ROUTLEDGE ENVIRONMENT AND SUSTAINABILITY HANDBOOKS

Routledge Handbook of Climate Change Impacts on Indigenous Peoples and Local Communities

Edited by Victoria Reyes-García,
With Santiago Álvarez-Fernández,
Petra Benyei, Laura Calvet-Mir,
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ROUTLEDGE HANDBOOK OF CLIMATE CHANGE IMPACTS ON INDIGENOUS PEOPLES AND LOCAL COMMUNITIES

This Handbook examines the diverse ways in which climate change impacts Indigenous Peoples and local communities and considers their response to these changes.

While there is well-established evidence that the climate of the Earth is changing, the scarcity of instrumental data oftentimes challenges scientists' ability to detect such impacts in remote and marginalized areas of the world or in areas with scarce data. Bridging this gap, this Handbook draws on field research among Indigenous Peoples and local communities distributed across different climatic zones and relying on different livelihood activities, to analyse their reports of and responses to climate change impacts. It includes contributions from a range of authors from different nationalities, disciplinary backgrounds, and positionalities, thus reflecting the diversity of approaches in the field. The Handbook is organised in two parts: Part I examines the diverse ways in which climate change – alone or in interaction with other drivers of environmental change – affects Indigenous Peoples and local communities; Part II examines how Indigenous Peoples and local communities are locally adapting their responses to these impacts. Overall, this book highlights Indigenous and local knowledge systems as an untapped resource which will be vital in deepening our understanding of the effects of climate change.

The *Routledge Handbook of Climate Change Impacts on Indigenous Peoples and Local Communities* will be an essential reference text for students and scholars of climate change, anthropology, environmental studies, ethnobiology, and Indigenous studies.

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A case study in south-eastern Senegal

Anna Porcuna-Ferrer, Théo Guillerminet, Benjamin Klappoth and Anna Schlingmann

Introduction

Smallholder farmers around the world observe inter- and intra-seasonal climate variability and change (Reyes-García et al., 2019; Savo et al., 2016) and use this knowledge to organise their agricultural practices according to local environmental conditions, including climate, soil, and water (Altieri & Nicholls, 2017; Rivera-Ferre et al., 2021). This is also the case for smallholder farmers in West Africa, where episodic droughts have traditionally affected the agricultural rain-fed systems (Nyong et al., 2007), with scientific evidence predicting increasing risks of crop failures due to rising temperatures and changes in the monsoonal rainfall (Carr et al., 2022; Sultan & Gaetani, 2016). At the same time, smallholder farmers also experience other environmental, socio-economic, cultural, and political changes, including demographic changes and rural–urban migration, increasing integration into global markets, the expansion of infrastructure and technology, and off-farm livelihood activities (Ensor et al., 2019). Moreover, this broad range of multi-scalar, multi-temporal, and interacting stressors have differentiated impacts depending on the context-specific vulnerability of individuals and communities (Bennett et al., 2016; O'Brien et al., 2004). Consequently, although research and policy have primarily addressed the impacts of specific stressors, for example, adaptation to climate change or economic development (Bennett et al., 2016), focusing on only one stressor bears the risk of missing unexpected and negative feedbacks and trade-offs produced by other stressors, thereby undermining environmental, social or economic objectives, maintaining or even increasing vulnerability, and potentially leading to maladaptation (Antwi-Agyei et al., 2018; Barnett & O'Neill 2010; Eriksen et al., 2011).

While climate change research considering multiple stressors and their interactions is on the rise (Räsänen et al., 2016), our understanding of context-specific interactions, interferences, and consequences of responses to climatic and other stressors is still limited (Ensor et al., 2019). Importantly, specific responses might have context- and group-specific impacts, for example, if the response favours some, but result in additional efforts, costs, or even negative outcomes for others

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(Segnon et al., 2021). Eriksen et al. (2011) argue that assessing responses from a sustainability perspective entails considering the interdependencies between environmental, social, and economic objectives to understand the vulnerability context in which adaptive responses are framed. Therefore, a thorough multi-stressor and multi-facet analysis that assess environmental, social, and economic implications of adaptation for different social groups is needed to anticipate trade-offs, avoid maladaptation, and foster long-term adaptation.

In response to this need, here we examine smallholder farmers' adaptive responses to multiple stressors in the context of climate change. Our specific objectives are to explore (i) the main changes in local agricultural practices, (ii) the drivers of those changes (also named 'stressors'), and (iii) associated costs, benefits, and trade-offs. In our analysis, we pay attention to the specific implications that changes in agricultural practices have for the different sustainability spheres (i.e., environmental, social, and economic) and social groups (i.e., across gender and wealth). Based on vulnerability and adaptation literature dealing with multiple stressors (e.g., McDowell & Hess, 2012; O'Brien et al., 2004; Tschakert, 2007) and intersectionality (Kaijser & Kronsell, 2014; Ravera et al., 2016a), our discussion enriches the debate on which of the changes in agricultural management practices, beyond bringing climate change resilience, also contribute to social justice, environmental integrity, and economically viable livelihoods (Eriksen et al., 2011).

The Bassari

We conducted research among the Bassari, located in the Kédougou region in south-eastern Senegal (Figure 13.1). The region is characterised by low altitude (approx. 80–380 m a.s.l.), tropical dry or savanna climate, annual mean temperatures around 28°C, and a unimodal rainy season from May to September dominated by the West African monsoon system (ANACIM, 2020; Sultan & Janicot, 2003).

