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Gender differentiated adaptation strategies considering climate risk perceptions, impacts and socio-technical conditions in Senegal's dry regions

Shalander Kumar, Soumitra Pramanik, Adjani Nourou-Dine Yessofou, Abhishek Das, Niyati Singaraju, Ranjitha Puskur, Therese Gondwe, Omonlola Nadine Worou, Sophia Huyer

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Contents

Abstract 1

1. Introduction 1

2. Data and methodology 3

2.1 Study location and sample distribution: 3

2.2 Methodology 4

3. Results and discussion 6

3.1 Household dynamics and agricultural activities 6

3.2 Understanding perceptions, barriers, and adaptation pathways in climate change: 10

4. Potential pathway for mainstreaming gender responsive climate resilient agriculture 18

5. Discussion 20

6. Conclusions 21

References 22

List of tables

Table 1: Household distribution by gender of head of household and respondent across study regions (%. 4

Table 2: Perceptions on the barriers that influence the farm households' ability to adapt to climate change (Q1-Q7). 5

Table 3: Households' basic characteristics. 7

Table 4: Primary activities of the households' head (%). 7

Table 5: Primary activities of the household members (%). 7

Table 6: Involvement of men and women members in different agricultural activities for major crops in the study regions (%). 9

Table 7: Response by household respondents for major drivers affecting farmer's capacity to adapt to climate change (%). 14

Table 8: Summary statistics of the variables included in Tobit model. 17

Table 9: Drivers and determinants of household's ability to adapt to climate change extremes: A Tobit regression analysis. 17

List of figures

Figure 1: Location of the Study regions and study households in Senegal..... 3

Figure 2: Responses towards perceptions of barriers that influence the farm households' ability to adapt to climate change 5

Figure 3: Distribution of Cropping Systems in the study region (%). 8

Figure 4: Household wise ownership of livestock and poultry in the study regions (in percentage, N=514). 10

Figure 5: Households with managing and milking of livestock by female (N=443). 10

Figure 6: Importance of livestock activities in the livelihood of household (N=490). 10

Figure 7: Gender wise distribution of perception to climate change and climate extremes among sample households (perception of the respondent). 11

Figure 8: Gender disaggregated perception of impacts of climate change on crop production and its related attributes (%). 12

Figure 9: Gender disaggregated perception of impacts of climate change on livestock and its related attributes (%). 13

Figure 10: Sex-wise distribution of farmers getting access to climate information/training on CSA (% household).....13

Figure 11: Distribution of index scores for household's ability to adapt to climate change (male). 15

Figure 12: Distribution of index scores for household's ability to adapt to climate change (female). 16

Figure 13: A conceptual framework for gender sensitive climate resilient agriculture in Senegal.....19

Abstract

This study analyses the gender-differentiated farmers' perception of climate risk and its impact, access to climate information, and adaptation strategies with the aim to develop gender responsive climate adaptation pathways in Senegal's dry regions. Study used data collected from 514 farm households through primary survey between May and June 2022 covering Kaffrine, Louga, and Thies sub-regions and multiple communes, including 5% women headed households and 12% women respondents. Through several interactions with key stakeholders, it became evident that while both men and women hold similar perceptions regarding climate risk and its impact on farming systems, women possess significantly less access to Climate Information Services (CIS) and Climate Smart Agriculture (CSA) technologies. The women farmers were found to be much more vulnerable to climate risks but often they rely on traditional coping mechanisms such as non-farm income through cottage activities, home gardening etc. rather than modern CSA technologies. Both men and women emphasized the importance of context-specific climate information to be shared with them. Barriers to climate adaptation, such as limited knowledge of CSA, inadequate resources, and dearth of timely climate information, were identified, underscoring the importance for community resilience. The Tobit regression analysis highlighted multifaceted determinants of households' ability to adapt to climate change, emphasizing the roles of gender empowerment, education, access to CSA and CIS, and regional disparities. The study underscores the importance of understanding community perceptions and drivers of adaptive capacity, addressing barriers, and based on empirical evidence we propose a gender-responsive pathway to climate-resilient agriculture. These insights and proposed pathways can help policymakers and practitioners to navigate the complex terrain of climate change effectively. Finally, these findings underscore the need for informed policy interventions, tailored strategies and appropriate institutional interventions to address cultural barriers and enhance women's role in farming decision making and access to CIS and CSA.

Key words: Climate risk perceptions; Climate resilient agriculture, Gender responsive, Tobit regression, Senegal

1. Introduction

Globally climate change has become the most significant challenge of modern times, confronting the lives and livelihood of vulnerable societies around the world including the smallholder farmers and demanding immediate and concerted action to secure a sustainable future for all (Javeed, 2023; Magombo et al., 2012; Morton, 2007; Voccia, 2011). Furthermore, vulnerability, resilience, and adaptive capacity have emerged as the three central components of climate risk research. Together they provide a framework for examining climate risk's impacts on the food security of smallholder households (Kumar et al., 2020). Smallholder agriculture where women play a major role, is highly vulnerable to climate change. However, due to variations in nature of roles and responsibilities, access to knowledge and cultural norms, men and women respond and adapt to climate threats differently (Aiswarya et al., 2023; Chandra et al., 2017; Khatri-Chhetri et al., 2020). Similarly, in the dry regions of Senegal, where the fragility of agricultural livelihoods is continually challenged by climate variability and change, a profound gendered analysis emerges as a crucial lens through which to understand and address the complex interaction of climate risk perceptions, coping strategies, access to climate information, and household resilience. In this region men and women experience climate change impacts on farming and livelihood differently due to unequal access to resources and services as women control less, poorer quality land, with insecure tenure, and have less access to cash, extension services, and agricultural organizations,

limiting their resilience (Perez et al., 2015; Carr et al., 2016; Assan et al., 2020). While Senegalese farmers of all genders perceive rising temperatures, shorter rains, and erratic rainfall as threats, their understanding of climate change causes and effects is limited (Tschakert, 2007). Women often have a broader and more long-term view of risks due to their responsibilities managing household resources but face more barriers to adaptation due to social norms and lack of access to information and resources (Ngigi et al., 2016). Djoudi & Brockhaus (2011) showed that in Northern Mali, men and women have developed different adaptation strategies to climate change based on traditional gender roles, with women hindered by loss of household labor, lack of resource access, and inability to influence decisions while women's vulnerability has been increasing in the short-term, long-term changes in gender roles could benefit them economically and socially. With women's critical role in farming systems there is need to find ways to adopt gender-responsive approaches for effective climate adaptation and food security measures (McKune et.al 2015; Cramer et.al 2016). Further, in the absence of a gender responsive approach, the full potential of climate resilient agriculture cannot be harnessed.

Farm households employ a range of strategies to cope and adapt to the impacts of climate variability and change. These strategies are driven by the available resources, knowledge, and socio-cultural norms. Study by Ullah et.al. (2017) in Pakistan highlights that effective adaptation strategies through crop diversification, improved seeds, afforestation, and judicious fertilizer use can be the specific copping strategy towards climate change impacts of farmers in both genders. In Senegal's dry regions, these coping mechanisms often involve diversifying livelihoods, altering cropping patterns, and seeking off-farm employment. The extent to which men and women can access and implement these strategies is influenced by their differential access to resources and opportunities (Brottem & Brooks, 2017; Diouf et al., 2019; Giannini et al., 2021; Houweling et al., 2012; Mertz et al., 2008). Timely receiving of climate information and training on climate resilient agriculture (CRA) are also key drivers of farmers capacity to adapt to climate change. However, gender disparities in farming related decision making, and access to climate information and climate resilient technologies, hinders women's ability to respond effectively to climate risks (UN Women, 2022). Understanding the gender differentiated barriers and potential opportunities to improve access to information, technologies and communication channels is important for crafting gender-responsive interventions. The gender disaggregated challenges to adoption of climate resilient agriculture are strongly driven by social, economic, and cultural factors and hence diverse in nature and extent in different regions. While there is literature on gender-disaggregated information regarding climate change impacts and adaptation strategies, empirical evidence on comprehending barriers and pathways for gender-responsive Climate Resilient Agriculture (CRA) implementation, particularly in Western and Central Africa (WCA), remains limited (Feyisa, 2022; Ogada et al., 2021). In WCA the gender inequalities in agriculture sectors are still relatively far greater. Huyer et al., 2021 proposed a broader framework which can be potentially useful to expand the reach of climate-resilient agricultural strategies, emphasizing gender and social inclusivity as well as women's empowerment principles. However, the current literature lacks region specific, evidence based and actionable framework that can promote gender responsive CSA and CIS.

Given the background, this study aims to comprehend how male and female farmers view climate risks and its effects, their access to climate information, and how they adapt to improve households' resilience in Senegal's dry areas. It also investigates the drivers and potential pathways to promote gender responsive CRA. Furthermore, the study insights will guide specific actions to support gender equality and strengthen the ability of farming communities to withstand climate changes in Senegal's dry areas, making sure that everyone benefits from efforts and contributes to boost climate resilience.

2. Data and methodology

2.1 Study location and sample distribution:

The study was conducted during the period of May-June 2022, aimed to investigate various aspects related to climate risk perceptions, coping strategies, access to climate information and climate smart agriculture technologies, and household resilience in the dry regions of Senegal with a gender lens. Data collection was carried out using a structured questionnaire, which allowed for systematic and comprehensive data gathering. In addition, we conducted six focus group discussions (FGDs) and several key informants' interviews in three sub-regions. Data were collected under AICCRA[1] (Accelerating Impacts of CGIAR Climate Research in Africa) project which was started in 2021 in six (6) African countries (Ethiopia, Kenya, Zambia, Ghana, Mali, Senegal) with the ambition to build technical, institutional, and human capacities needed to improve the transfer of climate-related information, decision-making tools, and technologies in support of climate change efforts.

