Everyday pathfinders:

A gender-sensitive analysis of climate impacts and adaptation of smallholder farmers in Fatick, Senegal

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by

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Declaration of Originality

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Abstract

The climate crisis jeopardizes rural livelihoods in the Sahel through existential food insecurity and the risk of famines. Climate impacts like dry spells, erratic rainfall and overall weather variability threaten rainfed agriculture. My thesis examines smallholders´ perception of climate change as well as climate impacts on agriculture and observes smallholders´ climate adaptation strategies in Fatick, a region in the West of Senegal. Therein, the thesis investigates how women and men smallholders approach climate adaptation differently and how gender-specific limitations in women´s and men´s adaptive capacity may hinder the way to successful adaptation. The research employs a mixed methods case study of smallholder farmers in the semi-arid region Fatick. From January to March 2022, I collected data through focus group discussions with 39 smallholders and a survey with 204 households, which was then used to construct an original composite adaptive capacity index to compare the adaptive capacity of men and women smallholders. The study adopts a context-specific, people-centered and participatory approach to illustrate and value various types of knowledge. Thus, local smallholders, particularly women farmers, become the center of this climate adaptation study.

My study shows that smallholders in Fatick, Senegal, are very much aware of the changing climate and changing conditions for agriculture. While adaptation efforts exist, successful adaptation is limited due to a lack of financial means, missing adaptation knowledge and limited access to information. Moreover, the gender-sensitive analysis of climate adaptation reveals that women smallholders predominantly suggest transformative climate adaptation which, however, fails to be realized due to women´s limited decision-making power in households. Consequently, I argue to merge transformative climate adaptation and transformative gender approaches to drive climate action and gender justice alike, thus not only contributing to sustainable rural development but also to sustainable livelihoods for all members of smallholders´ households and communities.

1. Introduction

The world is prone to unavoidable climate hazards like heatwaves, droughts and floods which will accelerate in the decades to come (IPCC 2022). The severity of the impacts of climate change has been reconfirmed by the alarming *2022 Report of the Intergovernmental Panel on Climate Change* (IPCC): Without exception, all life on earth is vulnerable to climate change, be it ecosystems or human societies (ibid.). Yet, in some regions of the world the exposure to climate change is particularly extreme. The Sahel is one such region, where impacts of the changing climate confront people with unpredictable weather variability and, consequently, with drastic food and water insecurity. Temperature projections for the Sahel predict a rise between 2.0°C and 4.3°C by 2080, compared to pre-industrial levels (Tomalka et al. 2021, 1). Precipitation trends for the Sahel are uncertain and vary across the region, making predictions difficult (NUPI and SIPRI 2021; Tomalka et al. 2021). Nevertheless, it is expected that future dry and wet periods will become more extreme (Tomalka et al. 2021, 1). Furthermore, *per capita* water availability will decline by 2080, mostly due to population growth (Tomalka et al. 2021, 1).

The consequences of climate impacts are immense, as large parts of the economy of Sahel countries are based on agriculture and the majority of rural households relies on rainfed agricultural production to sustain their livelihood (Day and Caus 2019; Tomalka et al. 2021). Therefore, the climate crisis jeopardizes the Sahel´s rural population through existential food insecurity and the risk of famines (ibid.). In light of the resonating COVID-pandemic and the war in Ukraine, supply shortage of staple foods and inflation further exacerbate the difficulties to sustain a living (World Food Programme 2022).

Against this backdrop, subsistence-based agriculture has been gaining political attention as a local resort in times of global market insecurities. At the same time, the need to adapt subsistence-based smallholder farming to climate change becomes more and more urgent. Smallholder farmers will need to adapt to drought- or flood-related crop stress and failure, and water management will become particularly important all over the Sahel after 2050 (Tomalka et al. 2021, 1). Thus, smallholder farmers ought to develop adaptation strategies that vary according to region, type of farming and socio-cultural factors (De Longueville et al. 2020; Nielsen et al. 2012). As the shifts in weather and climate become more drastic and farming systems are challenged fundamentally, the discourse community on climate adaptation calls to widen the scope of reaction from incremental towards transformative change (Fedele et al. 2019). Transformative solutions no longer exclusively consider initial agricultural activities. Instead, they strive to find alternative pathways that address underlying causes of smallholders´ vulnerabilities. Whether incremental or transformative, scholars and policy advisors stress the necessity to examine farm-level adaptation as a location-specific task (Chepkoech et al.

2020a) and to incorporate local priorities (Davis and Olayide 2020). The location-specific adaptive capacity of farmers reflects a pivotal research interest as it defines to what extent farmers will be able to deal with climate stresses and shocks.

Furthermore, research shows that men and women farmers experience climate impacts differently as women farmers face disproportionate challenges in the realm of climate change and adaptation (see Anugwa et al. 2020; Gallagher et al. 2020; Lehel and Sisto 2017). Within smallholder households, women are farmers, workers, entrepreneurs and carers. Yet, women´s capacity to adapt to climate change is oftentimes limited due to socially constructed gender roles and women´s low social status (Gallagher et al. 2020; Lehel and Sisto 2017). Empirical studies showcase that gender may constrain individuals from pursuing equal adaptation options, through a lack of access to or control over assets or through social or cultural limitations (Meinzen-Dick et al. 2014; Nyantakyi-Frimpong and Bezner-Kerr 2015; Perez et al. 2015). Although women´s scope of agency is limited by gendered social restrictions, women carry a household´s burden to adapt, as social structures oblige them to fulfill particular household tasks (Gallagher et al. 2020). These gender differences in climate adaptation have an alarming reach, as women play a crucial role in smallholder farming in the Sahel and worldwide: Almost half of the world´s smallholder farmers are female (Abass 2018). Furthermore, women produce 70% of food on the African continent (ibid.), highlighting the necessity to examine differences in adaptation options between men and women farmers.

Understanding smallholder farmers´ adaptation strategies and adaptive capacities is essential if climate change research and development efforts are to be successful (Jiri and Mafongya 2020, 968). In order to observe climate adaptation of smallholders in the Sahel, it is necessary to conduct a case-specific analysis of local climate impacts, adaptation strategies, adaptation gaps as well as the adaptive capacity of farmers. At the same time, it is imperative to observe women and men farmers separately, as women face disproportionate challenges in climate change, while representing a large proportion of smallholder farmers.

Therefore, my master thesis examines the adaptation strategies and adaptive capacities of men and women smallholders in a subsistence-agricultural community in the Sahel. It is designed as a mixed methods case study, portraying the perspectives of smallholder farmers in the region Fatick, in the West of Senegal. It answers the following sequential research questions:

1) RQ 1: What are smallholders´ local perceptions of climate change and impacts on subsistence agriculture?
2) RQ 2: What kinds of agricultural adaptation strategies do smallholders employ to respond to climate change?
3) RQ 3: (How) do men and women smallholders´ adaptation approaches differ?

4) RQ 4: How do gender differences in women´s and men´s adaptive capacity hinder successful adaptation?

Methodologically, my thesis pursues these consecutive questions in a twofold way: First, it provides a descriptive analysis of local perceptions of climate impacts (RQ 1) and practiced adaptation strategies in Fatick (RQ 2) in order to obtain an overview of the local status quo. Second, it compares smallholders´ suggestions for adaptation improvement from a gender-specific angle (RQ 3) and juxtaposes them with a gender-specific analysis of smallholders´ adaptation capacity (RQ 4). I collected the data for this study in January and February 2022, through focus group discussions with 39 smallholders and a survey with 204 households, which I used to construct a composite adaptive capacity index. My study adopts a context-specific, people-centered and participatory approach to illustrate and appreciate knowledge outside of academic climate science. Thus, local smallholders, particularly women farmers, become the center of this climate adaptation study.

Regarding the overall structure of the thesis, it begins with a literature review on climate adaptation and gender in agriculture. The following Chapter 2 draws on the literature to establish an analytical framework for my research (Chapter 3). In the following methodological section (Chapter 4), I present the overall research design consisting of the case selection, data collection and data analysis. This is followed by a presentation of results (Chapter 5) and a thorough discussion (Chapter 6). I conclude my thesis with final remarks how climate adaptation in Fatick may be approached in the future.

2. Literature Review

My thesis is embedded in the literature on climate adaptation and gender in agriculture. This chapter begins with the conceptualization of adaptation and adaptive capacity. Next, it provides a brief overview of the status quo of the academic debates on climate adaptation on the one hand, and gender in agriculture on the other. The literature review informs my analytical framework.

2.1. Climate adaptation

Conceptualizing adaptation

As stipulated by the IPCC (2022a, 2898) adaptation is "[t]he process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects." In contrast to coping as a short or medium response that aims at maintaining basic functions of people, institutions, organizations and systems (ibid.), adaptation

describes a long-term change. Among other specifications, scholars differentiate between planned and autonomous adaptation. While planned adaptation results from conscious strategic decisions, linked to policies and programmes, autonomous adaptation is practiced more organically, independently from climate change policies and programs (IPCC 2022b).

Adaptation can be further differentiated between incremental and transformative adaptation (ibid.). Incremental adaptation "maintains the essence and integrity of a system or process at a given scale" (Park et al., 2012 in IPCC 2021, 102). It addresses proximate causes by strengthening resilience of specific systems (Noble et al. 2014). In the context of agriculture, this includes activities from crop, land and water management. Transformative adaptation, on the other hand, "changes the fundamental attributes of a social-ecological system in anticipation of climate change and its impacts" (IPCC 2022b). It aims at systemic change and enforces social inclusiveness, for example through broader accessibility to information and resources like land and water. Recently, scholarly attention to transformative adaptation has risen, as can be observed in the *2022 IPCC Report*, reflecting a more extensive focus on the role of transformation and social inclusive adaptation approaches (Ara Begum et al. 2022, 76). In the *Fifth IPCC Report*, Noble et al. (2014, 836) already discuss the risks of reaching the limits of incremental adaptation in spheres that are most prone to climate impacts such as Sub-Saharan agriculture. Adaptation scholars opine that, instead of merely understanding adaptation as technological solutions like climate-proofing of infrastructure and insurance policies, adaptation should consider "human content and social context" (Jerneck 2018, 404) to envision more profound social change in livelihood activities or transformation, in order to account for the impacts on human-environmental relations (ibid.; Noble et al. 2014).

The examination of adaptation goes hand in hand with the assessment of the adaptive capacity to climate change which is understood as the "ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC 2022b, 2899). In the study of adaptive capacity, various types of resources and knowledge are examined that are necessary for the implementation of effective adaptation (IPCC 2021, 19). These include education and awareness of climate change, access to and control over equipment, agricultural inputs and financial or natural resources, as well as social networks.

Climate adaptation in recent academic debate

As climate impacts become more visible, adaptation increasingly plays a role in the academic and political sectors of, among others, agriculture, food systems and biodiversity. The climate adaptation discourse intersects with various academic fields and scholars link climate adaptation with different contemporary challenges depending on their discipline. Fischer et al. (2021), for example, frame the competition between three major contemporary research fields, as the "trilemma of land use" and

argue that climate action, food security and the conservation of biodiversity lodge competing claims for land use. To account for the growing relevance of climate adaptation, the *2022 IPCC Report* recommends incorporating climate adaptation in all discussions on climate action (IPCC 2022a).

The nexus between smallholders´ climate adaptation and food security is especially prominent in scientific debate (Amsallem and Hubert 2021; HLPE 2020; IPES-Food and ETC Group 2021). Consequently, the *High Level Panel of Experts on Food Security and Nutrition* (HLPE) recommends merging research on climate, subsistence agriculture and food systems by strengthening "participatory research, extension and farming service systems, particularly those that respond to the specific needs of small-scale agricultural producers, including women producers, to increase their productivity, diversify their production, and enhance its nutritional value and build their resilience, including with respect to climate change, according to the tenets of sustainable development"(HLPE 2020, 71). Studies from Moseley et al. (2019; 2022) or Davis and Olayide (2020), among others, respond to this research need by observing smallholder farmers´ roles in global food production.

Agroecology scholars observe climate adaptation aiming to connect ecological and social concepts with sustainable agriculture and food systems. Pimbert et al. (2021) define agroecology as "an alternative paradigm for agriculture and food systems that is simultaneously: (a) the application of ecological principles to food and farming systems that emerge from specific socioecological and cultural contexts in place-based territories; and (b) a social and political process that centers the knowledge and agency of Indigenous peoples and peasants in determining agri-food system policy and practice." Emphasizing the importance of people´s knowledge, indigenous systems and local institutions, agroecology combines research and action in a manner that values farmers´ context-specific experience. Agroecology "puts agriculture back into nature" (ActionAid UK 2022) and is a successful contributor to both, climate adaptation and mitigation, as a growing body of evidence reveals (ibid.; Altieri et al. 2015; Snapp et al. 2021). Stöber et al. (2017) and Chepkoech et al. (2020a) exemplify such agroecological approaches like the reintroduction and diversification of indigenous crops. Furthermore, they examine which agroecological practices smallholders use to adapt to climate change. Studies by Jiri and Mafongoya (2020), Bremer et al. (2019) and Orlove et al. (2010) focus particularly on the role of indigenous knowledge systems and their use in agricultural adaptation, highlighting the importance to link various types of knowledge systems with each other.

The counterpart to agroecology is the climate-smart agriculture (CSA) approach that strives to transform agricultural systems to support development and ensure food security under climate change following three main objectives: "sustainably increasing agricultural production and income; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible" (Asfaw 2017). The CSA concept was introduced by the FAO at the *2010 Hague Conference on Agriculture, Food Security and Climate Change*, and is internationally recognized and

applied by practitioners in the international development arena. However, CSA has been criticized by agroecologists to grant too much importance to climate mitigation and adaptation, at the expense of ecological principles and traditional farming practices (Shelton 2020).

Adaptive capacity is a research subject commonly linked to the Sustainable Livelihood Framework (SLF), developed by the UK Department of International Development (DFID) (1999). Scholars draw on the Sustainable Livelihood Framework to systematically study the adaptive capacity of smallholder farmers on a household level (see Abdul-Razak and Kruse 2017; Chepkoech et al. 2020b; Defiesta and Rapera 2014). According to DFID (1999), a livelihood encompasses capabilities, assets (including both material and social resources), and activities that are necessary to make a living. These assets can be divided into five main types of capital: economic, physical, natural, social and human capital. A sustainable livelihood is characterized by a high amount of assets in each of these capitals. Sustainable livelihood applies to individuals who can cope with and recover from stresses and shocks and maintain or enhance their capabilities and assets. A changing climate and extreme weather events are concrete examples of such stresses and shocks. Thus, various scholars have argued that adaptive capacity can be assessed through the SLF in order to examine a household´s assets to adapt to climate change (see Abdul-Razak and Kruse 2017; Chepkoech et al. 2020b; Defiesta and Rapera 2014).

2.2. Gender in agriculture

The agroecological approach corresponds well with the scholarship of gender in agriculture. Both discourses center on nature, care and local knowledge. This holds particularly true for critical feminist perspectives which aim for gender equality through social change (Farhall and Rickards 2021). In view of the disproportionate impacts of climate change on women, girls and female-headed households, development researchers and actors are advised to grant high priority to sex-differentiated data and gender analyses (NUPI and SIPRI 2021). To achieve this aim, scholars suggest more participatory research and the inclusion of women´s voices (Agarwal 2019; HLPE 2020). Afterall, the smallholder women in question know best what they need in order to secure and sustain their livelihoods more effectively (Anugwa et al. 2020; Mitchell et al. 2007; Paudel Khatiwada et al. 2018)[1]. Today, approaches from scholarship, policy and practice can be differentiated between gender-responsive and gender-

[1] It must be noted that the prevailing scholarship of gender in agriculture paints a binary, hetero-normative picture of men and women farmer households by discussing only the two genders male and female and their socially established relations and roles towards each other. This neglects the necessity to acknowledge non-binary understanding of gender. Ahmed (2008) criticizes that a binary lens of masculinity and femininity presumes the concept of a universal man and woman that falsely expects all men and all women to be alike, without any differences of individuals' identities. While my data collection and analysis are based on a binary comparison of men and women farmers, the thesis acknowledges and reflects the necessity to widen the understanding of binary and hetero-normative gender roles in the discussion chapter.

transformative paths (Farhall and Rickards 2021). On the one hand, gender-responsiveness spots gender-specific needs that women and men farmers may have. Doing so, the approach does not necessarily question inequalities that may arise from the socialization of gender. On the other hand, gender-transformative strategies aim at social change of gender roles in agriculture. Instead of targeting challenges for women farmers incrementally, structural gender inequalities are now approached at multiple scales, aiming at changing underlying social structures that are detrimental for women (and men) (Farhall and Rickards 2021). Transformative gender approaches intend to engage men, too, in order to question gendered responsibilities (Jerneck 2018, 411). This requires rethinking activities and features that are coded as masculine or feminine (Farnworth and Colverson 2015; Jerneck and Olsson 2013).

To integrate gender-transformative aims into global climate action effectively and sustainably, international organizations and large development institutions, such as the FAO, try to find synergies between climate adaptation and gender equality. To account for the disproportionate vulnerability of women smallholders in the face of climate change, the FAO incorporates gender-sensitivity into their practice by naming four main categories of gender inequalities within smallholder farming (Lehel and Sisto 2017). First, women have limited access to land tenure and to quality soil. Second, their access to financial resources and decision-making power over them are constraint. Third, women smallholders often lack access to extension and climate-related services to receive sufficient information on climate and weather changes. Fourth, women´s work burden increases with the need to adapt agricultural practices. To face these inequalities, the FAO includes gender analyses through which development researchers and practitioners can assess individual ability to climate risks, access to and control over assets and productive resources; access to climate information and services, institutions and markets; capacity to take on risk; specific needs and participation rates; and power relations such as decision-making within households and communities.

The FAO´s four categories of gender inequalities within smallholder farming can be complemented by further voices from the literature which also discuss limited decision-making power over productive resources as a main field of gender inequalities within smallholder farming (Gallagher et al. 2020; HLPE 2020; Rao et al. 2020). As one of the leading voices in the field, Kabeer has shaped the analysis of women´s empowerment by emphasizing the importance of agency and power (Kabeer 1999). Kabeer differentiates three types of agency: intrinsic agency, being the power to act independently and make free choices; instrumental agency, being the decision-making power through access and control over the self and resources; and collective agency, being the power to work with other people to achieve change. Kabeer´s concept of agencies and the previously discussed categories of gender inequalities serve as useful guidelines to establish an analytical framework for the research design of this study.

3. Analytical Framework

The following part presents analytical categories within smallholder adaptation, adaptive capacity and gender in agriculture which inform the research design presented in the subsequent chapter.