With a wetter climate than the northern regions, south-eastern Senegal was less affected by the Sahel droughts of the 1970s than most Senegalese regions. And although there are important interannual rainfall variations, historical trends show a partial recovery of the lack of precipitation

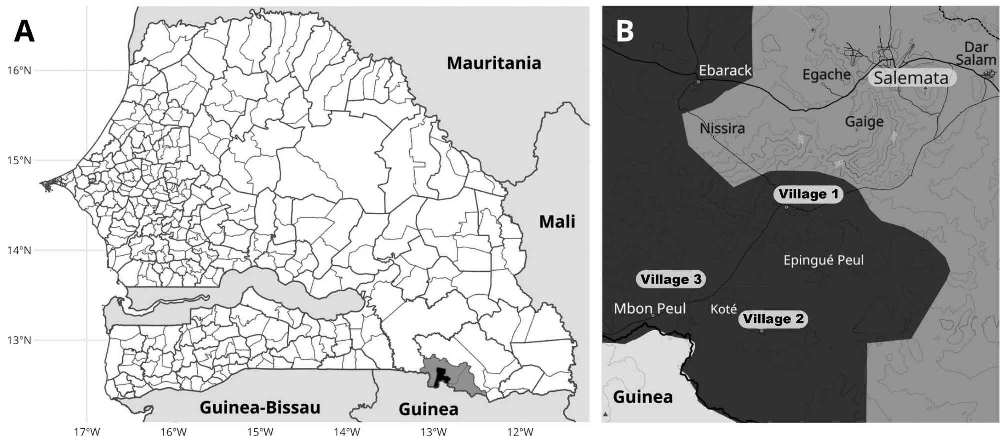

Figure 13.1 Map placing the study area within Senegal. The dark grey and the black polygons represent the department of Salemata and the commune of Ethiolo, respectively.

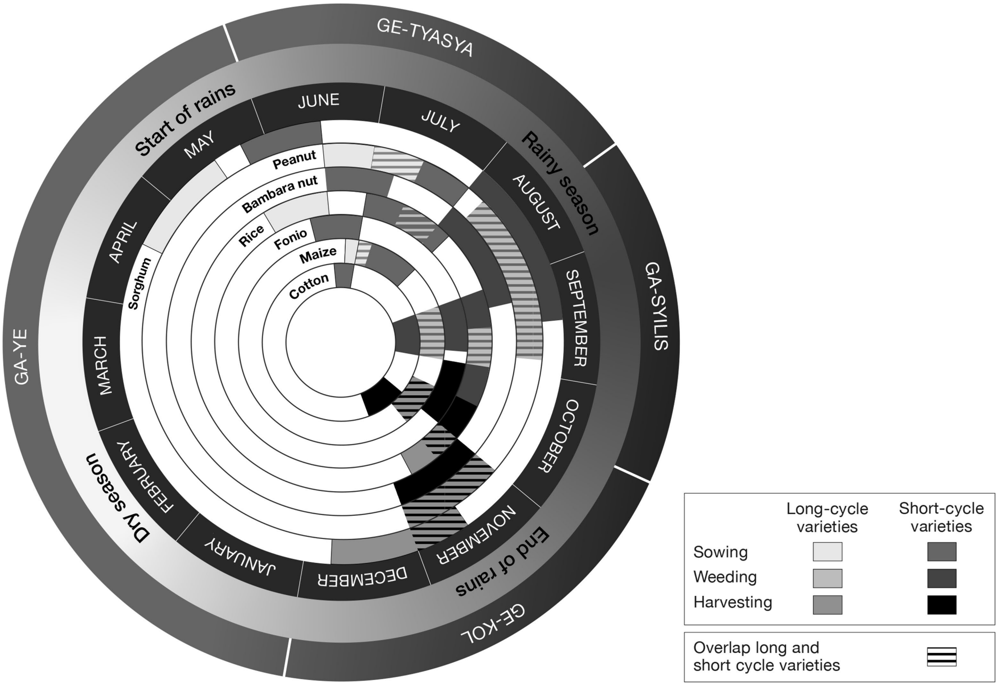

Figure 13.2 Bassari agricultural seasonal calendar.

from the 90s onwards. Nonetheless, future climate predictions for the West African region indicate a trend towards higher temperatures and shorter rainy seasons (Sultan & Gaetani, 2016).

Only 10% of the Bassari region's surface is cultivated and the remaining area preserves large forests and bushlands that are home to many wild flora and fauna. However, population density, currently below 20 inhabitants/km^2, is on the rise resulting in a gradual disappearance of forests and bushlands in favour of cultivated fields (UNESCO, 2011; Porcuna-Ferrer et al., 2023a). The Kédougou area hosts several ethnic minorities, among which we worked with Bassari.

Nowadays, the Bassari mostly rely on small-scale agriculture, which is highly dependent on the use of communal land and shared labour (Nolan, 1986). The importance of agriculture in Bassari life is reflected in the naming of the seasons (Figure 13.2). Agricultural activity is concentrated in the short rainy season. During the dry season, some women practice small-scale horticulture production (e.g., onions, tomatoes, salads, cabbages), while other Bassari engage in off-farm employment, including construction work, wage labour, art craft, tourism, and seasonal migration.