The study covered three sub-regions of dryland peanut basin of Senegal, namely Kaffrine, Louga, and Thies (figure 1), representing the diverse farming systems within the region. The study sites were spread across five communes, encompassing a total of forty locations. This wide geographic coverage ensured a comprehensive understanding of the different crop-livestock systems, agro-sylvo pastoral[2] and pastoral areas in Senegal. It captured the diversity of farming practices and their respective vulnerabilities to climate risks in the region.

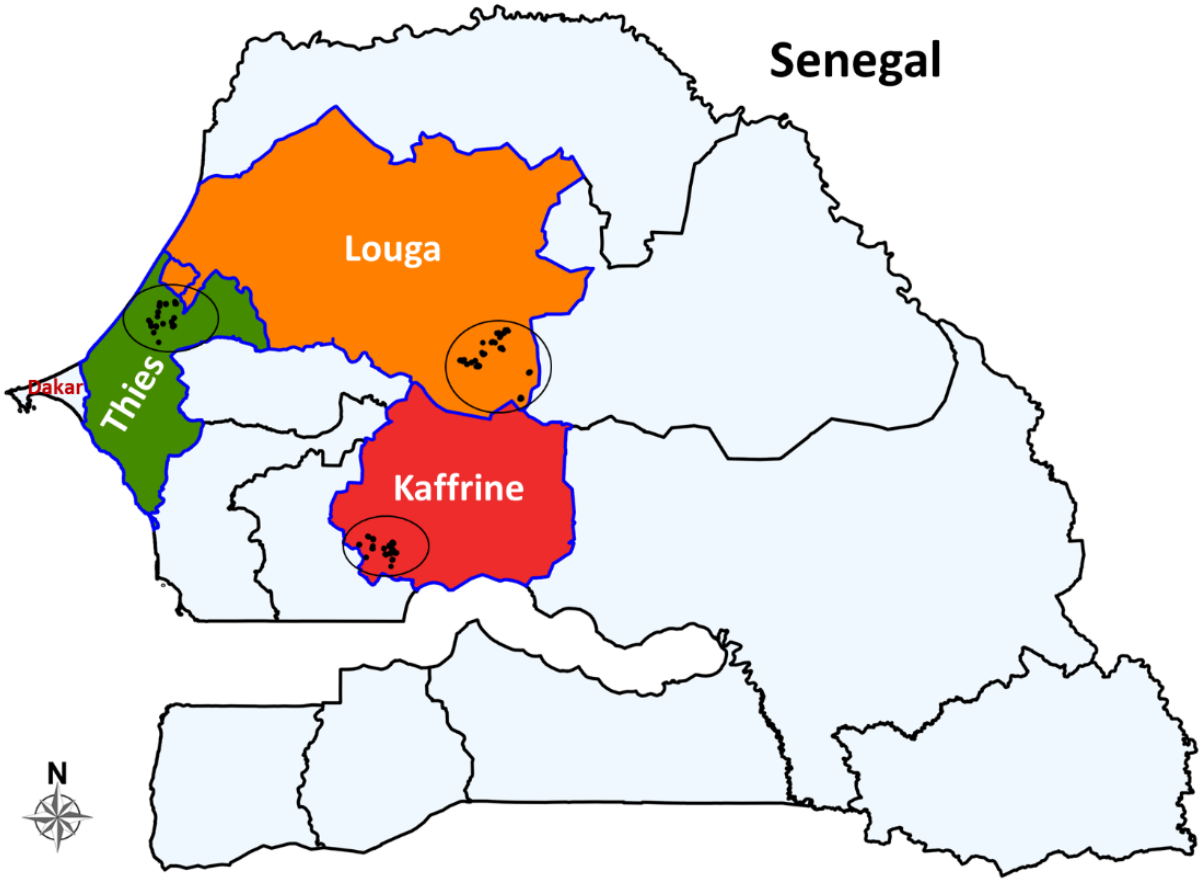

Figure 1: Location of the Study regions and study households in Senegal

Note: Black dots indicating location of the sample households in the study regions

[1] For details, please visit https://aiccra.cgiar.org/participating-organizations

[2] Agro-silvo-pastoralism is a production activity that combines pastoralism (extensive livestock husbandry on pastures) and agriculture in a partially wooded environment. This activity closely combines these three modes of land use, and might even articulate them on a single site (https://dicoagroecologie.fr/en/dictionnaire/agro-silvo-pastoralism/#:~:text=Agro%2Dsilvo%2Dpastoralism%20is%20a,them%20on%20a%20single%20site).

A total of 514 farm households were surveyed through interviews, providing valuable insights into the experiences, challenges, and perceptions of farmers in respect of climate change impacts and adaptation strategies in the targeted regions. The distribution of households across various sub-regions is presented in table 1, highlighting the gender composition of both household heads and respondents. The data illustrates that in the Kaffrine region, households with female as head comprised 6% of the total, while the majority, constituting 94%, were headed by males. The percentage of households headed by females were only 5% in Louga region and 3% in Thies region. The gender distribution of survey respondents was also similarly skewed, with 12%, 17% and 11% being female in Kaffrine, Louga and Thies regions respectively and rest of the respondents were male. In the aggregate, encompassing all regions surveyed (N=514), the pattern persists, with 5% of households headed by females and 95% by males. Furthermore, 13% of the respondents were female, while their male counterparts constitute 87%. These figures underscore the prevailing gender disparity in household leadership and respondent engagement across the regions under investigation. A low proportion of female headed households is reflective of Senegalese rural society. Therefore, we have used three ways to capture the gender dimension: i. classifying households as male and female headed, ii. Classify households based on male or female respondents, and iii. Effect of women related parameters such as their education, participation in community organization, access to climate information and extent of women led activities such as home gardening on household's ability to adapt to climate change.

Table 1: Household distribution by gender of head of household and respondent across study regions (%).

Region	By household head		By respondent	
	Female	Male	Female	Male
Kaffrine (n=179)	6	94	12	88
Louga (n=167)	5	95	17	83
Thies (n=168)	3	97	11	89
Overall (N=514)	5	95	13	87

By applying a gender lens and considering various factors such as geographic diversity and farming systems, the study aimed to provide a comprehensive understanding of climate risk perceptions, coping and adaptation strategies, access to climate information and climate smart agricultural technologies, and household resilience in the dry regions of Senegal. The findings of this research have the potential to inform policy and gender responsive climate adaptation pathways aimed at enhancing the resilience of rural communities in the face of climate change.

2.2 Methodology

The study first characterized the sample households, including gender wise households' characteristics, land ownership and income level; cropping system and gender disaggregated labour use and participation in different farming activities; access, importance and management of livestock; engagement of household head and household members in different activities; involvement of the households' member in community-based organization. Further we tried to capture and analyze gender wise perceptions on climate change phenomena, its impacts, and adaptation strategies. The study also analyzed the determinants that may influence the current level of farm household's ability to adapt to climate change. Finally, empirical evidence from the study and understanding of the social-cultural context based on several interactions with relevant stakeholders helped in envisioning gender responsive pathways for climate adaptation in the Senegal's dryland region.

To analyze the drivers of the current level of farmers ability to adapt to climate change limited by various factors, first an index was constructed as an outcome variable that represented current ability of the farm

household to adapt to climate change. To construct and quantify the current level of farm household's ability of adapt limited by different barriers we had framed seven questions based on a series of focus group discussion (FGD) with various stakeholders including respondents. The final list of questions has been presented in table 2.

Table 2: Perceptions on the barriers that influence the farm households' ability to adapt to climate change (Q1-Q7).

Question number	Particulars
Q1	Is lack of knowledge of CSA technologies a barrier to climate change adaptation?
Q2	Is lack of access to timely climate information a barrier to climate change adaptation?
Q3	Does lack of credit prevent you from using climate adaptation measures?
Q4	Is lack of access to drought resistant varieties and modern inputs a barrier to climate change adaptation?
Q5	Lack of access to appropriate agricultural machinery?
Q6	To what extent does lack of access to government/NGO/other support hinder climate adaptation?
Q7	Does the lack of access to mobile, radio, television, Internet prevents you from using climate information?

While constructing the index, each of the seven questions was accompanied by a comprehensive set of six distinct response scale measures, serving as a pivotal tool for the assessment of participants' perceptions and attitudes (figure 2). As part of the protocol, respondents were mandated to articulate their responses individually for every posed question. This comprehensive process depicted the viewpoints of each respondent for each question, allowing for a variation of understanding of each respondent across different questions. Following the collection of responses, a rigorous documentation process was undertaken, whereby scores were meticulously assigned in accordance with the participants' respective levels of consensus and the magnitude of their agreement. The response variations were thoughtfully designed to encompass a range of opinions, thereby facilitating a comprehensive potential understanding. By encompassing these diverse response categories, the study aptly accommodated a multitude of perspectives, enhancing the depth and comprehensiveness of the subsequent analysis.