3.1. Climate adaptation

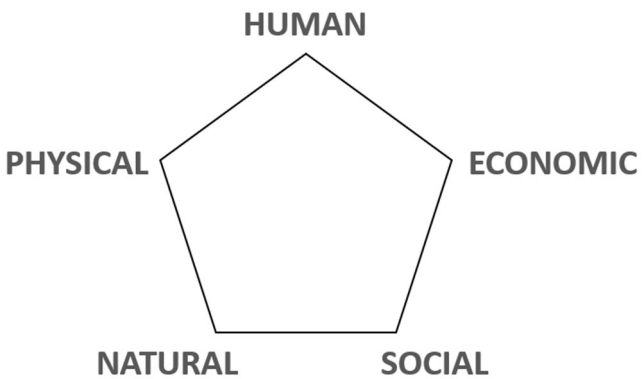
Farm-level studies by agroecologists and agronomists exemplify analytical categories for the examination of farm-level adaptation measures that can be adopted for this thesis. Chepkoech et al. (2020a, 851) suggest to differentiate between farm financial management strategies, water-use management strategies, farm production practices, planting calendars and crop portfolios. Similarly, Stöber et al. (2017, 422) establish the categories water management, land management, soil fertility management and crop management. Diallo et al. (2017, 710 ff.), observe local adaptation responses through the categories of fertilization and soil conservation; measures against soil erosion; water management; diversification of agricultural practices and improved cultivation techniques.

Combining the above categorization systems by Chepkoech et al. (2020a), Stöber et al. (2017) and Diallo et al. (2017), I employ the categories of "land and soil management", "crop management" and "water management" as benchmarks for incremental adaptation. In doing so, I examine if smallholders use coping, incremental or transformative adaptation the most and why. This way, smallholders´ adaptation gaps can be identified and compared. Further, it can be examined whether there is a need for farmers to invest more in incremental or transformative adaptation.

3.2. Adaptive capacity and the Sustainable Livelihood Framework

The SLF provides an asset pentagon that is used to develop indicators for the measuring of adaptive capacity (Chepkoech et al. 2020b). This approach is ideal for an analysis at the individual or household level as it is people centered and offers information for concrete local contexts (ibid.). For the operationalization of the SLF concept, various scholars have developed indicators that serve as proxies for the five different capital assets. Such indicators have been used to design

Figure 1
Asset pentagon of the Sustainable Livelihood

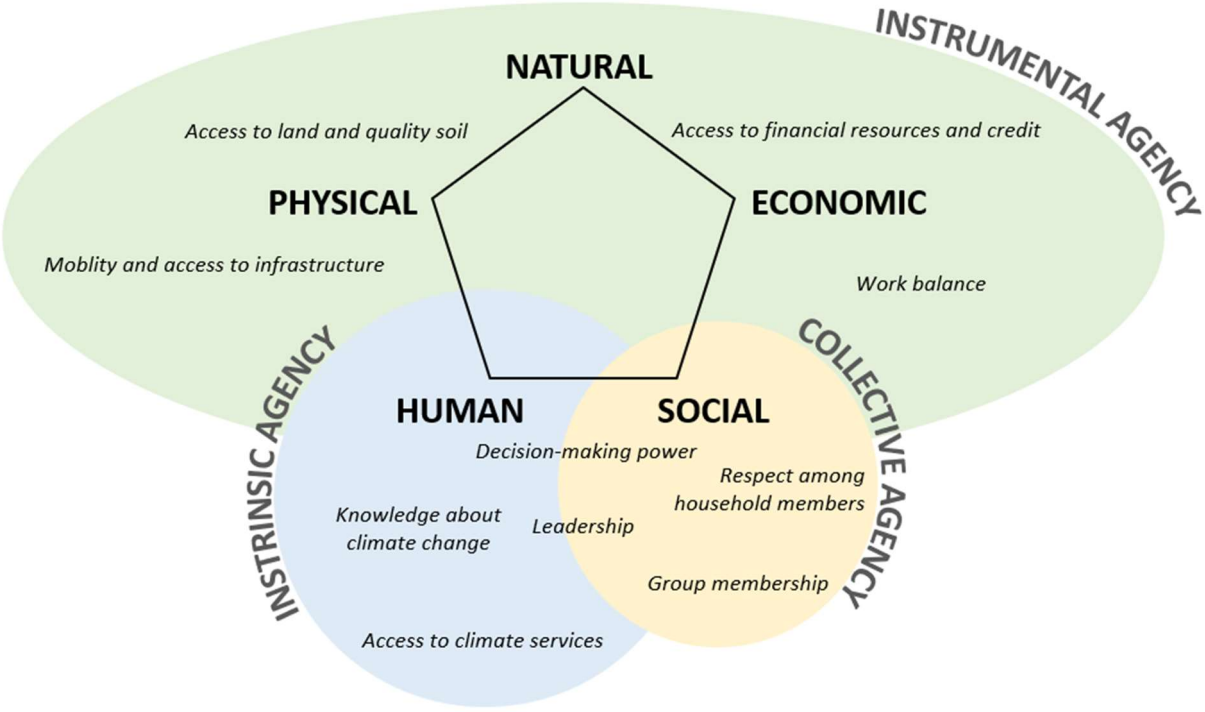


composite indices to conduct local level adaptive capacity analyses (Abdul-Razak and Kruse 2017; Chepkoech et al. 2020b; Defiesta and Rapera 2014; Ibrahim 2014; Shirima et al. 2016).

3.3. Gender in agriculture

The SLF and gender-transformative analyses share a focus on individuals´ capabilities and assets that are necessary to make strategic and sustainable choices for a living (DFID 1999; Kabeer 1999, 2008). This can be seen from the *2020 Report on the Progress and Uptake on the Fairtrade Gender Strategy*, where Gallagher et al. (2020, 24) lap Kabeer´s dimensions of empowerment with the five capitals from the SLF in order to illustrate that agency is the central aspect to transformative progress in the realm of women in agriculture. Similarly, in the design of the adaptive capacity index, my research incorporates gender-sensitive indicators in order to assess the adaptive capacity of smallholders from a gender-sensitive angle.

Figure 2
An analytical framework for the gender-sensitive analysis of adaptive capacity



3.4. Development of adaptive capacity indicators

This study draws on SLF indicators and gender in agriculture indicators to develop a context-specific adaptive capacity index in order to compare the adaptive capacity of men and women smallholders in Fatick, Senegal. The following section presents five main capitals and indicators that I used to compose

the adaptive capacity index. The computation of the index will be illustrated in the chapter on data analysis.

Economic capital

Economic or financial capital describes the level and diversity of income sources that contribute to wealth (Chepkoech et al. 2020b; Williges et al. 2017). Thus, this study examines the income diversity and agricultural diversity of the research participants. Studies have found that having a diversified income is positively linked to adaptive capacity (Abdul-Razak and Kruse 2017; Defiesta and Rapera 2014). Through diverse income sources, households can minimize risk if one of their occupations is affected by climate impacts. This study further investigates whether participants had an off-farm income and how much per capita income existed in a household. Off-farm income allows farmers to gain money in a short period of time. The quick provision of financial resources is important, as climate impacts may arise suddenly, requiring a timely purchase of inputs to adapt (Chepkoech et al. 2020b; Egyir et al. 2015). A high *per capita* income allows households to invest in climate adaptation measures (Gbetibouo et al. 2010). Access to credit is not considered for the indicator, as information on this is missing from most participants of this study.

Human capital

Human capital consists of the skills, knowledge and ability to provide labor and pursue different livelihood strategies (Chepkoech et al. 2020b; DFID 1999). Therefore, the indicator is composed of school years, years of farming experience, use of climate services and household size. More education leads to more knowledge and skills to respond to climate impacts (Defiesta and Rapera 2014). Chepkoech et al. (2020b) have shown that educated farmers are more receptive for forecasted information. Also, they use improved agricultural technologies that facilitate climate adaptation (ibid.). Experienced farmers are likely to have a higher adaptive capacity as they have gained local knowledge on agriculture and adaptation strategies throughout their years in farming (Abdul-Razak and Kruse 2017). Farmers´ access to climate services enables them to anticipate weather changes and extreme weather events and helps farmers prepare for them (ibid.).

Natural capital

Natural capital considers the access to natural resources such as land and water as well as the change of environmental conditions in one´s surroundings (Chepkoech et al. 2020b; Manlosa et al. 2019; Nawrotzki et al. 2012). The chosen indicators consist of type of land ownership, size of land, source of water and farmers´ perception of climate impact on agricultural activities. Farmers with limited land rights are less likely to invest in long-term adaptation technologies (Chepkoech et al. 2020b; Meinzen-

Dick et al. 2002). Limited land ownership also reduces farmers´ chances to receive formal loans (Chepkoech et al. 2020b). Farm size correlates with greater wealth and a higher likelihood to adopt new adaptation technologies (ibid; Deressa et al. 2009). Furthermore, larger farms allow for greater agricultural diversification (Chepkoech et al. 2020b; Egyir et al. 2015). The type of water source measures the security of access to water (Chepkoech et al. 2020b; Defiesta and Rapera 2014; Mayanja et al. 2022). The more reliable and the closer located the water source, the higher the adaptive capacity of a household. Households who have access to rain water only, depend on sufficient precipitation and have a lower adaptive capacity than households who may access water anytime through a rain-water storage system. Farmers´ perception of climate impacts indicates whether environmental circumstances lead to improving or worsening conditions to pursue agricultural activities (Manlosa et al. 2019). At the same time, it measures acceptance of climate change which increases the willingness and knowledge to adapt agricultural activities (Abdul-Razak and Kruse 2017).

Physical capital

Physical capital can be defined as basic infrastructure and inputs that support livelihoods (Chepkoech et al. 2020b; DFID 1999). For this study, the physical indicator is composed of the mode of transportation; ownership of a phone; livestock diversity; and agricultural inputs and technical equipment. Several authors use the proximity to the next market as an indicator for physical capital (Eakin et al. 2011; Manlosa et al. 2019). As this information is lacking from the study´s household survey, the mode of transportation was used instead. Based on Mayanja et al. (2022), one indicator describes the number of different livestock species in a household. The ownership of mobile phones increases farmers´ ability to receive weather-related information, to respond to weather changes and shocks (Manlosa et al. 2019) and to facilitate money transfer in case of disaster (McOmber 2020). Sufficient agricultural input and technical equipment provide farmers the necessary tools to adjust their agricultural practices to climate impacts and therefore strengthen farmers´ adaptive capacity (Chepkoech et al. 2020b).

Social capital

Social capital encompasses individuals´ abilities to engage and find support in their social surroundings. It includes people´s interpersonal networks, within and outside of the household as well as received respect from other household members and the ability to make livelihood decisions (Chepkoech et al. 2020b; Gallagher et al. 2020). This study assesses social capital with the indicators: membership with a farmers´ association; decision-making power about cultivated crops; over agricultural practices and management authority over the household´s resources. Membership at a farmers´ association strengthens the adaptive capacity of farmers as it enables them to lend money, share agricultural

inputs and technical equipment and distribute useful information on climate change adaptation (Chepkoech et al. 2020b; Defiesta and Rapera 2014). The indicators about decision-making provide crucial information on the adaptive capacity of farmers as the understanding of adaptive capacity and livelihood goes beyond the mere observation of assets. It is equally important to examine the possibility to decide over the available assets. It can be argued that this holds particularly true for transformative adaptation, where people require a certain authority and decision-making power to change common practices towards innovative ideas. In its endeavor to compare the adaptive capacity of men and women farmers, decision-making power is of particular research interest as studies suggest sex-specific inequalities (FAO 2017; Gallagher et al. 2020; McOmber 2020).

4. Research design

The study employs a mixed methods approach. While quantitative research allows to generalize and identify relationships and compare them, qualitative research provides more in-depth information on concrete sample groups and acknowledges the importance of context specificity (Gray 2009). Therefore, the combination of quantitative and qualitative approaches aims at creating a more holistic understanding of the research matter than the individual quantitative and qualitative parts could accomplish (Bryman 2007 in Gray 2009). My thesis mixes methods in both, data collection and data analysis. For data collection, a quantitative household survey parallels qualitative focus group discussions. For data analysis, I performed a descriptive statistical analysis through frequency and contingency tables. Also for data analysis, I examined the qualitative material from the focus group discussions through a structuring content analysis after Mayring (2015). In addition to the mixed presentation of contingency tables and focus group material, I developed a composite adaptive capacity index and performed an independent t-test, solely on the basis of the HH survey data. While I *collected* quantitative and qualitative research concurrently, thus independently from each other; I *analyzed* the results in a complementary manner by combining quantitative and qualitative results that illustrate overlapping but also different elements of the research topic (see Gray 2009, 205).

This chapter will present an overview of the research design. It will begin by justifying the case selection, will continue by portraying the data collection through the household survey and focus group discussions, and end by illustrating the qualitative and quantitative data analysis, including frequency and contingency tables, a structuring content analysis, a composite adaptive capacity index and an independent t-test to compare between the adaptive capacities of men and women smallholders.

4.1. Case selection

The study is embedded in the international research project NUTRiGREEN[2] which focuses on the promotion of African indigenous plants in regions in Senegal and Burkina Faso with the aim of increasing food security. The project is implemented by researchers from Cheikh Anta Diop University (UCAD) in Dakar, Senegal; the National Center for Scientific and Technological Research (CNRST) in Ouagadougou, Burkina Faso; the Swedish University of Agricultural Sciences (SLU) in Uppsala, Sweden; and the Centre for Rural Development at Humboldt University (SLE) in Berlin, Germany. In Senegal, the NGO APAF[3] acts as the local facilitator and establishes the link between the universities and the farmers. The close connection of this study to the NUTRiGREEN research project allows for synergies: generated data and logistical efforts are shared among myself as researcher of this thesis, the NUTRiGREEN project team, the facilitating NGO APAF and the participating smallholders.

Data was collected at the Senegalese site of the NUTRiGREEN project. For that, I visited the two research sites Nobandane and Diofior, in the Fatick region, which were chosen as research sites through convenience sampling (Etikan et al. 2016). The choice was made by the facilitating NGO APAF, based on the availability of water for the implementation of the NUTRiGREEN project, APAF´s gatekeeping potential in the area, and the geographic proximity to the APAF office in the city of M'bour. Furthermore, inhabitants of both sites engage in community farming activities, such as micro-gardening and agroforestry. At both sites, women farmers´ associations exist. The expertise of the women members of these associations was considered particularly fruitful for the collection of sex-aggregated information of smallholder farmers. The two locations lie in the region Fatick, in close proximity to the neighboring region Thiès. Nobandane (14.3210451|-16.6964295) is a village with dispersed farms counting 1,400 inhabitants[4] (Communauté Rurale de Loul 2004) and Diofior (14.1985674|-16.6534951) a small town with approximately 11,000 inhabitants[5] (CITY POPULATION 2022). At both sites, the majority of inhabitants belong to the Serer ethnicity (Communauté Rurale de Loul 2004).

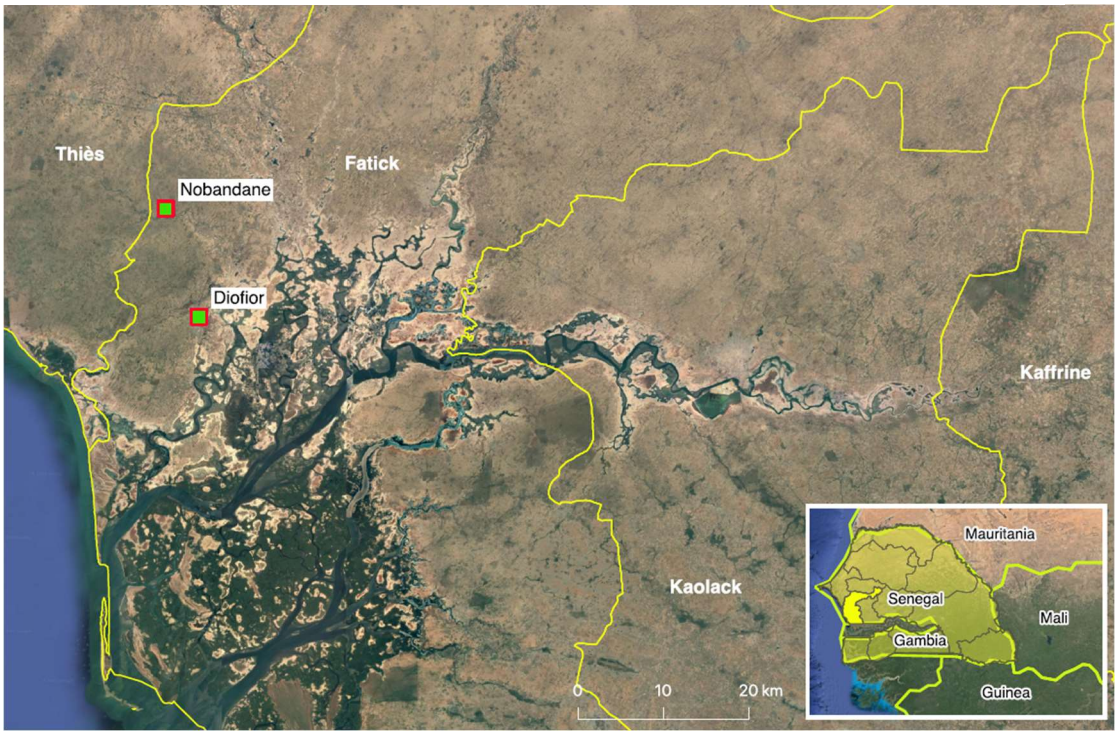
According to weather data that was collected at a location between the two study sites (14.25 - 16.75), average annual precipitation for the period between 1991 and 2020 was 658,9 mm. The data reflects a wide span between years of strong precipitation (max. 914mm in 2012) and weak precipitation (min. 458 mm in 2002). The study sites are in the Sudan-Sahelian zone which is semi-arid (Mertz et al. 2009). The dry season lasts 9 months, from the middle of October until the middle of June,

[2] More information on the NUTRiGREEN project can be accessed here: https://www.sle-berlin.de/index.php/forschung/nutrigreen.
[3] Association pour la Promotion de l´Agroforesterie et de la Foresterie.
[4] As of 2004.
[5] As of 2013.

with a cooler period between November and March (ANSD 2017). The rainy season lasts three months respectively, between mid-June and mid-October (ibid.).

Figure 3

Map of the two project sites Nobandane and Diofior in Fatick, Senegal



Note. The map was designed and provided by the NUTRiGREEN research project.

