SAHEL

Moving from Reaction to Action

Anticipating Vulnerability Hotspots in the Sahel

A Synthesis Report from the Sahel Predictive Analytics Project in Support of the United Nations Integrated Strategy for the Sahel

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SAHEL

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The executive summary was developed by UNHCR and PIK drawing on the findings of all submitted contributions (see list of contributors). The introduction (Chapter 1) was compiled by PIK with contributions from adelphi, OSCDS and Uppsala University (ViEWS). Chapter 2.1. on Climate Change was compiled by PIK with contributions from CHC and the Walker Institute. Chapter 2.2. on Food Security was compiled by PIK with contributions from CHC, IPAR and WFP. Chapter 2.3 was compiled by ViEWS with contributions from PREVIEW, UNDESA and UNU. Chapter 2.4 on Displacement and Migration was compiled by PIK together with CUNY/CIDR and DRC with contributions from UNHCR. The report further benefited from a cross-cutting analysis of vulnerability conditions in the Sahel by adelphi, CIDOB and ECDPM. The recommendations outlined in Chapter 3 are a product of the contributions received.

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PREFACE

In January 2021, Secretary General Antonio Guterres appointed me as the UN Special Coordinator for Development in the Sahel. I bear the privilege and responsibility of coordinating the implementation of the UN Integrated Strategy for the Sahel. UNISS was born in 2013 in response to the crisis in Mali and has since evolved to meet the changing needs and priorities of the ten UNISS Sahelian countries. It is implemented through the UN Sahel Support Plan as a way to ensure greater coherence and efficiency in the development agenda of the UN and its partners across this vast, and often troubled, region.

As a child of the Sahel, I am deeply concerned by the many interlinked challenges we are confronted with as a people. These include poverty, underdevelopment, insecurity, and vulnerability to climate change that leave the region prone to conflicts. They weigh heavily on our collective future, and particularly the futures of our talented and dynamic young people.

But these problems are not insurmountable. In my home country of Senegal we have a saying "C'est la pluie qui tombe petit à petit qui remplit le fleuve" (It is the rain that falls little by little that fills the river). We must work together to address the root causes that perpetuate poverty and instability in the region. We need to encourage cross-border cooperation, promote economic revitalization and inclusive growth, tackle climate vulnerability, provide clean energy and empower women and young people.

Doing all this requires a clear-eyed understanding of where we are now and where the trends are leading us. This is why I am delighted to introduce the first synthesis report on the Sahel of the Predictive Analytics project. This unprecedented collaboration, facilitated by our friends at UNHCR, has brought together more than twenty of the finest research organizations and universities to share their information and analysis on the long-term economic, social, political and environmental trends that are shaping the region. This analysis is a work in progress and is far from being the final word on the future of the Sahel. But collectively, this initiative has created a 'river' of data and analysis that will, I hope, provide us with new insights and ideas on how the Sahel can fulfil its great potential.

Our problems are solvable but require extreme commitment and dedication from all. Truly, the best way to get to where you want to be is to know where you are starting from, and to be able to anticipate the hurdles in your path. I entrust this report to you as a small contribution towards that goal.

Mr Abdoulaye Mar Dieye
United Nations Special Coordinator for Development in the Sahel

EXECUTIVE **SUMMARY**

Photo: RSS Secretariat

The Sahel faces mounting human security and development challenges due to the complex interplay of diverse and growing risks in the region, including climate change, environmental degradation, food and livelihoods insecurity, weak governance capacity, conflict and violence, and displacement. To reach the crisis prevention and resilience goals set out in the UN Integrated Strategy for the Sahel (UNISS) and break away from chronic patterns of crisis, we must galvanize existing potential in the region. Decision-making must be better equipped with forward-looking analysis based on integrated data and evidence that incorporates the region's major, cross-cutting issues and trends. Crisis prevention and resilience building is a shared responsibility that demands a wide range of expertise and collaboration across academic, policy and operational actors relevant to humanitarian action, development and peacebuilding. This includes the sharing of data and a range of methodological approaches that provide insight into the complexity of the Sahel as a foundational first step. For this reason, the inter-agency, inter-pillar Sahel Predictive Analytics project was established, from which this report has been produced.

Anticipating Risk Hotspots in the Sahel – a proof of concept

As part of its effort to promote innovation and enhance evidence-based support for sustainable development, the High-Level Committee on Programmes (HLCP) and subsequently the Chief Executives Board for Coordination (CEB) supported the initiation of a pilot cross-pillar inter-agency predictive analytics exercise, facilitated by the Office of the United Nations High Commissioner for Refugees (UNHCR), at the end of 2019. The Sahel Predictive Analytics project brought together a global consortium of leading academic institutions specializing in predictive analytics and strategic foresight approaches[1] to work on the nexus between climate change and other mega trends as factors contributing to new or exacerbated vulnerabilities, conflict, violence and displacement. Seeking to expand and improve current predictive models, the consortium explored how data availability and quality and its use for predictive analytics in the Sahel could be improved through a comprehensive data review process.

During over 50 discussions on data availability with UN system entities, several key data gaps were identified. The pilot thereby provides a proof of concept by demonstrating that unprecedented multi-stakeholder collaboration for data-sharing and good practice can provide much needed insight into the problems many UN system entities and other stakeholders are facing around data-sharing. It also highlights opportunities to work beyond silos for common outcomes and cross-fertilization and could help to identify persistent data gaps and limitations of modelling work. It is the first whole-of-UN system approach of its kind, moving beyond the siloed predictive analytics initiatives of the past.

As a product of the Sahel Predictive Analytics project, this report supports the implementation of the UNISS, the United Nations Sahel Support Plan (UNSP) and the work of the United Nations Special Coordinator for Development in the Sahel. The report was developed, and peer reviewed, by a consortium of agencies and research institutes to guide data-sharing, preparedness and evidence-based decision-making in the face of the growing interconnected risk landscapes in the region. The presented findings will support prioritization of resource allocation and preparedness measures by identifying where multiple risks overlap across the humanitarian-development-peace nexus allowing for well targeted anticipatory and early action. It can further support context analysis, planning, training and capacity-building, while also pointing out where additional data is needed.

The report compiles short-, medium- and long-term predictive analysis based on a range of data sources and methodologies developed from the perspective of different scientific disciplines and organizations. Taken together, they help to identify hotspots of interconnected risks across the region. The report includes promising practices and

1 Predictive analytics entail a variety of statistical and analytical methods to identify trends, patterns, or relationships among data that can then be used to develop models that predict future events or behaviour. Strategic Foresight is an "organizational capacity to gather and process information about the future operating environment, allowing for the creation of various scenarios of alternative, planned and desired futures. While they do not predict the future, foresight tools, methodologies and design processes are able to mine the external political, economic, social, technological and legal environments for trends and developments and leverage those insights to inform and improve decision-making today" (UN Envionment Management Group, 2021).

findings relating to the use of innovative data, predictive analytics and strategic foresight for the Sahel, though it is far from a complete picture of all existing modelling endeavours. The report brings together established modelling approaches across 17 areas and specifically adjusted models to the UNISS Sahel countries on projecting future violence, food security and internal climate migration. It explores possible scenarios for the future of the Sahel and can guide future predictive analytic endeavours from a methodological perspective. It is also intended to be the first iteration of a series of reports and lays the foundations for a continuous process of integrated risk and opportunity assessments and the development of integrated modelling.

The report is structured around four major risks identified as key drivers of vulnerability in the Sahel: (1) climate change, (2) food security, (3) conflict and (4) migration and displacement. For each risk, we provide an overview of the current situation in the region and then provide predictions of how those risks may change in the future under different climate change and development scenarios. We close by outlining strategic recommendations for a structural transformation of the way we work towards increased resilience.

Key insights for the future of the Sahel

Climate - The Sahel is projected to experience above average temperature increases and increasing climate extremes.

- In line with the findings from the Intergovernmental Panel on Climate Change (IPCC), models show that rising temperatures and more extreme weather conditions pose existential challenges to the Sahel region.
- Models project a temperature rise between 2.0 to 4.3°C by 2080 compared to pre-industrial levels, with higher temperatures and more temperature extremes projected for the northern part of the region.
- While precipitation trends have a higher uncertainty and spatial variability due to the yearly natural variability of rains, a projected annual precipitation increase of

Photo: UNDP Mali

up to 16mm by 2080 is likely across the region.
- Future wet and dry periods will likely become more extreme and the number of days with very hot temperatures or heavy rainfall will rise sharply.
- Projections indicate that a fifth of the population in the Sahel might be affected by at least one heatwave per year by 2080, leading to a fourfold increase of heat-related mortality.

