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REVIEW

Gender, intersectionality and climate smart agriculture in South Asia: A review

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Abstract

Food systems-based livelihoods are precarious for many of the most vulnerable and marginalised people, with climate variability and change posing a grave threat to food security. South Asia is expected to be one of the three most concentrated regions of hunger in the world by 2050. Whilst highly diverse in both socio-cultural systems and ecosystems, the majority depend on smallholder farming throughout the region. Transforming both agriculture and food systems is therefore critical to sustainable and equitable development and achieving food security. Yet the critical role of gender and intersectionality is still inadequately woven into this future. In this paper, we find little evidence of robust intersectional contextualisation in design and analysis of Climate Smart Agriculture practices. We examine existing evidence to illustrate how a nuanced understanding of gender relations and intersectionality can inform a climate smart approach to landscape and uses of the land to ensure food and nutritional security in the face of climate change. Gender segregated data analysis, which helps recognize the most vulnerable, is an essential underpinning to this transformed approach to policymaking and project design. Direct support is required, alongside structured interventions beyond the farm gate in relation to access to credit and finance, leadership and capacity building and an equity focussed transformation of national and regional policy frameworks on climate impacts. Focusing on literature from India, supplemented with wider South Asian research, we find that despite growing evidence on the relationship between gender, agriculture and climate change, an intersectional analysis of climate smart agriculture, including class, and caste and other social identities, remains limited.

1. Introduction

The world has returned to hunger levels not seen since 2005, and food prices remain higher in more countries than in the period 2015–2019 [1]. Along with conflict, rising cost of living, civil insecurity and declining food production, climate shocks pose a serious challenge to global food security [2,3] By 2021, the world's average temperature was 1.2°C above pre-industrial levels, and even if current targets pledged by nations are met, the world will reach between 2.0–3.6°C above pre-industrial levels by 2100 [4].

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As the most densely populated region of the world, South Asia faces a unique set of challenges and acute vulnerabilities to climate change in its efforts to achieve food security. Rising temperatures cause heatwaves, water stress and drought and floods, typhoons and glacier melt trigger disasters, the combination of which cause serious threats to food security and food production. The Global Climate Risk Index found that South Asia was the region most affected by extreme weather disasters in the last 20 years [5], whilst the IPCC Sixth Assessment report notes the impact of climate-related extremes of temperature on food security, nutrition and livelihoods to be '*particularly acute and severe*' for those living in Asia [6].

India, the largest country in South Asia, and the focus of this paper, possesses significant socio-economic and agroecological diversity. Smallholder farming predominates, with the main crops including rice, wheat, maize, pulses, fruits and vegetables. Climate change poses a significant future threat to yields: under potential average temperature rises of between 1–4°C by 2050, rice yields are expected to decline 10–30% by 2050 and maize by 25–70% [6]. Increased risks of droughts, floods, heat and erratic rainfall patterns are already having long-lasting impacts across the region, exacerbating pre-existing vulnerabilities and inequalities based particularly on gender and poverty [7]. Some areas of South Asia are recognized as climate 'hotspots'—such as the low-lying coastal areas (all of Maldives, much of Bangladesh and significant populations of Sri Lanka and India), which will suffer increasingly from sea-level rises, cyclone and erratic monsoon activity, or remote mountain communities and tribes in Nepal, Afghanistan, Bhutan and India, vulnerable to drought, floods, landslides and changes in temperature [6,8] [IPCC 2022, Tamang and Udas 2021], posing threats to landscapes, livelihoods and cultures.

Women have been highlighted as particularly vulnerable to climate change, and in South Asia, this is acute [9] At the broadest level, most South Asian cultures exercise restrictions on women's engagement, safety and participation in society. Women have low levels of social inclusion, justice and security relative to global averages, with all except Sri Lanka, Bhutan and Nepal placed in the bottom 40% of 177 countries worldwide and Pakistan and Afghanistan in the bottom 10% [10]. While there has been progress in the fields of education and health, the Global Gender Gap Report 2024 ranks South Asia last in terms of economic participation and opportunity for women and girls [11]. These constraints make it difficult for women to respond proactively to threats and opportunities in their lives.

Despite this general disadvantage, recent studies are beginning to point out that women are a diverse group, and the effects of climate change are much more intense for rural women, those engaged in agriculture and other primary sectors, and the landless, usually belonging to the lower castes and classes [12–14]. While using the term women, we refer in this paper to the ways in which multiple identities, of caste, economic class and gender (comprising aspects of intersectionality) together shape vulnerability to risks and disasters in India and more widely across South Asia.

Climate smart agriculture (CSA) refers to a collective of on-farm and off-farm practices and technologies that facilitate increased resilience to climate change. Yet, to be sustainable, it is important that they address issues of inequity. In this paper, drawing on available evidence, we explore how far gender is taken into account within CSA policies and practices, key to achieving the desired food security and nutrition outcomes in a changing climate.

In the next two sections, we set out our conceptual approach and methodology. Section 4 explores the different dimensions of Climate Smart Agriculture with a gender and intersectionality lens. In Section 5, we draw out key strategies for climate risk management based on our analysis. Section 6 concludes with key insights for policy.

2. Conceptual approach to understanding the relationships between gender, intersectionality and climate smart agriculture

People need access to safe and nutritious food to consume sustainably, to be able to engage in 'nature-positive' production (Nature-positive approaches are end-to-end solutions along the food value chain which act to reduce emissions and increase carbon capture, thereby limiting anthropogenic contributions to climate change; promote the regeneration, restoration, and protection of critical ecosystems to conserve biodiversity, protect land and water, reduce food loss and energy usage), develop equitable livelihoods and improve their farm and their family's resilience to climate change and other stressors. Three conceptual approaches underpin this paper. First, an understanding of the need to achieve **food security for a nation's population as a primary goal** - being able to reliably obtain, consume and metabolise sufficient quantities of safe and nutritious foods. People affected by food insecurity need to possess enough agency, finances and power to access this food, and to enable systemic changes if they are unable. [7,15]. Food security can be seriously impacted by many factors including short term weather/climate disasters, contextual agro-ecological and cultural conditions [16], food value chain and trade systems disruptions and government policies. Food security is a crippling issue for many nations, but India is one of those most affected: in 2023 around 195 million people in India were classified as undernourished, making up about a quarter of the world's undernourished population [1]. Food price inflation remains a major issue, and in July 2023, annual food price inflation in India exceeded 11%, the highest in a decade. With about 2°C average global surface temperature rise, climate-related changes in food availability and diet quality are further expected to increase nutrition-related diseases and the number of undernourished people, affecting millions, particularly among low-income households in South Asia [17].