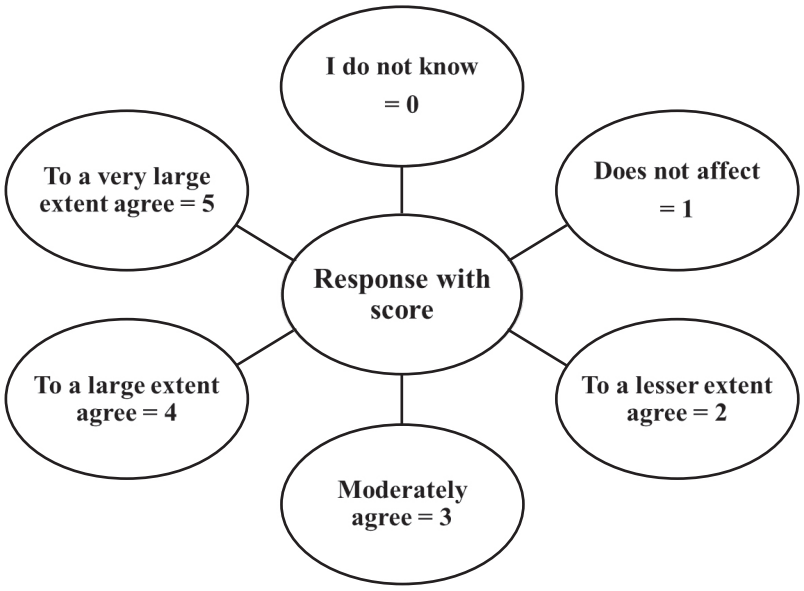

Figure 2: Responses towards perceptions of barriers that influence the farm households' ability to adapt to climate change

In the next step the average score for each respondent against their response was estimated. Respondents whose average scores were 0 have been excluded from the next level of estimation. Finally, the average scores were normalized and subtracted from 1 which represents the index of farm household's ability to adapt to climate change limited by different barriers for each respondent and represented in equation 1.

Index of household's ability to adapt to climate change (IACC) = $1 - \frac{(actual\ score - minimum\ score)}{(maximum\ score - minimum\ score)}$ (1)

The index scores, ranging from 0 to 1, indicate the level of households' ability to adapt, with higher scores signifying greater adaptation ability indicating that the household has good access to CSA technologies, CIS, and other require infrastructure and support to adapt to climate change. To facilitate further regression analysis, these scores were converted into percentages. The regression analysis aimed to elucidate the influence of key covariates, which reflected both the socio-technical context of respondents and households, on their ability to adapt to climate extremes and climate change impacts. Given that the outcome variable is a censored variable, bounded between 0 and 100, the most suitable regression method is Tobit regression. As defined, the Tobit regression method is a statistical technique applied when dealing with censored data. This occurs when some data points are only partially observed or constrained either from below or above. This method holds particular significance in fields such as econometrics and social sciences. It allows researchers to account for these data constraints effectively, enabling a more precise estimation of relationships between variables. The regression model can be expressed as;

$$Y = X\beta + \varepsilon \quad (2)$$

Where Y represents the latent variable, X denotes the matrix of independent variables, and β is the vector of coefficients to be estimated. represents the error term, assumed to be normally distributed with zero mean and constant variance.

3. Results and discussion

The outcomes of this study with gender lens are categorized into two sections: a) Household dynamics and agricultural activities, and b) Understanding climate change perceptions, barriers, and adaptation pathways. Each section is subdivided for clarity and simplifying the presentation of findings.

3.1 Household dynamics and agricultural activities

3.1.1 Gender disaggregated household's characterization:

The sample households exhibit distinct characteristics when comparing female-headed and male-headed households (table 3). On average, considering household size there is slight difference with 7.08 members in female-headed and 7.77 in male-headed households, resulting in an overall average of 7.74. Female-headed households had a higher proportion of adult females at 53%, while male-headed households had 45%. The heads of female-headed households were younger, with an average age of 44, while male-headed households had older heads at 53 years. Education levels also differed, with female-headed households having only 2.29 years of schooling for the head, while male-headed households had 5.44 years. Cultivated area was smaller in female-headed households (4.71 Ha) compared to male-headed (6.79 Ha). When it comes to per-capita income, male-headed households outperform female-headed households across all sources, with an overall total per-capita income of 272 USD for male-headed compared to 168 USD for female-headed. Table 4 and table 5 reveal the primary activities of household heads and households' members based on gender. In the surveyed female-headed households, agriculture takes precedence at 83.33%, slightly higher than in male-headed households. However, female-headed households were engaged more in animal husbandry (16.67%compared to their male-headed counterparts (9.18%)). Trade and job-related activities were primarily the engagement of male-headed households while female-headed households predominantly engaged in agriculture. Though

the agriculture was a dominant occupation for both genders, with a slightly higher involvement of male members (50.17%) compared to female members (44.79%). Male members were comparatively more engaged in animal husbandry (8.62%) then the females (4.34%), while females participated more in arts and crafts (7.15%) and some only in household care (21.55%). These findings underscore gender-based differences in household activities and responsibilities.

Table 3: Households' basic characteristics.			
Particulars	**Female headed**	**Male headed**	**Overall**
Household size (No)	7.08	7.77	7.74
Proportion of adult female	0.53	0.45	0.45
Age of head (years)	44	53	53
Head's years of schooling	2.29	5.44	5.30
Female years of schooling (age between 12 to 50 years)	3.40	2.69	2.72
Female highest years of schooling	6.25	5.11	5.17
Cultivated area (Ha)	4.71	6.79	6.69
Per-capita income from different sources (USD/year)			
Crop	55	89	88
Livestock	44	52	51
Non-farm sources	69	132	129
Total per-capita income	**168**	**272**	**268**

at the time of survey, the exchange rate was 1 USD = 625 CFA in Senegal

Table 4: Primary activities of the households' head (%).		
	Sex of the head	
Livelihood activities	**Female (N=24)**	**Male (N=490)**
Agriculture	83.33	81.02
Animal husbandry	16.67	9.18
Trade	0.00	1.84
Salaried job	0.00	1.43
Others	0.00	4.69
None	0.00	1.84

Table 5: Primary activities of the household members (%).		
Activities	**Female member (N=1958)**	**Male members (N=2019)**
Agriculture	44.79	50.17
Animal husbandry	4.34	8.62
Other farming activities	0.66	1.34
Arts and crafts	7.15	2.82
Trade	2.30	3.12
Study	13.53	15.16
Others	5.67	12.43
Only household care or none	21.55	6.34

3.1.2 Cropping system and labour participation in cropping activities:

In the study regions, groundnut, millet, and cowpea were the predominant crops, covering about 90% of the cropped area. Traditionally these major crops are considered as men's crops in Senegal. Men take all decisions including the choice of crop and cultivars, and activities from sowing to harvesting. Although women of the family do contribute as labour in performing various activities from sowing to post-harvest. As a result, household's women had limited scope to contribute to adopting climate smart agricultural practices to enhance the resilience of these crops. Most farmers in these regions cultivated two or more crops during rainy season under rainfed conditions and the details of the cropping system have been presented in figure 3. The distribution of cropping systems among households was diverse, with a significant majority of about 51% of the sample households opted for a Millet and Groundnut combination. The second most common choice was the combination of millet, groundnut, and cowpea together, accounting for 40% of households. Only a small fraction of households cultivated sole crop of groundnut (2.36%) or cowpea (1.18%), while an equally modest proportion focused solely on millet (1.97%). The combination of Groundnut and Cowpea was also chosen by only 2.36% of households, while Millet and Cowpea are cultivated by another 1.97%. This distribution highlights the varied cropping strategies employed by households, likely influenced by factors such as local climate, soil conditions, other resources, and farming practices.

After examining the cropping system, it was important to illustrate the involvement of men and women in various agricultural activities for major crops in the study regions (table 6).

Predominantly, men lead various tasks such as land preparation, sowing, harvesting, and threshing for millet, groundnut, and cowpea. In land preparation and sowing, men predominantly engage, while women's participation remains notably lower. However, women exhibit relatively higher involvement in weeding, pre-harvest maintenance, and, notably, in the harvesting activities for cowpea (about 6%), though their overall participation across activities remains markedly lower compared to men. Notably, women's engagement in threshing activities shows wider variation, with significant participation observed, particularly for millets (14%) and cowpea (12%). However, majority of the activities for these crops were undertaken jointly by male and female members of the households.

Though the women contributed a significant share of the labour required for millet, groundnut, and

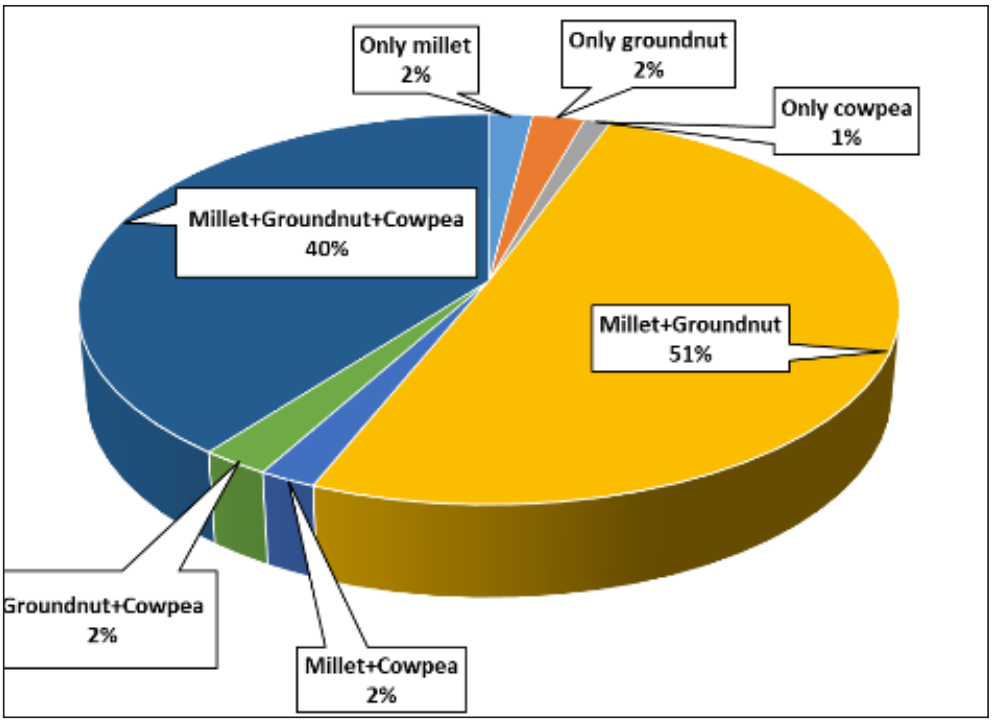

Figure 3: Distribution of Cropping Systems in the study region (%).

cowpea production either lonely or in jointly with their male counterparts, however, the FGDs and key informants' interviews informed that the women had a very little role in decision making pertaining to these crops. Only in a small proportion of the households, cowpea crop was fully managed by the women. The activities such as home gardening (vegetable production), goat rearing, poultry for eggs (not chicken) and local craft were led by women with their major role in decision making. These results highlight the complexity of gender roles in farming and stress the need for policies that ensure both genders' effective participation and role in decision making to harness the full potential of agriculture enterprise and achieve social sustainability.