Food Security - Intensifying climate impacts combined with socioeconomic factors could lead to aggravated food insecurity, resource scarcity and a deprivation of livelihoods, especially in rural areas.
- In the Sahel, the agricultural sector employs a majority of the population, creating a strong dependence of livelihoods and food security on weather trends and environmental conditions. Pressure on land due to rapid population increase, agricultural extensification and intensification, overgrazing, overcultivation and deforestation have resulted in land degradation and desertification. These developments have contributed to severe food insecurity affecting millions.
- Short-term predictions highlight that large parts of the Sahel already experience crisis levels of food insecurity, with some parts even reaching emergency levels.
- In the long term, yields of maize, millet and sorghum are projected to decline due to climate change across the region, putting even more pressure on already vulnerable rural populations.
- These trends show large differences between and within the countries. South-western Mali is projected to face a decrease of up to 17 per cent in millet and sorghum yields by 2080, while the eastern part of the country, as well as parts of southern Niger, could see increases of up to 55 per cent. Changes at local level will have major implications on the livelihoods of affected smallholder farmers, who will need to adapt to those changes to ensure continued agricultural production and secure their livelihoods.
- Water availability per capita is projected to decline drastically by up to 77 per cent until 2080 compared to 2000. This change is mostly driven by socioeconomic factors such as population growth and increased agricultural production, though climate change impacts will also play a role.

Conflict - Violence is expected to continuously erupt across the region unless the complex and interrelated key drivers of conflict are addressed and resilience to climate extremes is strengthened.
- Four groups of key conflict drivers are identified: conflict legacy, demographic dynamics and socioeconomic factors, poor governance and lastly societal vulnerability to climate extremes and other exogenous shocks.
- Strong feedback loops between climate change impacts and drivers of conflict are proven, in particular with poor governance, which enhances the risk of recruitment by armed groups and contributes to new or exacerbated violence.
- Throughout 2022, countries with the highest numbers of conflict fatalities in the past years, namely Nigeria, Mali, Burkina Faso, Niger, Cameroon and Chad, are projected to continuously face very high risks of conflicts.
- Senegal, Guinea, Mauritania and the Gambia, characterized by their relatively peaceful and stable situations, are likely to remain at a lower risk of conflict over the next year.
- Without transformative action targeting the key complex and interconnected drivers of conflict, armed conflict will continue to plague the region for years and most likely even decades.

Human Mobility - While climate change and conflict are expected to increasingly drive displacement and migration in the short- and long-term, some of the most vulnerable groups also face the risk of becoming trapped.
- The cumulative impact of both climatic and non-climatic shocks on households drives displacement and migration in the Sahel.
- Short-term projections show that displacement caused by conflict and persecution in the Sahel is likely to

increase to 8.9 million by the end of 2023, marking an increase of 1.4 million people compared to 2021. The increase will be driven by the major displacement crises in Nigeria, Cameroon and Burkina Faso, but also significant growth in displacement in Mali, Niger and Chad.
- People forced to leave their homes, due to conflict and weather-related hazards, face deteriorated living conditions and increased vulnerability. Refugee sites and settlements for internally displaced people are disproportionately concentrated in regions that are exposed to higher than average warming and climate hazards, including temperature extremes, flooding and drought.
- The intensifying severity of climate change impacts and environmental degradation, combined with the lack of alternative coping strategies in many communities in the region, is likely to decrease the agency of people to develop adaptive capacities, including migration.
- While safe and orderly migration can be a successful adaptation strategy for climate impacts and other shocks, migration outcomes differ substantially with some populations pushed into poverty spirals.
- In addition, socioeconomic impacts of climate change can lead to a further increase in the number of people who are trapped. Individuals who regularly migrate as a household diversification strategy may be more likely to become involuntarily immobile as the resources necessary to invest in migration dwindle. Trapped households and communities are usually marked by high vulnerability to climate impacts.

Data - The lack of available and accessible data is limiting predictive capacities for the Sahel.

- Data availability and accessibility in the region is hampered due to the lack of a data-sharing culture.
- There are large gaps in temporal and spatial coverage of available data as data collection efforts are often limited to one-off surveys or to specific regions. While such data compilations are often sufficient to inform singular qualitative studies, predictive analytics projects require a large amount of data points, with entries collected in a systematic and uniform manner, to adequately train and calibrate forecasting models.
- Due to a lack of standardization in data management, consistency in data gathering is compromised. There are differences in survey methodologies and definitions across regions that make it difficult to collate and compare data.
- The identified issues are not specific to the Sahel but a representation of the general challenges in the data landscape for predictions.

Strategic recommendations

This report shows that it is possible to anticipate short-, medium- and long-term changes in climate, food security, conflict and human mobility, which can help to identify existing and emerging risk hotspots before they escalate. Strategic foresight and subsequent advance planning for future risks is key to move away from reactive responses towards proactive decision-making and resilient development. Based on the projections and analyses conducted as part of this report, drawing from the comprehensive data review process and in close consultation with various stakeholders and experts, strategic recommendations were developed that can be clustered into three broad topics: (1) adaptation, (2) governance and (3) data availability and quality:

- **Regional and international collaboration needs to be enhanced to improve data availability and quality in order to build upon and improve predictions and foresight.** Aligned with the United Nations Secretary-General's Data Strategy, a culture of transparency, proactive collaboration, reinforcement of national and subnational statistical capacities, data standardization and data-sharing must be instilled. Some of the identified issues in data management will require administrative and governance solutions, such as a method for streamlining and simplifying data-sharing processes. Others will require methodological and organizational interventions in future data collection efforts, such as a greater consistency in temporal and geographic coverage and methods used by various organizations. Profound knowledge on predicting food insecurity, crop yields, changing weather patterns and existing inter- and intra-group conflicts will support humanitarian responses, sustainable development and protection in the Sahel.

- **Increasing investments in local capacity-building and context-specific long-term adaptation measures across the Sahel, in particular in the agricultural and livestock sectors, is essential in order to promote resilient livelihoods and enhance food security as a mitigator of future conflict and displacement.** To drive meaningful change towards durable peace and prosperity in the Sahel, governments must address structural and governance issues while making a concerted effort to build local and national capacity to enhance societal resilience to climate extremes and other exogenous shocks. This can be supported by strengthening cooperation across borders and with inputs from all sectors of the community, including women, youth, indigenous people, people with disabilities, displaced persons and other potentially marginalized groups. Multidisciplinary research can generate knowledge on new and best placed approaches to climate adaptation and thus enables the development of preventive approaches. Overall, climate change adaptation measures need to be mainstreamed in regional, national and local policies and programmes, as well as in international cooperation projects and efforts to implement UNISS.
- **Strengthening good governance practices is key to handling the interrelated risks from climate change, demographic pressure and violence in the region.** For enhanced preparedness and the implementation of ambitious policies without widespread social unrest, it is essential to have good governance, equal distribution of benefits and the protection of civil liberties. The rule of law must be strengthened, including customary and traditional justice systems, particularly where they relate to the coherence of rules that govern access to land and land tenure security. Moreover, the inclusivity of public institutions and social networks must be enhanced to foster greater representation of marginalized groups. Enhancing collaboration through area-

Photo: UNDP Mauritania

based approaches can strengthen local governance, which is a central element to enhance trust between a state and its population.

Notwithstanding the above risks and bottlenecks, the Sahel is a promising region with considerable natural, cultural and human resources. Predictive analytics can be an instrument in supporting the sustainable use of these resources for human progress.

The Sahel sits on one of the largest aquifers in Africa. With appropriate investments, including solar powered pumps and enhanced water management, these significant groundwater resources could especially benefit water stressed rural populations. The region further holds great potential for ecological restoration. The process of regreening has already started and, according to the United Nations Convention to Combat Desertification (UNCCD), tree coverage has improved in many areas over the past years (UNCCD, 2021; UNCCD, n.d.). This is a clear sign of the vast potential to restore land productivity and biodiversity via resilient and sustainable agricultural and livestock practices. In addition, the Sahel has an immense productive potential for renewable energy including abundant solar energy capacity. Only 49 per cent of the Sahelian population has access to electricity and only 12 per cent access to clean cooking (IEA et al., 2021) which provides enormous opportunities not only for renewable energy markets but also to improve health, protection, education and livelihoods. Moreover, the region can profit from a dynamic young population that can serve as a vital vector for development. Around 64 per cent of the Sahelian population is less than 25 years old, making it one of the most youthful regions worldwide (UNDESA, 2021). This demographic dividend is and should be mirrored and considered in employment, education and training programmes in order to maximize young people's potential, including their human agency, innovation and entrepreneurial spirit.