Diofior and Nobandane are situated in the Groundnut Basin that is known for its rainfed cultivation of groundnut and millet. Other crops such as maize, rice and cowpea as well as fruits and vegetables are also cultivated (WATHI and KAS 2017). In the last 100 years, groundnut was cultivated as a monoculture, which has severely impacted soil health in the region (Resilient Food Systems 2020). Livestock and fishing complement the main economic activities. However, commercial activities also play a significant role: While inhabitants are mostly engaged in retail, only few are involved in wholesale trading (WATHI and KAS 2017). Most of the agricultural products are sold in small quantities at weekly markets (ibid.). Concerning their economic profile, the two project sites have different characteristics: While Nobandane´s population remains primarily engaged in agricultural activities, Diofior experiences a process of urbanization and income diversification in the sphere of commerce and crafts.

Furthermore, the rural region is characterized through its young population: More than half of the population of Fatick is under 15 years old (ANSD 2017). The literacy rate lies at 43%, with 50% of women and 36% of men respectively (WATHI and KAS 2017). In 2006, the school enrolment rate lied at 77%, with 79% of girls and 75% of boys (ibid.). Life conditions are mostly very simple: 51% of households live in huts and 53% of households access their water through wells. 14% have access to electricity and 86% use firewood for fuel. 31% do not own any means of production. Women

associations play a pivotal role in society. They have high visibility in commercial activities and in the context of community development (WATHI and KAS 2017).

One of the most pressing environmental challenges in the region of Fatick is soil degradation by salinization, which is perpetuated through a decline of annual rainfall (ANSD 2017; Sall et al. 2019). Even more, freshwater sources are encroached by salt water, leading to an increase in soil salinity (Resilient Food Systems 2020). Additionally, there is an inter-annual irregularity in precipitation that brings along periods of dry spells on the one hand or erratic rainfall on the other (ANSD 2017; Sall et al. 2019). Moreover, the temperature in the area is increasing, impacting the vegetation, cultivated crops, livestock and the regions´ inhabitants (Sall et al. 2019). Today, large parts of the Groundnut Basin are barren (WATHI and KAS 2017). In Fatick, 34% of the soil is considered infertile, making agriculture a challenging activity. Furthermore, the access to water through wells and pumps remains difficult in the region. In Fatick, 46% of villages are situated further than 2 kilometers away from a water source (ibid.).

This illustration of the project sites provides background information that is essential to contextualize the data collection, analysis and results section of the thesis.

4.2. Data collection

The data collection process contains of a household survey and focus group discussions. During both processes, it was assured to adhere to ethical research standards, which will be further depicted below.

Quantitative data collection

In the context of the new NUTRiGREEN project, a baseline household survey was designed to collect information about smallholders´ demographics, their incomes, farming and market activities and challenges, consumption patterns, and perceptions of climate change. Questions on farmers´ climate change perception and adaptation were primarily drawn and adapted from the SLE´s experience with similar research projects in East Africa[6] and Indonesia[7]. The methodology was moreover inspired by the approach taken by Limantol et al.´s research (2016) who employed a case study on climate change on rainfed agriculture in Ghana. In Fatick, the household survey contained 61 questions and was

[6] A sup-topic of the research project HORTINLEA (Horticultural Innovation and Learning for Improved Nutrition and Livelihood in East Africa), investigated climate change and ecological sustainability of horticultural value chains in Kenya, as can be seen here: https://www.sle-berlin.de/index.php/forschung/abgeschlossene-projekte/hortinlea/teilprojekt-8.

[7] Within CRAIIP (Climate Resilient Agriculture Investigation and Innovation Project) smallholders, NGOs and scientists established climate field schools in Indonesia to test innovative agricultural practices regarding their climate resilience. The project information can be accessed here: https://www.sle-berlin.de/index.php/forschung/abgeschlossene-projekte/craiip.

conducted in the predominant local language Serer, by 10 students from Cheikh Anta Diop University Dakar[8].

The sample group for the household survey was chosen through convenience sampling (Etikan et al. 2015). 204 smallholder farmers were interviewed in the period of February and March 2022. To be eligible for the interview, participants had to be heads of households that mainly base their livelihoods on subsistence agriculture. The interviewers used APAF staff as gatekeepers. Once they had started interviewing, they continued to choose participants randomly during their visits at the sites, based on accidental encounters with smallholders in Nobandane and Diofior. The data includes valid responses from 109 women and 94 men. 102 valid answers are from Diofior, 101 from Nobandane. The software Kobo Toolbox was used to register all answers digitally. The household survey was prepared in joint efforts by the Dakar and Berlin project members including myself.

Qualitative data collection

In the same area of Fatick, Senegal, qualitative data was collected to gain more thorough insights into climate change impacts, adaptation strategies and gender-related challenges. The methodology for the collection of qualitative data is based on the Participatory Rural Appraisal (PRA) approach, as portrayed by Chambers (1994) and further developed by Narayanasamy (2009). PRA is an interdisciplinary method that aims at collecting information in cooperation with local people at a specific site in order to address questions that are relevant for the participants (Reason and Bradbury 2008). PRA is based on the understanding that local knowledge should inform development studies and action. Its main objectives are not only investigation and analysis, but also planning, action, monitoring and evaluation (Chambers 1994). Through the cooperation between researchers and locals, PRA may create local ownership of knowledge and empowerment of the local co-researchers involved (ibid.). As external researcher, it is of highest importance to stay aware of one´s own lack of inside knowledge and to leave room for the expertise and the lived experience of locals. Hence, the data collection process followed structured planning and clear objectives, but remained flexible to respond to local suggestions and unexpected circumstances.

Based on preliminary discussions with the SLE and the local NGO, I decided to converse with smallholder farmers through focus group discussions (FGDs) because the open format and interaction between smallholders is a comfortable setting that encourages discussion and sheds light on topics that are most relevant for the research participants (Schulz et al. 2012). Two different discussion formats were designed. In the first format (FGD1) smallholder farmers discussed the climate sensitivities of crops and climate change adaptation measures more thoroughly than in the household

[8] The household survey for the sites in Burkina Faso was translated to Mooré and was conducted by students from the National Centre for Scientific Research and Technology in Ouagadougou respectively.

survey (see Annex A.1.). A second format (FGD2) focused on gender and climate change (see Annex A.3.). For the selection of focus group participants, purposive sampling was applied. The pool of the 204 interviewees from the household survey was considered by the local NGO staff to select 22 women and 17 men smallholders with the will and expertise to participate in more profound discussions about farming, climate impacts and adaptation strategies. Thus, the sampling process was built on local networks which facilitated the organization of the time, place and invitation of participants. Due to time constraints, the FGDs were only held in Nobandane.

FDG1 took place four times in January and February 2022, with groups of 4 to 7 same-sex farmers. FDG2 was conducted twice, with 8 and 10 women respectively. FGD1 contained activities with picture cards of cultivated crops and adaptation measures. Participants examined a printed portfolio of crops and adaptation measures, and commented whether they used the crops and applied the measures. The visualization gave participants the opportunity to associate thoughts about the crops and adaptation measures. This way, I tried to avoid a question bias to let the discussion as open as possible. Additionally, participants also mentioned what crops or adaptation measures were missing from the picture cards. FGD2 included a role play in which the participating farmers put themselves into the role of regional agricultural decision makers. In short speeches, participants presented their desired solutions for the improvement of their living conditions.

The interviews for the household survey and the FGDs were held in the local language Serer and French. The FGDs were moderated by me and the local NGO facilitator who was also responsible for translation. Before the discussions, I presented the aim and the content of the FGDs to the NGO facilitator to familiarize him with the research and to assure whether the design of the group discussions was appropriate. The results of the focus groups were documented through audio records and manual result matrices (see Annex A.2. and A.4.). After each day in the field, the results were discussed with the NGO facilitator. This allowed to clarify aspects and to gain a more detailed insight into local particularities that were raised by the focus groups.

Additionally, I kept a research journal throughout the field research period to save impressions and observations concerning the research experience. The aim of the journal entries was to stay aware of my own positionality and to filter my subjective interpretations of the observed. At the same time, I tried to capture the research experience in my position as a white female researcher that certainly impacted the way in which the participants engaged in the data collection process. While my outsider position as a white person may have created barriers; my role as a woman might have facilitated the task to discuss gender-related inequalities with women smallholders. As argued by Whitehead (2004), collected data is the product of an intersubjective process between investigators and research participants. Thus, findings are unavoidably influenced by experiential and personal perceptions of the research participants and researchers. Journal entries and debriefing discussions with the NGO

facilitator helped to recognize and reflect on the unavoidably biased mindset and subjective reactions that I, as external researcher, brought and received in the field.

Ethics

All methods applied adhere to ethical standards and a declaration of informed consent was collected from all participants. For the FGDs, an informed consent form was printed and presented to the participants which could be signed by writing or thumbprint. The household survey ensured the interviewees´ consent digitally, through an audio record that was registered through Kobo Toolbox. The declaration of consent can be found in Annex A.7. Before the declaration of consent, participants were presented with the research aim and had the opportunity to ask questions about the usage of the data. Participants were particularly interested in their benefits from the findings. Therefore, it was ensured that the findings will be presented and shared with the engaged NGO APAF. Thus, the findings will be translated, visualized and made locally accessible for the participants. Additionally, as suggested by Gallagher et al. (2020), a preliminary analysis was already conducted swiftly after data collection and presented to the APAF staff members to validate the findings and to check for possible misunderstandings.

4.3. Data analysis

The analysis contains various parts: The creation of frequency distributions and contingency tables about the household data; a qualitative structuring content analysis of the focus group data; a composite index of adaptive capacity and the application of an independent t-test to compare the adaptive capacity indices of women and men farmers.

Frequency and contingency analysis

Frequency and contingency tables were performed in order to examine the following key questions from the household survey:

1. What are your biggest agricultural challenges?[9]
2. What are the biggest obstacles that prevent you from adapting your agricultural activities?[10]
3. How do you adapt your agricultural activities to climate change?[11]

[9] Household survey question 27.
[10] Household survey question 43.
[11] Household survey question 42.

Frequency distributions illustrate the frequency of the different answers provided by participants. Contingency tables display the multivariate frequency distribution between men and women smallholders. Both were created with pivot tables through Excel.

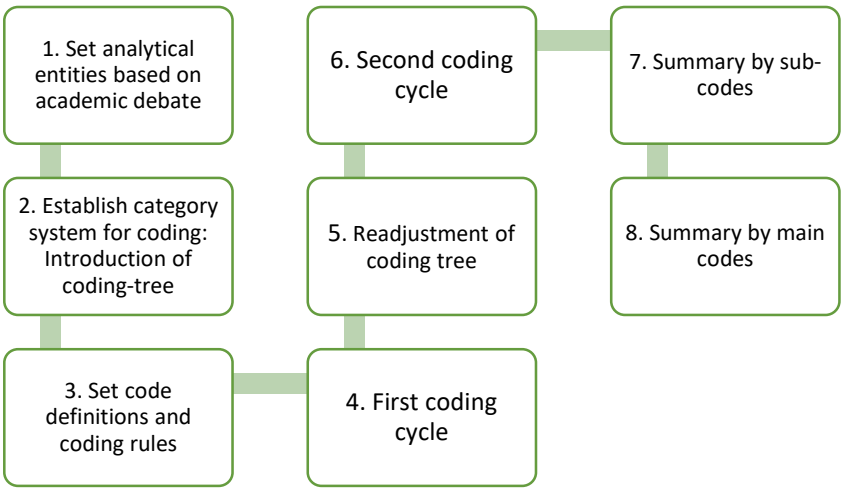
Structuring content analysis

The data from the FGDs was analyzed according to Mayring´s (2015) structuring content analysis[12]. The analysis allows to extract and summarize particular topics from the FGDs to filter relevant material responding to the research questions. To this end, the analytical process followed eight distinct steps:

In a first step, the FGD data was categorized into three main "structural dimensions" (Mayring 2015, 48), that were derived from the research questions and based on the literature review. These dimensions were "climate impacts on crops", "adaptation" and "gender". The structural dimensions were therefore deductively derived; they structured the data from the beginning and provided information on which phenomena occur in which research contexts. In a second step, a deductive coding tree was established for the coding procedure. In a third step, code definitions and "anchor examples" (ibid.) were established to define coding rules. In a fourth step, the entire material was coded through the software MAXQDA, based on the *a-priori* coding tree. During this process, memos were used to highlight how codes should be complemented or altered. In a fifth step, the coding tree was readjusted and inductively created codes and sub-codes were added. In a sixth step, a second coding cycle was conducted on the basis of the *a-posteriori* coding tree. In a seventh step, the material was summarized by sub-codes. The eighth and final step consisted of summarizing all main codes. Together, this procedure describes the deductive-inductive qualitative content analysis which resulted in a structured summary of the research phenomena.

Figure 4

Procedure of a structuring content analysis developed according to Mayring (2015)



[12] The coding system, coded segments and code summaries can be accessed through Annex B.

Adaptive capacity index

For the comparison of the adaptive capacity of men and women farmers, I developed a composite index. The index measures to what extent men and women farmers have equal assets at their disposal in order to sustain their livelihood in the face of climate change. In accordance with the SLF (see Figure 1), the index was composed of the five indicators: economic, human, natural, physical and social capital. Each capital was measured through four sub-indicators that were designed as illustrated earlier in the analytical framework. Ideally, such indicators are established through expert interviews and rankings. However, due to time constraints, this study draws on indicators that have been designed in previous studies (see Chepkoech et al. 2020b; Abdul-Razak and Kruse 2017; Defiesta and Rapera 2014; Manlosa 2019).

Independent t-test

For the construction of the composite index, the responses from relevant questions of the household survey were translated into a simple scoring system (as in Chepkoech et al. 2020b). Table 1 serves to illustrate the scoring. For example, farmers received one point for each source of income. The table also depicts the questions from which the sub-indicators were established. In a following step, the values for each sub-indicator were normalized within the range of 0 to 1. The OECD (2008) emphasizes that normalization is a necessary precondition for the comparison of data as data sets are usually composed of different measurement units. Hence, the scores were normalized through min-max-normalization, according the following formula, proposed by Fritzsche et al. (2014):

$$X_{i=0to1} = \frac{X_i - X_{Min}}{X_{Max} - X_{Min}}$$

where

X_i represents the individual data point to be transformed;

X_{Min} the lowest value for that indicator;

X_{Max} the highest value for that indicator; and

$X_{i=0to1}$ the new value to be calculated, i.e. the normalized data point within the range of 0 to 1.

Table 1 exemplifies the design of the indicator “economic capital” and the scoring intervals for its sub-indicators. The entire list of indicators (economic, human, natural, physical and social) and their sub-indicators can be found in Annex C.

Table 1

Exemplified design of the composite variable "economic capital" and its indicators

	Variable	Source	Description	Grouping	Scores	Normalized scores
1.	**Economic capital**					
1.1.	Off-farm income (Q 9)	Chepkoech 2020; Gerlitz et al. 2017		Yes	1	1
				No	0	0
1.2.	Diversity of income sources (Q 9)	Abdul-Razak and Kruse 2017; Chepkoech 2020; Defiesta and Rapera 2014; Eakin et al. 2011	Each agricultural activity counts as one whole activity. Pension counts. Retirement does not.	0-1 source	1	0
				2 sources	2	0,33
				3 sources	3	0,66
				> 3 sources	4	1
1.3.	Diversity of agrcultural activities (Q 18)	Defiesta and Rapera 2014; Eakin et al. 2011; Gerlitz et al. 2017		1 activity	1	0
				2-3 activities	2	0,5
				4-6 activities	3	1
1.4.	Income (Q 11)	Gbetibouo 2010, World Bank 2020	The distinction is made between monthly *per capita* income that lies under or over the international poverty line of low income countries (1,90 USD PPP or 469,5 FCFA). Yet, one must be careful with this measure as it is simplified.	< 13.146 FCFA	0	0
				> 13.146 FCFA	1	1

As applied by Chepkoech et al. (2020b), each indictor consists of four sub-indicators. The maximum value for each indicator is 4. The index is formed from a sum of scores for each sub-indicator. Thus, 100% adaptive capacity are expressed by a score of 20. However, it must be noted that this index is not capable of measuring the absolute adaptive capacity of smallholder farmers, as there does not exist an internationally recognized quantitative ideal of smallholders´ adaptive capacity. Rather, as this study is particularly interested in the analysis of sex-specific differences in adaptation, the index is designed to systematically compare men and women farmers´ adaptive capacities with each other. Thus, a simple composite index sufficed to detect possible sex-specific differences. It was assumed that the adaptive capacity of smallholders does not vary between sexes. The hypothesis was tested through an independent t-test that compared the overall indices as well as each of the five capitals based on the participants´ sex. The hypothesis was tested at a 5 %-level of significance.

The end of data analysis illustrates the point of departure for mixing the various types of results. The different analyses are used to complement each other in the following chapters on results and discussion.

5. Results

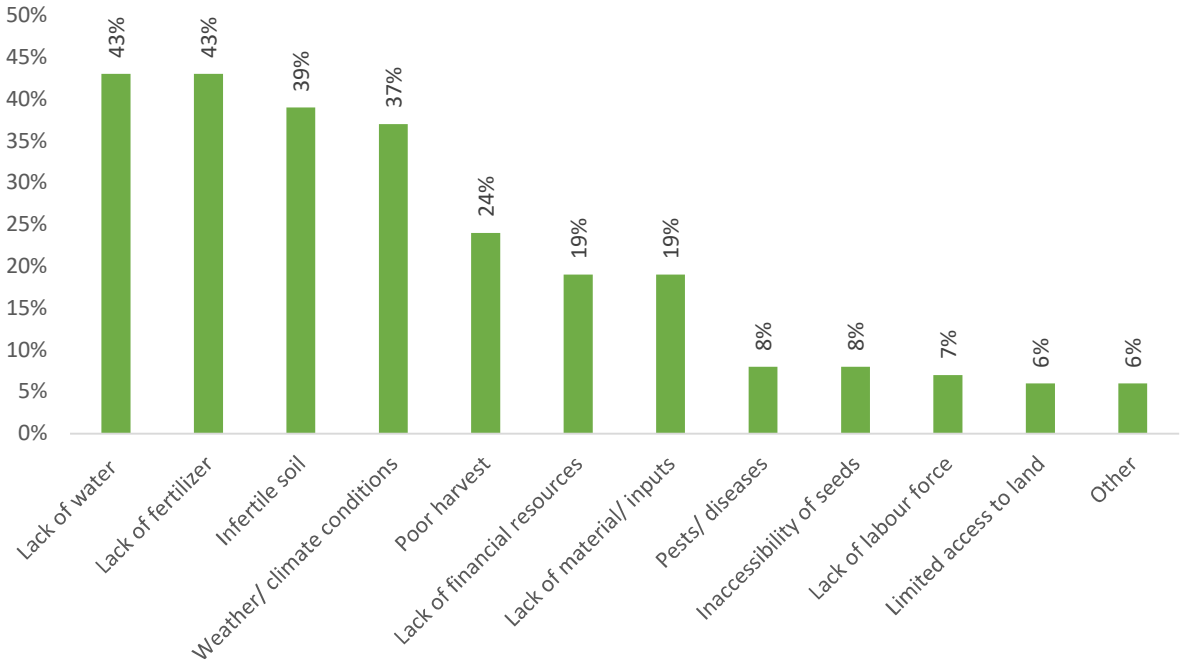
The presentation of the results proceeds in a twofold way: The first part depicts a descriptive analysis of local climate impacts and practiced adaptation strategies, in order to obtain an overview of the local

status quo. Thus, it illustrates the farmers´ greatest agricultural challenges, the perceived effects of climate change on agriculture, as well as the most common adaptation strategies. The second part focuses on gender differences in adaptation strategies and adaptation capacity. It compares men and women smallholders´ suggestions for adaptation improvement and concludes with the presentation of results from the adaptive capacity index. The second part provides a foundation for the gender-specific analysis of adaptation strategies and adaptive capacity of the local smallholders which will be at the center of the following discussion.