Table 6: Involvement of men and women members in different agricultural activities for major crops in the study regions (%).

Activities	Millet			Groundnut			Cowpea		
	Only male	Only female	Both male & female	Only male	Only female	Both male & female	Only male	Only female	Both male & female
Land preparation	59.41	0.42	40.17	58.71	0.62	40.66	55.02	1.31	43.67
Sowing	50.84	0.21	48.95	52.70	0.41	46.89	45.85	2.18	51.97
Weeding and pre-harvest maintenance	45.61	1.05	53.35	46.06	1.45	52.49	41.05	2.18	56.77
Harvest	40.38	0.63	59.00	40.25	0.62	59.13	31.88	6.11	62.01
Threshing	43.51	14.23	42.26	49.17	3.11	47.72	34.93	12.23	52.84

3.1.3 Livestock ownership, care, and its importance to the rural dryland livelihood:

Livestock ownership and care are integral to rural dryland livelihoods. These animals provided not only sustenance but also economic stability. They were a source of nutrition, income, and cultural significance for communities, making effective management crucial for the well-being and resilience of those living in these dry regions.

In the study regions, livestock and poultry played a significant role in household livelihoods. Figure 4 indicates that a considerable percentage of households, 35%, own cattle, while sheep and goats were even more prevalent, with 75% and 47% ownership, respectively. Poultry, including chickens were also widespread, owned by 48% of households. Whereas figure 5 reveals that female actively participated in livestock care, with 23% managing livestock and 11% responsible for milking. This reflects their vital role in animal husbandry. Figure 6 highlights the farmers' perception on the importance of livestock activities to the households. A significant 89% considered it "extremely important," while 40% rated it as the highest level of importance. This underscores that for the majority, livestock was a cornerstone of their livelihoods. Therefore, these figures together illustrate that livestock, including cattle, sheep, goats, and poultry, were not just common in the study regions but also essential for rural households. Females were actively involved in their management, and for most families, these animals were of paramount importance, ensuring both sustenance and economic stability.

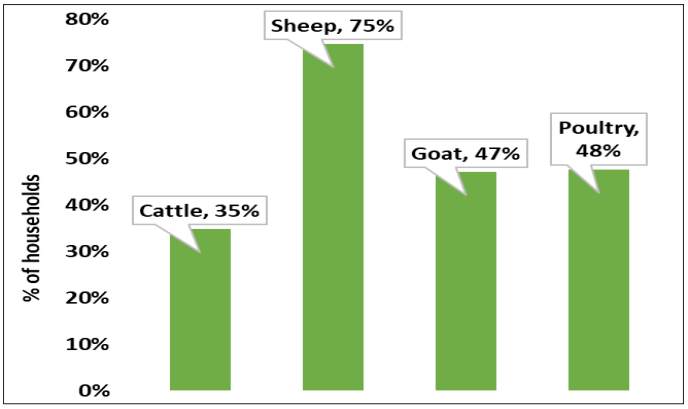

Figure 4: Household wise ownership of livestock and poultry in the study regions (in percentage, N=514).

Figure 5: Households with managing and milking of livestock by female (N=443).

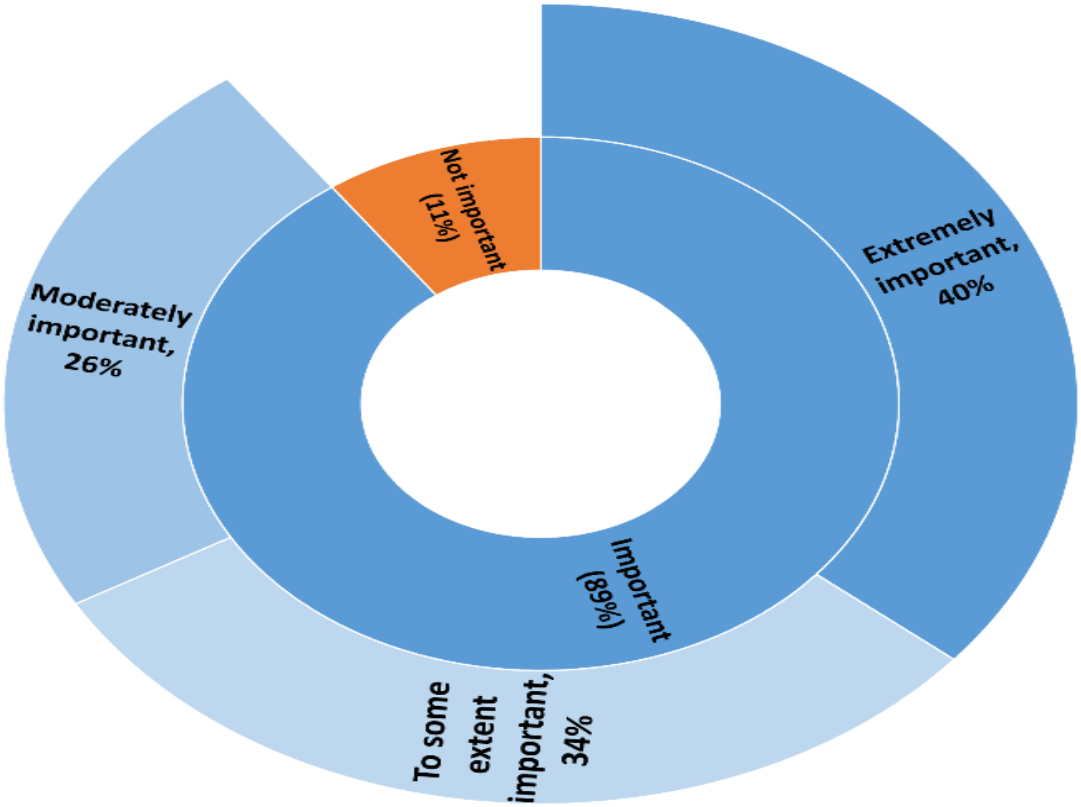

Figure 6: Importance of livestock activities in the livelihood of household (N=490).

3.2 Understanding perceptions, barriers, and adaptation pathways in climate change:

3.2.1 Understanding Community Perceptions of Climate Change:

The initial step in developing gender-responsive climate adaptation strategies and initiatives within agricultural and rural communities was to gain insight into the distinct perceptions and awareness of these communities regarding climate change and its present and future repercussions. In this context we started by finding out what people in these dryland regions think about climate change now and in the future. We asked both men and women three important questions: (1) Have you heard of climate change before? (2)

Do you think climate change is a big deal? (3) Do you believe climate change is really happening? These questions helped us understand how much people are aware about climate change and their perception on its effects on their lives and serving as the foundation for developing inclusive and gender-responsive strategies for climate adaptation in these communities. The final outputs of the above three questions have been presented in figure 7. In our survey, we asked both men and women in farming areas about climate change concept, its importance and impact to their livelihoods and out of 514 respondent 87% were male and remaining were female. Among the all-male and all female respondents nearly everyone, male (94%) and female (90%), mentioned that they heard the word climate change and out of those 93% male and 92% female realized that it is a significant issue. When it comes to believing if climate change is real, almost all men (98%) and all women (100%) said yes it was a significant issue. These results show that most people in these areas are aware of climate change, see it as an important phenomenon, and believe it is happening. This information helps us understand their knowledge and concerns about climate change.

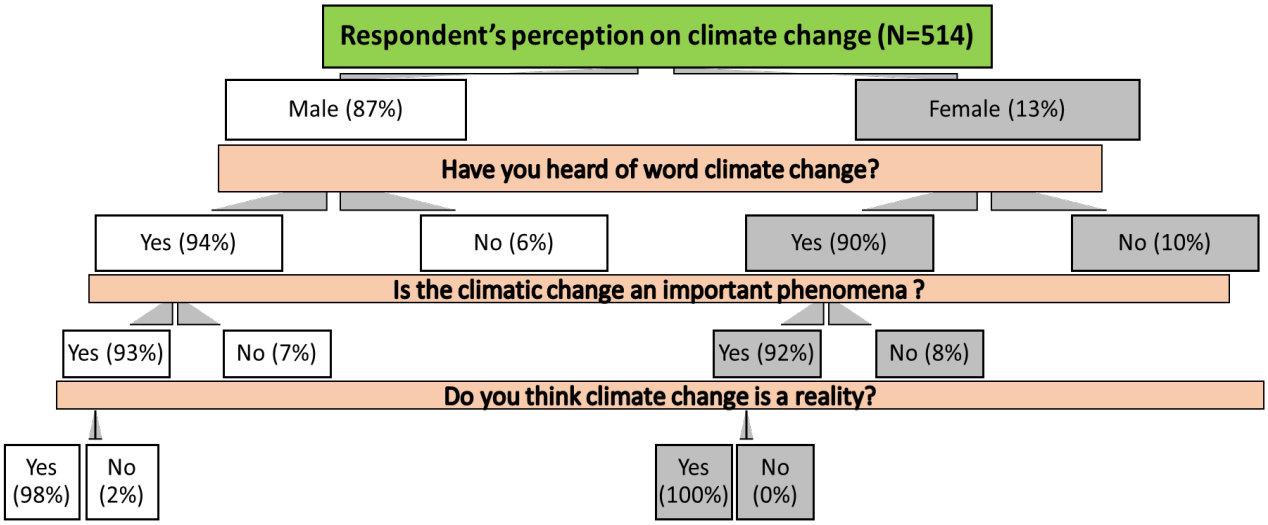

Figure 7: Gender wise distribution of perception to climate change and climate extremes among sample households (perception of the respondent).