Second, we are guided by a **conceptual understanding of gender and intersectionality** and how these might play out in the pursuit of improved food security. A **gendered** approach to development has two strands: the first, known as 'Women in Development' (WID), is a simple understanding that the roles of women and men differ, that gender divisions of labour are common in agriculture, and this has effects on the access to and control over both resources and benefits. Participation in agricultural development initiatives can then be encouraged by paying attention to the design and monitoring of projects created for the inclusion of those previously excluded. The second approach, 'Gender and Development' (GAD) uses gender analysis to contribute to an understanding that deeper, transformative approaches to development are needed that empower women and men to participate and lead more fully in social groups and institutions, challenging and changing existing structures and practices [18].

More recently, the concept of **intersectionality** has added a further useful lens to highlight that people differ not only by gender but also through a range of other social and political identities that influence their well-being significantly, including ethnicity, age, caste, race, class, religion, sexuality, education, family status and disability. Empirical studies from Nepal and India have shown how overlapping identities of caste, economic class and gender influence vulnerability to disasters and climate risk, including abilities to migrate [12,19–21]. An intersectional approach recognises that people's lives are shaped by their identities and social relationships, which combine to create intersecting forms of privilege and oppression depending on a person's context and existing power structures such as patriarchy, ableism, colonialism, homophobia and racism [22]. An intersectional approach goes beyond a description of differential impacts, to investigate the dynamic interactions between contextual factors, agents of change and their transformational potential.

The third key concept of Climate Smart Agriculture (CSA), initially developed in 2010, is now quite well known. Reflecting the increasing importance of climate change on farming and rural livelihoods, its three pillars comprise: a) sustainably increasing productivity, improving incomes and livelihoods, b) building adaptation and resilience to climate change; and c) reducing greenhouse gas emissions (GHG) (Fig 1)[23].

Whilst there is variability in precise definitions, these three pillars are frequently used within the CSA literature to group a range of approaches and agricultural innovations that incorporate an understanding of climate change into their design at different scales and across many stakeholders along the agricultural value chain - from inputs to production to food waste. While the first two pillars focus on improving livelihoods and adaptive capacity, the final one on reducing emissions also includes the conservation benefits of CSA in terms of biodiversity and soil health, amongst others. In practice, however, the focus continues to be placed on scientific understandings and technical changes at farm or landscape level, though power relations, institutional, infrastructure, market and policy aspects are also vital for the successful and equitable implementation of climate smart interventions intended to deliver sustainable benefits to men, women and the wider environment [24,27]. In this paper, we recognise the limitations of the focus of much literature to date on pillars 1 and 2 on mainly farm-level technical innovations. We bring in wider systemic examples of efforts to support CSA where evidence is available.

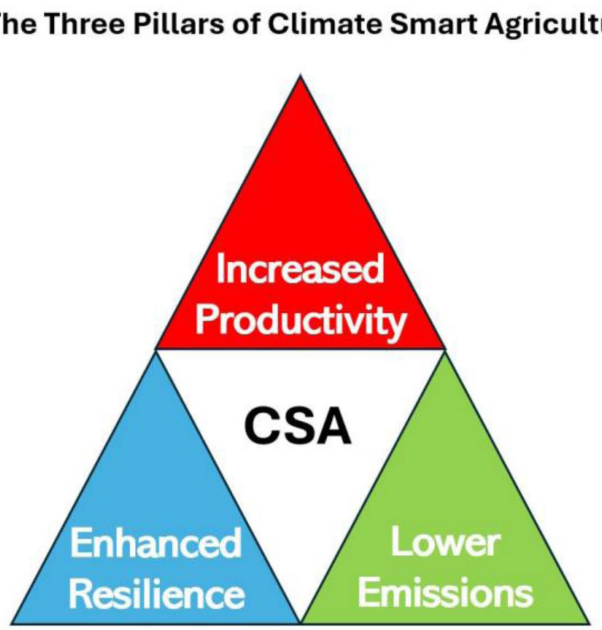
More recently, Huyer et al. [28] have developed a useful conceptual framework to better understand gender and social inclusion aspects of climate resilient agriculture, paying attention to labour burdens, control over resources, social norms and agency (Fig 2). This framework highlights the links between policy and institutional change across scales from household, farm and community networks to the larger landscape of state policies and market mechanisms. Four key areas of change are suggested: a move towards equality in access, use and benefits from institutions and services, promoting women's voice and participation in policy making and governance, generating field-based evidence on what works for gender equality and building mechanisms for gender-inclusive finance. There are, however, few analyses of how far the most transformative aspects of gender, intersectionality and climate justice have been integrated into both 'climate-smart' agricultural policy and practice.

In this paper we seek to fill this gap. Drawing on existing evidence, we illustrate how a nuanced understanding of gender and intersectionality can inform a sustainable, climate smart approach to landscape and uses of the land (crop cultivation and beyond) that will provide food and nutritional security in the face of the challenges of climate change.

3. Methodology

This paper is based on a comprehensive literature review to gather and analyse data relevant to gender, intersectionality, and climate smart agriculture. The literature review encompassed a wide range of sources, including academic journals, reports from international organizations and case studies from South Asia. Key words used to search for relevant reports or papers included 'gender', 'climate smart agriculture' (or 'CSA'), 'sustainable agriculture practices', 'women's adoption of CSA', 'caste and gender intersectionality in agriculture/farming/CSA', 'influence of caste, class and social identities in agriculture', 'access to resources for agriculture', 'influence of women-friendly agricultural technologies', 'climate finance', 'climate change policy' and 'food security'.

Limitations in the literature were immediately clear. We observed that most South Asian countries do not generate or analyse sex-disaggregated data consistently in this field. This could be due to multiple reasons including low capacity to capture fine-grained, local level



Increased sustainable productivity and improved livelihoods

Climate Smart Agriculture focuses on increasing productivity through sustainable intensification and improvements in resource-use efficiency. Increasingly this focuses on the wider pathways to improved sustainability of production and the nutritional quality of production. This pillar offers considerable potential for increasing agricultural incomes and the resilience of rural livelihoods.