5.1. Perceived agricultural challenges

The household survey asked smallholders to name their prevailing agricultural challenges. In descending order, participants listed the following as the four predominant agricultural challenges: lack of water (43% of participants), lack of fertilizer (43% of participants), infertile soil (39% of participants) and weather/ climate conditions (37% of participants). The results from the FGDs depict that water scarcity and drought are acute challenges that the farmers of the region undergo today. Water scarcity was the predominant topic of all focus groups. It was not only mentioned frequently but it was also discussed very profoundly. Participants stressed that water was needed for all farming work: “Without water, there is nothing. We use it for all of our activities: livestock, agriculture, the household” (Gender 13|11). The lack of water therefore affects the overall living conditions.

Figure 5
Greatest agricultural challenges



While water scarcity describes a long-term condition, dry spells and floodings depict extreme weather events which smallholders have faced recently. For 2021, women farmers referred to two

extreme weather events that their village Nobandane was exposed to: erratic rainfall and a dry spell. The erratic rainfall occurred in August 2021 and led to a flood, as one FGD participant summarized: “Our farmland was flooded. The crops that do not adapt well to water were really destroyed. It was very difficult with the yield. It was also really difficult to go and buy things somewhere” (Gender 13|1). The river near the village overflowed and the inhabitants could not use the bridge that connects them to the outside world. They were stuck for several days, without access to a market. Additionally, trees fell and houses were under water. One person died.

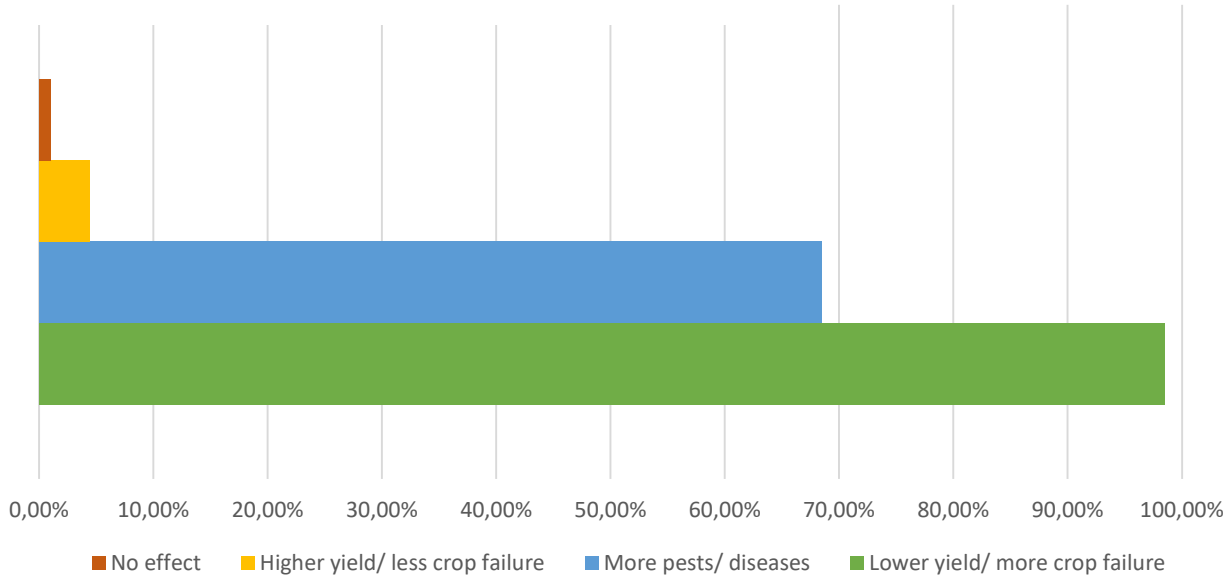
Throughout the rest of the season, the region experienced a dry spell, as the focus group participants thoroughly discussed. One participant reported: "The lack of rain that we had this year will be very difficult for us. We have nothing for this year. Today, we have practically no yield. The rain has stopped" (Gender 13|3). The main concerns of smallholders during both, the flood and the dry spell, were the loss of yield and the inaccessibility of food and basic products.

5.2. Climate impacts on agricultural production

The vast majority of survey participants perceive climate impacts and named exclusively negative effects of climate change on agricultural production: 98% of participants reported to perceive lower yields or crop failure, 68% more pests and diseases, while only 4% perceived either higher yields or crop failure and 1% of participants did not notice any affect at all [13].

Figure 6

Perceived effects of climate change on agriculture



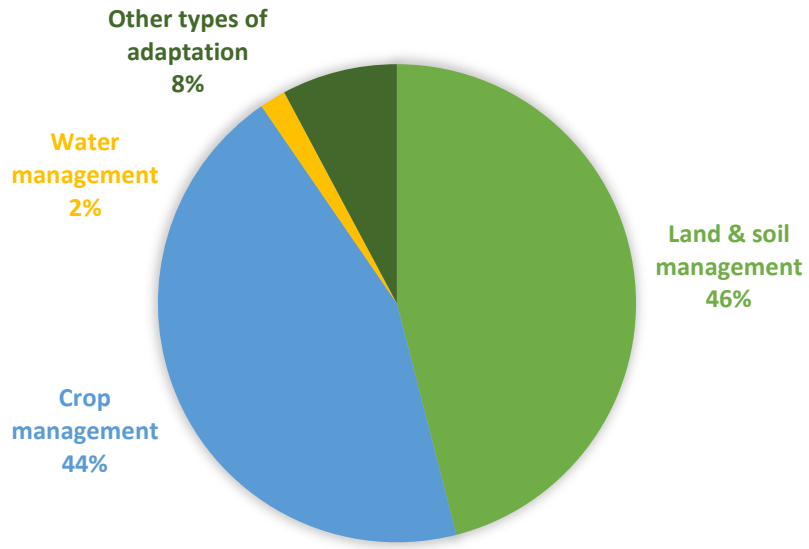
[13] Since the categories “lower yield” and “more crop failure” as well as “higher yield” and “less crop failure” have been merged into one category each, their total does not equal 100%.

In the FGDs, the smallholders also discussed climate impacts on crops and shared their experiences with crop fragilities towards weather and climate impacts. Crop cultivation suffers particularly from water scarcity. Thus, water scarcity is the main reason for smallholders to abandon the cultivation of certain plants, such as rice, sweet potatoes, potatoes and rock melon.

5.3. Practiced adaptation measures

The vast majority of adaptation measures are associated with either land and soil management (46% of measures) or crop management (44% of measures). Water management, however, is not a common pathway to climate adaptation, as it accounts for merely 2 % of adaptation measures. Other types of adaptation make up 8% of all listed measures.

Figure 7
Practiced adaptation measures



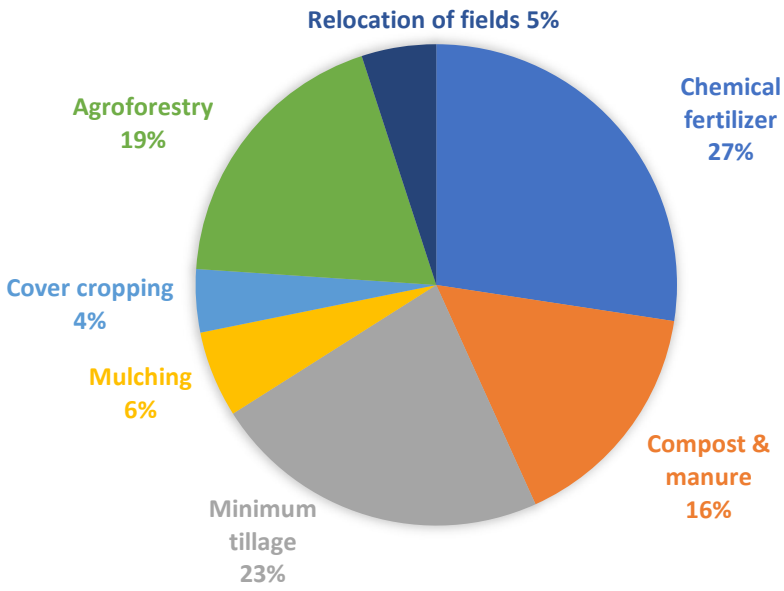
Land and soil management

In the context of land and soil management, smallholders mainly adapt their agricultural practice through the application of fertilizer; minimum tillage and agroforestry. Mulching, cover cropping and the relocation of fields are not very common adaptation measures of the sample group. With 27% of all land and soil activities, the application of chemical fertilizer is the most practiced land and soil management measure, followed by minimum tillage, representing 23% of activities. In the FGDs, biological fertilizer appeared as the most prominent soil management measure. Participants of all focus groups stated that they did not have sufficient amounts of manure to apply on all their fields. Consequently, they rotate application. Various participants stressed that they preferred to use manure and compost over chemical fertilizer and would like to apply it more often and in larger quantities, if

they had it available: "We prefer compost because we don´t have to buy it. Also, it fertilizes the soil. Chemical fertilizer destroys the soil. Also, it is very expensive" (Adaptation 10|20).

The household survey reveals that agroforestry accounts for 19% of all land and soil management measures. This responds to the answers in the FGDs where the majority of farmers stated to implement agroforestry. Furthermore, participants are interested in reforestation, as one farmer explained: "We think it will prepare us for the changing climate. We have heard that trees attract rain and make a better climate" (Adaptation 16|25). This awareness has to be contextualized in so far as the study´s participants have been selected through the NGO APAF which promotes agroforestry in the area. Therefore, the high awareness and implementation rate of agroforestry by the sample group may not be representative for the region.

Figure 8
Land and soil management measures



Crop management

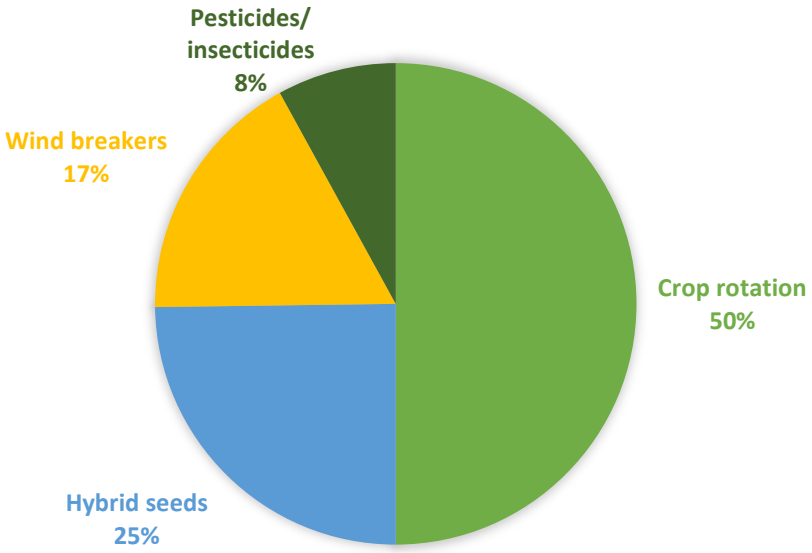
Concerning crop management, the most practiced adaptation measure is crop rotation, accounting for 50 % of all crop management activities. 25% of crop management measures are attributed to the use hybrid seeds, i.e. varieties that are adapted to drier climate. The measures are followed by the use of wind breakers to protect crops from augmenting winds (17%). Only 8% of crop management measures describe the application of pesticides and insecticides.

In the FGDs, two adaptation measures stood out: vegetable cultivation and the use of hybrid seeds. Vegetable cultivation was not initially considered an adaptation measure in this study. However, it was added as smallholders explicitly named it as a measure to adapt to changing climate. Vegetable cultivation is an agricultural practice that has not existed for a long time in the region of Fatick. Through

the FGDs and conversations with agricultural experts, it was found that smallholders originally only cultivated cereals. One participant explained that vegetable production was introduced rather recently, also to make use of farmers´ free time during dry season: "In the past, we didn´t even know about vegetable gardening. Today, this has changed a lot. Now, everybody does it" (Adaptation 10|14).

Hybrid seeds were also a present topic in the FGDs. All participants of the discussions stated that they used adapted seed varieties. This particularly concerns the cereal crops sorghum, groundnut, cowpea and millet. The farmers use hybrid seeds as they have a short cultivation period. They see an advantage in obtaining a yield rapidly, within four to six weeks. It is also explicitly stated that the participants consider the hybrid seeds climate resilient as they have been altered in order to resist both, high exposure to water as well as lack of water.

Figure 9
Crop management measures



Other types of adaptation

The "other types of adaptation" measures are rather equally distributed, with the use of climate services, such as forecasts, being the most frequent answer (27%) and the cutback on livestock being the least frequent answer (5%). The FGDs shed light on the unwillingness to decrease either crop cultivation or livestock. For the farmers, both practices go hand in hand, due to practical and cultural reasons: Animals are used to prepare the fields. Also, their manure is used to fertilize the soil. Culturally, the Serer consider animals as necessary for their reputation as well:

> Abandoning livestock to focus on cultivation is not an option. Here, we love having animals. With the Serer it´s like that: When you do agriculture and you don´t own livestock, you have

nothing. When you cultivate, you are obliged to have farm animals. […] It´s cultural. (Adaptation 9|22)

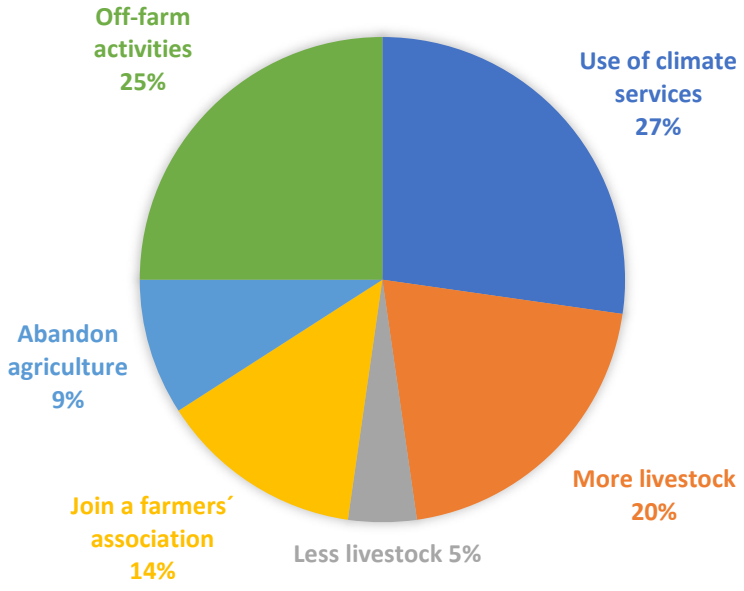
Two noteworthy adaptation measures that occurred during the FGDs were market activities as well as migration or mobility. One way to engage in the market activities of the area, is the strategy of petty merchandise ("petite merchandise") where farmers buy and resell agricultural products during the same market visit. One participant explained that they may go to the market with 500 FCFA (ca. 0.75 USD). There, they can buy a kilo of millet or cowpea for 150 FCFA and try to resell it for 200 FCFA, in order to make a surplus of 50 FCFA (ca. 0.08 UDS). Participants stressed that without the participation in the local market, they would not have anything at all to sustain their livelihood:

> With this small merchandise, you can at least gain a little bit of money. It´s a strategy for us to cope with the situation. If we didn´t do it, it would be very difficult for us to get through. Other than that, we don´t have the means to work with anything else. (Adaptation 13|8)

Migration was also discussed in the focus groups. However, it is not a very prominent adaptation option among the smallholders. One participant explained that, in Nobandane, migration has become a less present topic with the beginning of vegetable cultivation:

> In the past, we did have a rural exodus. After the rainy season, the youth migrated to Dakar, Thiès, M´bour. To the big cities. To find a job. This has changed a lot. Look, you could not even find young people at the village after the rainy season. Today, people stay here again after the rainy season because they do vegetable gardening. Now, the youth stay to grow vegetables. (Adaptation 10|23)

Figure 10
Other types of adaptation



Water management

In the household survey, only 2% of all named adaptation measures fall under the category of water management[14]. It can be assumed that water management does not play a significant role in adaptation as there is simply not enough water available. This assumption was confirmed in the FGDs where farmers explained that, during rainy season, cereal crops are cultivated, based on rainfed agriculture. After the rainy season, the water is not sufficient for field irrigation. Instead, farmers use the remaining rain water for the household and for the animals. Thus, rain water collection is practiced on a small scale only. One female participant illustrated:

> We women collect rain water in tubs that we usually use in the household. For example, to do the dishes[15]. When it rains, we bring out the tubs. We use the water only for cleaning. We don´t water our plants with this water though. (Adaptation 8|6)

5.4. Adaptation obstacles

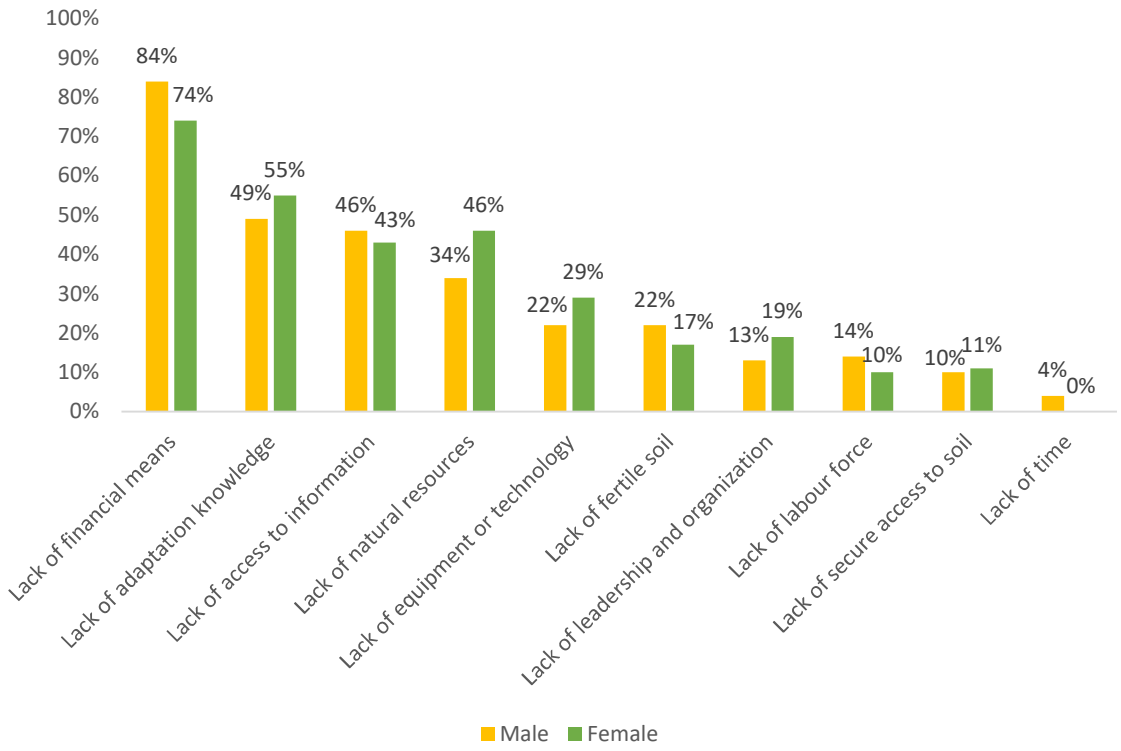
The lack of financial means is the principal obstacle to climate adaptation; it was named by 79% of all survey participants. This is followed by a lack of knowledge about adaptation options as the second prominent obstacle that affects 51% of survey participants. 44% of participants saw an adaptation obstacle in lacking access to information and 40% in lacking natural resources.