Bassari farming system is organised into four agroecological field types, cultivated with different crop species and managed distinctly (Table 13.1). On average, households cultivate a mean area of 2.1 ha (min: 0.4 ha; max: 9.5 ha). The typical cropping pattern of Bassari smallholders is the rotation of cereals (sorghum, *Sorghum bicolor*; maize, *Zea mays*; fonio, *Digitaria exilis*) and legumes (peanut, *Arachis hypogaea;* Bambara groundnut, *Vigna subterranea*). In the plains, the Bassari also cultivate rice (*Oryza sativa*), which is not subject to crop rotation, and

Table 13.1 Local taxonomy of field types and the main crops and management practices associated

Field type (local name)	*Description*	*Cultivation season*	*Main food crops*	*Crop rotation*	*Fertilisation*	*Irrigation*
'Oxenga'	Soils poor in organic matter (often shallow), mostly on hilly terrains	Rainy season (June–October)	Sorghum, peanut, Bambara groundnut, cotton, fonio (maize)	Yes	Slash-and-burn, fallow system. Few chemical inputs, mostly only in cotton	No irrigation, rain-fed
'Eden'	Soils rich in organic matter with a fine texture, mostly located in the plains or valleys ('bas-fond') and near the streams.	Rainy season (June–October)	Rice, maize	No	Mostly use of chemical inputs	No irrigation, rain-fed
'Eden'		Rainy season (June–October)	Tubercules: taro, yam	No	Mostly use of biological fertilisation – e.g. tree leaves and branches, and ashes	No irrigation, rain-fed
'Eden'		Dry season (November/ December–May)	Horticulture: tomato, salad, aubergine, carrot, onion, etc.	No	Use of both, chemical and biological fertiliser (mostly NPK and/or cow dung)	Irrigation, well water
'Enam'	Soils surrounding the households, usually rich in organic matter	All year	Maize, fruit trees, spices, vegetables	No	Fertilised by the livestock kept in the household	No or only punctual irrigation

small-scale horticulture. The main cash crop is cotton (*Gossypium hirsutum*), cultivated as part of a farming contract system (Porcuna-Ferrer et al., 2023b).

Research methods

Data were collected between November 2019 and March 2020, and benefited from the authors' long presence in the community – 16 months in total, between 2019 and 2021 – and the support of four Bassari research assistants. Before starting data collection, we received ethical approval from the Autonomous University of Barcelona (CEEAH 4903) and obtained the permits to conduct the research from the relevant village authorities.

Sampling and data collection were conducted according to the criteria described in the Local Indicator of Climate Change Impact (LICCI) protocol (Reyes-García et al., 2023), summarised below.

Sampling

We worked in three villages in the Bassari country, with 109, 55, and 24 households, respectively. To select participants for semi-structured interviews, we used 'quota sampling' aiming at capturing the diversity of knowledge across gender, age, and wealth. In total, we interviewed 34 men and 13 women from different households, the main social and economic structuring unit in the site. We have a lower sample of women because they were generally less available for interviews; 10 participants were <40 years old, 17 were between 40 and 60 years old, and 20 were >60 years old. Household wealth was defined with the help of the research assistants and based on local conceptions. Research assistants classed households into three groups taking into account herd size, polygamy, cultivated area, and possession of material assets: low resources (~40% of households), intermediate (~50% of households), and wealthy (~10% of households).

Data collection and analysis

To understand how multiple stressors affect the local agricultural system, we first asked interviewees to describe changes in on-farm management practices that they have observed since their youth, including changes in the type of cultivated crop species and varieties, changes in management practices in the different stages of the cultivation cycle – including seed selection and acquisition, land preparation, sowing, cultivation, harvesting –, and changes in post-harvest treatment, storage, and commercialization. For each reported change in local agricultural management practices, we asked the interviewee to explain what had driven such changes.

We additionally explored positive and negative experiences associated with each change in agricultural management practices and recorded the age, gender, and wealth group of each interviewee to assess benefits, costs, and trade-offs for different social groups.

Before presenting our main results, we acknowledge two main limitations of this work. First, our data were not collected to systematically analyse how power relations shape farmers' adaptation options. However, farmers' explanations of the costs, benefits, and trade-offs of different agricultural management practices, together with our understanding of the site dynamics, allowed us to identify that farmers' responses to multiple drivers can simultaneously lead to positive changes for some groups and negative consequences for others. Second, the limited time frame of our research makes it difficult to fully understand or evaluate the long-term outcomes of farmers' strategies. However, results from our empirical work shed light on the complexity of local farmers' adaptation to multiple drivers.

Results

Bassari farmers have adapted their agricultural practices in response to environmental and socio-economic drivers including: (1) climatic (i.e., declining crop yields due to changes in precipitation, temperature, and fog), (2) demographic (i.e., higher land pressure due to population increase and labour shortages due to migration), (3) economic (i.e., increasing monetization of the livelihood system through market integration, which caused higher cash dependency, higher reliance in off-farm activities, and trends towards economic efficiency), (4) social (i.e., increasing influence of NGOs and extension services, and decrease in community's social capital such as communal work and reciprocity), and (5) cultural (i.e., weakening of traditions and cultural norms and changing dietary preferences). These drivers have generated impacts in the local farming system and shaped changes in agricultural management practices, including changes in crop species and varieties, changes in seed management, and changes in soil cultivation practices (see Figures 13.3 and 13.4). Agricultural management changes come along with certain benefits, costs, and trade-offs for different sustainability spheres and social groups, as we next outline.