It is thus crucial to strengthen inter-agency cooperation and use the best available science to instil an ethos of anticipation and preparedness that builds on these assets to guide a structural transformation, and a new narrative, within and for the Sahel.

Interplay of Risks in the Sahel

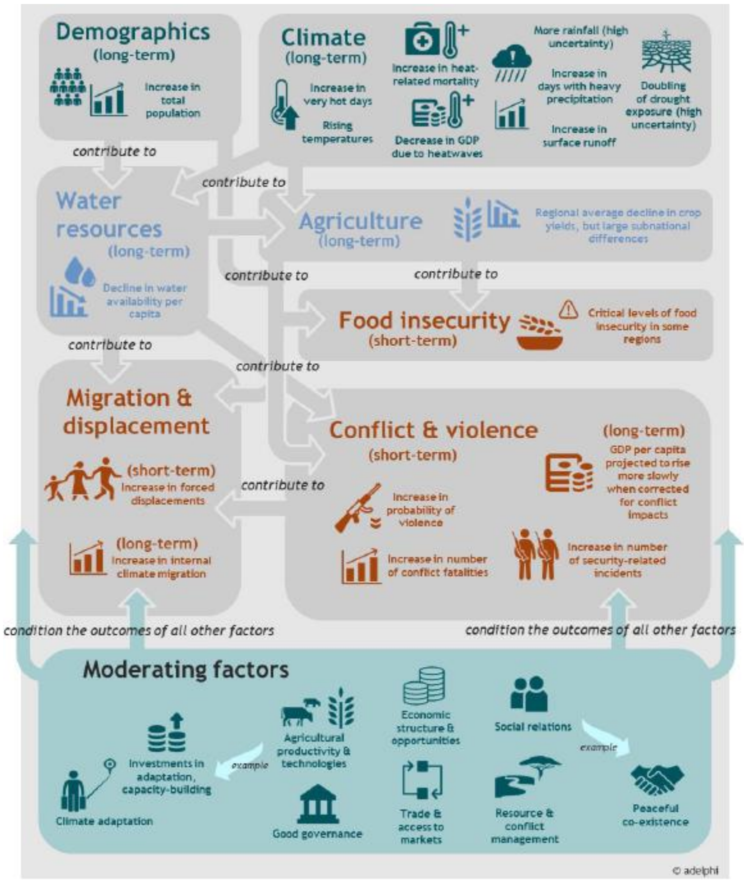

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Photo: UNDP Mauritania

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Abbreviations

ACLED	Armed Conflict Location and Event Data Project
CCSA	Committee for the Coordination of Statistical Activities
CEB	United Nations System Chief Executives Board for Coordination
CHC	Climate Hazards Center
CIDOB	Barcelona Centre for International Affairs
CIDR	City University of New York Institute for Demographic Research
CIESIN	Center for International Earth Science Information Network
CILSS	Interstate Committee for Drought Control in the Sahe
CMIP	Coupled (Climate) Model Intercomparison Project
CSU	Colorado State University
CUNY	City University of New York
DGAP	German Council on Foreign Relations
DRC	Danish Refugee Council
ECDPM	European Centre for Development Policy Management
ECOWAS	Economic Community of West African States
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FFO	German Federal Foreign Office
GCMs	Global Climate Models
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HDI	Human Development Index
HLCP	United Nations High-level Committee on Programmes
HRP	Humanitarian Response Plan
IDMC	Internal Displacement Monitoring Centre
IDP	Internally Displaced Person
IFORD	Institut de Formation et de Recherche Demographiques
IMF	International Monetary Fund
ISIMIP	Inter-Sectoral Impact Model Intercomparison Project
IPCC	Intergovernmental Panel on Climate Change
IPAR	Initiative Prospective Agricole et Rurale
IRIS	International Recommendations on Internally Displaced Persons Statistics
IRRS	International Recommendations on Refugee Statistics
ND-GAIN	Notre Dame Global Adaptation Initiative
NGO	Non-Governmental Organization
NPP	Net Primary Productivity
OECD	Organisation for Economic Co-operation and Development
OSCDS	United Nations Office of the Special Coordinator for Development in the Sahel
PA	Predictive Analytics
PIK	Potsdam Institute for Climate Impact Research
PREVIEW	Predictions-Visualisation-Early Warning team
PSP	Participatory Scenario Planning
PVCCI	Index of Physical Vulnerability to Climate Change
RCP	Representative Concentration Pathway
SSP	Shared Socioeconomic Pathway
UCDP	Uppsala Conflict Data Program
UNCCD	United Nations Convention to Combat Desertification
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNECA	United Nations Economic Commission for Africa
UNHCR	United Nations High Commissioner for Refugees
UNISS	United Nations Integrated Strategy for the Sahel
UNSC	United Nations Statistical Commission
UNSP	United Nations Sahel Support Plan
ViEWS	Violence Early-Warning System at Uppsala University
WACAFI	West Africa Context Analysis and Foresight Initiative
WASCAL	West African Science Service Centre on Climate Change and Adaptive Land Use
WMO	World Meteorological Organization
WRSI	Water Requirement Satisfaction Index

INTRODUCTION

Photo: RSS Secretariat

The objective of this report is to support UNISS in enhancing data-driven and evidence-based anticipatory action, in order to better respond to the growing interconnected risk environment in the Sahel. It provides guidance for enhanced coordination around data and outlines strategic recommendations resulting from the predictive modelling analysis for policymakers.

This report synthesizes predictive analytics[2] and strategic foresights[3] from a total of 12 contributions, received through the Sahel Predictive Analytics (PA) project. This is a research consortium, facilitated by the UN Refugee Agency (UNHCR), consisting of 19 world-leading organizations that unite best practices in predictive modelling from different scientific disciplines. Each contribution focused on a specific research area - such as climate impacts, natural resources, human security, livelihoods and human mobility - and provided predictive analysis to anticipate trends in the Sahel. The Sahel PA project thereby aims to guide data-sharing, preparedness and evidence-based decision-making at the policy level.

Predictive analysis allows the exploration of different scenarios for the future development of specific sectors, making it a strategic tool to answer "what if?" questions. It can point out the role of different variables as drivers for trends, such as the influence of a changing climate on yields, or the impact of conflict legacy on the likelihood of future conflict. Understanding how current trends may influence possible future scenarios allows for anticipatory, targeted and timely action. However, predictive modelling and analysis bear some limitations. Past and present trends cannot predict the future with certainty, as new and unexpected events may influence future pathways. Sudden onset, high-impact events, such as an unexpected political turnover or a disaster, are generally hard to predict or factor into long-term projections.

2 Predictive analytics entail a variety of statistical and analytical methods to identify trends, patterns or relationships among data that can then be used to develop models that predict future events or behaviour (Nyce, 2007).

3 Strategic Foresight is an "organizational capacity to gather and process information about the future operating environment, allowing for the creation of various scenarios of alternative, planned and desired futures. While they do not predict the future, foresight tools, methodologies and design processes are able to mine the external political, economic, social, technological and legal environments for trends and developments and leverage those insights to inform and improve decision-making today." (UN Environment Management Group, 2021).

Yet, even when recognizing that we cannot know everything, modelling and projections enable policymakers to consider alternative futures and plan more strategically.

This report is structured around four major risks identified as key drivers of vulnerability in the Sahel: (1) climate change, (2) food security, (3) conflict and (4) displacement. Each chapter first explains the current risk situation, followed by predictions on how these risks are projected to evolve in the coming years and decades. The report highlights the interconnectedness of different key drivers of vulnerability and gives concrete policy recommendations on how to address the growing risk landscape and improve anticipatory action along the humanitarian-development-peace nexus in the region.

1.1 The Sahel

The Sahel, forms a natural border between the Sahara Desert to the north and the tropical savannas to the south. The region spans 5,900 km from the Atlantic Ocean in the west to the Red Sea in the east (United Nations, 2021). As summarized by Biasutti (2019) "The name Sahel refers to the semi-arid region stretching longitudinally from Senegal in West Africa to Sudan and Ethiopia in East Africa and latitudinally from just north of the tropical forests to just south of the Sahara desert (roughly between 10 ° and 20 °N)." However, there is no universally defined list of countries of the Sahel.

The ten Sahelian countries considered in this report include Burkina Faso, Cameroon, Chad, the Gambia, Guinea, Mali, Mauritania, Niger, Nigeria and Senegal, in accordance with UNISS (see Figure 1).