Enhanced resilience and adaptation to climate change

Climate Smart Agriculture approaches encompass strategies aimed at reducing the vulnerabilities of farmers and agricultural ecosystems to climate-related risks and shocks. These strategies include a range of practices designed to enhance resilience by building capacity and contributing to the long-term sustainability and adaptability of farming systems.

Lower greenhouse gas emissions

This pillar emphasises the importance of implementing agricultural practices that both reduce greenhouse gas emissions and restore soil fertility, conserve biodiversity and mitigate risks associated with climate change. CSA approaches can reduce or remove (mitigate) greenhouse gas emissions caused by farming through supporting nature-based methods and can reduce the use of fossil fuels through the agricultural value chain. CSA supports carbon sequestration, the maintenance of healthy soil ecosystems and supports a wide range of species, enhancing the overall stability and sustainability of agricultural landscapes.

Fig 1. Pillars of climate smart agriculture. Source: Adapted from Campbell [24], with text adaptation from Lipper et al. [25] and Van Wijk et al. [26].

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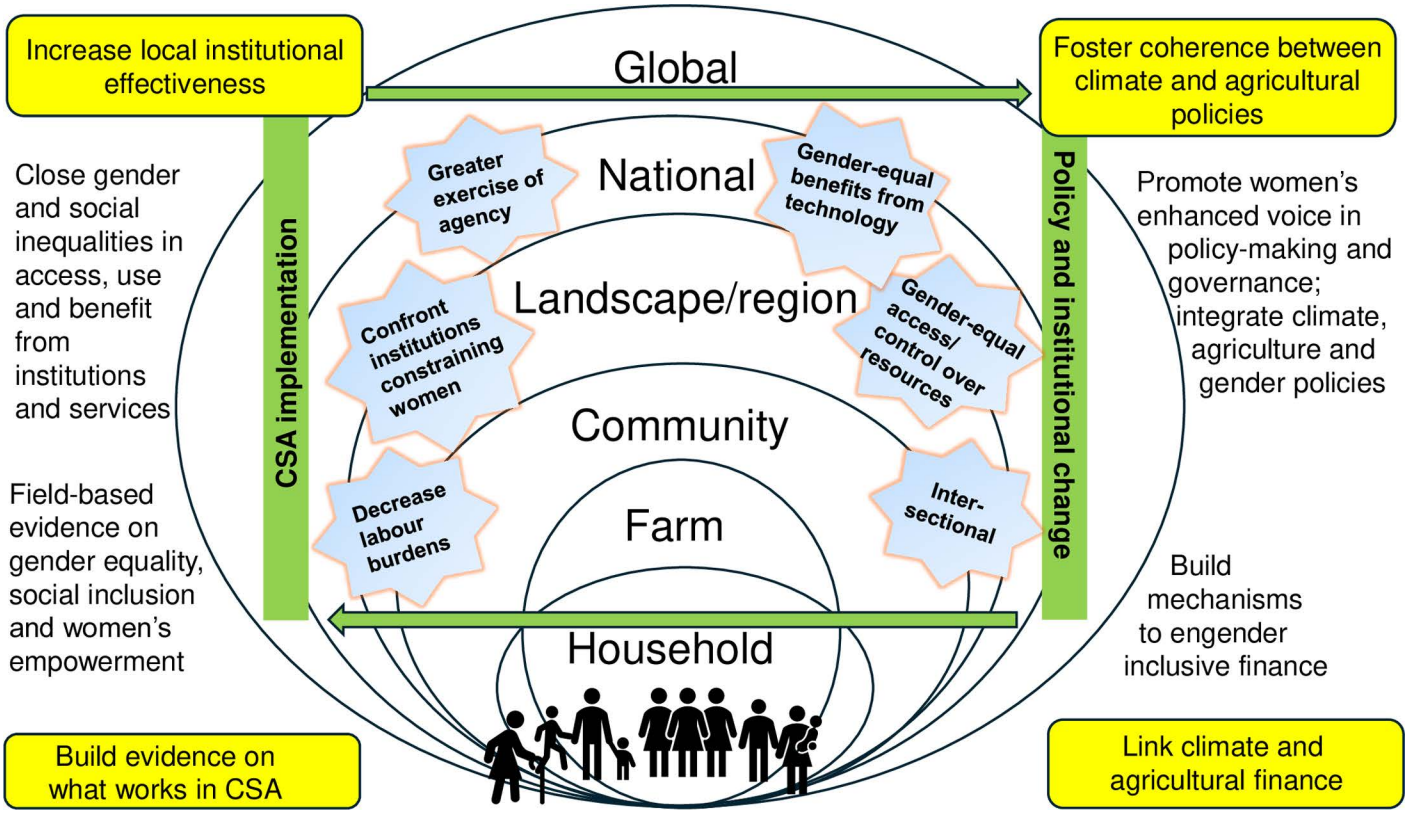

Fig 2. Gender equality and empowerment in climate resilient agriculture. Source: Adapted from Huyer et al. [28].

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data especially in remote regions and management of agricultural data across multiple organisations. India, for example, does not have a single portal for all agricultural data, hence different methodologies and levels of disaggregation apply to different variables. The lack of sex- and gender-disaggregated data underlines a deeper problem of the invisibility of activities of both men and women and potentially vulnerable groups.

However, new methodologies are currently being developed to collect and analyse more nuanced, multi-dimensional data, taking account of intersecting identities of caste, class, ethnicity, age, marital status and land-holding size [29,30]. One early example is Livelihoods as Intimate Government, developed using multiple methods for more nuanced intersectional livelihoods decisions in sub–Saharan Africa [31]. In Asia, while Gartaula et al. [32] have explored mechanisms for gender-responsive mitigation in rice cultivation in India, Chanana-Nag & Aggarwal [33] (2018) evaluate multiple factors such as labour, credit and market access for female farmers, in analysing the gender-sensitivity of selected interventions. Such analyses can help develop policy instruments to limit the negative impacts of climate change on gender equality.

More recent developments in these approaches consider co-production methodologies incorporating different forms of knowledge, chains of explanations across scales, a focus on intersectional identities, tools for data gathering combining visual methods, and qualitative comparative analysis [30]. Research across the board highlights the need to reflect the 'compounding' rather than purely 'additive' factor of individuals with identity characteristics assessed as either marginalising or increasing vulnerability. Quantitative methodologies

for intersectional approaches are also beginning to be developed and tested in other fields and sectors [34,35]. Within development interventions and innovations, an intersectional approach can support more socially responsible scaling strategies, including practical applications, such as GenderUp [36,37].