Adoption of new crop species

The most prominent change in agricultural management practices refers to the adoption of new crop species. Traditional Bassari staple crops were sorghum, fonio, and Bambara groundnut. The adoption of new crops and in particular rice and maize (for subsistence) and cotton and horticulture (for sale) were common changes mentioned by farmers. The introduction and expansion of horticulture (2000s) and cotton (1970s) is relatively recent. Rice (19th century) and maize (1930s)

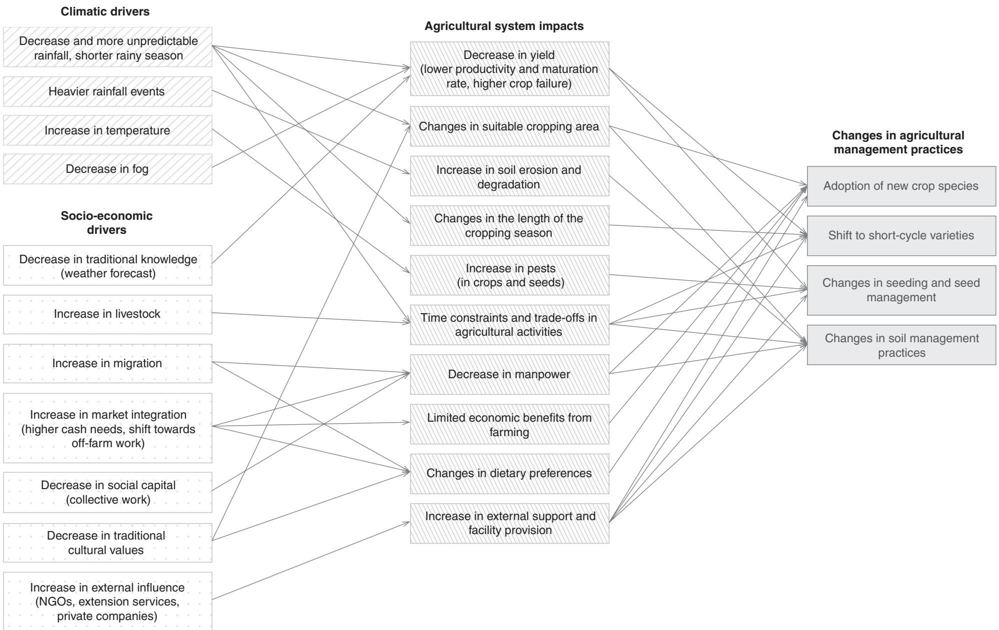

Figure 13.3 Conceptual map showing multiple drivers and impacts on the Bassari agricultural system and resulting changes in agricultural management practices.