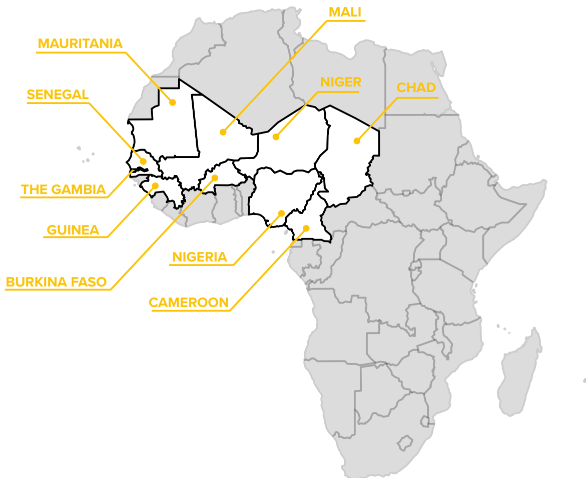


Figure 1: The 10 Sahelian countries in accordance with the UNISS

These countries share long-standing cultural and political linkages and intrinsically interconnected socioeconomic, political and security dynamics (Day & Caus, 2019).

As Sahel economies are highly reliant on farming and pastoralism, livelihood and food security is strongly linked to weather trends and environmental conditions (Crawford, 2015). In the past years, changes to the ecosystem have fuelled a food scarcity crisis and competition over resources, putting millions of people at risk of food insecurity (Day & Caus, 2019). Dependence on livestock and agriculture makes approximately 50 million people in the Sahel highly vulnerable to the impacts of climate change.

These risks have been amplified by recurrent disasters over recent decades. Niger and Mauritania, for instance, are among the top 10 countries with the highest share of the population affected by natural hazard-related disasters between 2000 and 2019 (CRED & UNDRR, 2020). Desertification and shifting rainfall patterns have altered the routes of cattle-herding communities, bringing them across farmland during the harvest season. This has provoked violent clashes between herdsmen and farmers, especially in countries such as Nigeria, Mali and Burkina Faso (Day & Caus, 2019; Udeh, 2018). In addition, weak government capacity and the fact that areas of the Sahel continue to be afflicted with corruption restrict the ability of Sahelian states to invest in climate adaptation.

Meanwhile, temperatures in Africa are projected to rise faster than the global average increase during the 21st century (Niang et al., 2014). Accordingly, the University of Notre Dame Global Adaptation Index (ND-GAIN) ranks all 10 Sahel countries amongst the countries most vulnerable to climate change and least ready to adapt to it, with Chad ranking lowest globally (see Figure 2).[4]

Socioeconomic situation and demographics

Sahelian countries are home to a very young population with an increasing life expectancy, high levels of fertility and population growth rates (UNDESA, 2019), even though mortality

4 At the time of writing, out of 182 countries, the ND-GAIN Country Index provides the following rankings: Senegal (132), Mauritania (140), Guinea (144), Cameroon (145), the Gambia (145), Burkina Faso (158), Nigeria (161), Mali (170), Niger (176) and Chad (182). Source: University of Notre Dame, 2021.

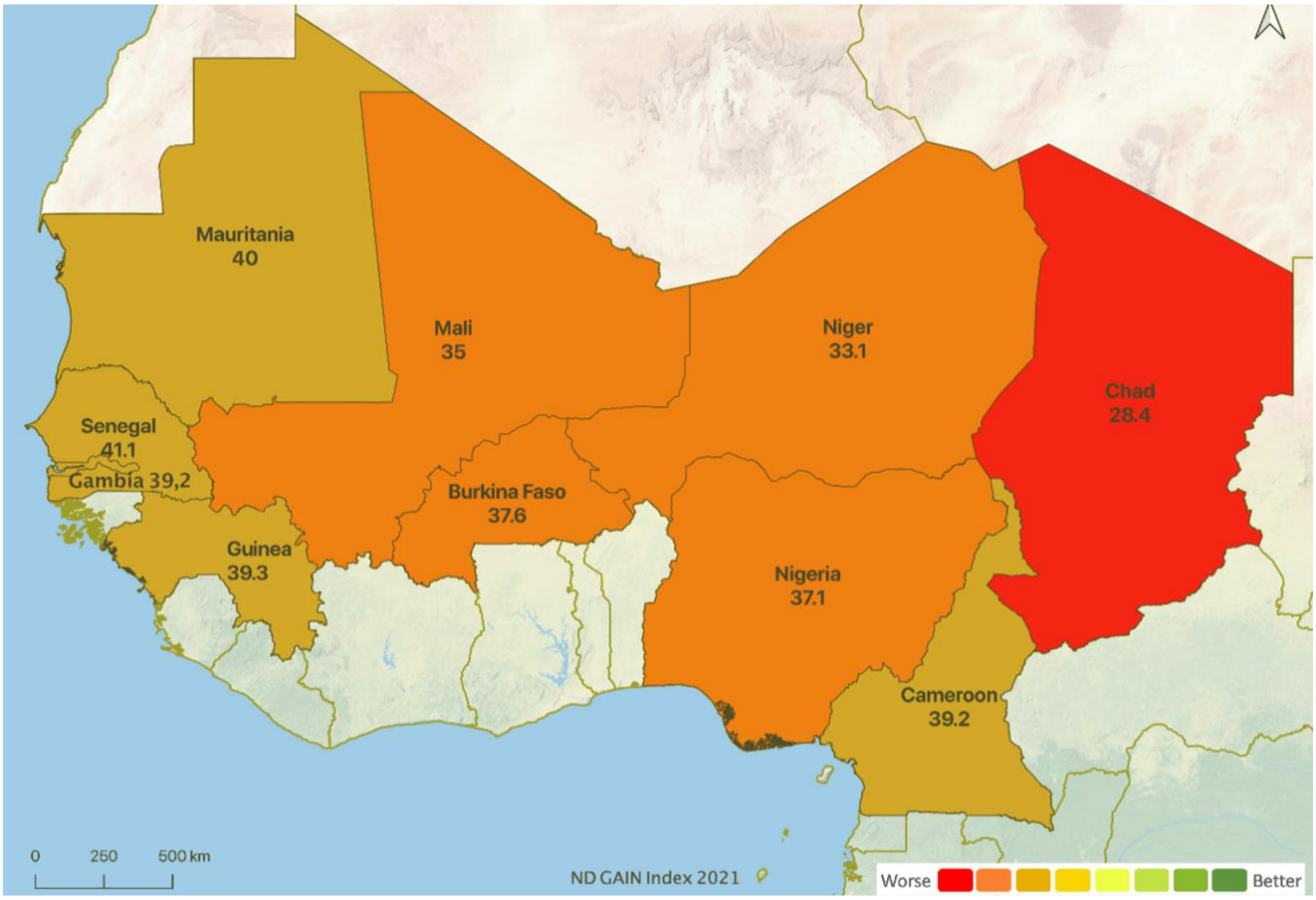


Figure 2: ND-Gain Country Index captures a country's vulnerability to climate change combined with its readiness to improve resilience. The index ranges from one (most vulnerable, least ready) to 100 (least vulnerable, most ready) with 28.4 being the lowest value addressed to a state (Source: University of Notre Dame, 2021).

rates of children under five remain relatively high (World Bank, 2019a). The total population stood at 351 million in 2020, with Nigeria being the most populous country with 206 million inhabitants. Considering that annual population growth rates ranged between 2.5 per cent and 3.8 per cent in 2020, the total population is projected to grow to 455 million in 2030 and 712 million in 2050. While fertility has been declining throughout the region, current national levels of total fertility are still high, ranging from 4.4 to 6.8 births per woman. As a result, the UNISS countries have relatively youthful populations. About 44 per cent of the population is below 15 years of age, around 64 per cent is less than 25 years old and only about 4 per cent is aged 60 years or above. By comparison, 25 per cent of the global population in 2020 was below the age of 15, 41 per cent below the age of 25 and 13 per cent above the age of 60. Current estimates of life expectancy at birth range from 55 years in Chad to 68 years in Senegal (UNDESA, 2019).