There are no drastic gender differences found in the perceived obstacles to adaptation. Among women smallholders, the lack of natural resources, the lack of leadership and organization as well as the lack of equipment and technology were named slightly more often as obstacles to adaptation than among men smallholders. Lack of time and lack of labor force were obstacles that men smallholders named more often than women smallholders.

As for the FGDs, the most prominent obstacles to adaptation are lacking equipment and lacking financial means. The strongest coding overlap between adaptation measures and adaptation obstacles was found between water management and lack of equipment and lack of financial means. Participants noted that their agricultural activities require more elaborate means to collect and store larger quantities of rain water. However, the smallholders stressed that they lack the resources to build cisterns or retention basins to collect and store water. Nevertheless, they explicitly stated that a water storage system would help them to deal with water scarcity. Additionally, they prefer retention basins over cisterns, as they could store larger quantities of water. The participants also desire more efficient irrigation systems like drip irrigation or sprinklers.

[14] Due to the limited practice of water management measures, there is no graph illustrating the distribution.
[15] The tubs have a limited capacity. They can contain up to 20 liters each.

Figure 11
Adaptation obstacles



Furthermore, participants explained that one obstacle to agricultural practice and adaptation occurs through grazing animals that destroy their fields, by grazing or poaching the soil[16]. For protection, smallholders would like to plant more thorny plants like euphorbia around their fields to prevent the grazing animals from entering their plots. One participant added that this would give them the opportunity to expand their vegetable cultivation and also engage in off-farm activities, as they would not be obliged to stay near the fields to protect their vegetables. However, they lack the financial resources to attain sufficient fencing plants. Consequently, cultivation becomes more cumbersome when the yield must be protected from livestock:

> Vegetable gardening is very challenging because of the animals who run around freely and who search for food. We don´t have the means to protect our fields from livestock. Before, there were thorny bushes and trees. They could be used as a natural type of fence. But the trees don´t exist here anymore. And we don´t have the means to buy another type of fence. (Adaptation 17|26)

[16] While conflicts over natural resources between farmers and pastoralists are also a prominent topic in the research area (NUPI and SIPRI 2021), this case study describes the trespassing of animals belonging to neighboring farmers. Therefore, my findings do not describe a herder-farmer conflict.

Interestingly, women highlighted different adaptation obstacles and needs than men, as they did not only discuss explicit farm-related adaptation, but also considered market and community development within the realm of adaptation. Women smallholders emphasized their willingness to participate in market activities to sell their home-made products:

> We have participated in a workshop about the transformation of fruits and vegetables[17]. But we don´t have the means to apply the knowledge. The knowledge is there. The motivation is there. But we are lacking the means. We need equipment. (Gender 15|6)

To sell processed vegetables and fruits in the form of juices, syrups, jams or soaps, the women farmers stated that they would require access to sugar and oil and equipment such as tubs, buckets, gas and pots. Furthermore, access to electricity would allow the women to maintain fridges which could facilitate their home production and would increase their capability to gain a little income. Additionally, the women called for better market accessibility through a closer market location to their village. Furthermore, it was particularly women smallholders who suggested to diversify their livelihoods through an increase in vegetable cultivation:

> We need to find a mechanism, for example projects to enhance the living conditions of our families. For example, with a project of growing vegetables. If there is a bad yield of cereals, we could at least still try to grow vegetables. We could organize ourselves. (Gender 15|5)

Another one adds: "I want a field next to my house for the women so that they can grow vegetables close to the house" (Gender 14|1).

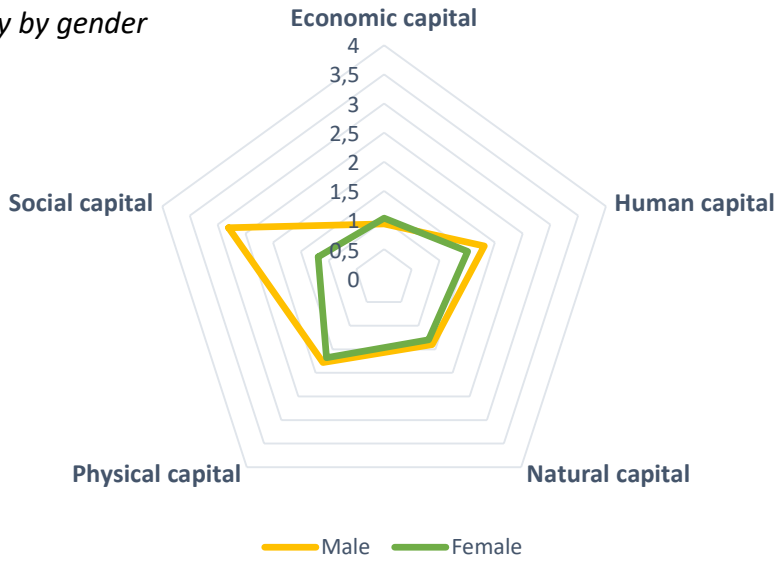
Besides medium- or long-term adaptation needs, women participants explicitly discussed coping strategies to respond to acute situations of food insecurity in order to ensure the livelihood of their households. An extreme example of coping was described by one woman participant: "We have to try to get through. We need to change the amount of food to cook: If we used to cook with 10 kilos, we will cook with 5 or 6 kilos today, to really try to get through" (Gender 13|6). One women group called for the establishment of an emergency community fund among the members of the women farmers´ association. The women reckoned that an emergency fund could better prepare them for extreme events like the flood and subsequent dry spell that they have experienced in 2021.

[17] This workshop took place outside of the cooperation with APAF and was organized by an external organization. During FGDs, the women smallholders explained that the workshop was targeted at women. Therefore, the women´s eagerness to engage in food processing and market activities needs to be contextualized in so far as men did not have the same knowledge to develop similar strategies.

5.5. The gender-sensitive adaptive capacity index

Gender differences between men and women farmers´ adaptive capacity were examined through an independent t-test. The results suggest that the adaptive capacity of men and women farmers differs significantly.

Figure 12
Adaptive capacity by gender



The divergence between men´s and women´s adaptive capacity is particularly due to the drastic differences of social capital between men and women farmers. Further significant differences between the sexes can be observed in human capital. The following section illustrates the findings of each capital while particularly focusing on the significant differences between the sexes. Table 2 lists the adaptive capacity scores of men and women smallholders. The p-value indicates whether there is a significant gender difference in each of the five livelihood capitals[18].

Table 2
Adaptive capacity scores of men and women smallholders

Adaptive capacity	Scope	Mean score		P-value
		Male	Female	
General adaptive capacity	0-20	8,732979	6,709266	0,000***
Economic capital	0-4	0,9390426	1,035872	0,4152
Human capital	0-4	1,804681	1,506697	0,0001**
Natural capital	0-4	1,403085	1,299633	0,0997
Physical capital	0-4	1,77766	1,674404	0,2381
Social capital	0-4	2,808511	1,192661	0,000***

*, **, ***, **** indicates significance at P<0,1; 0.05; 0,01; 0,001 respectively.

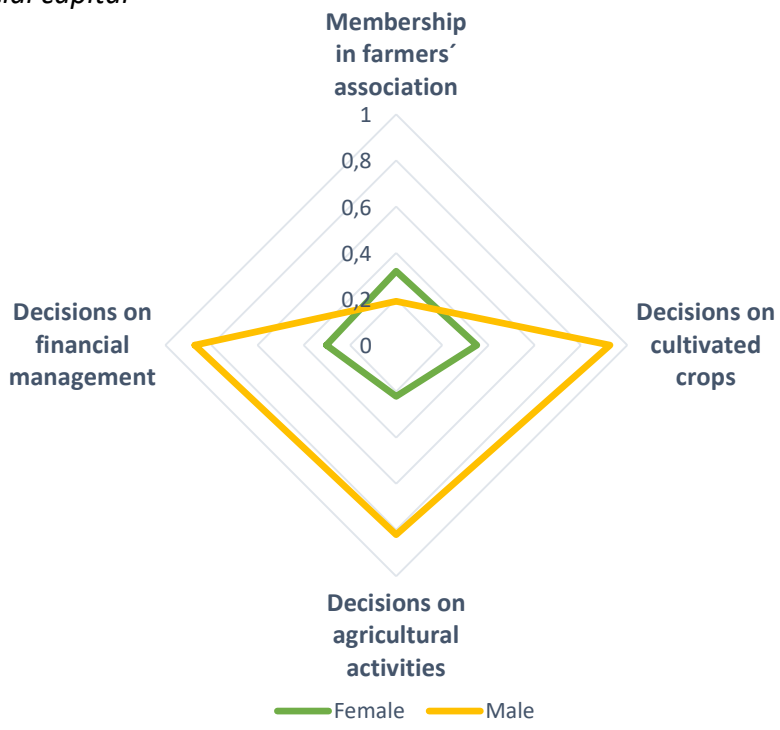
[18] Annex C contains additional t-test tables for each of the capitals and their indicators.

Social capital

Men and women farmers´ adaptive capacity diverges most in the sphere of social capital. The adaptive capacity index detects severely higher decision-making power of men farmers over women farmers. 93% of male participants stated that they decide which crops their household cultivates; whereas only 35% of women did. 82% of men decide for their households on general agricultural activities while 22% of women participants confirmed to make these decisions. Regarding the decisions on financial management, 87% of men manage the household´s finances while 30% of women stated that they decide. Solely in the indicator membership in farmers´ association, women score higher than men. 32% of women farmers belong to association while only 19% of men do.

Figure 13

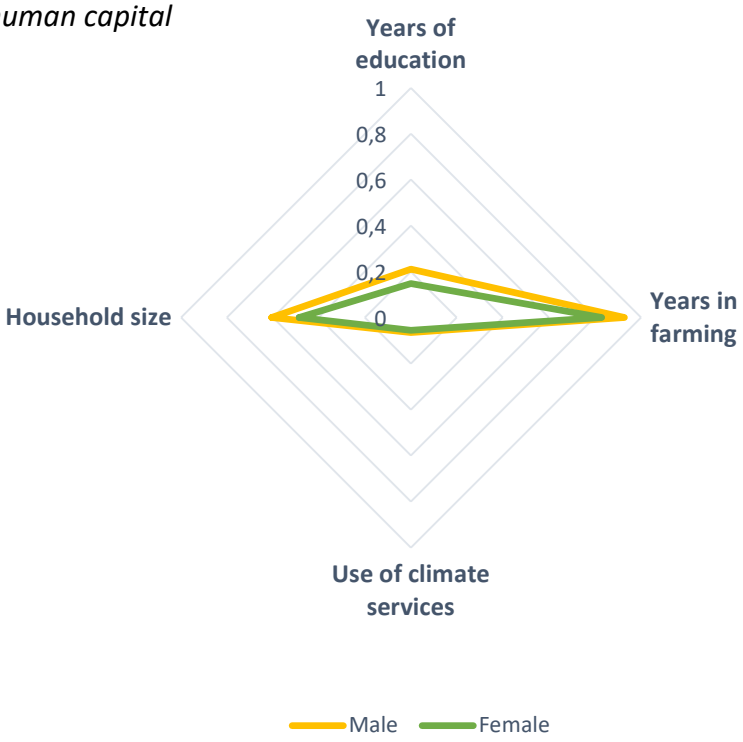
Indicators of social capital



Human capital

Regarding human capital, men farmers score higher overall than women farmers, constituting a slightly significant difference. In particular, men score higher in years of education. As for years of farming experience, men also take a slight lead, although the vast majority of both groups have life-long farming experience. With an average size of 10.1 household members, male-headed households are bigger than women-headed households, that have an average size of 8.3 household members. Finally, no gender difference can be established in the use of climate services. Both groups have very low user rates: Merely 6% of all women and men use climate services.

Figure 14
Indicators of human capital

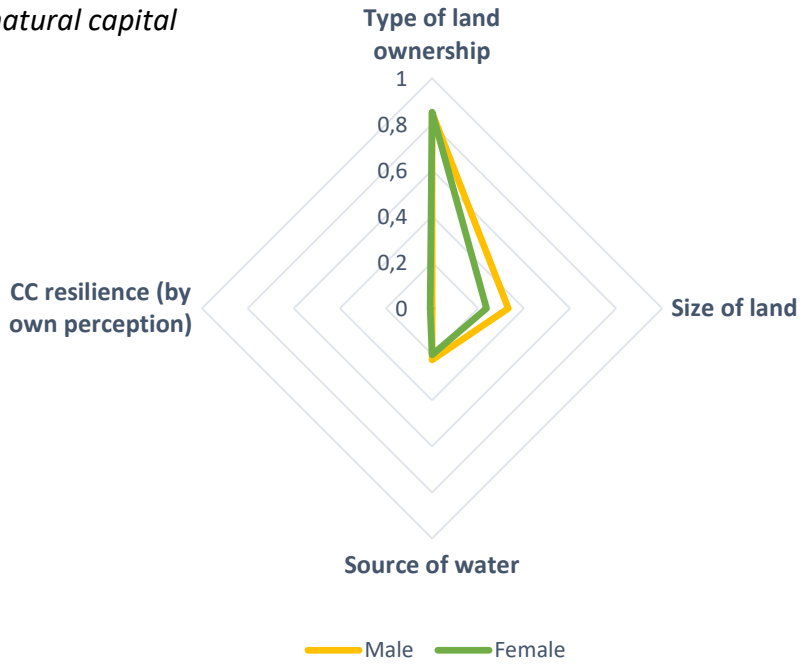


Natural capital

The gender-specific t-test did not find any differences between men and women smallholders regarding the water sources or the smallholders´ perception of climate change resilience. At first sight, there are also no drastic differences observable concerning ownership and land size. Men have slightly bigger plots, but the difference is insignificant. However, this finding is complemented by a statement from a FGD where one woman explained that women farmers have access to community fields, if they asked for it:

> We need to go to the mayor to receive a field. The soil belongs to the community. It is necessary to go see him and present a project to show him what we want to do with the field. Then he can give us a hectare of soil. It is community soil, managed by the mayor. It is him who grants the right to cultivate the fields. (Gender 13|12)

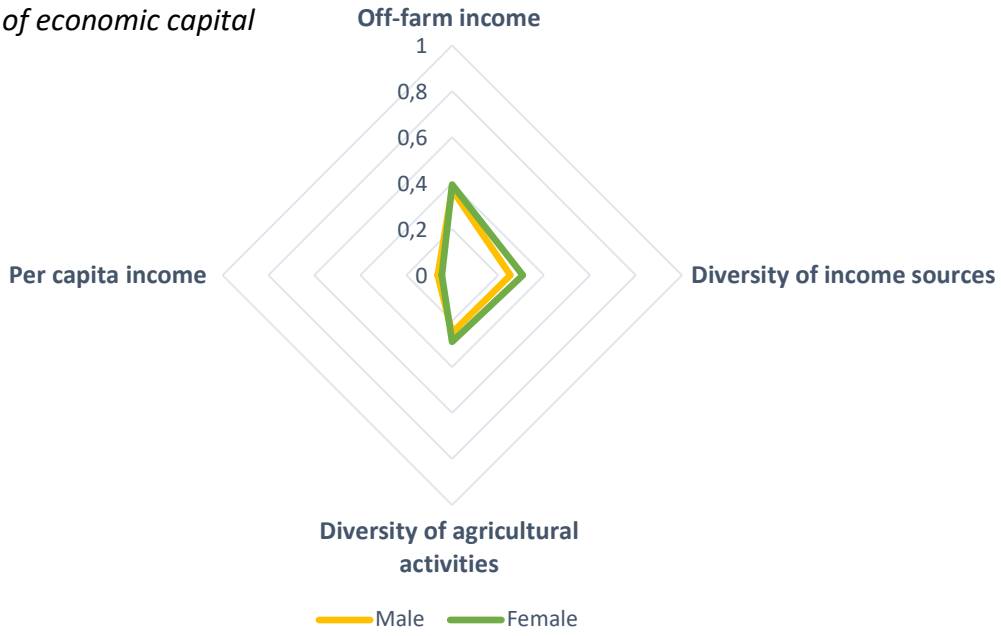
Figure 15
Indicators of natural capital



Economic capital

Women- and men-headed households did not differ in *per capita* income. For participants of both sexes, the income is strikingly low. In the entire sample group, there are only 4 women and 6 men whose income lies above the international poverty line of 1.90 USD or 470 FCFA per day. The average *per capita* income of female-headed households lies at 4,542 FCFA (7.24 USD) per month. Male-headed households have on average 6,117 FCFA (9.75 USD) *per capita* at their monthly disposal. 39% of women and 37% of men farmers have an off-farm income in addition to their agricultural activities. Women farmers take a modest lead regarding the diversity of general income sources and the diversity of agricultural activities.