4. Gender and intersectionality within climate smart agriculture

This section examines empirical evidence and studies on the intersection of Climate-Smart Agriculture (CSA) approaches with gender, delving into the intersectionality of CSA with gender and socio-economic identities relevant to India, particularly caste and class, analysing both the available evidence and gaps in the literature. For the purpose of this paper, we adopt the definition of the caste system in India as a hierarchical social order determined by birth. The Scheduled Castes (SC) and Scheduled Tribes (ST), as defined by the Indian Constitution, occupy the lowest rungs of this hierarchy. The disparities between upper castes and the Scheduled Castes, Scheduled Tribes, and what are known as 'Other Backward Classes' (OBCs) manifest in social, economic, and agricultural contexts, significantly impacting access to land ownership, technology, information, credit, and other essential resources for sustaining and advancing agriculture-based livelihoods.

4.1. Increased sustainable productivity and improved livelihoods

Arable and livestock farming, fishing, forestry and migration are the main sectors where gender and intersectional-responsive resilience planning could improve livelihood opportunities, increase yields and improve outcomes for women and disadvantaged groups in rural areas. Technological improvements are an important part of addressing resilience and mitigation challenges in agriculture. However, a gender-blind and intersectionality-blind approach to technology can cause greater increases in inequality if marginalised and disadvantaged groups are unable to benefit. Gender-responsive technologies are those which are based on the needs and interests of women farmers, are affordable and accessible to them, reduce time and labour contributions and increase their control over outputs and incomes.

Technologies introduced to reduce women's drudgery can also reduce the total manual labour requirements. This can have different, and perhaps unexpected, impacts on different groups of women. While women landowner-farmers may benefit from labour-saving technologies and practices if they reduce the demands on their time and labour, poor or landless women, who rely on income from farm labour, may lose jobs and incomes, as seen from the example of introducing mechanical threshers in Bangladesh [38]. Similarly, a conservation agriculture technology, direct rice seeders, eliminated the need to transplant rice (an important source of wage labour and income for women) and affected household incomes in areas where they were introduced [39]. Recent evidence suggests that mechanized tilling has contributed to a 22% decline in women's agricultural labour in India between 1999 and 2011 [40]. Further, significant caste-based disparities exist in farm machinery ownership, with Scheduled Castes (SC) and Scheduled Tribes (ST) less likely to own machinery compared to the upper castes [41,42]. These disparities are further compounded by gender, as women from SC and ST communities are even less likely to own farm machinery than women from the upper castes. Hansda [43] provides an intriguing perspective based on yearlong ethnographic fieldwork in Bihar, Eastern India, exploring gendered perceptions of who can operate machinery such as weeders. Farm machinery use is often categorized as "heavy work" and assigned to men. However, Hansda's study reveals that upper-caste men perceived SC and ST women as capable of heavy labour, whereas women from their own households were deemed "unaccustomed to hard labour," reflecting deep-seated caste and gender stereotypes. It is therefore vital

to distinguish between technologies that reduce women's paid versus unpaid labour and assign priority to technologies that reduce unpaid labour.

Similar is the case with access to agricultural extension information. Krishna et al. [44] found that the lower castes rarely benefited from agricultural extension services, and in areas where they were in a majority, no one benefited. In order to strengthen livelihoods and incomes, governments, innovators and other stakeholders need to ensure not just the affordability and usability of technologies, but equally consider the gendered social norms and relationships underpinning their use.

To enable real progress for women farmers, Ajith[45] identifies a need for a comprehensive and inclusive approach that organizes women producers, provides long term sustainable support, and creates better access to financial services and markets. The Rural Urban Distribution Initiative (RUDI) is an agri-based enterprise under the Self-Employed Women's Association (SEWA), in Gujarat, India, seeking to build an integrated sustainable food value chain that ensures gender inclusion through a women-owned and managed supply chain. RUDI directly connects farmers to end-users, using its own procurement channels, processing centres, packaging units, and distribution network. Smallholder farmers sell their produce to the RUDI network, where it is graded, processed, and packaged into affordable packages and redistributed into the villages by SEWA's sales force, known as *Rudibens* or RUDI Sisters. This ensures that small farmers receive fairer returns, landless labourers gain employment, and a million households now have access to food and nutrition security. The model also benefits women farmers by enabling them to become entrepreneurs, acquire new skills and technology, market collectively, eliminate exploitative middlemen, and increase their earnings. It is an end-to-end agricultural solution that ensures food security while providing multiple livelihoods to rural women and youth. A distinctive feature of the model is the seamless integration of digital technology, creating an efficient value chain through RUDI RSV, a customized mobile application hosting information for all its sales and marketing initiatives [46,47].

Through RUDI, SEWA is empowering women farmers as change agents and critical market actors, demonstrating that by enabling direct market linkages to guarantee better prices, creating farmer-owned supply chains, member-owned cooperatives, and through value-added activities such as setting up processing centres managed by rural women, farmers can enhance their income-generating potential. Restrictions on women's mobility, driven by social norms, safety concerns, and time poverty caused by their dual responsibilities in domestic and agricultural work, can significantly hinder their ability to access markets for selling agricultural produce. There is need for more in-depth analysis exploring the compounded impact of these barriers confronting women, particularly at the intersections of caste and class in India, and how they can be effectively overcome. Sensitivity to context, taking on board the social and gender realities on the ground, appear then to be critical for success [48].