Apart from a recent general economic recession due to the COVID-19 pandemic, the region is marked by steady economic growth. The economic growth rate varies widely within the region and gross domestic product (GDP) per capita covers the spectrum from $565 in Niger to $2,091 in Nigeria (World Bank, 2021a). The overall economic growth rate in the Sahel is higher than the continental average and is based on the export of primary goods (Day & Caus, 2019). Nonetheless, people in the Sahel are affected by multiple interrelated crises. The economic growth has not been inclusive and, together with rapid population growth, has not led to improvements in living standards or more resilience. In particular, the rural areas in the northern regions of the Sahel have not been able to benefit from this growth and lack access to social services and basic infrastructure (Day & Caus, 2019). Countries of the Sahel are almost uniformly categorized as “least developed” by the UN, based on low per capita income, poor health and education indicators and high economic vulnerability to shocks (UNDESA, 2021). Nearly 50 per cent of the region lives in extreme poverty (Day & Caus, 2019; World Bank, 2021b). The states of the Gambia and Cameroon represent exceptions since only a relatively small proportion of the population,


Photo: RSS Secretariat

10 per cent and 26 per cent respectively, live in extreme poverty (World Bank, 2021b). Instability, poverty, violence, corruption and unequal access to resources are among the main factors limiting human development in the region. Sahelian countries rank among the lowest scoring countries on development indices, such as the HDI and the Gender Development Index (UNDP, 2020).

At the macroeconomic level, the countries of the Sahel are mainly characterized by low economic diversification and low levels of productivity and competitiveness in regional and global markets (UNECA, 2019). About two-thirds of the population relies on agriculture, fishing and pastoralism for livelihoods, with nearly no diversification of income sources (Heinrigs, 2011). The agricultural sector employs more than 70 per cent of the population in Mali and Niger and more than four-fifths of the population in Burkina Faso. Even though agriculture contributes greatly to the GDP in the region, it has remained rudimentary at the subsistence level (CASCADES, 2021).

Even though the region faces several drivers of risks to national and regional stability, there is great potential for sustainable growth as well. Seven out of 10 countries have seen improvements in governance over the past decade (Mo Ibrahim Foundation, 2020) and all countries have improved their HDI over the past decade (UNDP, 2020). With abundant natural resources, including a great capacity for renewable energy and rapidly growing societies, a more stable Sahel region offers tremendous potential. On the other hand, if conflicts in the region continue to fester and institutions lack the integrity and capacity to provide for good governance, the challenges to already vulnerable populations will mount (Day & Caus, 2019).

Security and the humanitarian situation

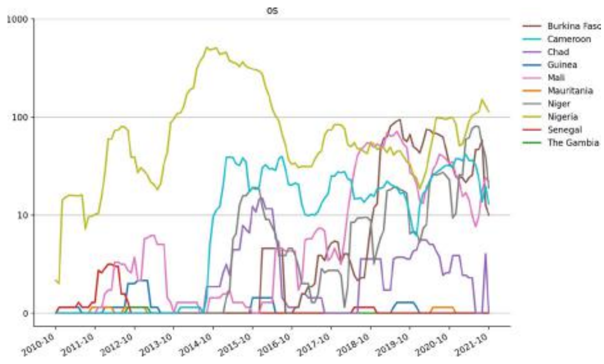
In the past decades, the Sahel region has been among the most violent areas in Africa, experiencing conflicts, political crises, communal violence and violent extremism. These conflicts are increasingly unfolding in an overall fragile and unstable institutional context. The 2011 collapse of the Libyan regime and subsequent armed uprisings in northern Mali have created a surge in armed activity across many parts of the Sahel, fuelled by massive flows of weapons and the movement of armed groups into the region (Koné, 2020). Porous national borders have allowed international criminal groups to spread in the region and establish vast trafficking networks (Day & Caus, 2019).

In general, the failure of state institutions to adequately serve marginalized populations has been a driving cause behind armed insurgencies and violent extremism (Day & Caus, 2019; Hegre & Nygård, 2015; Nett & Rüttinger, 2016; Raineri, 2018). Armed Conflict Location and Event Data (ACLED) show that abuses by government forces are inherent to prevailing conflict dynamics in the central Sahel, and these actors routinely commit atrocities with impunity (Nsaibia, 2020).

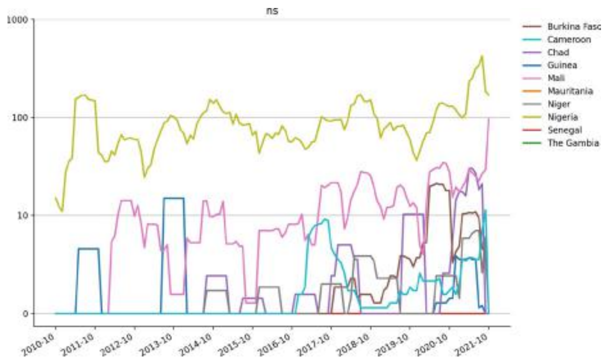
While non-state conflicts, such as between farmers and herders, have been present in the Sahel for centuries, the proliferation of weapons and involvement of political elites and armed groups have made these communal conflicts more violent and deadly in recent years, as illustrated by Figure 3c, especially in Burkina Faso, Mali, Niger and Nigeria (Nsaibia & Duhamel, 2021). Historical grievances and social inequalities, as well as incongruous or biased rules for governing the access to resources, are important factors underpinning communal violence in the Central Sahel (CASCADES, 2021).

Violent extremist groups, such as Al Qaeda in the Islamic Maghreb (active across parts of Mauritania, Mali and Niger) and Boko Haram (active in Nigeria and the Lake Chad Basin), have in turn exploited local grievances and social inequalities (Day & Caus, 2019; Faleg &

(a) State-based violence



(b) One-sided violence



(c) Non-state violence

Figure 3: Conflict history for three different types of political violence by number of fatalities

Note: Trends in monthly fatalities due to organized political violence over 2010–2021, log scales. The lines have been smoothed for legibility. See Chapter 2.3 for definitions and more information. Source: UCDP 21.0.3 (global), adapted for the report.

Mustasilta, 2021). This has contributed to the high number of fatalities from armed conflicts involving a government of a state (state-based conflicts) and violence perpetrated by an armed actor against unarmed civilians (one-sided violence) in Nigeria, Niger, Burkina Faso and Cameroon in recent years (see Figure 3a-b).

The Sahel has traditionally been characterized by high levels of human mobility, in particular seasonal and circular migration as a means to secure livelihoods and cope with weather conditions. Such mobility includes nomadism, transhumance, rural-urban migration and temporary migration to neighbouring countries (CASCADES, 2021). As a result of widespread insecurity and socioeconomic pressure, much of the region - excluding Mauritania, Guinea, the Gambia and Senegal - has experienced large-scale displacement, which has risen progressively in recent years (see Figure 4). By the end of 2021, over 6.5 million Sahelians were internally displaced by conflicts and hundreds of thousands were seeking shelter outside their country of origin. The ten Sahelian countries host over 1.5 million refugees (UNHCR, 2021). Most internally displaced persons (IDPs) are clustered along the border areas of Niger, Chad and Nigeria, or in the Liptako Gourma region, which includes regions of Burkina Faso, Mali and Niger. The impact of population movements is often felt most acutely along the borders of countries, where weak state capacity meets cross-border violence and transnational illicit flows (Day & Caus, 2019).

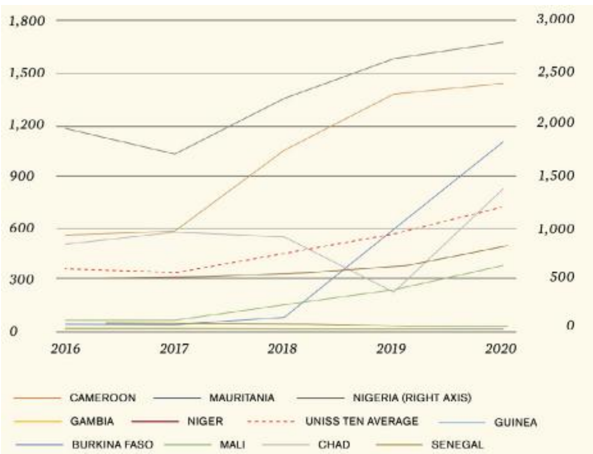


Figure 4: Total displacement across the ten UNISS countries from 2016-2020 (per thousand, Sources: UNISS, UNHCR and IDMC).

1.2 The need for anticipatory planning

To reach the goals set out in the UN Integrated Strategy of the Sahel, it is essential to move away from the largely reactive approach the UN, governments and other stakeholders have taken in the region so far. Rather we must move towards a forward-looking, evidence-based and risk-informed development pathway, along the humanitarian-development-peace nexus, that is able to address the growing multi-causal risks in the region.