3.2.2 Gender-Disaggregated Perceptions of Climate Change Impact on Crop and Livestock:

This section presents the analysis of gender disaggregated perception of climate change impacts on crop and livestock production. In this respect after a series of consultations with different stakeholders including farmers, we identified 18 different attributes illustrating impact of climate shocks, 11 relates to crops and 7 for livestock which are presented in the figure 8 and 9. The agreement about the perception of the degree of impacts for different attributes have been presented on a three-point scale - 'low to moderately agree', 'strongly agree' and 'very strongly agree', response such as don't know and does not impact were not considered in the analysis. The gender disaggregated (with 67 female respondent and 447 male respondents out of 514 household's) comparisons of perceptions regarding the impacts of climate change on both crop production and livestock revealed intriguing patterns. In the crop production analysis, males consistently expressed stronger agreement across various attributes. Notably, 76% of male respondents strongly or very strongly agree on reduced crop yields, surpassing the 64% of female respondents. Similarly, 70% of male respondents agree on financial losses due to extreme weather events, while only 67% of females share this sentiment. Interestingly, some categories do show slightly higher agreement percentages among female respondents, like the 63% agreement on escalating conflicts between farmers and herders compared to 61% among males. Shifting focus to perceptions regarding livestock, males again exhibit stronger agreement, consistently surpassing their female counterparts. For example, 55% of male respondents strongly or very strongly agree on decreased milk production per animal per day, compared to 49% of females. A similar pattern holds for other attributes, including

milk quality decline, nutritional quality of fodder, and limited availability of high-quality fodder. These gender-based disparities highlight the need for tailored climate resilience strategies. Recognizing that male respondents generally harbor more noticeable concerns about the impacts of climate change on agriculture and livestock is vital. This difference in perception of climate change impact might could also be because mainly the men control and make decisions on these major crops, women contribute mostly as labour. Policymakers and interventions should consider these differences to effectively address the specific needs and perceptions of both male and female stakeholders in the face of changing climatic conditions.

Since large majority of both men and women farmers perceived climate change as a significant threat to their crop-livestock systems, the conditions can be considered appropriate for scaling CSA technologies and CIS. In the study region it was found that out of 514 households about 78% of these received climate information or some kind of training on climate adaptation from credible sources, while 22% of the households did not have any access to climate information. However there exist a huge gender inequality, as among the 78% who had access to climate information services or CSA training, it was the male members in 73% households and only in 5% of the households the female members received climate-related information or training on CSA. (Figure 10).

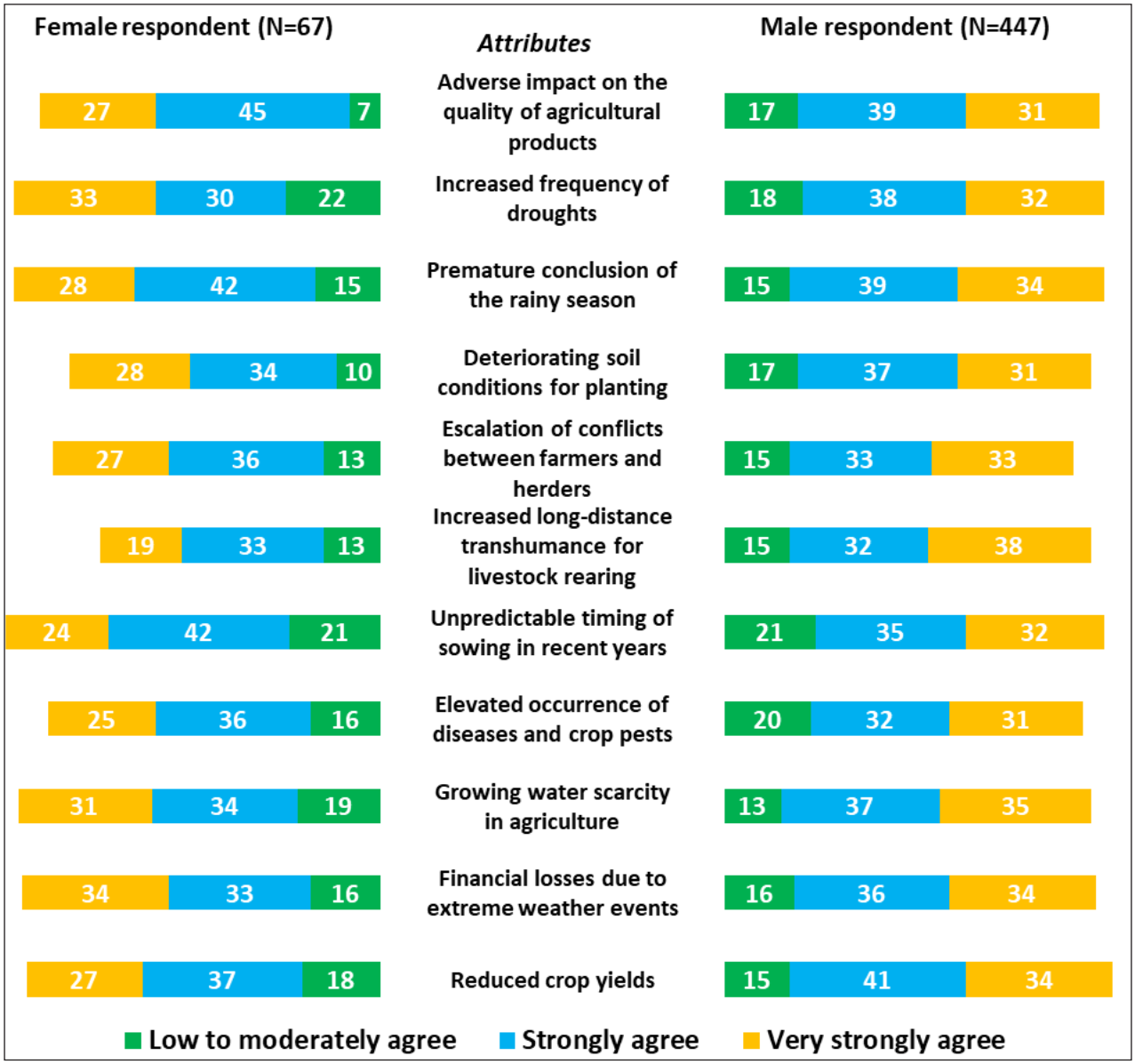

Figure 8: Gender disaggregated perception of impacts of climate change on crop production and its related attributes (%).

Figure 9: Gender disaggregated perception of impacts of climate change on livestock and its related attributes (%).

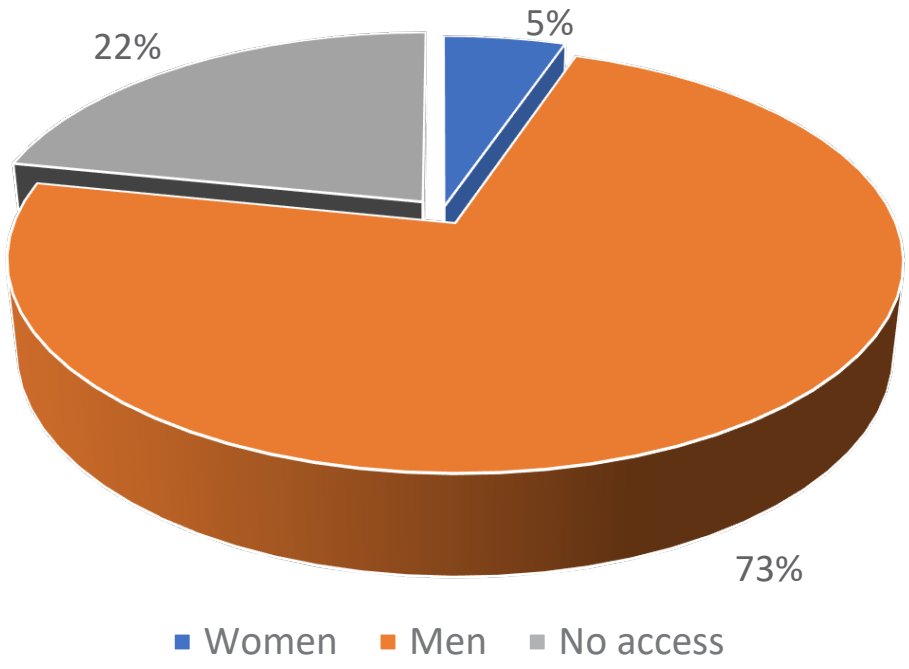

Figure 10: Sex-wise distribution of farmers getting access to climate information/training on CSA (% household).

3.2.3 Identifying Barriers to Climate Change Adaptation:

The responses from household respondents regarding the major drivers affecting farmers' capacity to adapt to climate change and represent by seven distinct questions, with each response categorized by a numerical score representing the level of agreement or impact was crucial. Table 7 summarizes the respondents' perception on critical barriers that affect households' capacity to adapt to climate change. Firstly, a significant 64% of respondents agree that a lack of knowledge about Climate-Smart Agriculture (CSA) technologies hampers their adaptation efforts. This underscores the need for increased education and awareness programs. Secondly, 60% of participants viewed the absence of timely climate information as a notable barrier. Access to such information is crucial for making informed decisions in the face of changing weather patterns. The result also highlights financial constraints, with 58% of respondents agreeing that the lack of access to cost effective credit hinders their climate adaptation measures. This points to the importance of financial support mechanisms. Furthermore, a substantial majority of 67% believe that the lack of access to drought-tolerant crop varieties, seed and modern farming inputs was a significant barrier. Access to appropriate agricultural machinery was also considered a barrier by 77% of respondents, emphasizing the need for improved mechanization. Government, NGO, and other support are seen as crucial, with 72% of respondents emphasizing its importance. Finally, 55% of participants agree that limited access to communication tools like mobile, radio, television, and the Internet impedes their ability to effectively use climate information. This highlights the need for better connectivity and information dissemination channels. Overall, addressing these barriers is essential for enhancing community resilience to climate change.