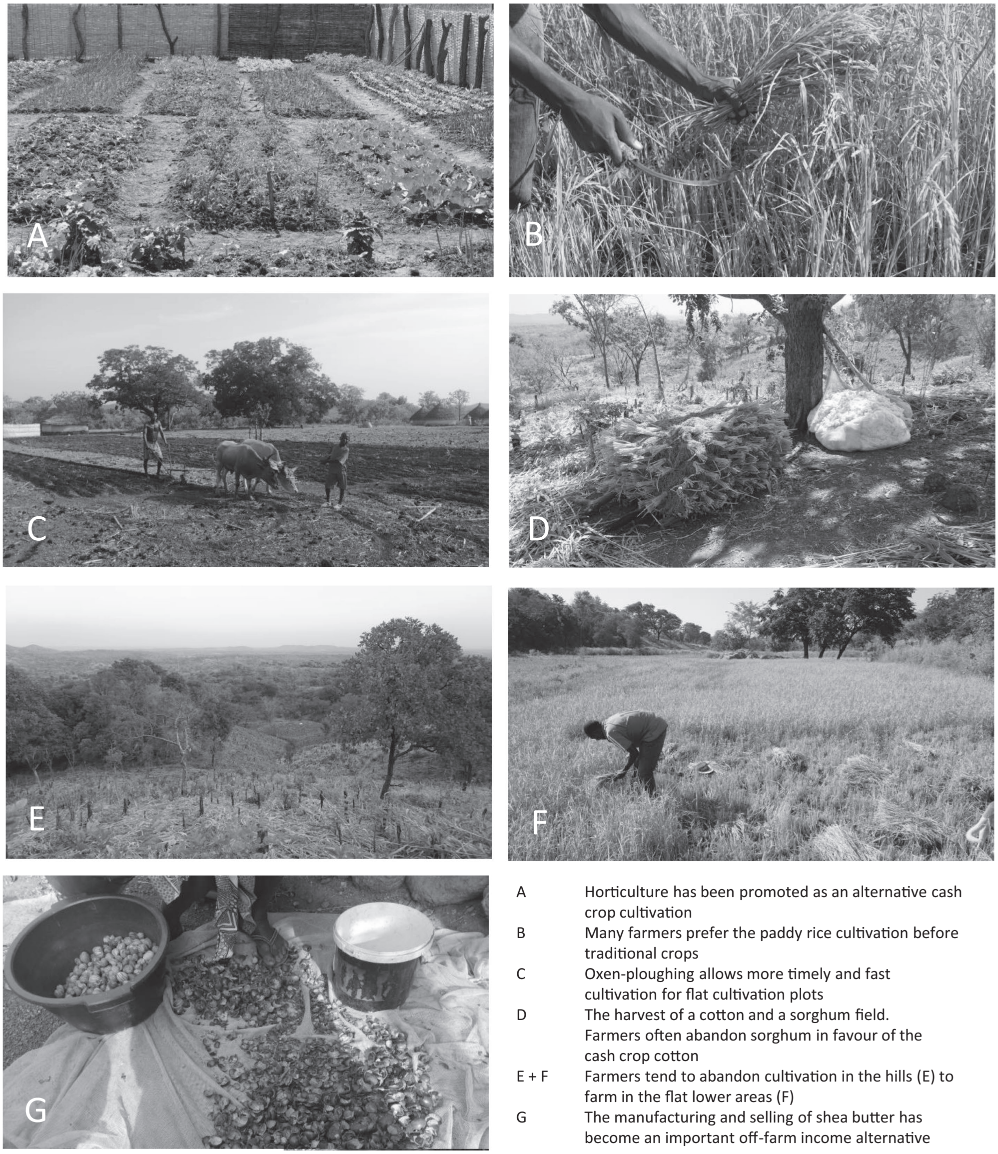

Figure 13.4 Examples of changes in Bassari agricultural practices as a response to different impacts on the agricultural system. Pictures by B. Klappoth, 2019–2020.

have been in the Bassari farming system for a longer time, although their cultivation has experienced a dramatic increase in the last decades. As a direct consequence of adopting new crops, farmers have reduced or even abandoned the cultivation of traditional crops. Due to the higher water and soil fertility requirements of maize, rice, and horticulture, the switch from traditional to new crops also entailed a change in the cultivation location, from hilly areas to the plains (see Porcuna-Ferrer et al., 2024).

Drivers

The adoption of maize and rice involved a mix of economic, social, and cultural reasons. Farmers justified the adoption of maize and rice arguing that these crops provide high yields and require less labour than traditional crops. Among the Bassari, agricultural labour is becoming a limiting factor due to off-farm migration in search for jobs that provide cash income, the decrease in the number of common agricultural working days, and the increase of children schooling (who traditionally were an important help in the fields). Moreover, development projects (in coordination with the Senegalese government) – which intensified their presence in the Bassari area in the recent decades – play a key role in the introduction of new high-yielding rice and maize varieties. Dietary preference for maize and rice have also contributed to the adoption of these crops.

Farmers mentioned mainly economic and social considerations for the adoption of cotton and horticulture. Increased cash needs and the role of external agents – NGOs for the introduction of horticulture and a state enterprise (later privatised) for cotton – were mentioned as the main drivers of cotton and horticulture adoption. Nowadays, cotton is the main source of agricultural income and all interviewed farmers referred to the need to cover the rising costs of living – for example, children's schooling, food, and access to health services –, as well as the rising demands for commercial goods like smartphones or motorbikes. In the discussions with women farmers, they mentioned that horticulture has become increasingly popular because the facilities provided by NGOs – for example, seeds and materials for fencing – make the commercialization of vegetables profitable. None of the farmers interviewed mentioned that their decisions to adopt new crop species reflect a response to climatic stress.

Costs, benefits, and trade-offs

The need to change the planting location was the most frequently mentioned trade-off derived from rice and maize adoption. Given their water requirements, rice and maize cannot be cultivated in the hills, like Bassari traditional staple crops. This shift aggravates land scarcity and promotes unequal land access, also reinforced by population growth and cultural changes in the land tenure system, which has shifted from commonly managed user rights defined by kin groups to private property. The cultivation of maize and rice lowers the value of hilly land and intensifies land pressure in the plains. Bassari recognised that "*[Now] the fields are smaller, and it is difficult to find land in the plains. (…) We are many more people!*" (Anonymous, female farmer, February 2020). In the past, higher-status and wealthier households preferred hilly land. The less desirable plains – characterised by a dense vegetation, soils non-suitable for traditional crops, and protected by cultural taboos – were only used by households settled in the village margins or by ethnic groups who arrived later to the area (e.g., Pular). Nowadays, only those households who traditionally inhabited or cultivated the plains, or very wealthy households who can use their financial and social status to borrow land from others, can cultivate the plains and therefore adopt new and higher-yielding crop species. Interviewees expressed additional concern about the expansion of agriculture into sacred and protected areas like the river basins with dense riparian forests, where, in the past, taboos banned cutting the trees.

Farmers claimed that rice and maize have high water requirements that make them generally more susceptible to dry spells than their traditional crops. However, they also mentioned this drawback to be compensated through the higher water retention capacity of the soils in the plains, which reduces the risk of water stress that occurs in hilly areas. Farmers also referred to the high needs for fertilisers and pesticides as a trade-off for the adoption of rice and maize. According to farmers, the growing demands on land limit the use of traditional crop rotation and fallow periods, which leads to declining soil fertility and increasing soil degradation. Consequently, as fields in the plains are rarely rotated or left fallow and as the new crops have high soil nutrient requirements, regular fertilisation is needed. Some farmers also noticed that the reduction of fallow periods and the lower quality of purchased seeds leads to a greater presence of pests, which requires the application of more pesticides.

For horticulture, farmers reported problems with water scarcity and conflicting interests between household consumption and irrigation needs. This problem was mainly presented by women, who also saw an increase in their work burden due to water scarcity: "*Before sunrise is when there is more water. If you want to irrigate your crops, you need to wake up very early*" (Anonymous, female farmer, March 2020). Horticultural activities also generate disparities, since only some neighbourhoods have access to land suitable for horticulture. As a woman farmer explained: "*I would cultivate tomatoes, onions, and lettuce if I had a place*" (Anonymous, female farmer, March 2020).