UNISS and UNSP

The UN Integrated Strategy for the Sahel (UNISS) was developed in 2013 in response to the Malian crisis and aims to tackle the structural problems of the Sahel that make

Figure 5: Linkages between the three UNISS pillars and UNSP priority areas (Source: UNISS)

the region vulnerable to conflicts, such as poverty, underdevelopment and governance challenges. The strategy covers the period 2018-2030 and promotes an integrated and regional approach to the activities of the UN and key actors in the Sahel, to tackle the problems and bring greater coherence to broader international interventions in the region. It targets 10 countries, namely Burkina Faso, Cameroon, Chad, the Gambia, Guinea, Mali, Mauritania, Niger, Nigeria and Senegal, and aims to help implement identified priorities to achieve the 2030 Agenda for Sustainable Development and the African Union Agenda 2063.

In 2018, the implementation of the UNISS was given greater impetus through the UN Sahel Support Plan (UNSP) – an operationalization instrument aimed at promoting coherence and coordination for greater efficiency and the achievement of results within the framework of the UNISS. The UNISS and UNSP are interlinked around three specific pillars and priority areas (see Figure 5).

In response to Member States' call for strengthened collective and integrated engagement across the Sahel region[5], the Secretary-General appointed a Special Coordinator who leads collective efforts, including financing, to implement the UNISS and its Support Plan for a scaled-up UN development response for the Sahel. Since January 2021, Mr. Abdoulaye Mar Dieye of Senegal has acted as the Special Coordinator

5 Security Council Resolution 2391 (2017) and the ECOSOC Resolution 2020/2.

for Development in the Sahel.

In line with the UNISS and UNSP, the United Nations Economic Commission for Africa (UNECA) prepared a study, entitled 'Sahel 2043: towards a resilient, inclusive and prosperous Sahel region' (2019), that provides a comprehensive, forward-looking strategic orientation to build national and international partners' effectiveness towards the structural transformation agenda of the Sahel (UNECA, 2019).

The Sahel Predictive Analytics project

In support of the UNISS, the UNSP and the UN Special Coordinator for Development in the Sahel, the Sahel PA project seeks to increase the preparedness of the UN system and other key stakeholders in the region to respond to growing multi-causal and interconnected risks and challenges in the Sahel. It helps to unite predictive modelling, strategic foresight and machine learning techniques that show where risk hotspots are likely to emerge in the Sahel, with particular attention to how climate change and disasters may contribute to new or exacerbated risks in these areas. To exemplify, climate change often acts as a vulnerability multiplier, exacerbating other risk factors such as tensions over already scarce resources or the limited access to livelihoods. It is this complex interplay of risks that makes the use of early action even more important.

The project further addresses the need for improved data-sharing and accessibility and brings together data owners with modelling experts. This helps facilitate information-sharing within the UN system and across research institutes and ultimately helps to avoid duplication of efforts. The project is grounded in the belief that science plays a critical role in guiding decision-making. It is the first "whole-of-United-Nations-system" approach of its kind, going beyond siloed predictive analytics initiatives developed by different organizations. The Sahel PA project is in line with the System-wide Road Map for Innovating UN Data and Statistics and the UN Secretary-General's Data Strategy.

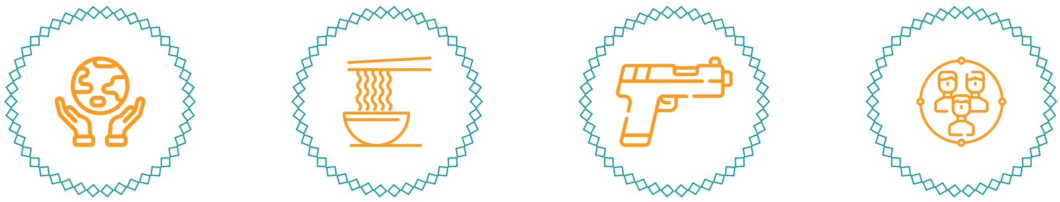
The first seed of the Sahel PA project was planted in October 2019, during the 38th session of the UN High-level Committee on Programmes (HLCP). Member organizations discussed innovative ways to enhance data-driven and evidence-based support for sustainable development and called for the establishment of a cross-pillar, inter-agency project on predictive analytics. The Sahel PA project launched in February 2020 under the coordination of the Office of the Special Advisor on Climate Action at UNHCR and with the Sahel region selected as a pilot. UNHCR first held consultations with UN entities, academic institutions, non-governmental organizations (NGOs) and private sector research institutions to understand the needs and challenges for predictive analytics in the Sahel. Exploratory research affirmed that responsible data-sharing was still not common practice in the UN system, with data and statistics remaining dispersed across and within organizations. Huge data gaps and standardization issues were common, as data formats, indicators and general management processes lacked consistency. The Sahel region has no centralized data repository that unites humanitarian, development, peacebuilding and security information.

The partner organizations of the Sahel PA project are adelphi, the Climate Hazards Center (CHC) at University of California Santa Barbara, the Barcelona Centre for International Affairs (CIDOB), the Center for International Earth Science Information Network at Columbia University (CIESIN), Colorado State University (CSU), Institute for Demographic Research (CIDR), Danish Refugee Council (DRC), German Council on Foreign Relations (DGAP), European Centre for Development Policy Management (ECDPM), Institut de Formation et de Recherche Démographiques (IFORD), Initiative Prospective Agricole et Rurale (IPAR), Potsdam Institute for Climate Impact Research (PIK), the Prediction-Visualisation-Early Warning team (PREVIEW) at the German Federal Foreign Office (FFO), United Nations Department of Economic and Social Affairs (UNDESA), United Nations University Centre for Policy Research (UNU-CPR), University of Kassel, the Violence Early-Warning System (ViEWS) project at Uppsala University, Walker Institute at the University of Reading, and the West African Science Service Centre on Climate Change and Adaptive Land Use (WASCAL).

CURRENT AND PROJECTED **RISKS**

Photo: UNDP Nigeria

The following chapter explains the current and future risks identified as the four key drivers of vulnerability in the region:



Climate Change (Including Environmental Degradation)

Food Security

Conflict

Migration and Displacement

Each sub-chapter is based on a combination of in-depth analyses conducted by the project consortium partners as part of the Sahel PA project, highlighting the interconnectedness and cascading effects of these risks.

BOX 1: SHARED SOCIOECONOMIC PATHWAYS (SSPS) AND REPRESENTATIVE CONCENTRATION PATHWAYS (RCPS)

The future emissions scenarios used in this report are based on the standard set of future scenarios used in the IPCC framework.

Different emission scenarios are grouped and represented by the seven Representative Concentration Pathways (RCPs), which are defining a radiative forcing[6] achieved in 2100 (see Figure 6). The RCPs are labelled after the additional radiative forcing level reached in the year 2100 relative to pre-industrial times (+1.9, +2.6, +3.4, +4.5, +6.0, +7.0 and +8.5 W/m2, respectively) (Van Vuuren et al., 2011). RCP2.6 represents the low emissions scenario assuming that through strong policy intervention, greenhouse gas emissions are reduced drastically, keeping global warming well below 2˚C. RCP6.0 represents a medium to high emissions scenario. RCP8.5 assumes more or less no interventions and thus undiminished emissions.

Shared Socioeconomic Pathways (SSPs) outline a narrative of potential global futures, including estimates of broad characteristics such as country-level population, GDP or rate of urbanization (see Figure 7). Five different SSPs outline future realities according to a combination of high and low future socioeconomic challenges for climate mitigation and adaptation. SSP1 envisions an optimistic trend for human development with substantial investments in health, education, well-functioning institutions and economic growth and, at the same time, a shift towards sustainable practices. SSP3, on the contrary, shows a pessimistic development trend with increasing inequalities and prioritization of regional security. SSP2 represents the “middle of the road” pathway (O’Neill et al., 2017).

6 Radiative forcing is the change in energy flux in the atmosphere caused by natural or anthropogenic factors of climate change as measured by watts / $metre^2$ (IPCC, 2013).

Note: No uncertainty ranges are shown and reported, as to create the recommendation datasets for CMIP5, central estimates have been assumed closely in line with central estimates in IPCC AR4. Taken from Meinshausen et al. (2011).