Table 7: Response by household respondents for major drivers affecting farmer's capacity to adapt to climate change (%).

Major drivers of farmers capacity to adapt to climate change	I do not know (score =0)	Does not affect (score =1)	To a lesser extent agree (score =2)	Moderately agree (score =3)	To a large extent agree (score =4)	To a very large extent agree (score =5)
Is lack of knowledge of CSA technologies a barrier to climate change adaptation?	8	2	12	14	33	31
Is lack of access to timely climate information a barrier to climate change adaptation?	6	3	11	19	32	28
Does lack of credit prevent you from using climate adaptation measures?	5	8	11	18	25	33
Is lack of access to drought resistant varieties and modern inputs a barrier to climate change adaptation?	4	4	9	17	30	37
Lack of access to appropriate agricultural machinery?	3	2	6	11	31	46
To what extent does lack of access to government/NGO/other support hinder climate adaptation	5	2	7	15	29	43
Does the lack of access to mobile, radio, television, Internet prevents you from using climate information	3	6	14	21	28	27

3.2.4 Drivers and determinants of households' ability to adapt to climate change:

As the ultimate objective of the present study was to design pathways for gender responsive climate resilient agriculture in Senegal. Therefore, it was important to analyze the drivers and determinants that influence the ability of farm households to adapt to climate change and climate shocks. The value of the index of the household's ability to adapt was constructed as explained in the methodology section. The index indicated that to what extent the household is constrained or not in its climate adaptation efforts due to various drivers, the higher value of index indicates the greater ability of the household to adapt to climate change and climate shocks. The distribution of index scores representing the household's ability to adapt to climate change gender disaggregated has been presented in figure 11 and 12. Among the male respondents (N=433), 86% of the households had achieved a score of less than the threshold (50%) score and displayed a diverse spectrum of adaptation ability, ranging from the lowest score of 0.00 to an impressive maximum score of about 92%, however, only 14% of these households achieved a score of 50% or above, denoting a very low level of households' ability to adapt to climate change and a pronounced need for enhancing the capacity to adapt . Similarly, the households with female respondents (N=60), exhibited a comparable distribution pattern, ranging from 0.00 to a maximum score of about 86%, however merely 11% of them achieved the 50% threshold score or more, indicating a similar trend of lower adaptive capacities. The above analysis indicates a large majority of the households were constrained in adopting CSA and CIS across gender. A Tobit regression method was used for further analysis as the outcome variable ranged from 0 to 100 as mentioned in the methodology section. In the regression analysis the study considered 493 households out of total 514 households as households with 0 average score and households without any engagement in agricultural activities were not included in the final model. A summary of the variables considered a possible determinant that may constrain or aid the ability of the farm household to adapt to climate change is presented in table 8.

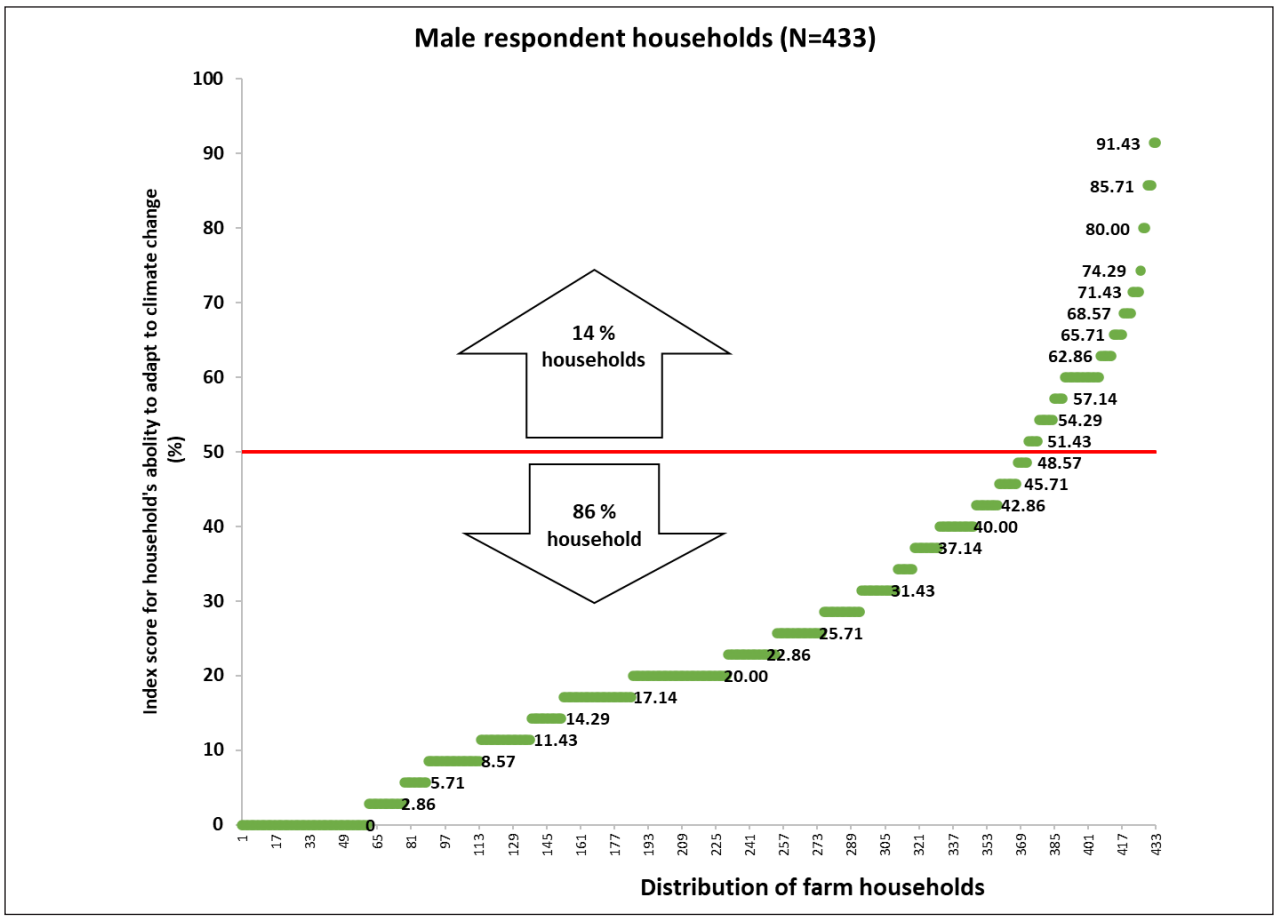

Figure 11: Distribution of index scores for household's ability to adapt to climate change (male).

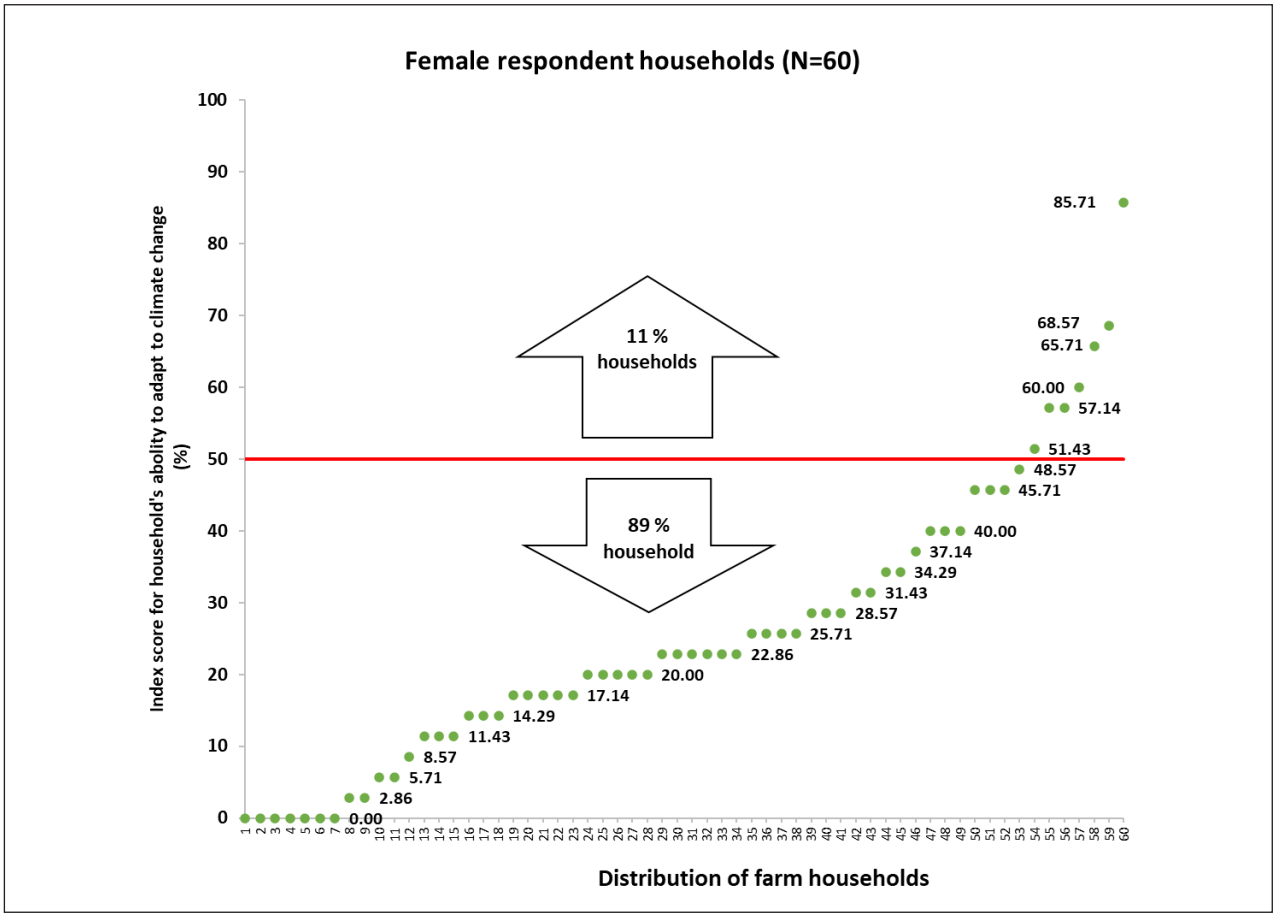

Figure 12: Distribution of index scores for household's ability to adapt to climate change (female).

