural, and policy related reasons, simply making stoves available on the market is not enough to achieve consistent household adoption.

Stoves cost approximately US\$60, which for individuals living with less than \$1/day, is prohibitive (Ramanathan et al., 2017). Additionally, stoves require frequent maintenance. Project Surya is piloting novel strategies to overcome this financial barrier and incentivize use among female heads of household (Ramanathan et al., 2017). Through the Surya initiative, women receive personal loans from rural banks to make the initial investment. Then, the use of each stove is monitored by a wireless sensor that registers stove usage, which is translated into tons of carbon mitigated. Women are compensated US\$6 for each tCO₂ which equates to roughly US\$32 per stove per year. The quarterly returns are distributed directly into an electronic bank account, established in the woman's name, that can be accessed through a mobile phone. Additionally, women are being trained to fix stoves, enabling entrepreneurship and female business leadership. Sustained engagement with five hamlets within the Indo-Gangetic plains resulted in a high degree of clean technology adoption and a subsequent reduction in black carbon emissions by 40%. These and similar pilot programs have demonstrated substantial decreases in lower respiratory infection in children and chronic obstructive pulmonary disease and ischemic heart disease in adults (Wilkinson et al., 2009).

5. Recommendations

Women play a vital role in the societal response to climate change, and their participation at all levels has been shown to result in greater responsiveness to citizen's needs, often resulting in sustainable outcomes (Kratzer & Masson, 2016; UNDAW, 2001). While GOI's National Action Plan on Climate Change (NAPCC) acknowledges that certain groups of women are vulnerably to negative impacts of climate change, the assessment of the effects of climate change does not differentiate between genders nor does its outline of mechanisms that support adaptation call out measures to address this heightened risk (GOI, 2008). As a result of the Lucknow Conference the following practices to support an integrative policy approach were proposed (Failey, 2017).

“the NAPCC's assessment of the effects of climate change does not differentiate between genders or acknowledge the unique vulnerability of poor women, not does its outline of mechanisms that support adaptation call out measures to address this heightened risk.”

5.1. Ensure Participation

Recognizing women's roles as educators, caregivers, holders of knowledge, and powerful agents of social change positions women to effectively design and implement culturally acceptable interventions where they are needed most. Women should be empowered as key stakeholders at the outset of any project with the understanding that combining scientific data and community knowledge will yield better results.

5.2. Enhance Multisectoral Coordination

Comprehensive strategies to integrate gender vulnerability into climate adaptation and mitigation are needed. Women's health issues can be integrated into multiple levels of planning, including: disaster risk reduction, transportation, water management, infrastructure investment, and agriculture. Private-public partnerships can be leveraged to codesign impactful products and services, such as solar cookstoves and sustainable agricultural practices. Developing mechanisms for reporting and regular analysis of gender dimensions using common indicators within all sectors will increase transparency and cooperation in achieving this cross-sectoral goal.

5.3. Prioritize Education

Investment in skills and capacity building among women will foster leadership and strengthen resilience. Education regarding the gender specific health threats of climate change is needed among policy makers and can be integrated into public health messaging.

5.4. Enhance the Usefulness of Health Outcome Data and Statistics

There is a great need to improve public health surveillance and data collection in India (and in all low-middle income countries). Collecting high-quality gender-disaggregated data will enable better understanding of gender-climate-health associations. Additionally, health data may be integrated with agricultural, meteorological, and water supply data to identify vulnerable regions and populations and allow for predictive modeling that can inform community-based interventions.

5.5. Enhance Preplanning for Disaster Risk Reduction

A comprehensive assessment of women and men's assets and vulnerabilities is foundational to any risk reduction plan. Such assessments not only provide a more in depth understanding of the effects of climate change, but also reveal the political, physical, and socioeconomic reasons why individuals suffer disproportionately. This creates a stronger opportunity for effective intervention.

5.6. Redefine Success

Women's health outcomes and economic prosperity can serve as surrogate markers for development, disaster risk reduction, and climate adaptation and should be used as indicators for project and policy success. Similarly, regions with poor health outcomes should be identified as *hot spots* for current and future vulnerability to climate change.

6. Conclusions

Low-middle income countries, such as India, have significant social, geographic, political, and environmental realities that make all citizens, but especially women, vulnerable to climate change. Simultaneously, India has a tremendous opportunity to guide the global trajectory on climate change by adopting sustainable development practices. While gender has been increasingly factored into international climate policy, progress has still been slow in India to reduce gender-based health disparities and to involve women in climate change mitigation, adaptation, and disaster risk reduction and management. Local solutions are a starting point for implementation, but in order for such solutions to have significant impact on future climate scenarios, scaling them up is essential. This process may be accomplished through proactive investment strategies, sensitization of policy makers in ministries of health and family welfare, high-level political engagement with the implementation of the UN landmark agreements, and integration of a gendered perspective into national, state, and local level climate adaptation plans. Additionally, the need for compliance with the monitoring processes advocated by the SDGs and the Sendai Framework are critical to address the complex interactions between poverty, gender-based social discrimination, and climate change that threaten to amplify gender-based health disparities.

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