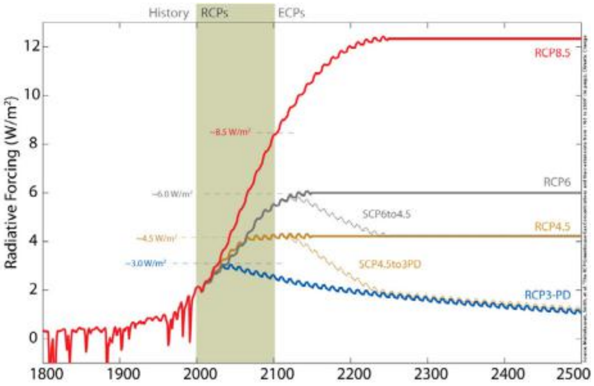


Figure 6: Global Anthropogenic Radiative Forcing for the high RCP8.5, the medium-high RCP6, the medium-low RCP4.5 and the low RCP3-PD.

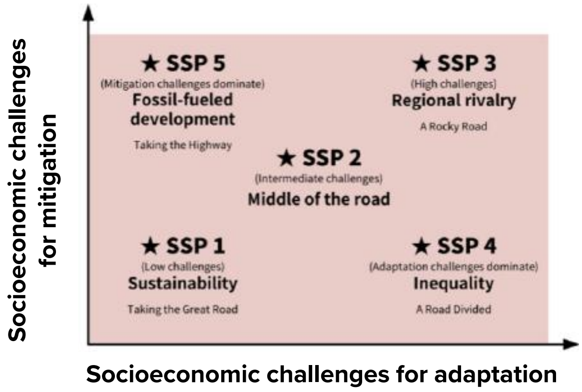


Figure 7: The SSPs of the IPCC guided scenario set (Source: O'Neill et al.,2016

2.1 Climate Change

The Sahel is a semi-arid region acting as a zone of transition between the Sahara Desert to the north and tropical savannas to the south. As shown in Figure 8, it comprises several, quite diverse agro-ecological zones, which divide the Sahel into latitudinal sections, moving from a mainly arid climate in the north to a more humid climate in the south. The northern part, covering most of Mauritania, Mali, Niger and Chad is dominated by arid-warm tropics with little to no rain throughout most of the year. Subsequently, most parts of Senegal, the Gambia and Burkina Faso, as well as the south of Mali, Niger and Chad and the north of Nigeria are characterized by a semi-arid warm tropical climate with a pronounced dry-wet seasonality. Below that, sub-humid to humid warm tropics dominate the climates of Guinea, the south of Burkina Faso, Nigeria and Cameroon. Here, rainfall is abundant, standing in stark contrast to the northern parts of the Sahel, where water is extremely scarce.

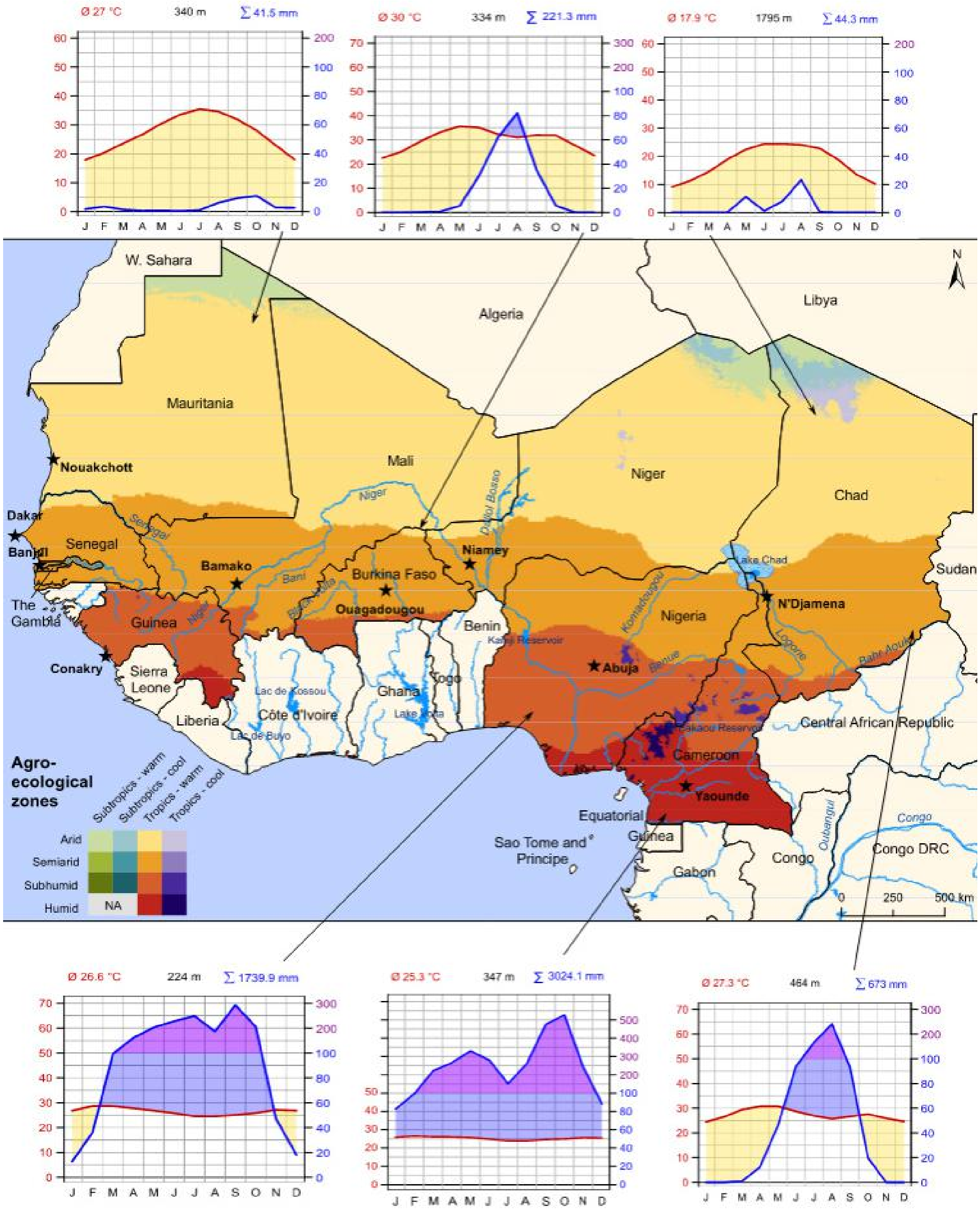


Figure 8: Map of the Sahel showing agro-ecological zones and location-specific examples of annual temperature and rainfall patterns

Mean annual temperatures range from 21°C to 31°C with lower values in southern Cameroon and higher values in south-western Mauritania. Annual precipitation ranges from 10 mm in northern Niger to 3,800 mm in western Cameroon. Most parts of the Sahel have one rainy season in the summer months of the northern hemisphere. Regions closer to the Saharan desert receive a small amount of rain around August. However, in regions further south, for example southern Nigeria, the rainy season is much longer, pausing only around December and January.

In general, water resources in the Sahel are distributed unequally both over space and time. Some countries, such as Nigeria, have abundant water resources, while others, such as Burkina Faso, have to deal with water scarcity (Oyebande & Odunuga, 2010). Here, too, the length of the rains is influenced by latitude, with regions closer to the Saharan desert exhibiting rainy seasons of only one month in length, up to almost 10-11 months in length in the southern sub-humid tropical regions.

The Sahel is further irrigated by 11 main rivers which are part of the basins of Lake Chad, Niger, Queme, Volta, Comoé, Bandama, Sassandra, Senegal and the Gambia-Gorubal (UNCCD, 2019). More than 40 per cent of the water supply in Mali and Chad and 90 per cent in Mauritania and Niger comes from outside each country's boundaries. River run-off depends on climatic and related evapotranspirative conditions, with a high seasonal variability in the semi-arid regions. This can cause severe drought conditions in the dry season, when water demand is highest, and catastrophic floodings in the wet season, with often little national capacity to store or redirect excess water (Faye et al., 2019; Oyebande & Odunuga, 2010). In some parts of the Sahel, surface water is limited and often seasonal, making groundwater a primary source of water for many people in the region (USAID, 2017). Ongoing deforestation and environmental degradation are further limiting the ability of the soil to absorb excess water, thereby contributing to soil erosion and flooding. The Institute of Policy Analysis and Research (IPAR) estimates that if the current trend of land degradation continues, more than half of the cultivated agricultural area in Africa could be lost by 2050, with people in the most vulnerable situations living in the most degraded areas.