The Tobit regression analysis provided valuable insights into the determinants of the ability of the household to adapt to climate change shocks, focusing on the " index of the household's ability to adapt mediated through various technology and infrastructural factors" as the outcome variable, where higher values signify higher ability to adapt (table 9). Gender played a significant a role, with males exhibiting a higher level of adaptation (0.5301) compared to females though the difference is not statistically significant. Engagement in the community-based organizations, especially the involvement of female members of the household, significantly enhanced its ability to adapt to climate change, with each additional female member becoming part of the community-based organizations contributing extra 3.3432 units to the adaptation ability. Notably, training on CSA/CIS had a substantial positive effect, contributing a remarkable 4.71 units to adaptation ability index, highlighting the importance of building capacity on climate resilient technologies and CIS use. In the case of agriculture, various practices played pivotal roles. Cultivated area coefficient indicate positively significantly influence of landholding size on the household's ability to adapt, with each additional hectare contributing 0.3623 units suggesting that relatively larger farm households were better placed to adapt to climate change. The proportion of total cultivated area dedicated to crop rotation had a substantial positive impact, with a coefficient of 10.6661, suggesting that sustainable farming practices significantly enhance adaptation ability. Furthermore, cultivation of vegetables through home gardens (12.7160) and cowpeas (5.5125) which mostly empower the women in the household, positively contributed to adaptation ability of the household, underlining the importance of diversified agriculture and increased participation of women for enhancing the climate resilience. Additionally, livestock ownership presents an intriguing relationship. While an increase in total livestock units was associated with a decrease in adaptation ability (-0.3291), but the square of total livestock units had a positive effect (0.0022). This indicates a nonlinear relationship, suggesting that an optimal livestock threshold would be needed for maximizing adaptation ability. Finally, regional disparities were evident,

with the Kaffrine region (12.2149) and Louga region (6.5298) exhibiting significantly higher levels of adaptation compared to the reference Thies region. These findings collectively emphasize the multifaceted nature of drivers influencing household's ability to adapt to climate change, encompassing social, infrastructural, educational, CSA and CIS related, and regional dimensions.

Table 8: Summary statistics of the variables included in Tobit model.	
Explanatory variables	**Mean**
Respondent's gender (Male=1, Female=0)	0.88
Respondent's age in years	51.00
Respondent's education in years	4.97
Female members of household involved in any community-based organization (No)	0.14
Does any of the female members of household received training on CSA/CIS (yes=1, otherwise=0)	0.05
Cultivated area- land holding size (Ha)	6.75
Proportion of total cultivated area practiced as crop rotation	0.81
Do you cultivate vegetable or home gardening (Yes=1, No=0)	0.07
Do you cultivate cowpea as diversification strategy (Yes=1, No=0)	0.45
Total livestock unit (No of TLU)	8.22

Note: TLU is tropical livestock unit

Table 9: Drivers and determinants of household's ability to adapt to climate change extremes: A Tobit regression analysis.	
Variables	**Coefficients**
Respondent's gender (Male=1, Female=0)	0.5301
Respondent's age in years	-0.0425
Respondent's education in years	-0.0057
Female members of household involved in any community-based organization (No)	3.3432**
Does any of the female members of household received training on CSA/CIS (yes=1, otherwise=0)	4.7111
Cultivated area- land holding size (Ha)	0.3623*
Proportion of total cultivated area practiced as crop rotation	10.6661***
Do you cultivate vegetable (Yes=1, No=0)	12.7160***
Do you cultivate cowpea (Yes=1, No=0)	5.5125**
Total livestock unit (TLU)	-0.3291**
Square of total livestock unit	0.0022**
Region dummy (Thies region = 0)	
Kaffrine region	12.2149***
Louga region	6.5298**
Constant	5.5925

Note: *p<0.10, **p<0.05, ***p<0.01

4. Potential pathway for mainstreaming gender responsive climate resilient agriculture

The concept of mainstreaming gender-responsive climate-resilient agriculture represents a critical pathway for addressing the repercussions of climate change while advancing gender equality within the agricultural sector (Huyer et al., 2021). This approach serves to empower women and foster enduring agricultural resilience in the context of climate change. In the case of dryland region of Senegal, among the 78% farm households only in 5% households' women had access to CIS or training on CSA. Moreover, the women had little role in decision making for major crops of millet and groundnut but had a significant role as farm workers. The radio and mobile message were the farmers' major source of climate information in the region. However women's access to CIS was poor due to the factors such as a small proportion of farm women had a mobile phone, the timing of radio broadcast was in conflict with the timing of women's household responsibilities, often various programs and project registered the men for receiving CIS, and the climate advisories through radio and mobile messages didn't focus on women's activities such as vegetable home gardening, goat rearing and small scale agro-value addition. Further in the instances where women had access to CIS could hardly use it for climate risk management in the farming systems because of their limited role in decision making. Under these conditions gender-responsive approach is needed not only to improve the welfare of farm women but also critical to improve the resilience of overall farming systems through enhanced capacity of the women workers who significantly contribute to undertaking various farm activities. Therefore, based on this empirical research using primary household level data, extensive consultations with various stakeholders and key informants as well as secondary information we have conceptualized a comprehensive framework portraying a potential pathway for gender-responsive, climate-resilient agriculture in dryland regions of Senegal. It characterizes the barriers and drivers of current sub-optimal pathways and recognizes the unique vulnerabilities and strengths of both women and men in agriculture, emphasizing a fair access to resources and decision-making. The pathway framework combines climate-resilient agriculture strategies including climate information services (CIS) and climate smart agriculture (CSA) practices such as drought-tolerant crops and cultivars, crop rotation, efficient water use, crop-livestock integration, farm diversification, scale appropriate mechanization and diverse income sources among others. It reflects factors that constrain women's access to CIS and CSA and results in their very low level of participation in decision making on major crops like millet and groundnut in the context of Senegal. Gender-responsive policies and capacity strengthening at farming system and value chain scale can play a critical role in promoting women's leadership and decision making in farming system that may improve their access to and, use and utility of climate information and CSA technologies improving the climate resilience of agricultural value chains. By considering gender dynamics and barriers, the pathway envisioned in the framework aims to boost agricultural resilience and food security, and lessen the impact of climate change, creating fairer and more sustainable farming communities. Our interactions with various stakeholders and a few case studies suggest that organizing the farm women as collective group for example 'groundnut women farmer association or self-help group' can help break the social barriers that restrict their decision making and effective participation in major crop production.

Figure 13 illustrates the comprehensive framework, which encompasses two primary components: one, the existing system and factors that are driving the current system and second, the innovative actions and structural change that can bridge the gap between these components, aiming to foster a gender-inclusive expansion of CIS and CSA technologies. These expansions would occur through both the targeted interventions within the current system, and by empowering women through institutional innovations, actions and enabling policies that improve their participation in the farming systems and value chains and enhance the climate resilience. In essence, this framework can serve as a guiding beacon for policymakers, practitioners, and researchers in their collective efforts to create a more equitable, climate-resilient, and sustainable future for agriculture. The framework underscores the importance of integrating gender-sensitive approaches into climate-resilient agriculture to address the complex challenges posed by climate change effectively. Finally, the framework proposes the pathways by which we can progress towards a gender responsive scaling of CIS and CSA to improve resilience of farm and food systems in the drylands of Senegal.