Figure 16
Indicators of economic capital

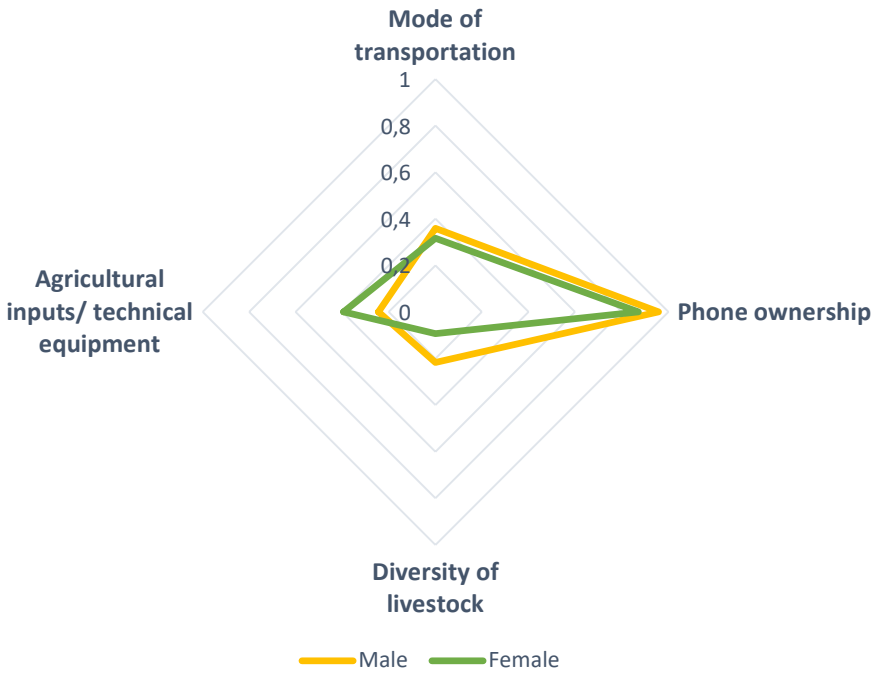


Physical capital

In the context of physical capital, it is worthwhile to note that 76% of men farmers reported that they lack agricultural inputs and equipment; while only 61% of women reported the same. Men however, have a more diversified portfolio of livestock. Meanwhile, men and women farmers have similar access to transportation. Phone ownership is also rather equally distributed: 96% of men own a phone, as do 87% of women.

Figure 17

Indicators of physical capital



While the adaptive capacity index reveals similar assets of men and women smallholders in the spheres of natural, economic and physical capital, it also spots significant differences in human capital and a drastic difference in social capital, particularly highlighting a discrepancy between men´s and women´s decision-making power.

6. Discussion

In the following, I will answer the research questions based on different parts of the mixed methods analysis. I swiftly answer RQ 1 through the analysis of agricultural challenges and perceived climate impacts on agriculture, as derived from the frequency and contingency tables and summarized in Figure 5 and 6. For the discussion of RQ 2 and RQ 3, I draw on the household survey and qualitative content analysis on adaptation strategies, compiled by Figures 7 to 10. Finally, I respond to RQ 4

through the results of the adaptive capacity index and the independent t-test that are portrayed by Figures 12 to 17.

RQ 1: What are smallholders´ local perceptions of climate change and impacts on subsistence agriculture?

It is remarkable that this study´s participants have a high awareness of climate change and its detrimental impacts on agriculture. 98% of participants associate climate change with less yield or more crop failure. Thus, it can be concluded that the rural society in the region of Fatick is aware of climate change. Furthermore, the climate change impacts perceived by the smallholders of this study are in line with analyses and projections by climate scientists. In fact, both record similar threats and challenges for smallholder agriculture in rural Senegal, which can generally be observed in the Sahel. For instance, smallholders list the greatest agricultural challenges, namely the lack of water, lack of fertilizer and infertile soil. In parallel, climate scientists depict climate change in the Sahel as occurring largely through changes in precipitation and temperature (Mbow et al. 2019; Tomalka et al. 2021).

The similarity of smallholders´ perception and climate scientific projections is an encouraging observation because only the shared perception of climate change and its detrimental impacts may lead to climate adaptation (De Longueville et al. 2020; Stöber et al. 2017).

It is now of interest, what type of climate adaptation strategies could be included to respond to the climate impacts on agriculture in Fatick.

RQ 2: What kinds of agricultural adaptation strategies do smallholders employ to respond to climate change?

Linking the practiced adaptation measures of the research participants (see Chapter 5.2.) with the main adaptation concepts that were portrayed in the literature review (see Chapter 2.1.), the adaptation strategies by smallholders in Fatick can be categorized into coping, incremental and transformative adaptation[19]. In the following, I will illustrate which results fall into coping, incremental and transformative adaptation and compare the strategies to the current academic debate. Therefore, each of these sub-sections will begin with the original finding of this study, which will then be embedded into the literature.

[19] Additionally, all measured adaptation measures can be classified as autonomous adaptation. As the rural population receives little institutional support from the state, planned adaptation barely exists. Consequently, smallholders rely on autonomous actions.

Coping

Coping strategies of smallholders in Fatick can be classified as the strategy of petty merchandise (i.e. to buy and resell small amounts of crops for a little surplus) and the reduction of food being cooked. My study categorizes these strategies as coping, because participants named them during FGDs when describing their short or medium response at maintaining basic functions of people and systems (see IPCC 2022). Scholarship discusses coping as a reaction that may sometimes be necessary, but insufficient, in light of more drastic weather and climate changes (Jiri and Mafongya 2020; Noble et al. 2014). They predict that smallholder farmers will increasingly fail to cope effectively. This can be exemplified by the coping strategy to decrease food intake. When smallholder households reduce the amount of food due to drought and insufficient staple crops, this may have drastic implications on their health, with particularly sever effects on women, youth and children (Anugwa et al. 2020, 1078). Hence, scholarship suggests that communities should focus on anticipation rather than on reaction to emergencies. Nevertheless, in a context in which sustaining a livelihood may be a daily challenge, one should bear in mind that this recommendation is easier said than done.

Incremental adaptation

Most smallholders´ activities in the realm of land, soil and crop management fall into the category of incremental adaptation. The participants use these strategies to sustain a long-established system of rainfed crop production. Considering current and future water scarcity in the area, my study argues that land and crop management measures risk being unsuccessful when they are not complemented by a water management system, including water irrigation, water harvesting and water storage.

Model projections from PIK and UNHCR indicate that water saving measures are expected to become more important all over the Sahel after 2050 (Tomalka 2021), resulting in an increase of crop water demands and a necessity of irrigation practices (Elliott et al. 2014). Although land, soil and crop management measures (like composting with minimum tillage or crop rotation) improve soil nutrients and enhance water stress through improved soil water relations (Aggarwal et al. 2018, 10), water occurrence will not suffice to sustain current agricultural practices. Scholarship stresses the potential of enhanced irrigation that can help communities access, economize and convey scarce water resources in the risk of drought (Kuang-Idba et al. 2016). For example, they state that rainwater may be harvested from roof catchments and stored in cisterns or retention basins for dry season (ibid.). Chepkoech et al. (2020a) also state that it is common for smallholders to use wastewater from the kitchen to water vegetables. The current and very basic irrigation type of watering by can may be altered through drip irrigation, overhead or sprinkler, pipe, furrow or gravity irrigation (ibid.).

Transformative adaptation

My study classifies vegetable cultivation outside of the rainy season, market participation, the improvement of infrastructure as well as education and awareness about climate change as transformative adaptation strategies of smallholders in Fatick. As the FGD participants reported, vegetable cultivation was not part of traditional agriculture in the region. In recent years, however, farmers expanded their crop portfolio to vegetables which can also be cultivated outside of the rainy season. Although vegetables represent a relatively small part of the overall agricultural production, they have become an important contributor to food security and a common livelihood activity in smallholder farming (CIAT and BFS/USAID 2016) due to their low land, water and labor costs, compared to cereals (Hoekstra and Mekonnen 2012). However, Fehr and Moseley (2019) found that small-scale commercialization of vegetables is only advisable for farmers with a source of affordable water. Otherwise, they may enter the commercial market without the ability to perform sustainably (ibid.).

My study finds that the main practices of smallholders fall into the category of incremental adaptation through soil, land and crop management. In the context of incremental adaptation, there is almost no water management practiced, especially due to lacking financial means, missing adaptation knowledge and limited access to information (see Figure 11). Coping is practiced as an act of necessity, whenever extreme weather events occur. Transformative adaptation is especially practiced in the realm of vegetable adaptation. Transformative approaches are further desired through measures like market activities, improvement of infrastructure and education. While most of these transformative measures are requested by the smallholders, they are currently not implemented in Fatick, due to lacking resources and missing information on adaptation.

The smallholders´ focus on coping and basic incremental adaptation measures stands in contrast to recent academic advice which emphasizes the necessity to develop more transformative adaptation solutions. While coping and incremental adaptation are necessary for the smallholders to sustain their livelihood, the scholarly perspective calls for more holistic and long-term adaptation to climate change. This holds particularly true in the face of increasing weather variability. In light of the projected increasing water scarcity, it may be worthwhile for smallholders to additionally focus more on off-farm activities. By doing so, they can diversify their livelihood, limiting their dependence on agricultural viability.

While RQ 2 provides an overview of practiced adaptation strategies, it remains yet unclear whether there are gender differences between adaptation approaches. A closer look into the FGD-based results will reveal how adaptation approaches differ between men and women smallholders.

RQ 3: (How) do men and women smallholders´ adaptation approaches differ?

Regarding coping and incremental and transformative adaptation from a gender-specific angle, my study draws on the results of the FGDs to make three main observations:

1. Coping is a joint effort of men and women smallholders, while women carry the additional burden to sustain the household in times of distress;
2. Incremental adaptation is mainly promoted by men smallholders;
3. Ideas and will for transformative adaptation are particularly observed in the group of women smallholders.

In this section, my thesis will discuss each of these observations and contextualize them with voices from literature. I will particularly elaborate on observation 3, as transformative adaptation is of key interest in the current academic debate.

1. Coping is a joint effort of men and women smallholders, while women carry the additional burden to sustain the household in times of distress.

In case of extreme weather or climate events like erratic rainfall, floods or dry spells, men and women smallholders report to act in joint efforts, as family units. In Fatick, it is not only the women who are responsible for coping. Instead, everyone is involved. The activity of petty merchandise, for example, is practiced by men and women equally. However, the analysis of the FGDs also reveal that joint efforts do not cover household chores. This can be illustrated by a statement from one of the women´s discussion groups: “Our fields are family fields. We work together on them. But before meal times, the women cook and the men continue on the field” (Gender 2|17).

My study finds that, in cases of climate-related events, the demand to fulfil care work intensifies women´s work burden and requires them to improvise. Women are the ones who simultaneously keep the household running, feeding their families. Their responsibility increases in extreme situations, as women and men smallholders deem it the women´s duty to provide proper meals for everyone. In extreme situations women are the ones who decide to reduce the quantity of rice and who resort to traditional meals with available ingredients even when there is almost no food available. Hence, due to this gendered division of responsibilities, women smallholders carry the main burden to respond to food shortage. This study´s observation that women bear the additional burden of the household is consistent with other studies which depict women as primary care takers of the household who carry a heavier burden during climatic shocks and stresses in food production (Anugwa et al. 2020; Perez et al. 2015). Diouf´s (2011) study of smallholder women in Senegal confirms this assumption. Various studies go even further than this thesis and find that women may reduce their own food intake, in their obligation to nurture their families (Anugwa et al. 2020; Lewis and Serna 2011). In sum, the analysis of the FGD material reveals that there is a clear distinction between joint responsibility of men

and women for the farm, and exclusive responsibility for women to fulfil the care work in the household.

2. Incremental adaptation is mainly promoted by men smallholders.

Looking at incremental adaptation within the scope of land, soil and crop management, this study finds that men are the driving force behind it. When asked about practiced or desired adaptation pathways, male FGD participants mainly offered incremental technical solutions and referred to improved irrigation systems, fertilizing techniques and hybrid seeds. My findings are therefore in line with previous literature advancing that men favor technical solutions while women are more risk-aware and willing to change their habits (Georgetown Institute for Women, Peace and Security, 2015, 55). Existing literature also finds this phenomenon in other spheres, such as politics or climate science: Women tend to consider the human dimension of climate change more often while men focus on technical and physical aspects of it (Kato-Wallace et al. 2016; Masood 2021). My study confirms such previous results in the specific case of smallholder climate adaptation.

3. Ideas and will for transformative adaptation are particularly observed in the group of women smallholders.

Suggestions for transformative adaptation were predominantly discussed by women smallholders. Participants´ ideas reached from working in communion through women associations over the improvement of infrastructure and market accessibility, to commercialization of processed fruits and vegetables. My study finds that women engage in networks to join labor forces and to be able to bear potential risks together, as female FGD participants explicitly call for women specific fields and emergency funds. The willingness to engage in networks might be explained by the benefits of sharing risks as Perez et al. (2015) have convincingly argued in their extensive study on smallholders´ livelihoods in nine West and East African countries. Perez et al. (2015) also show that women smallholders often grow products in groups on communal land and share the harvest; or establish collective funds to cover school fees or labor force for their farms.

The women smallholders´ willingness to increase market activities, that is detected in my study, is in line with studies from Diouf (2011) and Pouye et al. (2010) who found that women smallholders in rural Senegal diversify their activities by selling vegetables or spices on local markets or in their neighborhoods. Pouye et al. (2010) stress that the revenue of these women flows into the household budget, as women specifically state that they earn money for their husbands and children. While FGD participants did not explicitly mention the revenue flows of such activities, the research of Pouye et al. (2010) suggests that even though women might practice useful transformative ideas, these may not necessarily translate into personal benefits. In fact, while women may promote transformative

strategies for agricultural adaptation, their use may not impact the established gender roles at the household level. The decision-making power over the money earned through new activities will likely remain in the hands of the male heads of the household.

This study furthermore confirms that women consider vegetable cultivation as a way to diversify their livelihood options in the face of climate change. This finding is in line with studies by Anugwa et al. (2020) and Perez et al. (2015), which recognize differences in the livelihood strategies adopted by men and women in the area of on-farm strategies, including home gardening (mostly practiced by women) and growing orchards (mostly practiced by men). I therefore argue that vegetable cultivation can be regarded as a women-specific transformative strategy to adapt to climate change. Furthermore, my study shows that women desire fields for vegetable cultivation that are closer to their houses, while men did not mention this explicitly. Considering Anugwa et al. (2020), this comes as no surprise because women are responsible for food preparation in the household and want to grow vegetables around the homestead for convenience.

Accordingly, I conclude that women´s engagement in farming and saving associations or in vegetable cultivation and processing serve as apt examples of a pragmatic, and simultaneously a transformative adaptation approach. Women smallholders focus on easily implementable agroecological strategies that are both, community and nature based. Reasons for differences in adaptation approaches between men and women smallholders might be found in ecofeminist literature, as will be elaborated in the following.

Reasons for gender differences

My research shows that women are important drivers of transformation in the sphere of farming, providing strategies that reach beyond mere agricultural activities. They tend to understand adaptation in a holistic way, taking into account impacts of climate change and necessary reactions, not just for their land, plants and livestock, but also for their children, households and communities. This does not mean, however, that women are *inherently* better suited to lead transformative adaptation. Rather, women´s upbringing and their social responsibilities offer potential for greater emphasis on social implications of climate change (Nagel and Lies 2022; O'Neill et al. 2010). Early post-developmentalist Ashish Kothari (1988) and ecofeminist scholar Vandana Shiva (1988) have highlighted the female connotation of ecology, making a case for women´s holistic knowledge for conserving land, water and forests. More recent case studies from Senegal, Ghana and Bangladesh, among others, showcase grassroots women´s groups that have developed strategies to respond to challenges regarding energy, forestry, agriculture, water resources and trade (WHO 2014). Empirical research furthermore shows that rural women can pinpoint their needs to secure and sustain their

livelihoods while synchronizing off-farm economic activities with their farm work (Dary and Kuunibe 2012; Mitchell at al. 2007; Paudel Khatiwada et al. 2018).

While men farmers are not entirely absent from transformative adaptation processes, gender roles and socialization restrain male participation at the forefront of transformation and agroecology. Kato-Wallace et al. (2016) argue that masculine and feminine ideals may affect men´s and women´s different perceptions and responses to climate change: While boys and young men grow up to be assertive and unafraid, girls and young women learn to be emotionally caring towards their surroundings. Men who may actively contribute to caring or nurturing activities may therefore appear as weak and effeminate in the eyes of their peers.

The discussion of RQ 3 has highlighted how gender roles and socialization may define the way in which smallholders adapt to climate change. This evokes the question to what extent women and men farmers have the capacity to pursue their adaption approaches.

RQ 4: How do gender differences in women´s and men´s adaptive capacity hinder successful adaptation?

The transformative potential in women´s approaches to climate adaptation is promising. However, the capacity to practice transformative adaptation depends on the agency to forge new paths. The findings of this study´s adaptive capacity index can be discussed in the context of the analytical framework of different types of agencies (see Figure 2).

According to the adaptive capacity index, collective agency to work with other people to achieve change, is more pervasive among women smallholders. During FGDs, it became furthermore obvious that the women participants often referred to themselves as a collective that would approach crop cultivation, processing or selling in joint efforts. In contrast, the adaptive capacity index detects that intrinsic agency to act independently and make free choices and instrumental agency through access and control over the self and resources are not assured with regard to one central aspect: decision-making power.

Men smallholders decide over financial resources as well as about agricultural practices and about the types of crops to cultivate. Consequently, women´s transformative approaches to climate adaptation are blocked due to their lack of decision-making power, be it about agricultural practices, type of food consumed or spendings. My study thereby confirms findings from the existing literature. For instance, Kato-Wallace et al. (2016) explain that while rural women play a major role in agriculture, they often have little power to cultivate crops that are more resilient to climate change. The OECD likewise affirms women´s limited decision-making power about agriculture and adaptation strategies and details that women often lack agency to negotiate new tools or technologies to secure livelihood (McOmber 2020, 14). One explanation for this imbalance is offered by Nagel and Lies (2022). Observing

that the main responsibility to respond to climate change is adjudged to men, they explain that men favor technical solutions that are coded as masculine. As my study likewise finds that men favor technical solutions, it may be assumed that women´s suggestions are not considered in decision-making processes due to their less technical and thus less appreciated characteristics. Therefore, my study has showcased the pervasiveness of traditional gender roles in the region under study which might further substantiate the suspicion that "traditionally" female or male coded activities continue to be connected with women and men farmers.