The dairy industry provides a second example of how income improvements can support women's abilities to improve their livelihoods, linked to climate smart agriculture techniques. This industry has rapidly expanded in recent years to produce 20% of global milk supply, with women comprising a third of cooperative society members [49]. A major contributor to greenhouse gas emissions, the industry however provides an important alternate source of income for rural dwellers, especially women. Women-led associations and cooperatives have been enabled to cope with climate change impacts, including threats to water and fodder supply, through technologies, including improved grasses and herbaceous legumes (as noted in the following section 4.2), value-addition processes and capacity building. As women do the daily work around dairy cattle, membership of cooperatives facilitated women's involvement in decisions especially around fair remuneration for their work [50,51]. Women dairy

cooperative members in Bihar were able to earn over 200% more than non-members (Rs 5469/month vs Rs 1743/month) [52]. Several lessons are offered by this example. First, it is important to recognize the different roles played by women and men, in order to tailor programmes to provide gender-responsive services, improve incomes and nutrition in poor households, and enhance sustainable development [53]. Secondly, it is important to increase women's participation in social development and ecosystem management, recognizing their critical role in carbon management and livestock production [54]. Finally, it needs to be recognized that livestock ownership also reflects the intersections of gender, class and caste, with the Scheduled Castes and small and marginal farmers owning smaller numbers of draught and milch animals, but larger numbers of poultry [55]. This disparity stems both from resources available to the household, but also notions of 'purity' associated with different types of livestock and entrenched social norms that dictate which castes are deemed 'appropriate' to rear certain animals.

These findings underscore the pervasive influence of caste and class hierarchies on agricultural livelihoods and are important to consider in the discourse of improving livelihoods through CSA. The next section explores the subject of resource control which plays a major role in both adaptation and mitigation.

4.2. Building resilience and adaptation to climate change

Farmers are increasingly aware of the impacts of climate change on their farms, and keen to modify their practices. Over the last fifteen years or more, programmes of training, awareness-raising and suites of climate resilience and mitigation tools have been developed and are being implemented globally through governments, local and international development initiatives, agriculture extension agents and informal and formal private agriculture [56]. With the rolling out of these initiatives, it has become apparent that the ability to shape, access and benefit from these activities is mediated by gender and wider intersectional attributes including household characteristics. Many CSA approaches focus on adoption of farm-based technical innovations including water management, use of climate resilient farming approaches and crop varieties (Table 1). In the multi-stakeholder agency study on the factors shaping women's ability to adopt a number of recommended CSA practices, women's access to and control over

Table 1. Relative importance of gender-specific resource access in successful adoption of on farm climate smart agriculture practices.

CSA options/practices	Labour available (females/ youth)	Female access to Land	Female access to water for farming	Female access to cash to spend
Stress-tolerant varieties	Medium	**High**	Low	**High**
Conservation agriculture	Low-medium	**High**	Low	Low
Improved home gardens	**High**	**High**	**High**	**High**
On-farm tree planting	High start; lower over time	**High**	**High**	Medium
Small-scale irrigation	Medium	**High**	**High**	Medium
Fodder shrubs	**High**	**High**	Medium	Low-Medium
Herbaceous legumes	**High**	**High**	Medium	Low-Medium
Improved grasses (e.g., Napier)	**High**	**High**	Medium	Low
Livestock genetic Improvement	Low-High	Low	**High**	Medium

Adapted from World Bank, FAO, and IFAD [1], modified by authors.

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land emerged as a major limiting factor, alongside the availability of labour, access to water, and access to finance or credit for investment [39].

Understanding the differing constraints faced by men and women for various climate smart agricultural options is a crucial initial step in designing resilient agricultural projects and programs. The data in Table 1, largely based on expert opinion highlights female access to, and control over land as a near-universal problem. Secure land ownership tenure and access have long been a challenge for women, minority and disadvantaged rural dwellers across most of South Asia [57,58], with tenure security seen as critical for building resilience to vulnerabilities, shocks and stress especially in a changing climate [59]. Women in India own a relatively small percentage of agricultural land. Approximately 14% of women are landowners, accounting for only 11% of the total agricultural land in rural areas [60]. Similarly, whilst the Scheduled castes comprise more than 20% of the population in Nepal, they own only 1% of arable land and often work in near-bonded conditions [61,62]. Their lack of access to land in turn limits their access to credit, labour and technology, constraining their role in managing emissions. Although women perform the majority of labour-intensive farming operations, they have limited roles in decision-making.

Related to the above, access to credit and finance for investment plays a crucial role in building equitable capacity amongst vulnerable communities to both mitigate the effects of climate change and adapt. Governments in some South Asian countries have provided access to credit linkages through self help groups of women and extension services through relevant government schemes, and alongside a growth in male remittances [63], credit does not always seem to be a constraint (see Table 1). However, women's access to cash is often limited to small amounts obtained through micro-finance, and insufficient for major investments. In India the Kisan Credit Card (KCC) was introduced to improve access to finance and provide lower interest credit to farmers than local moneylenders [64]. However, access to this credit across groups disadvantaged by gender, caste or minority status has been uneven. Of 400 farmers surveyed in Maharashtra who had accessed credit, only 18% belonged to socio-economically marginalized castes [65]. In another survey of 529 women farmers in Bihar, only 10% had successfully accessed Kisan Credit Cards [66]. Additionally, women from lower castes frequently face exclusion or restrictions from participating in certain self-help groups (SHGs) [67]. Farnworth et al. [68] examined women's roles in wheat farming as both decision-makers and labourers in Madhya Pradesh, Central India and found that while self help group bylaws did not explicitly exclude women based on caste, most SHGs in the villages studied included women from specific castes. Women from the Basor community—the lowest sub-caste within the Scheduled Castes (SC)—were not part of any self help group.

While water can be a constraint for several of the practices, particularly interesting is the analysis of labour. Improvements to home gardens and cultivation of fodder shrubs, legumes and grasses all require additional labour, usually women's labour, leading to a rise in work burdens and time poverty, without necessarily a commensurate control over income from these activities. In a time-use survey across two agro-ecological contexts in India, Rao and Raju [69] found women performing agricultural work almost on par with men, alongside undertaking 95% of domestic work. Amongst the landless castes and tribes, time deficits for women were intense in the peak agricultural periods, with adverse effects on their own and children's health. Despite women's involvement in most agricultural activities, men as landowners are considered the principal farmers [70,71]. Similarly, in the Hindu Kush Himalayan region of Nepal, when men migrate to *kharka* (pastures for herders), the women bear the triple burden of reproductive and productive work, as well as community management responsibilities. Women must regularly supply food and other necessities to the men

in the *goth* (temporary animal sheds comprising 50 animals on average) [8,72]. Yet, women themselves experience bone-related health issues due to lack of sufficient nutrition and rest, especially during pregnancy and after childbirth [73]. This lack of recognition and invisibility of women's labour, often unpaid, is not only embedded socially but is also prominent in agricultural policy.