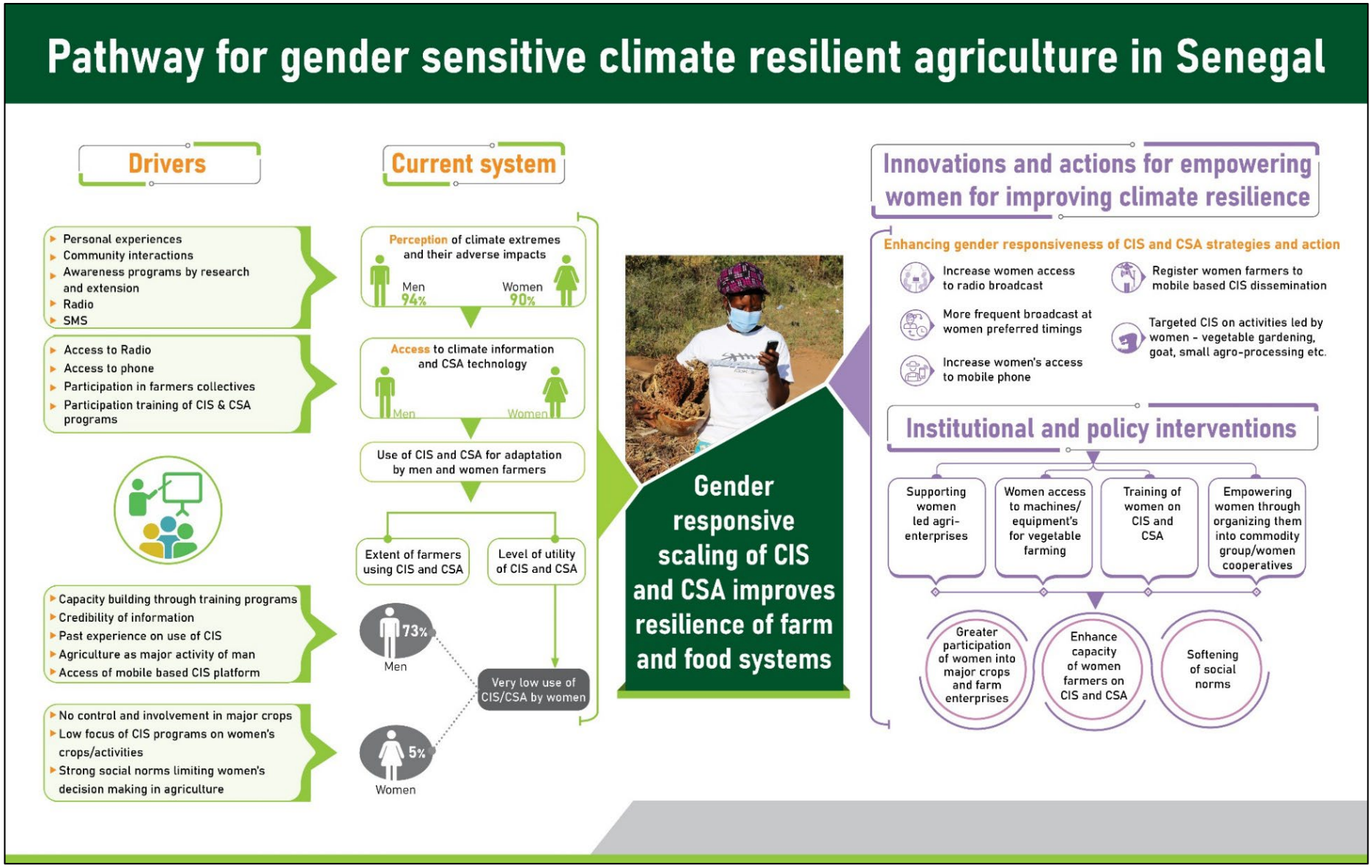

Figure 13: A conceptual framework for gender sensitive climate resilient agriculture in Senegal.

Source: Authors' conceptualization based on the present empirical study

5. Discussion

The major focus of our research was to develop gender-responsive climate adaptation pathway and strategies in agricultural and rural communities within the dryland regions of Senegal. This process commenced with an exploration of the communities' perceptions and awareness of climate change and its implications as well as current adaption strategies. We conducted surveys and asked both men and women three critical questions: (1) Are you familiar with climate change? (2) Do you consider climate change a significant issue? (3) Do you believe climate change is occurring? Our findings revealed that most of the respondents were aware of climate change, recognized climate change as a significant issue and believed in the reality of climate change and in line with findings reported elsewhere in the literature, that suggest that a majority of respondents were aware of increased frequency of climate shocks, recognized it as a significant issue, and believed in its reality (Salem et al., 2022; Rehman et al., 2021; Pandve et al., 2011).

Majority of the farmers both men and women strongly or very strongly felt that the climate change has been negatively impacting the crop-livestock yields, farm income and resulting in escalation of conflicts between farmers and herders due to increased competition for fodder biomass. Similarly, more than half of the respondents strongly or very strongly felt that the increasing frequency of climatic shocks were resulting in decreased milk production per animal. The gender-disaggregated analysis suggests that the gender inequality has two major implications: one, the women are at disadvantage because of their poor access to CIS and CSA technologies and second, the poor participation of farm women in decision making related to major crops of millet and groundnut as well cattle production that lead to far sub-optimal level of climate adaptation. Several studies have found that the women farmers are less involved in farm management across a range of farm decisions (Ambler et al., 2021; Kawarazuka et al., 2022; Mariola Acosta & Feindt, 2020; Shibata et al., 2020). These and our present study suggest that women face structural disadvantages based on gender. Because of this social structural barrier even if women have access to CIS and CSA, they may not make much use of it for adaptation in a major part of the farming systems.

The analysis of drivers and determinants influencing farm households' ability to adapt to climate change and climate shocks, reveals interesting trends. Three determinants particularly stand out which strengthened the ability of a household to adapt to climate change. The analysis shows a very low level of the capacity of most of the farmers to adapt to climate change, but the women's capacity was still lower than the men farmers. The participation of the female members of household in community-based organization around farming for example women farmers producers group for groundnut or goat keeping or seed production and adoption of home gardening which was mostly controlled by women had a strong positive impact on the ability of the household to adapt to climate change. This outcome of enhanced ability of farm household to adapt was achieved through women empowerment route. Those women who were part any community-based organization for farming were able to break the social barriers and were allowed by the family to make decision and fully manage all the activities from production to marketing even for major crops like millets and groundnut. The home gardening which was mostly undertaken by women enhanced their financial situation, however women's home gardening need support to harness full potential such as CIS targeted to home gardening, access to small equipment, small solar water pumps for irrigation etc. The third strategy identified was diversification through cowpea had positive effect on the ability to adapt. The cowpea crop was allowed to be managed by women to certain extent as per the cultural norms. Thus, enhancing women access to CIS and CSA and build their capacity as suggested in section 4, and empowering them by enhancing their true participation in the farm decision making through suggested institutional innovations can significantly contribute towards achieving gender equality goals and improving resilience of the

dryland farming systems. The other factors that contributed positively were the land holding size and adoption of crop rotation. These findings matching with previous scholarly frameworks, as exemplified by Huyer (2021), underscore the necessity of concerted efforts at multiple levels to amplify gender and socially inclusive Climate-Resilient Agriculture (CRA) strategies. Furthermore, Khoza 2021 and Khoza 2020 both propose gender-sensitive frameworks facilitating the adoption of climate-smart agriculture (CSA) among smallholder farmers, with an emphasis on fortifying resilience and mitigating gender-based vulnerabilities and disparities whereas Brisebois (2022) explores into the gender-specific dimensions of CSA initiatives in Kenya, underscoring the imperative to confront persistent gender disparities and power dynamics within climate-oriented actions.

6. Conclusions

This study of rural households in the dry regions of Senegal has revealed multifaceted dynamics of diverse crop-livestock systems with climate and gender lens. Notably, female-headed households stand out with smaller sizes, younger heads, lower education levels, smaller landholdings, lack of access to CIS and CSA technologies, and significantly lower per-capita incomes compared to male-headed households. These disparities underline the structural challenges faced by female-headed households as well as women members of the men headed households and thus there is a need for targeted interventions to correct these imbalances. Acknowledging and addressing the unique needs and constraints of women farmers both in the female-headed and male-headed households is essential for building gender and socially inclusive resilient farming systems and harness the full development potential of these regions.

The gender-disaggregated analysis highlighted the division of labor within these households' showing agriculture as a dominant occupation for both genders. The women farmers exhibit a stronger focus on agriculture particularly in the post-harvest crop threshing and value addition whereas male-farmers were more diversely engaged in animal husbandry and trade-related activities besides crop cultivation. The complexity of gender roles in farming underscores the need for policies that leverage the complementary skills of both genders for sustainable agricultural development.

The development of actionable strategies for gender-responsive climate adaptation actions necessitate an understanding of the unique perceptions, communities' awareness on climate change and its impacts, their access and use of climate information and climate smart agricultural technologies. Our analysis revealed a widespread awareness and acknowledgment of climate change reality and its significance among the farmers community, forming a fundamental basis for understanding their concerns and perspectives.

The perceptions study of climate change's impacts on crop and livestock production identified gender-oriented disparities and underscore the need for climate resilience strategies that address these differences, recognizing that men often hold more prominent apprehensions about climate change's implications for agriculture and livestock. Addressing barriers to climate change adaptation is another critical aspect of our study. The findings showcase substantial challenges, including a lack of knowledge and access to CSA technologies, the lack of timely climate information and agro-advisories, financial constraints, limited access to drought-tolerant crop varieties seed, fertilizers and modern farming inputs, inadequacy of appropriate agricultural machinery, and constrained communication tools.

Tobit regression analysis provides insights into the determinants of farm households' capacity to adapt to climate change, emphasizing the complex interplay of gender, education, climate resilient agricultural practices and technologies, and regional disparities. These findings underline the complicated interaction of social, educational, agricultural, and regional aspects influencing climate change adaptation, laying the groundwork for informed policy interventions and tailored strategies. Improving farm women's

participation in farming decision making and their capacity on CSA and CIS can significantly enhance the households' capacity to adapt to climate change. In Senegal where the proportion of women-headed farm households is very small, the gender responsive strategy needs to focus more on empowering the women intra-household to achieve equality and harness the power of both men and women farmers to improve resilience of the agricultural value chains.

In conclusion, our study offers a comprehensive understanding of rural life in the study regions in the context of climate change, emphasizing the importance of addressing gender disparities, promoting sustainable agricultural practices, and recognizing the central role of livestock in the well-being and economic stability of households. The current structure of the farming systems with dominant role for men in decision making as well as less focus of CSA and CIS efforts on women has led to sub-optimal adaptation outcomes. Based on this study we propose a comprehensive framework portraying a potential pathway for gender-responsive, climate-resilient agriculture in dryland region of Senegal which recognizes the unique vulnerabilities and strengths of both women and men in agriculture, emphasizing fair access to resources, knowledge, technologies, and decision making.

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