Cotton has high requirements for fertilisers and pesticides, representing a form of intensified agriculture that demands more labour to fumigate and fertilise plots, and additional cash to purchase external inputs, thereby creating higher market dependence. Cotton is mostly cultivated by men, who also control the income from cotton sales, which is often used to buy status items (e.g., smartphone, motorbike) and – according to women interviewed – not invested in family expenditures. Hence, the shift towards cotton cultivation had negative implications for women's control over household income and decision-making.

During the 'cotton boom' in the early 2000s, many families almost entirely switched to cotton, reducing the area dedicated to self-consumption. However, in the face of yield failure, low cotton market prices, or unexpected cash needs (e.g., in case of illness), these households became food insecure. Nowadays, most households keep a balance between cotton and subsistence crops. Still, big shares of land and labour are put into cotton cultivation and the proportion devoted to subsistence crops has declined. To compensate for the lack of cultivated subsistence crops, women search for alternative strategies to ensure household food security (e.g., through off-farm work), while at the same time supporting cotton cultivation. In other words, cotton cultivation competes with subsistence crops for land and labour, thereby challenging family food needs and increasing women's work burden.

Shift to short-cycle varieties

The shift from long- to short-cycle varieties was a change commonly mentioned by Bassari farmers and affecting maize, rice, peanut, and fonio, for which short-cycle varieties are available. For sorghum, farmers mentioned adopting a medium-cycle variety. No short- or medium-cycle varieties are available for Bambara groundnut.

Drivers

Farmers reported climatic stressors, scheduling conflicts with other activities (i.e., livestock rearing and off-farm work) and external influences as the main drivers of the shift to short-cycle varieties. Farmers considered traditional long-cycle varieties vulnerable to the changing climate, especially regarding unpredictable rainfall, shorter rainy seasons, and more frequent dry spells. They also explained that in the past, the rainy season lasted from May to October and allowed the cultivation of long-cycle crops, whereas nowadays the rain lasts from mid-June to September and only allows for short-cycle crops and varieties. Respondents also mentioned that in the past communities relied on fog at the end of the rainy season for the final maturation of long-cycle crops, like certain sorghum varieties. Nowadays, however, fog is scarce and too unstable to ensure the final maturation of long-cycle crops.

Farmers also referred to trade-offs between long-cycle varieties and livestock rearing. Free-ranging livestock is kept in communal land during the dry season and at the end of the growing season, when crops are harvested. This practice increases the risk of crop damage by grazing livestock, especially for long-cycle varieties. Farmers also mentioned that the shorter growing cycles fit better with the seasonality of off-farm jobs.

Finally, farmers mentioned that the adoption of short-cycle rice, maize, and peanut varieties was supported and subsidised by NGOs and government development programs, which increases profits by reducing investment costs.

Costs, benefits, and trade-offs

Farmers attributed positive traits to some of the traditional long-cycle varieties that are being lost, which were perceived as more productive, less vulnerable to pests and weeds, more robust to low soil fertility, more durable when stored, and more tasty and nutritious.

Changes in seeding and seed management

Farmers reported three main changes regarding seeding and seed management: (1) changing seed storage techniques by applying chemical pesticides, especially for legume seeds; (2) shifting the planting calendar from the beginning of June to the beginning of July; and (3) re-seeding more often due to the increasing difficulty to find the right moment to seed.

Drivers

Farmers argued that changes in seed storage practices were a response to higher seed degradation from pest infestations due to temperature increase. Pest infestations particularly affected legume crops like peanut and Bambara groundnut. As one farmer explained: "*There are too many insects in the seeds. Before you could store them from one cropping season to the next. Nowadays if you leave it, at the moment of seeding you will just find powder*" (Anonymous, female farmer, January 2020). They acknowledged that the new seed storage practice was initially promoted by NGOs, who used to distribute chemical pesticides for free, although now farmers have to buy them.

Farmers explained the shift in planting schedules as a response to the delayed and shorter rainy season and the higher frequency of dry spells. Farmers described that they cannot seed when the first rain arrives, as they used to do, because no other rains follow, and the germinated seeds dry out: "*Sometimes you organise a big common agricultural working day hoping that the first rains will follow soon, but if the rain does not arrive, you lose everything*" (Anonymous, male farmer, January 2020). At the same time, the shorter rainy season forces farmers to harvest earlier, compared to the past. Seeding later but harvesting earlier makes shifting to short-cycle varieties necessary. Otherwise, crops do not reach maturity before the end of the rainy season, resulting in significant yield losses. As one middle-age male farmer said: "*If you seed too early, you risk that the seeds will dry out in the field; but if you seed too late, crops will not reach maturity*" (Anonymous, male farmer, February 2020).

Unpredictable rainfall, the decreased reliability of traditional indicators of weather forecast, and the loss of weather forecasting knowledge were all considered factors increasing the difficulty to identify the right time to seed.

Costs, benefits, and trade-offs

Additional costs, including risks, were mentioned in relation to changes in seed storage methods. Since NGOs do not freely distribute chemical pesticides anymore, farmers with less economic resources cannot afford buying them and continue to apply traditional forms of seed storage (e.g., mixing seeds with ashes and certain wild plants that keep insects away). Moreover, some farmers complained about the toxic effects of chemical pesticides on human health and refused to use them.

Altogether, there are more costs in accessing and storing seeds, including an increased risk of seed losses during storage and a large dependency on external seed sources (e.g., markets, NGOs). For example, several women farmers mentioned incidents of spurious seeds or of seeds that did not correspond to the announced crop variety. Some farmers also attributed pest infestations to the purchase of seeds from markets or unreliable sources.