Merging transformation efforts

Both, in the field of climate adaptation and gender and agriculture, scholars call for transformation, as piecemeal changes of current systems are insufficient to tackle the immense challenges of climate change. The overlap between transformative gender and transformative ecological climate adaptation can be used as encouragement to join efforts in a common struggle. Kothari detects that "[f]emininity and ecology […] are natural allies, mutually synergizing and often found in practice to be synonymous" (in Shiva 1988). In fact, research confirms that changes in the control over resources and inputs between men and women farmers lead to more holistic considerations of food and nutrition security (Meinzen-Dick et al. 2012). Jerneck (2018) portrays a best-case scenario in which adaptation would tackle inequality, food-insecurity and ill-health simultaneously and synergetically, while understanding gender as one defining factor in the context of smallholder agriculture. In order to unlock this transformative potential, it is worthwhile to focus policy and practice efforts on women´s decision-making power and men´s acceptance of femininely coded adaptation pathways.

7. Conclusion

This thesis has examined climate impacts and climate adaptation in the context of smallholder farming in the region Fatick in the West of Senegal. It has observed smallholders´ perception of climate change and impacts on agriculture as well as their strategies to adapt to climate change. Furthermore, it has investigated possibly diverging adaptation strategies of men and women farmers and tested for gender-differences in smallholders´ adaptive capacity. My study shows that smallholders in Fatick are very much aware of the changing climate and changing conditions for agriculture. This is an encouraging observation as the awareness for climate change is a necessary condition to anticipate impacts and to adapt to them. However, while adaptation efforts exist in Fatick, successful adaptation is limited due to a lack of financial means, missing adaptation knowledge and limited access to climate services and information. Regarding the gender-sensitive analysis of adaptation strategies, the study reveals that men smallholders favor technical solutions while women predominantly suggest nature- or community-based strategies that can be categorized as transformative climate adaptation.

Considering the promotion of transformative adaptation in current academic debate, the transformative pathways proposed by women smallholders are favorable. Yet, the comparison of men´s and women´s adaptive capacity reveals that the transformative potential in Fatick fails to be realized due to women´s limited decision-making power in households.

Limitations

There are several limitations to the approach of this study. First, it must be noted that the adaptive capacity index was specifically designed to draw a comparison between men and women smallholders. Thus, it does not aim at evaluating the absolute adaptive capacity of smallholders in Fatick and cannot express in which capital smallholders achieve the highest scores. To examine differences between capital assets, scholarship suggests to let regional or local experts weigh the indicators in order to reach a representative picture of adaptive capacity in the respective region (see Abdul-Razak and Kruse 2017; Defiesta and Rapera 2014). One the one hand, this was not done due to time constraints. On the other hand, my thesis examines the differences of assets between men and women. Against this backdrop, the design of the index serves its purpose. Secondly, and relating to the latter point of limitation, it is noteworthy that equal adaptive capacity between genders does not mean that the general adaptive capacity is high. The equal use of climate services illustrates this well: While men and women smallholders score equally in these indicators, their general average lies at 5-6%; hence, it is very low.

Thirdly, acknowledging Doss and Kieran´s (2014) suggestion that gender analyses require data from women and men alike, it can be argued that the format of FGD2 on gender-specific climate impacts and adaptation should have been performed with men smallholders, too. Based on the qualitative data of the study, I can specifically attribute strong potential for transformative climate adaptation to women, without being able to compare it under the exact same circumstances to the transformative potential of men smallholders. Nevertheless, I consider the findings valid as they illustrate women´s holistic understanding of livelihood and climate adaptation, notwithstanding men´s climate adaptation strategies. Furthermore, thanks to the mixed methods approach, different types of data were triangulated in order to examine climate adaptation from various angles. Thus, the overall findings aspire to reflect a balanced picture of climate impacts and adaptation of smallholders in Fatick.

Lastly, it can be criticized that the study did not take into account the heterogeneity within the groups of women and men smallholders. Aspects like age, health, ethnicity or financial status, among other things, are factors that argue strongly against a one-dimensional examination of inequalities. Intersectionality, thus the understanding of multiple factors determining either privilege or marginalization and discrimination (Crenshaw 1989), is a crucial concept for the investigation of gender-related (in)equalities. While this was considered during the design of the data collection and analysis, it was decided to limit the study to the comparison between genders because a further

disaggregation of the data would have imperiled the representativeness of each subgroup if smaller groups based on further intersectional qualities would have been considered. Therefore, further studies could examine how multiple, overlapping factors of inequalities might result in different levels of adaptive capacity among smallholders.

Outlook

While awareness on climate change and the necessity to adapt to its effects has arrived at the center of society in Fatick, Senegal, more may be done to promote agroecological transformative solutions. Currently, decision-making power is lacking, especially for women, who are closely affiliated with the agroecological transformative paradigm. At the same time, the discourse community of gender in agriculture calls for gender transformative approaches, aiming at social change of gender roles in agriculture. Consequently, I argue to merge transformative climate adaptation and transformative gender approaches to drive climate action and gender justice alike. This can be achieved by focusing on participatory development in climate adaptation, community strengthening and the questioning of gender roles. Through this, women smallholders could gain more leeway to participate in decisions that concern agriculture and finances. For the overall adaptation process of smallholder farmers, this would be a promising path, as smallholder women have shown that they have the ideas to drive change towards transformative adaptation that would be beneficial for the entire households. These measures would not only contribute to sustainable rural development but also to sustainable livelihoods for all members of smallholders´ households and communities. Eventually, they may even unleash transformative power, in both gender and agriculture.

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Annex A
Data collection

1. Focus Group Discussion 1: Climate change perception and adaptation. Guideline.
2. Focus Group Discussion 1: Climate change perception and adaptation. Record of results.
3. Focus Group Discussion 2: Gender, climate change and adaptation. Guideline.
4. Focus Group Discussion 2: Gender, climate change and adaptation. Record of results.
5. Questionnaire for the NUTRiGREEN farmer household survey.
6. Information Sheet.
7. Consent Forms.

Note: The data collection material as well as the study information sheet and consent form were created in English and translated to French afterwards. The annex contains the English version of the data collection material.

Annex A: Data collection

A.1. Focus Group Discussion 1
Climate change perception and adaptation
Guideline

Goal: Exploring the perception of climate change, impact on crop cultivation and adaptation strategies through the perspective of smallholder farmers.

Group size: 5 smallholder farmers of same sex.

Before getting started
• Upon arrival of participants, there will be a possibility for everybody to sit, chat and have a cold drink before we get started. • Welcoming and introduction of myself and facilitator. • Introduction of project, research topic and relevance for the farmers. • Explanation of the purpose of group discussion (i.e. to ask farmers groups as local experts). • Explanation of the role of the facilitator and myself. • Assure the participants that their responses will be used for the purpose of research and analysis only and information will remain confidential/ anonymous and will not be shared with anyone other than the researchers of the study. • Ensure that all participants understand the process in which they are to be engaged and request for their voluntary consent. Collect informed consent form with thumb print. • Urge participants to refer to own experiences and invite them to actively participate.

Main question	**Sub questions**	**Tool**	**Record of results**
1.Can you introduce yourself? (15”)	What is your name? How old are you? What is your main occupation? When did you start farming?	**Pass a ball around in a circle.**	Group profile
2. What plants do you grow most? (30”)	Do you cultivate the same plants like when you started farming?	**Work with picture cards of plants to arrange three piles**: 1. Plants that used to be cultivated in the past, 2. Plants that are cultivated now, 3. Plants that are not cultivated at all. Continue with the picture cards of plants that are cultivated now and do a **vote count** how many farmers grow each plant.	Matrix of plant sensitivity
	If you changed the cultivation, why did you do it?	**Open question**: Ask why they changed cultivation.	

	Do you cultivate more or less different crops than in the past?	**Vote count**: Who cultivates more than in the beginning? Who cultivates less than in the beginning? **Open question:** Why?	
3. How is each plant affected by changing weather and climate? (20”)	What happens if plant x is exposed to too much rain? What happens if plant x does not get enough water?	**Plant sensitivity ranking:** Under the two scenarios too much rain and not enough rain, farmers will be asked to reflect the effects on various plants, estimating if the effects are higher/ lower yield, more or less crop failure, and more/ less pests and diseases under the two scenarios too much rain and not enough water.	Matrix of plant sensitivity
4. Which plants are the most resilient to weather changes? (15”)		**Vote:** Each farmer gets three seeds and can pose them on the picture of the plants that they find most resilient.	Matrix of plant sensitivity
Break with little snack and/ or energizing game			
5. What are the climate change adaptation measures of smallholder farmers? (30”)	What are the adaptation measures that you use the most?	**Present picture cards** and farmers who use the method stand up.	Matrix of adaptation measures
	What are their benefits?	**Open question:** From the ones who are standing up, one will be asked what the benefits of the adaptation strategy are.	
	Which practices do you not use but would like to use? What would you need for it to work?	**Pass a ball around in a circle:** Ask each farmer to pick one measure and explain why they don`t use it and what they would need to make it work.	
6. Do you practice other methods that are not on the pictures? (20”)	What are their benefits?	**Brainstorming**: In the plenary, additional adaptation measures will be collected that have not been on the list.	Matrix of adaptation measures

	Can you use any more support for them?	**Follow-up question** to each named adaptation measure.	

A.2. Focus group discussion 1
Climate change perception and adaptation
Record of results

1. **Group Profile**

FGD Number:_____ Location:_____ Date:_____ Male/ Female group:_____

No.	Name	Age	Main occupation	Years in farming
				…

Matrix of plant sensitivity

Plant (incl. number of farmers who name it)	Plant of today or of the past?	If not longer cultivated, explanation why	Reaction to too much rain (yield, crop failure, pest/ diseases)	Reaction to too much drought? (yield, crop failure, pest/ diseases)	Most resilient to weather change (incl. explanation why)
					…
Plant (incl. number of farmers who name it)	**Plant of today or of the past?**	**If not longer cultivated, explanation why**	**Reaction to too much rain (yield, crop failure, pest/ diseases)**	**Reaction to too much drought? (yield, crop failure, pest/ diseases)**	**Most resilient to weather change (incl. explanation why)**
					…
More or less crop diversity than in the beginning? Why?					

2. Matrix of adaptation measures

Adaptation measure	**Number of farmers using strategy**	**Benefits of strategy**	**Number of those interested in usage**	**Reasons not to use strategy**	**Resources necessary to use strategy**
					…
Adaptation measure	**Number of farmers using strategy**	**Benefits of strategy**	**Number of those interested in usage**	**Reasons not to use strategy**	**Resources necessary to use strategy**
					…

A.3. Focus Group Discussion 2
Gender, climate change and adaptation
Guideline

Goal: Examination of gender-related impacts of climate change and adaptation within the realm of agricultural production.

Group size: 8-12 smallholder women farmers.

Before getting started
• Upon arrival of participants, there will be a possibility for everybody to sit, chat and have a cold drink before we get started. • Welcoming and introduction of myself and facilitator. • Introduction of project, research topic and relevance for the farmers. Include a short presentation of preliminary findings of FGD 1. • Explanation of the purpose of group discussion (i.e. to ask farmers groups as local experts). • Explanation of the role of the facilitator and myself. • Assure the participants that their responses will be used for the purpose of research and analysis only and information will remain confidential/ anonymous and will not be shared with anyone other than the researchers of the study. • Ensure that all participants understand the process in which they are to be engaged and request for their voluntary consent. Collect informed consent form with thumb print. • Urge participants to refer to own experiences and invite them to actively participate.

Annex A: Data collection

Main question	Sub questions	Tool	Record of results
1.Can you introduce yourself? (10”)	What is your name? What is your favorite fruit or vegetable?	**Pass a ball around in a circle.**	Group profile (demographics will already be found out during participant selection)
2. Who is responsible for what type of work? (20”)	In the household? In land preparation? In cultivation/ maintenance? In harvest/ post-harvest?	**Activity profile**: The plenary is asked who performs particular tasks: men, women or both. If both, it is asked who spends more time with the task.	Activity profile matrix
3. Who has access to and who decides over activities and resources? (25”)	Over land and productive resources? Over productive activities? Over finance?	**Access and control profile**: The plenary is asked who has a. access and b. control: men, women, or both. If both, it is asked if one gender has more access/ control	Access and control profile matrix
4. Who has access to weather and climate information and training? (15”)	Do you follow a weather forecast?	Participants who answer with yes **stand up**.	Access to Weather and Climate Services Matrix
	How do you get the information (radio, TV, household, community, other)?	**Follow-up question** is posed to the participants standing up.	
	Have you already participated in agricultural trainings?	Participants who answer yes **stand up**.	
	Did you have the opportunity if you wanted to? Did other members of your household participate?	**Follow-up questions** are posed to those remaining seated.	
Break with little snack and/ or energizing game			
5. How have you coped with an extreme weather event of the past? (25”)	How did you hear about the extreme weather event? Who was the first to know and how is the message distributed? What problems did you face?	**Open question**: Ask group to tell about an extreme weather event from the past that they all remember. Guide them with sub-questions. Collect information from their shared experience.	Extreme weather report matrix

	What kind of help was available? What happened to men during the event? To women? To boys? To girls? Who was impacted the hardest? What happened to the harvest? Who was responsible for getting food? How?		
6. In the face of climate change, is there anything you need for your agricultural practice or the wellbeing of you and your family? (25")		**Role play:** Participants are asked to imagine: You are the minister of agriculture and climate and you visit this village. What can you promise the women farmers to improve their work? Take 5 minutes and give a short statement.	Role play record

A.4. Focus group discussion 2
Gender, climate change and adaptation
Record of results

1. Group profile

FGD Number:_____ Location:_____ Date:_____

No.	Name	Age	Main occupation	Years in farming	Mode of transportation	Education	Marital status	Number of household members [adults, children, elderly (<64)]
								...

2. Activity profile matrix

Activities	Who does the work?	
	Men	**Women**
Reproductive activities		
Household tasks		
Cleaning		
Fetching fuelwood		
Fetching water		
Storing fuelwood		
Storing water		
Preparing food		
Taking care of children		
Washing clothes		
Productive activities		
Land preparation		
Land clearance		
Ploughing		
Constructing stone bunds		
Constructing wind breakers		
Preparing furrow farming		
Cultivation and maintenance		
Seed selection		
Weeding		
Daily maintenance		
Composting		
Mulching		
Watering		
Applying fertilizers/ pesticides		
Harvest/ post-harvest		
Harvesting		
Threshing		
Storage		
Processing		

3. Access and control matrix

Resources	**Access**		**Control**		**In case there is no access or control for women, can women still participate in some way? How?**
	Women	**Men**	**Women**	**Men**	
Land					
Agricultural equpiment					
Employers					
Fertilizer					
Seeds					
Water					
Fuel wood					
Income					
Savings					
Credit					
Agricultural Training					

4. Weather and climate services matrix

Do you follow a weather forecast?	Yes: _____ No: _____
How do you receive the weather forecast?	Radio: _____ Mobile Telephone: _____ Newspaper: _____ TV: _____ Smartphone: _____ Community: _____ Other household member: _____ Other: _____

Have you participated in a climate training?	Yes: _____ No: _____
Did you have the opportunity to participate at a training if you wanted to?	Yes: _____ No: _____
Did other members of you household participate? Who?	
Remarks	

A.5. Questionnaire for the NUTRiGREEN farmer household survey

Questionnaire reference number : **Name of investigator :** **DATE:_____/_____/__2022** **Start time_____ End time_____**
INTRODUCTION OF THE RESEARCHER Hello, my name is _____. I am a student at Université Cheikh Anta Diop de Dakar (*UCAD*) and we are working with a group of researchers from Humboldt University in Berlin, Germany. We are currently working on a research project on traditional plants in West Africa, with the aim of understanding what farmers in Fatick grow in their gardens or fields, how they do it, what their challenges are, what products they sell (and where) and what food they buy. The information we receive from you helps us to get an idea of the situation and the needs of the farmers in Fatick. Information will be shared with the university, NGOs and the political level. The results will also be shared with you. We hope that you and other residents of Fatick will benefit from the information gathered.

The interview will be anonymous, and we guarantee confidentiality. Of course, your cooperation is voluntary.

DATA CONSENT FORM for the household survey

My name is _____.

I live in Fatick, Senegal, and I agree to participate in this household survey conducted by the NUTRiGREEN project.
I agree that the information I provide can be shared with the university, NGOs and the political level. My cooperation and information is voluntary.