Climate change is driving rural-urban migration, largely by men in India, and whether a response to sudden stress or an attempt to diversify, is resulting in the increased feminisation of agriculture [19,74]. Women perform significant tasks, both on-farm as well as non-farm activities. Their participation in the sector is increasing but their work is treated as an extension of their household work, and adds to their work burdens, given their existing responsibilities for domestic and care-work [75]. In some instances, migration can also lead to an increase in women's decision-making power and incomes and therefore enable better preparation on-farm and investment in climate resilient approaches. For example, as a result of men migrating to peri-urban and urban areas from Gorakhpur, Uttar Pradesh, women in rural areas of origin started growing vegetables and accessing local markets for sale. With profits increasing by up to US$200 annually, this has enabled women to start their own dairy businesses and buy consumer durables for their homes [76]. This change required support and facilitation by a non-governmental organisation yet has enhanced women's capacity to cope with and adapt to adverse climate events by enabling them to overcome constraints related to the restricted access to information, credit and financial institutions, decision-making power and control over resources more broadly [77,78].

An intersectional approach examines both the barriers for adoption of new approaches across multiple groups, and the potential impacts of these interventions on intersectional and gender equity. A study by the World Bank et al. [39] evaluated the relative contribution (high, medium, low) of specific CSA practices to the three Climate Smart Agriculture pillars—Increased productivity (food and nutrition security), enhanced resilience (adaptation) and lower emissions (mitigation) (see the first three columns of Table 2). Assessing across a range of on-farm practices developed and adopted as part of CSA, the authors estimate the impact on women in terms of their control of income generated, labour investment and potential productivity benefits in South Asia, noting that impact will vary across contexts (Table 2).

The suggested practices promote both adaptation and food and nutrition security, though we note an interesting variation in women's control over income generated by different practices. Improved home gardens, as noted in Table 1, require high inputs of labour, and need land, water and financial investment as well. However, the benefit to women from both increases in productivity and any income generated is high. This is because home gardens are generally seen as an extension of women's cooking and food provisioning roles, rather than as a productive activity. Considered a part of women's domestic roles, women therefore frequently retain control over the produce and income. In areas where agriculture markets are far-away from the farm, restrictions on women's mobility can however lower the overall income earned through produce marketing [79].

It is not the same in the case of on-farm tree planting: while women do spend time and contribute labour, their control over income from fruit trees is variable. In some communities, this could be a result of social stigma, while in others, as income from the activity increases, control can shift from women to men. Conservation agriculture similarly can significantly boost crop yields in certain conditions but may be less effective under specific water or soil constraints and can increase women's labour burdens [38]. Investing in research to co-develop context-sensitive CSA options with both women and men, will help bridge the considerable knowledge gap faced by local and national policymakers in developing adaptation and mitigation plans.

Table 2. Impacts on women of on-farm practices of CSA.

Climate Smart Practices—contribution to the pillars	Pillar 1 Increased productivity	Pillar 2 Enhanced resilience and adaptation	Pillar 3 Lower emissions	Time burden	Income impact: Women's control of income derived	Women's potential benefit
Stress-tolerant varieties	High	High	Low	Low	Low	Medium
Conservation agriculture	High	High	Medium	High	Low	High
Improved home gardens	High	High	Medium	Low	High	High
On-farm tree planting	Low-Medium	High	High	High	Low	Medium
Small-scale irrigation	High	High	Low	Low	Low-Medium	High
Fodder shrubs	High	High	Medium-High	Medium	High	Medium
Herbaceous legumes	High	High	Medium	Medium	High	High
Improved grasses (e.g., Napier)	High	High	Medium	Low	High	High
Livestock genetic improvement	Medium-High	High	Medium	High	Low-High	High

Adapted from World Bank, FAO, and IFAD [39], modified by authors of this chapter.

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Potential benefits of this approach are evident from the case of Uttarakhand, on the southern slopes of the central, western Himalayas, one of the world's most threatened ecosystems, vulnerable to disasters such as flash floods, cloud bursts, melting snow in the mountains, and droughts and flooding in the fertile lowland Terai at the foot of the Himalayan mountains. Villages where women played a critical role in deciding cropping patterns and managing natural resources, particularly forests, were better equipped for resilience to climate change, long term food security, and improved livelihoods. Women here employed an integrated approach of traditional farming, forest management, livestock rearing, and soil and water conservation. They balanced the production of cash crops and local varieties to meet daily cash needs and ensure food and nutrition security [56].

In these settings, during droughts and floods, while cash crops can suffer up to 95% losses, local millet varieties like Ramdana, Kauni (foxtail millet), Mandua, and Madira are less impacted and can provide livestock fodder in worst-case scenarios. Women also manage forests sustainably, promoting mixed forests over monocultures of pine, positively impacting groundwater recharge, biomass availability, and providing herbs and animal fodder. Their rich and diversified knowledge and skills from managing natural resources, livestock care, and agriculture-based livelihoods, has ensured a survival of indigenous methods of health maintenance, lower dependence on markets for food and nutrition needs, alongside maintaining and promoting biodiversity and agricultural genetic diversity [80,81].

Adaptive strategies are not gender-neutral, as vulnerability is differentiated by socio-economic factors, livelihoods, people's capacity and access to knowledge, information, services and support. Expectations of gender roles and norms also shape coping strategies. An analysis of gender roles and relations, differentiated by intersecting social identities, with the above examples noting poverty, caste, ethnicity, landlessness, household headship, physical terrain as important determinants, is then critical to ensure that adaptation practices suggested by CSA not only build resilience to climate change, but are also equitable and sustainable long term.

4.3. Lower greenhouse gas emissions (mitigation)

The third pillar of the CSA approach aims to reduce and/or remove greenhouse gas (GHG) emissions. Relevant initiatives include efforts to improve production efficiency (thereby reducing emissions for each calorie or kilo of food, fibre and fuel produced, processed and used), reduce emissions through avoiding deforestation for agriculture and increasing the sustained uptake of CO_2 from the atmosphere through managing soils, trees and the wider landscape as carbon sinks. Greenhouse gas (GHG) emission reduction is a critical global priority, and empowering women in agricultural decision-making roles can significantly contribute to this goal.