Changes in soil management practices

Farmers mentioned two main changes related to soil management practices: the shift from the hand hoe to the oxen-plough and the construction of stone-bands and half-terraces on fields.

Drivers

When asked about the reasons for shifting from the hand hoe to the oxen-plough, most farmers referred first to reduced workload and lower labour demand. The oxen-plough was also related to the increased cultivation in the plains, which allows more efficient ways of ploughing the soil. Several farmers additionally mentioned that owning an oxen-plough was beneficial under current unpredictable rainfall conditions, since the oxen-plough allows quick soil preparation and seeding, thereby offering farmers more flexibility, compared to the hand-hoe. The main reason for farmers to place stone-bands or trunks along the contours of hilly fields, or building half-terraces, was the prevention of soil erosion in response to more frequent flash floods. Both measures were introduced by NGOs and development projects, which made oxen-plough available and trained farmers on the use of stone-bands and terraces on hilly terrains.

Costs, benefits, and trade-offs

Farmers mentioned that the benefits of the oxen-plough are not accessible to everybody. For example, a middle-aged woman explained:

> *If you own an oxen-plough, as soon as the rain comes, you seed. But if you do not own it, then you will have problems, you need to wait for your turn* [the oxen-plough is usually shared in exchange for work, some people also rent it] *and sometimes when they come to plough your field, it is too late*.
>
> (Anonymous, female farmer, February 2020)

Regarding the construction of stone-bands or terraces on hilly fields, interviewed farmers agreed that labour and time constraints were the main factors that hindered the wider implementation of this practice.

Discussion

We structure the discussion around the three main findings: (a) farmers adapt their agricultural management practices in response to multiple stressors; (b) changes in agricultural management practices imply trade-offs among environmental, social, and economic factors; and (c) the distribution of costs and benefits arising from adaptation varies across social groups.

Changes in agricultural management practices are driven by multiple stressors

Changes in farming practices such as changing crop species and varieties and market-based horticulture have been documented and conceptualised as "climate change adaptation strategies" in Senegal (Mertz et al., 2009; Ruggieri et al., 2021) and the world (Schlingmann et al., 2021).

However, the predominant focus on climate change as a main driver of change masks the socio-political root causes of household and individual vulnerability (Ribot, 2014). As our case study shows, farmers do not only switch to shorter-cycle varieties due to the shortening of the cropping season, but also due to labour constraints, higher yields, and dietary changes. In this regard, drivers of change in Bassari agricultural management practices are multifactorial, with socio-economic, political, and cultural stressors being as salient as climate change in guiding farmers' decisions. Other studies have also documented that climate change is not necessarily the main or unique stressor driving livelihood changes in local communities (Nyantakyi-Frimpong & Bezner-Kerr, 2015). Multiple, compounding, interacting, and intertwined stressors that are deeply entangled in the integration of smallholder farmers' communities into globalisation and capitalist economies – such as new economic opportunities and cash needs, population growth, and the weakening of cultural norms and traditions – strongly determine community's and households' vulnerability and are perceived to be equally or even more relevant than climatic stressors (Ensor et al., 2019).

Still, the fact that non-climatic challenges are currently perceived as more significant for local farmers does not downplay the need for adaptation to the mounting threats of climate change. In the light of our findings and in line with McDowell and Hess (2012) and Izquierdo and Schlingmann (2024), we argue for the importance of designing climate change adaptation interventions that allow farmers to better confront multiple stressors according to their own needs and priorities.

Costs and benefits of changes in agricultural management practices result in trade-offs between environmental, social, and economic factors

Our results show that changes in Bassari agricultural management practices entail different costs under the different sustainability spheres, which can have contradicting and sometimes unwanted trade-offs for local communities, leading to maladaptive outcomes and increased vulnerability.

A response that is beneficial with respect to one stressor might be insufficient or ineffective, or even conflict with addressing other stressors (Bennett et al., 2016). For example, a response to new economic conditions does not necessarily increase climate resilience and a response to climatic stressors is not necessarily economically beneficial or viable, as it happens when there is a mismatch between climate-compatible crops and market-driven demand for those crops (O'Brien et al., 2004). Our case study illustrates trade-offs between environmental, social, and economic costs that can lead to maladaptive outcomes. For example, the increase of marketable horticulture and cotton cultivation (short-term economic benefits) contributes to the abandonment of traditional crops, like sorghum, fonio, or Bambara groundnut, which are generally better adapted to local environmental conditions and droughts (environmental costs) (Abrouk et al., 2020; Hadebe et al., 2017; Mayes et al., 2019). Switching to cash-crops can improve households' income (economic benefits), but the additional need for irrigation (i.e., horticulture) can put stress on water resources (environmental costs) and potentially lead to conflicts because of different demands and interests (social costs) (Akinyi et al., 2021; Antwi-Agyei et al., 2018). Similarly, an increasing dependence on research-improved drought-resistant short-cycle seeds of introduced crops (environmental benefits), increases households' vulnerability to market uncertainties and price fluctuations (economic costs) (Galappaththi & Schlingmann, 2023). Introduced crops also tend to be more susceptible to pests, resulting in frequent application of chemical pesticides with risks to human health (social costs), environmental degradation (environmental costs), and additional cash needs (economic costs) (Akinyi et al., 2021; Dhakal & Kattel, 2019). Growing a mixture of traditional crops would allow households to have effective strategies against food insecurity in the face of reduced landholdings, changing rainfall patterns, and decreased soil fertility (environmental and social benefits). However, growing traditional crops implies high labour requirements and low income, since they are not yet integrated into market logics (economic costs) (Galappaththi and Schlingmann, 2023).