Name and date :

No	**A Socio-economic issue**	**Answers**
1	**Sex** (m/f) :	
2	**Age:**	
3	**Are you a full-time or part-time farmer?** ❍ Full-time ❍ Part-time	
4	**What other paid job(s) do you have?**	
5	**What is your level of education?** 1= no formal education 2= Primary school 3= partial primary school 5= secondary school 6= Diploma/certificate 7= University 8= Adult education 9= Other (indicate) - studied in Arabic	
6	**Which of the following statements best describes your level of literacy?** 1= Can't read or write 2= I can read and write to some extent 3= I can read and write	
7	**Total number of household members :**	
8	**What is your marital status?** 1= Single 2= married 3=divorced 4= widowed 5= does not want to answer 90= other (indicate)	

9	**What are the main sources of income for your household?**	
10	**Which member of the household is responsible for managing income sources?** 1= Head of household 2= collectively	
11	**Approximately how much income do you generate per month in your household? Suggest a range of values.** 1. 0 - 25.000 2. 25.000 - 50.000 3. 50.000 - 75.000 4. 75.000 - 100.000 5. 100.000 <	
12	**Do your farming activities contribute to your household income?** (1=yes 2=no)	
13	**Which means of transport do you use?** (several answers possible) 1= private car 2= motorbike 3= bicycle 4= donkey(s) 5= horse 6= tractor 7= no transport 90= other (indicate)	
13 b	**Are you the owner?** 1= private car 2= motorbike 3= bicycle 4= donkey(s) 5= horse 6= tractor 7= no transport 90= other (indicate)	
B Agricultural activities		
14	**In your household, who is the main decision-maker in agricultural decisions?**	
15	**How long have you been a farmer?** In years	
16	**What is the size of your plot(s)** in hectares	
17	**Do you own the land you farm?** 1= owned by me/my spouse 2= owned by a family member 3= owned by a group of farmers/collective 4= communal property by the village	

18 a	**What speculations do you produce?** 1= only field crops 2= Livestock only - grazing 3= a mixture of crops and livestock 4= vegetables 5= Fruit 6= poultry 7= Peach 8= Beekeeping	
18 b	**What type of animals do you keep?** 1= cow(s) 2= goat(s) 3= sheep(s) 4= chicken 5= guinea fowl 6= quail 7= pigs 8= donkeys, mules, horses 9= no animals 90= other	
19 A B C D	**Indicate all the crops you grow** - multiple answers possible **Cereals** 1= sorghum 2= millet 3= maize 4= rice5= fonio 90= other, please specify **Cash crops** 1= cotton ❍ 2= groundnut ❍ 3= Cashew nuts ❍ 4= cowpea ❍ 5= sesame ❍ 6= tea ❍ 7= coffee ❍ 8= sugar cane ❍ 9= rubber ❍ 90= other, please specify **Root and tuber** 1= cassava ❍ 2= sweet potato ❍ 3= potato ❍ 4= yam ❍ 5= taro ❍ 90= other, please specify **Vegetables**	

E	1= Spinach ❍ 2= Kale ❍ 3= Cabbage ❍ 4= green beans ❍ 5= tomatoes ❍ 6= pepper ❍ 7= cucumber ❍ 8= onions ❍ 9= aubergine (black) ❍ 10= Local aubergine - Diakhatou ❍ 11= pumpkin ❍ 12= Bambara groundnut ❍ 13= okra ❍ 14= White caya *(Cleome gynandra L.)* ❍ 15= Jute pith (*Corchorus olitorius)* ❍ 16= amaranth ❍ 90= other, please specify	
F	**Fruit** 1= mango ❍ 2= honeydew melon ❍ 3= watermelon ❍ 4= Cream apple (*Annona squamosa L.)* ❍ 5= guava ❍ 6= hibiscus ❍ 7= tamarind ❍ 8= papaya ❍ 9= lawyer ❍ 10 = lemon ❍ 11 = orange (Tangelo**)** ❍ 12= Jujube *(Ziziphus mauritiana)* ❍ 90= other, please specify **Trees** 1= oil palm ❍ 2= shea ❍ 3= moringa ❍ 4= baobab ❍ 5= Kaga *(Detarium microcarpum)* ❍ 6= Zamnin (Acacia macrostachya) 7= doussié(Afzelia africana Smith**)** 8= Desert date palm -sump *(Balanites aegyptiaca*) 9= False kapok tree (*Bombax costatum*) 10= cassia tora (*Senna tora)* 11= Wild capricorn (Capparis sepiaria Linn.) 12= Holy garlic pear (*Crataeva adansonii*) 13= olom (Diospyros mespiliformis) 14= Grape tree *(Lannea microcarpa*) 15= Pearl tree (Maerua angolensis)	

	16= cowpea / African locust bean (*Parkia biglobosa*) 17= Camel foot/ Ngui guis (Piliostigma reticulatum) 18= maad/Made *(Saba senegalensis)* 19= marula (*Sclerocarya birrea)* 20= Monkey oranges (Strychnos innocua) *21=* busumba amata/ tarhat / (*Leptadenia hastata)* 90= other, please specify	
20	**Who decides what crops to produce in the household?** 1= me 2= my husband 3= my wife 4= child(ren) 5= all members 90= other (specify)	
21	**How do you decide what to plant next?** 1= I always plant the same thing 2= according to the seeds I have 3= according to the season 4= according to market demand 5= according to my production plan 6= according to my buyer's production plan 7= according to the crop rotation plan 8= based on the recommendation of the extension officer 9= as decided by the cooperative 10= depending on current drought/available water/forecasted weather 90= other (indicate)	
22	**Where do you get the seeds?** 1= clean 2= family, friends, neighbours 3= cooperative 3= Commercial seed supplier 5 = company (contract farming)	
23 a	**Do you save seeds?** (1=yes 2=no)	
23 b	**If yes, for which crop(s) do you save seed?**	
24	**Do you treat the seeds?** (1=yes 2=no)	
24 b	If yes, from which culture(s)? 1= coating seeds 2= Soak the seeds before planting	
25	**What is your main source of water? Please indicate whether it is for supply or agriculture?** 1= rainwater	

	2= rainwater collected in one or more tanks 3= river 4= dam 5= drilling/wells 6= tap water / government water 90= Other (please specify)	
26	**How do you prepare your soil before planting?** several answers possible 1= manual plough 2= Plough with machine/animal 3= apply compost 4= Apply chemical fertilizer 5= I weed	
27	**Do you practice any of the following?** 1= zai 2= half moons 3= terraces 4= cover crops 5= mulching, e.g. with *Acacia tumida* or millet) 6= Crop rotation 7= Natural pest control practices ...neem oil 8= natural fertilizer	
27 b	**If you use compost, where does it come from**? 1= I do it myself 2= neighbours 3= an NGO/women's group 4= I buy it 5= "latrine" compost (...) 90= other	
28	**What are your biggest agricultural challenges?**	
29	**How much of the food you eat do you grow?** 0-25% □ 25-50% □ 50-75% □ 75-100% □	
30	**Are you part of a farmers' organisation/cooperative?** (1=yes 2=no)	
30 b	**If yes, what are the main advantages of being part of a farmers' organisation?** 1= access to seeds 2= access to fertiliser 3= access to credit 4= I receive training 5= access to land for planting 6= Access to tools and machinery 5= marketing support (transport and sales) 6= collective production activities 90= other	

31	Do you buy **inputs** (e.g. seeds, compost, fertiliser, tools, etc.)? (1=yes 2=no) If yes: where?	
32	**Do you receive free inputs** (e.g. seeds, compost, fertiliser, tools, etc.)?	
32 b	**If so, what (e.g. seeds, compost, fertiliser, tools etc.) do you receive?** **and from whom :**	
C Traditional plants		
33	**What traditional plants do you use?**	
34	How would you rate the following statements? Categories : (--): strongly disagree (-) (-): disagreement (0) Neither Agree nor Disagree (+) (+): agreed (++): strongly agree ( ) cannot answer	

a		not at all in agreement				strongly agreed	
		- - -	-	0	+		
	1. Traditional plants are an essential ingredient in a meal	❍	❍	❍	❍	❍	□
	2. Traditional plants are food for the poor	❍	❍	❍	❍	❍	□
	3. Traditional plants are easy to buy	❍	❍	❍	❍	❍	□
	4. Traditional plants are easy to sell	❍	❍	❍	❍	❍	□
	5. I use traditional plants for medicinal purposes	❍	❍	❍	❍	❍	□

D Processing and retailing		
35	**Do you process your crops?** (1=yes, 2=no)	
35 b	**If yes, what treatment do you perform**? 1= crop cleaning 2= Sorting the crops 3= Solar crop drying 4= Crop conditioning 5= kitchen 6= ferment 7= grinding 8= Fruit juice	
36	**Do you have problems selling your crops? (excluding livestock)** CHOOSE ALL THAT APPLY 1= no local markets/clients 2= limited transport/no transport available	

	3= low prices 4= I don't have enough products - I could sell more 5= I have no problem selling	
37	**To whom do you sell your crops/products**? 1= I sell at the market, indicate which one 2= intermediate 3= via the cooperative 4= over the fence 5= at the local shop 6= in the village/neighbours 7= to an NGO, if so which one : 8= I do digital marketing (facebook, whatsapp....) 90= other (indicate)	
37 c	**How are your products transported to market?** 1. use of the bicycle 2. motorcycle 3. walking 4. donkey cart 5. horse-drawn cart 6. car 90. Others.....	
38	**How much do you earn per week from your farming activities?** 0 = nothing 1=up to 5,000 CFA 2= 5,000 - 9,999 CFA 3= 10.000 - 19.999 CFA 4= 20.000 - 29.999 CFA 5= 30.000 - 39.999 CFA 6=40,000 -49,999 CFA 7= more than 50.000 CFA	
E Perception of climate change		
39	Do you think the weather/climate has changed since you lived in this area? a. Yes ____ b. No ____ c. I don't know...	
40	**What are the main effects of climate change in your region?** 1=Temperature increases 2=Temperature decreases 3= No more flooded fields 4= More drought 5= Start of rain then dry period 6= More rain in total per year 7= Less rain in total in 8= Too much rain during harvest 9= The dry season is getting longer	

	10= Dry season becomes shorter 11= The rainy season is getting longer 12= The rainy season is getting shorter 13= More irregular rainfall 14= heavier rain 15= More freezing rain (hail) 16= More rainy days 17= Fewer rainy days 18= No change 19= Other, please specify__.	
41	**How does climate change affect your agriculture?** several answers possible 1= Lower yields 2= Higher yields 3= No more crop failure 4= Less crop failure 5= No more parasites 6= more diseases 7= No effect 90= other please specify	

42 **Climate perception**

I will read you some simple statements. Answer the questions on a scale from totally agree to totally disagree. Try to think about the changes you have seen since you became a farmer in your village.

Categories :
(--): strongly disagree
(-) (-): disagreement
(0) Neither Agree nor Disagree
(+) (+): agreed
(++): strongly agree
( ) cannot answer

Questionnaire Since you are a farmer in this village:	not at all in agreement - - -	 - -	 0	 +	strongly agreed	cannot answ
1. The daytime temperature has increased.	❍	❍	❍	❍	❍	□
2. The night-time temperature has risen.	❍	❍	❍	❍	❍	□
3. The amount of rainfall during the rainy seasons has increased.	❍	❍	❍	❍	❍	□
4. Extremely heavy rainfall/flooding occurs more frequently.	❍	❍	❍	❍	❍	□
5. Extremely dry periods are more frequent.	❍	❍	❍	❍	❍	□
6. The number of days per year when we had dust storms increased.	❍	❍	❍	❍	❍	□
7. The number of extremely hot days per year has increased.	❍	❍	❍	❍	❍	□

	8. Harmattan winds (dry winds from October to March) have increased in intensity. ❍ ❍ ❍ ❍ ❍ □	
43	**How are you adapting your agriculture to these climate changes? "I....** 1= ...use better seeds (e.g. drought resistant seeds) 2= ...use climate services (weather forecasts) 3= .... install drip irrigation 4= ...I moved my fields to another site 5= ...use more compost and manure to increase organic matter 6= ...use windbreakers 7= ...building stone dams 8= ...practice crop rotation 9= ...use cover crops 10= ...start with water management (harvesting and storage), if yes: which one_____ 11= ...minimum tillage 12=... mulching 13=... cultivation on raised beds 14=... agroforestry and tree planting 15= ...agriculture in furrows 16= ...more water (by hand) 17= ...abandon agriculture 18 ...more livestock 19= ...reduced number of livestock 20= ... doing non-agricultural work 21= ...join farmers' groups/associations 22=...use more chemical fertilizers 23=---- use more herbicides 24= ... use more pesticides/insecticides 90= ... other, please specify_____	
44	**What are the main constraints/difficulties that prevent you from changing your farming methods?** 1= lack of knowledge of alternative methods 2= lack of access to information 3= lack of money and financial capital 4= lack of natural resources, e.g. a water source 5= lack of leadership and organisation 6= lack of time 7= lack of safe access to land 8= lack of fertile land 9= lack of available labour 10= lack of access to tools and technology 90= other, please specify	https://springerplus.springeropen.com/track/pdf/10.1186/s40064-016-2433-9.pdf
F Consumption pattern		
45	**In your household, who is the main decision-maker regarding consumption (choice of meals)?**	
46	**Where do you buy the food you do not produce yourself?**	

	1= neighbours 2= Local shop 3= local market 4= supermarket 90= other, please specify :	
47	**What food products do you buy?** 1= basic products (bread, pasta, rice, porridge...) 2= vegetables 3= fruit 4= meat, fish, chicken, beans, nuts 5= Dairy products (milk, yoghurt, cheese) 6= Oils, fats, sweets and candies	
48	**What are the most important considerations (mi) when buying food? Top 3** That the product is : 1= healthy ❍ 2= cheap ❍ 3= local ❍ 4= fresh ❍ 5= I know where it comes from ❍ 6= traditional ❍ 7= Tasty ❍	
49	**How much do you usually spend on food per week?** 0= nothing 1= up to 3,300 CFA 2= 3,300 - 6,600 CFA 3= 6,600 - 13,100 CFA 4= 13.100 - 20.000 CFA 5= more than 20.000 CFA	
G Household Food Insecurity Experience Scale (FIES)		
50	**Have you or other members of your household been worried about not having enough food due to lack of money or other resources?** 1= Yes 2= No 3= I don't know 4= I don't want to answer	
51	**Thinking about the last 12 MONTHS, were there times when you or other members of your household were unable to eat healthy, nutritious food due to lack of money or other resources?** 1= Yes	

	2= No 3= I don't know 4= I don't want to answer	
52	**Have you or other members of your household eaten a poor variety of food due to lack of money or other resources?** 1= Yes 2= No 3= I don't know 4= I don't want to answer	
53	**Have you or other members of your household had to skip a meal because you did not have enough money or other resources to buy food?** 1= Yes 2= No 3= I don't know 4= I don't want to answer	
54	**Thinking about the last 12 MONTHS, were there times when you or other members of your household ate less than you thought you should because of a lack of money or other resources?** 1= Yes 2= No 3= I don't know 4= I don't want to answer	
55	**Did your household run out of food because there was not enough money or other resources?** 1= Yes 2= No 3= I don't know 4= I don't want to answer	
56	**Were you or other members of your household hungry but did not eat because there was not enough money or other resources to buy food?** 1= Yes 2= No 3= I don't know 4= I don't want to answer	
57	**Have you or other members of your household gone a whole day without food due to lack of money or other resources?** 1= Yes 2= No 3= I don't know 4= I don't want to answer	
H Main sources of information		
58	**What are the three most important sources of agricultural information/news for you?**	

	1= radio 2= TV 3= Local newspaper 4= neighbours 5= shopkeeper in the village 6= Community leaders 7= parents 90= other, specify	
59	**Do you have a mobile phone?** (1=Yes, 2=No)	
59 b	**Do you have access to the internet via your phone?** (1=Yes, 2=No)	
60	**Do you access social media?**	
60 b	**What type of social media do you use?** 1=Facebook 2=Twitter 3= Instagram 4= WhatsApp 5= TikTok 90= other, please specify 6= I do not use social media	
60 c	**For what purpose do you use social media?** 1= General news 2= Agricultural information 3= Weather update 4= Jobs 5= Marketing 6= Exchange with friends and family 7= Entertainment	
61	**What are your three favourite sources of information?** 1= NGO 2= neighbours 3= Extension service 4= Family and friends 5= women's group 6= radio, TV or newspaper 90= other, please specify	

A.6. Information Sheet

Local perceptions of climate change and farm-level adaptation strategies from smallholder farmers in Fatick, Senegal

In the face of climate change, we witness an increasing number of weather volatilities and extreme weather events. The Sahel is especially sensitive to the challenges of agricultural production during climate change as it is exposed to changes in precipitation patterns and an increase in extreme weather events. In Sahel countries, agricultural production is strongly dependent on precipitation and is structured according to interannual variability (through rain and dry seasons). The majority of rural households rely on agricultural production. Crop cultivation is usually based on rainfed agriculture, making smallholder farming highly vulnerable to uncertain changes in rainfall and extreme weather events. To reduce the vulnerability of the subsistence farming sector, it is necessary for smallholder farmers to be aware of changing climate conditions in order to develop adaptation strategies.

Purpose of study: This master thesis seeks to address smallholder farmers´ perception to climate change as well their strategies to adapt to the changing climate. It focuses on the perspective of smallholder farmers from the Fatick region in Senegal. It is based on the understanding that local knowledge should inform development studies and action. Thus, information is collected in cooperation with local people at a specific site in order to address questions that are relevant for the participants.

Procedures: Focus group discussions will be conducted with farmers from the villages DiofiorFa et Nobandane in the Fatick region. Your participation in this study is entirely voluntary and ends after the focus group discussion. The focus group will last for 2 hours.

Benefits: The information you will provide will be analyzed and included in climate schools from the *Nutrigreen* project that will take part in your villages. This way, you can use the information to develop climate change awareness and to improve adaptation strategies in agricultural production.

Risks / Discomforts: You will not be exposed to any physical or other danger when you take part in this study. I estimate that the interview may take 2 hours of your time but I will ensure that the discussion is interactive enough to reduce the discomfort associated with answering questions for such a long time. However, you can refuse to answer any question you are not comfortable with, revoke of stop your participation at any point in time without consequences.

Confidentiality: All the information that will be collected in this study will be treated in strict confidence and will be used for the intended purposes only. The information will only be accessible to the study investigators, the *Nutrigreen* project team, and members of review boards. I will not share any information with other organisations and individuals. Your statements will be fully anonymised and you will not be identified by name in the dissemination of findings or any publication resulting from this study.

Voluntary participation: Participation in this project is completely voluntary. You have every right to refuse to participate or withdraw from the study at any point in time without any consequences to you.

Questions/Persons to contact: If you have questions or concerns about this project, you may contact Kasia Schwartz (master student of Freie Universität Berlin) via email (katas45@zedat.fu-berlin.de) or telephone (+221 785911713); Fatimata Diop (director of APAF Senegal) via email (khadimoctar2615@yahoo.com) or telephone +221 77 373 68 93; or Dr. Silke Stöber (thesis supervisor) via email (silke.stoeber@agrar.hu-berlin.de).

A.7. Consent Form

I have been adequately informed of (and/or I have read and understood) the purpose, procedures, potential risks and benefits of this study.

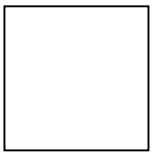
I have had the opportunity to ask questions about it. Any questions that I have asked have been answered to my satisfaction.

I know that I can refuse to participate in this study without any consequences. I understand that if I agree to participate, I can withdraw my consent at any time.

I understand that any information collected will be treated confidentially.

I freely agree to participate in the study. After signing below, I will receive a copy of this consent form.

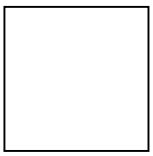
Name of participant: _____

Signature or Right Thumb Print _____ 

Date: ------/-------/--------

I agree to my interview to being recorded. All recorded files will be stored in a data secure location under passport-protection and deleted after the interview is transcribed into a word-file.

Name of participant: _____

Signature or Right Thumb Print _____ 

Date: ------/-------/--------

I have adequately informed the participant of the purpose, procedures, potential risks and benefits of this study. I have answered all questions to the best of my ability and the participant has agreed to take part in this study.

Name of study personnel:_____

Signature:_____ Date--------/--------/-------

Note: The link to the digital consent forms is included in the household survey. It is only accessible to the NUTRiGREEN research team and will therefore not be shared in this annex.

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