Rice cultivation is the fourth largest source of GHG emissions [82]. Rice transplanting and associated activities account for up to 22% of the total time spent by women family members and 46% of women wage labourers. Hence, combining the reduction of women's labour burden and GHG emissions from rice cultivation could have significant social, economic, and environmental implications in rice-growing areas. This has been attempted through the introduction of two technologies - direct-seeded rice (DSR) and machine transplanting (MTR) - to replace the conventional method of transplanting rice. A study covering 641 rice-growing districts in India where the two technologies were introduced observed the potential for reducing women's drudgery in rice transplanting by 610 (75%) and 748 (92%) million labour days respectively. The MTR and DSR could help reduce 402 and 494 million male labour-days as well. While these technologies have a huge potential for reducing the back-breaking work involved in manual transplanting for women engaged as unpaid household workers, improving their health and wellbeing, as noted in section 4.1, they could have negative consequences for rural women whose livelihoods primarily depend on agricultural wage labour [32]. Further, the adoption of these technologies depend on their affordability, but equally the ability of women to make decisions contrary to normative stereotypes that discourage women from operating machines.

A further example comes from the Climate-Smart Village (CSV) approach that incorporates climatic risk management in local adaptation policies, plans and village development programs [83]. The approach was tested in 25 villages of Betul district in Madhya Pradesh, dominated by the Scheduled Tribes. The intervention used an institutional approach, basing itself on the formation of Village Climate Management Committees involving 80 women's self-help groups (SHGs) representing 900 women farmers [83]. Women farmers run custom hiring centres to provide access to affordable and relevant climate smart technologies and practices, including farm machinery [84]. Given its strength on the ground, the approach has been successful in increasing the yield per hectare of wheat by 35% and income from wheat by 44%, alongside reducing emissions (through improvements in yield per ha).

Resource control and ownership appear to play a major role in the effectiveness of CSA approaches. Additionally, a transformative and integrated approach to climate smart agriculture requires greater attention to gender and intersectional relations, both in terms of who controls resources and who takes decisions, across scales.

5. Gender and intersectionality in climate risk management strategies

Whilst there are many assessment frameworks, the level of climate risk is understood in recent IPCC assessments to be a product of interactions between climate-related hazards and the "exposure and vulnerability of the affected human or ecological system to the hazards". Each are dynamic over time and space, with varying likelihood of occurrence and magnitude [85]. More recent analyses outline approaches for managing complex risks with compound drivers

and response mechanisms [86]. Effective risk management strategies incorporate climate-sensitive decision-making approaches that reduce vulnerability associated with climate risk. The latest IPCC Report highlights South Asia as one of the most vulnerable and exposed regions of the world, which bears the 'compound challenges' of high poverty, low access to basic services, wealth and gender inequality and governance challenges [17]. While early response systems, dynamic resource allocation rules, financial instruments including insurance, infrastructure design are all important for managing climate risks, critical to this process is an understanding of people's gendered position across different institutional levels, from the household to markets and the state [87]. We consider several of these in relation to gender and intersectional approaches in agriculture.

First, climate risk research in agriculture has tended to focus on long term impacts and temperature extremes. Socio-economic research costs the impacts of uncertainties; econometric models integrate long term weather and crop variables with household surveys to draw conclusions on the impacts of climate on yields, farm income, food security and coping strategies [88]. More emphasis is given to coping practices before and after the climate risk than during the cropping season. There has been significant progress in understanding the detail of the risk on the agricultural crop cycle for many major crops, and some focus on what are called 'Critical Moments' within this cycle. However, much work remains to be done to integrate the sophistication of some projections and models to the level of an intersectional, responsive and dynamic programme to understand and support farmers as a heterogenous category, differentiated by gender, age, size of land-holding, amongst other factors [89]. Further, very little research has been done into the less commercial staple crops that are used more in times of food insecurity, and often labelled 'women's crops' [90].

Secondly, recent research from Pakistan, Bangladesh, Nepal and Bihar in India illustrates that adaptation to, and resilience building for, climate change is highly gendered [12]. Men are more likely to know about, plan and implement adaptation measures to climate change in rainfed farming areas, reflective of male dominance over crop farming in these areas [91,92]. Other studies demonstrate the continuing difficulty in some cases to bring women into the discussion, as researchers are often unable to interview women [93]. The IPCC explicitly notes that women now constitute a higher proportion of farmers due to male out-migration for employment, putting women at greater risk from climate vulnerability. The report also acknowledges vulnerable populations as including indigenous peoples, older and low-income groups, women, children, people with disabilities and minorities as being more at risk, including to their health, from climate change [6].

Intersectionality needs to be at the heart of research methodologies on resilience and adaptation building for both *proactive (*ecosystems, technology and livelihood changes) and *reactive (*biodiversity management and livelihood security) strategies [13]. Intersectional variables are context specific, and can include gender, caste, schooling, age, household size, participation in training and informal networks and access to various types of assets (land, credit, irrigation), awareness of wider change and distance to markets. Ravera et al. [13] (ibid) found that engagement with technology, including CSA, was higher in households where women are involved in agriculture, where households have access to land and irrigation (wealthier) and local markets are at a distance. Where women were strongly engaged in agricultural tasks and decision-making, they were more likely to manage social ties, knowledge and agro-biodiversity (e.g., diversifying fields and home gardens, sharing seeds). Conservative livelihood security changes (reducing outgoings) were more likely amongst older farmers. They show how bundles of strategies are prioritised and adopted depending on socio-ecological context, mediated by gendered decision-making in the household. The findings clearly demonstrate that making assumptions about choices of 'farmers' as a homogenous category is flawed.

Thirdly, looking at the specific area of Early Warning Systems (EWS), one of the key elements to climate disaster preparedness, Brown et al. [94] claim that a gender unaware approach to EWS will likely exacerbate marginalisation and vulnerability of groups with less power and influence. In their study of Nepal and Peru, they find that gender inequality and social marginalisation increased vulnerability to disasters, as these groups were generally excluded from the Disaster Risk Reduction policies, strategies and decision-making processes. Cultural norms, social marginalisation and gender-based violence reduced security in responding to disasters. However, recent studies point to the potential of timely mobile phone-enabled climate information services and agro-advisories in India to enable women and poor farmers to take appropriate decisions and adopt climate smart practices [95,96].