In this regard, adaptation to the most impacting stressors in the short term can limit long-term adaptation options and climate resilience when they deliver maladaptive outcomes for one of the different sustainability spheres (McDowell & Hess, 2012; Porcuna-Ferrer et al., under review). Only when farmers' responses reduce harm in all three spheres, they can be considered sustainable adaptation (Eriksen et al., 2011; Wilson, 2014), which emphasises the need for research and policy to design and evaluate climate change adaptation options by considering their trade-offs between environmental, social, and economic spheres in order to avoid lock-ins that could increase future climate vulnerabilities.

Costs and benefits of changes in agricultural management practices are unequally distributed across social groups

Another important finding of our research is that changes in agricultural management practices entail different costs, benefits, and trade-offs for different social groups, with the least vulnerable bearing the benefits and the most vulnerable (i.e., women and poor households) often bearing the costs. Gender or access to financial, physical, and natural capitals define who in the community or within a household can implement and benefit from certain changes in agricultural management practices. This is specifically the case of the usage of oxen ploughing, cotton cultivation, horticulture, and the relocation of fields to the plains, which increased the benefits of some groups and the costs of others. For example, in the study area, the adoption of the oxen-plough mostly benefited a very small number of wealthy households with direct access to an oxen-plough. This is in line with other studies that highlight how unequal access to physical and natural assets affects the scheduling of seasonal agricultural activities of poor households (Roncoli et al., 2001). Regarding cotton cultivation, underlying inequities between men and women in cash access and decision-making influenced their capacity to benefit from cotton expansion, which points to the importance of intra-household power dynamics to access adaptation options – see also, Ravera et al. (2016a). Moreover, our results add empirical evidence to the literature that argues that the implementation of certain adaptation strategies, besides reinforcing pre-existing inequalities, can also entail the renegotiation of local power relations (Ravera et al., 2016b). This is the case for horticulture and the relocation of agricultural fields to the valleys where differential land access between households defined their adaptive capacity and thereby created new inequalities. For example, market-oriented horticulture of water-demanding vegetables enhanced the climatic sensitivity of women with limited access to land with wells, as confirmed by other studies (e.g., Labeyrie et al., 2021).

While the analysis of how the intersection of power and social relations shapes adaptation processes receives increasing scholarly attention (e.g., Kaijser & Kronsell, 2014; Ravera et al., 2016a), it still remains largely unexplored for rural farming communities of the Global South (see Onta & Resurrección 2011 and Carr & Thomson, 2014 for exceptions). Results from our case study reinforce the notion that power-dynamics largely depend on context-specific socio-economic and biophysical characteristics that either catalyse or constraint farmers' adaptation options (Carr & Thompson, 2014; Kaijser & Kronsell, 2014; Thompson-Hall et al., 2016). Our results also offer empirical insights into how power dynamics are not fixed but changing under new conditions as people adapt to change. These findings thus make clear that adaptation is not an homogenous process that equally benefits all community members and highlight the importance of considering how multiple dimensions of social identity interact and jointly influence how farmers differently experience, manage, and benefit from changes in agricultural practices (Ravera et al., 2016b). We argue for the need for grounded power-sensitive approaches as a first step before any intervention to foster climate change adaptation at the local level.

Conclusion

Bassari agricultural system and management practices are impacted and steered by various stressors, from climate change to increased land-scarcity, increasing monetization of the economic system, and changes in social capital and cultural norms. Bassari farmers are responding to those multiple and simultaneously occurring changes by modifying their farming practices. The analysis of changes in agricultural management practices from a 'sustainable adaptation' perspective (*sensu* Eriksen et al., 2011) and using an intersectional approach shows that not every change can be considered a sustainable adaptation, nor equally beneficial for all social groups.

From these results, we derive two important conclusions. First, changes in agricultural management practices have multiple trade-offs derived from different environmental, social, and economic costs: what in the short-term seems a good adaptation option to one stressor can in fact erode access to important assets and therefore, lower farmers' future adaptive capacity to respond to other stressors. An overemphasis of policies on market demand as the only or most important stressor affecting subsistence farmers may deviate attention from other equally important stressors (e.g., climate change), overall resulting in increased vulnerability. Second, our results offer new empirical evidence about the underlying contextualised factors that shape response options and outcomes for different social groups. The changes in agricultural management practices implemented by Bassari farmers led to benefits for some groups, but to costs to others, increasing the burden of the most vulnerable (i.e., women and poor households). We argue that it is important to include power and gender analysis as a first step for any intervention aiming at fostering local adaptation.

Our arguments aim to put the threats posed by climate change on agricultural systems in the context of the multiple cultural, environmental, political, and economic dynamics that intersect with them shaping the life and practices of smallholder farmers of the Global South. Understanding farmers' adaptation processes in their broader context, paying attention to additional risks, unequally distributed costs, and long-term trade-offs allows us to understand climate change impacts within the lived experiences of local communities, and help design adaptation strategies that efficiently reduce vulnerability to climate change and other impacts. Climate change policies should prioritise long-term and multi-beneficial adaptation measures, while avoiding responses that reproduce existing inequalities and undermine farmers' long-term resilience. Adaptation policies should be designed from a holistic intersectional approach that considers multiple-stressors, trade-offs, and power-dynamics.

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