Fourthly, a growing area of interest in climate risk management is around finance and access to credit. Across South Asia, one increasingly finds women's assets being used for managing climate risk [97]. In the case of South India, Solomon and Rao [98] found women's gold being used for the digging of new wells and deepening of existing wells in the context of recurrent drought. Gender proofing financial investment has been recognised by several public sector and multilateral investment organisations such as the Asian Development Bank [99]. Examples such as the Rural Urban Distribution Initiative (RUDI) supporting gender inclusion along the agricultural value chain through organisation of women into cooperatives and micro-enterprises, are evidence of the need for such a strategy. Yet, at both global and national level, climate finance is not allocated using gender or intersectionality as key variables. Only four Indian states, in their State Action Plans on Climate Change, recognize intersectional aspects of gender, caste and class [100], and advocate for the need to build adaptive capacity and sustainable livelihoods through the development of CSA and climate smart villages [101]. The Climate Smart Villages concept has in Haryana state of India, developed a holistic approach focusing on climate smart practices related to wet and dry rice, reducing water use, improving soil health and bringing economic rewards, along with improving information flows around farm prices and weather [102]

Finally, the inclusion of gender and intersectionality within climate change processes in national and international policy frameworks is key. Since the Rio Conference in 1992, gender equality has been highlighted as an important issue, strengthened in the National Adaptation Plans formulated over the last decade. Much of the language at the international level focuses on gender above other intersectional vulnerabilities (e.g., COP25 Work Programme on Gender and Gender Action Plan and Nationally Determined Contributions Partnership Gender Strategy) [103], despite the use of intersectionality in the wording of the Paris Agreement, 2015. A study of sub-national level adaptation plans across 28 Indian states reveals considerable diversity in terms of attention to gender and intersectionality in these plans [100]. There is need for more nuance.

Nepal has integrated gender in its multiple policy instruments linked to climate change, as has Bangladesh. Nepal has appointed National Gender and Climate Change Focal Points (NGCCFPs) and set up a climate framework to facilitate cross-sectoral, gender-responsive approaches, actively enhancing opportunities for women's engagement in climate processes. Nepal also focuses on community forestry for mitigation as part of its National REDD+ Strategy 2018 and Emission Reduction Program, with women participating in leadership roles [104]. The Agriculture Development Strategy 2015–2035 and Disaster Risk Reduction Strategic Action Plan (2018–2030) underline the role of women in management of natural resources in contexts of severe climate events and focus on enhancing the adaptive capacity of women, men and marginalised groups [105]. Local Adaptation Plans of Action (LAPAs) emphasize gender trainings, analysis and strengthening of participatory processes. These factors have been included in Nepal's climate budgeting protocol as well [105,106]. While implementation

gaps may remain, due to constraints of funding, political will and follow-up monitoring, a nuanced and well thought through policy framework, providing a useful list of potential activities, is definitely a good starting point for change [77].

6. Conclusion

South Asia's history, cultural and ecological diversity provide a complex backdrop to the growing challenges of climate change, and strategies to ensure environmentally sustainable, adequate nutrition and food for the region's population. Focusing on the example of climate smart agriculture interventions in this paper, we draw out both specific and general points for adaptation policy and practice.

First, while there is considerable research on gender and agriculture more broadly, the intersectionality of gender with multiple socio-economic identities, including those of caste and class, remain largely unexplored in emerging research on Climate Smart Agriculture in India and South Asia. There is an urgent need to improve the conceptual frameworks, research methodologies and analysis of the gender and intersectional impacts of climate change in the subsectors of agriculture, fisheries and forestry in order to address this research gap. These sectors need better information on how multiply-disadvantaged groups are marginalised, and what works to promote their empowerment, and food, nutrition and livelihood security, in a context of growing climate variability and uncertainty. CGIAR's recent scoping review on gender-disaggregated data in climate smart agriculture through interviews with 11 development industry experts reported similar conclusions: that gender still isn't mainstreamed into projects, let alone intersectional aspects [107]. Some work is starting to emerge, with Tavenner et al [29] suggesting an approach that: a) frames questions with an understanding of power relations; b) selects most relevant intersectional axes; c) co-creates key analytics with participants; d) selects appropriate sampling and method; and e) identifies themes in analysis that are informed by intersectionality. They note that there is theoretical complexity involved so that social groups are not homogenised, but at the same time it is important to avoid fragmenting categories so far that some fade from view (e.g., gender, which is often central).

Second, understandings of social differences and their potential impact on the adoption of technologies and interventions to promote climate resilience and mitigation can be better utilised to design programmes that address specific needs and challenges, while minimising social inequalities. Interventions need to address both the winners and losers from improved technologies and practices. Local contextual knowledge is essential to support effective change and transformation.

Third, inclusive, farmer-centred capacity building, dialogue, and leadership is essential for adaptation, mitigation and livelihood security. Representation and voice are key elements of social and gender justice, yet often taken for granted. Projects need to build this into their implementation plans as in the case of the RUDI initiative. Building partnerships are key to fostering innovations and increased connectivity through digital improvements offer a tool to do so. Finally, many examples of success exist, demonstrating strategies that can enable the disadvantaged to adapt. It is essential to build on these examples, to support a detailed context-relevant prioritisation and rolling out of National Adaptation Plans and Nationally Determined Contributions, and financing that has at its core a focus on the triple challenges of social equity, food security and environmental sustainability.

Two main lessons emerge for policy. First, an understanding that CSA involves actions beyond the farm level is essential. Farm level responses to build resilience and to promote low carbon activities are important, but these examples demonstrate the need for building livelihoods through the lens of adaptation, resilience and mitigation. And as part of these, investment in the fundamental building blocks of rural development remain as important

as they were decades ago, but now need to be developed with climate change understanding, through climate resilient infrastructure, gender-sensitive markets and climate-aware agricultural extension efforts. In examples drawn on in this review, we can see that the pillars of CSA are still treated as isolated from each other in many cases; more effort is needed to explicitly design holistic approaches.

Second, policy development and impact analysis should move towards gender-transformative approaches that focus on outcomes rather than 'outputs' of interventions; acknowledgement that gender and intersectional analysis are critical, and should include understanding of disability, socio economic status, caste/ethnicity, religion, gender identity, marital status and sexual orientation [108]. These should be woven through international and national policies on climate risk management and finance relating to agriculture, access to resources and agroclimatic information and reduced drudgery especially around unpaid work. Proactive efforts to listen to and engage with marginalised groups and explicitly consider the impacts of potential risk management interventions on vulnerability, participation, power and decision-making, are urgently needed.

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