Past Climate

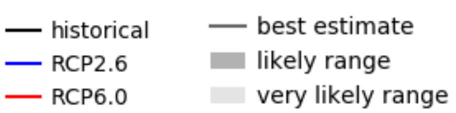
Since the 1970s, the region has experienced an increase in temperatures by at least 0.6°C to 0.8°C. Near surface temperatures have risen, with cold days and cold nights decreasing and warm days and warm nights increasing (New et al., 2006). Rainfall in the Sahel, controlled by the West African monsoon, has experienced substantial multidecadal swings and an overall reduction during the course of the 20th century (Biasutti, 2013). During the second half of the 20th century, the Sahel experienced a major shift in climate, moving from a relatively wetter period in the 1950s and 1960s to a dryer climate in the 1970s and 1980s leading to severe droughts, which caused humanitarian crises with millions of deaths and hampered development (Nicholson et al., 2000).

Rainfall variability in the Sahel has been, and continues to be, very high, both between and within years, with the driest year seen in the Niger River basin (1984) also having experienced the heaviest single rainfall event in 30 years (Oyebande & Odunuga, 2010). Higher rainfall rates paired with an intensification of rain events returned to the Sahel in the 1990s, which are still below the levels of the pre-drought period of the 1940s and 1950s (Dong & Sutton, 2015). The Senegal River basin has still not recovered from the droughts. The rainfall decrease of 20 per cent has diminished the current water resources by 30-40 per cent below the level of the 1960s (Oyebande & Odunuga, 2010).

If not otherwise stated, the climate projections are based on climate data and climate impact simulations carried out in phase 2b of the ISIMIP project (ISIMIP2b; see www.isimip.org and Frieler et al. 2017). All impact model simulations are based on the same

Climate Projections

How to read the line plots:



Lines and shaded areas show multi-model percentiles of 31-year running mean value under ROP2.6 (blue) and ROP6.0 (red). In particular, lines represent the best estimate (multi-model media) and shaded areas the likely range (central 66%) and the very likely range (central 90%) of all model projections.

How to read the map plots:

Colours show multi-model medians of 31-year mean values under RCP2.6 (top row) and RCP6.0 (bottom row) for different 31-year periods (central year indicated above each column). Colours in the leftmost column show these values for a baseline period (colour bar on the left). Colours in the other columns show differences relative to this baseline period (colour bar on the right). The presence (absence) of a dot in the other columns indicates that at least (less than) 75 per cent of all models agree on the sign of the difference. For further guidance and background information about the figures and analyses presented in this profile kindly refer to the supplemental information on how to read the climate risk profile.

harmonized input data including climate data from four global climate models (GCMs, see methodological information in Annex A). These four GCMs were selected from the larger CMIP (Coupled (Climate) Model Intercomparison Project) ensemble, based on criteria including data availability, model performance and climate sensitivity for the Sahel (Frieler et al.,2017). Future climate projections and related impacts on different sectors in the Sahel were made until 2080 under different climate change scenarios (called Representative Concentration Pathways (RCPs)). The climate projections were published as part of the Climate Risk Profile conducted by PIK for the Sahel PA project (see Tomalka et al., 2021).

Temperature change and heat risk indicators

In response to increasing greenhouse gas (GHG) concentrations, air temperature over the Sahel is projected to rise by 2.0 to 4.3°C (very likely range) by 2080 relative to the year 1876, depending on the future GHG emissions scenario (see Figure 9). Compared to pre-industrial levels, median climate model temperature increases over the Sahel amount to approximately 2.5°C in 2080 under the scenario with an ambitious climate policy (RCP2.6.). Under the medium / high emissions scenario RCP6.0, median climate model temperature increases amount to 3.6°C in 2080. The highest increases are projected for north-eastern Mauritania and north-western Mali, with temperature increases of up to 3.0°C in the period 2000–2080 and under RCP6.0. The lowest temperature increases are projected for western Senegal, which will see a 1.6°C increase.

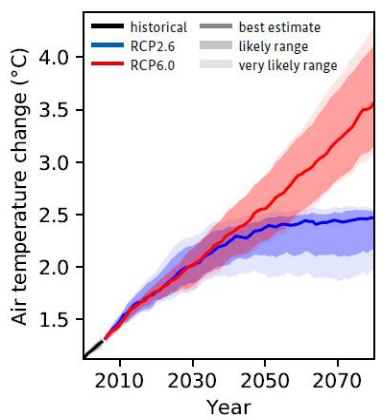


Figure 9: Air temperature projections for the Sahel for different GHG emissions scenarios.

In line with rising mean annual temperatures, the annual number of very hot days (days with a daily maximum temperature above 35°C) is projected to rise substantially and with high certainty, in particular over north-eastern Guinea and southwestern Mali (see Figure 10). Under the medium/high emissions scenario RCP6.0, these regions are projected to see 125 more very hot days per year in 2080 (see Figure 10). The northern half of the Sahel experiences a much smaller increase in the number of very hot days, but it already exhibits a high number of very hot days per year. Temperatures above the threshold of 35°C present a clear threat to human health, as well as to animal health and productivity and crop production (Carleton & Hsiang, 2016; Christidis et al., 2019). Large temperature increases, especially in the more humid southern Sahel, could be particularly dangerous for the elderly, small children and already sick people (Sarr et al., 2019). High levels of humidity exacerbate the temperature effect as it limits the human body's ability to cool itself down. Heat-related mortality is projected to rise as a result of warming temperatures and the associated increase in frequency of heatwaves. Under RCP6.0, the population affected by at least one heatwave per year is projected to increase from 4.3 per cent in 2000 to 19.9 per cent in 2080. Furthermore, under RCP6.0, heat-related mortality will likely increase from 2.4 to 9.6 deaths per 100,000 people per year by 2080.

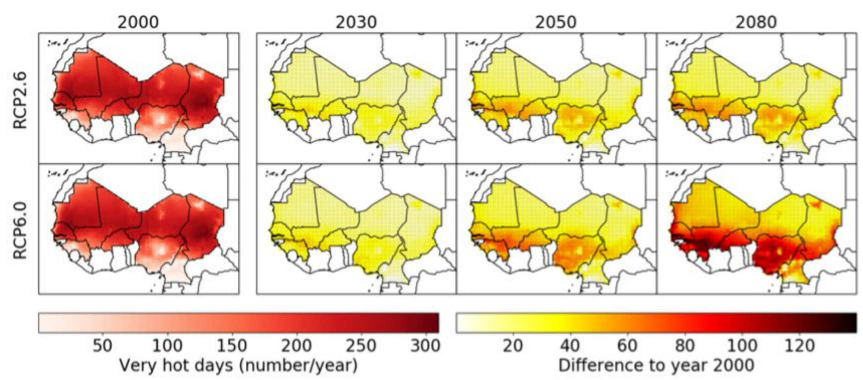


Figure 10: Projections of the annual number of very hot days (daily maximum temperature above 35°C) for the Sahel for different GHG emissions scenarios.

Precipitation

Future projections of precipitation are much less certain than projections of temperature change due to climate models' difficulties in simulating precipitation mechanisms and the Sahel's high natural year-to-year variability (see Figure 11).

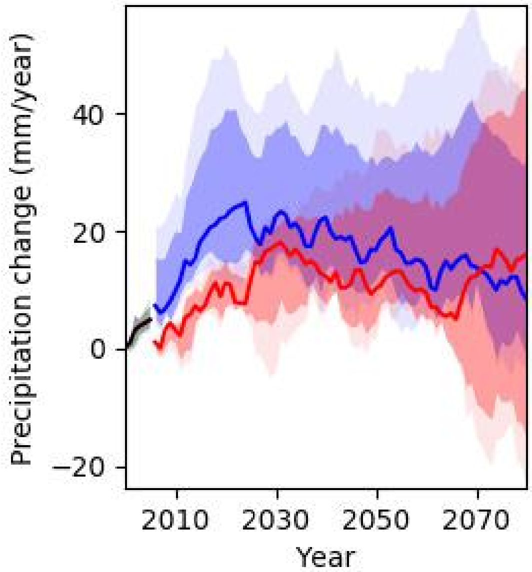


Figure 11: Annual mean precipitation projections for the Sahel for different GHG emissions scenarios, relative to the year 2000.

Out of the four climate models underlying this analysis, two models project a decrease in mean annual precipitation over the Sahel and two models project an increase, with median model predictions differing only slightly from current precipitation levels.

In response to global warming, heavy precipitation events are expected to become more intense in many parts of the world due to the increased water vapour holding capacity of a warmer atmosphere. At the same time, the number of days with heavy precipitation events is expected to increase. This tendency is reflected in climate projections for the Sahel, with an overall increase in the number of days with heavy precipitation.[7] However, there are regional differences in the direction and magnitude of change.

For example, northern Chad is projected to experience 7.6 more days with heavy precipitation in 2080. Also, other parts of the eastern Sahel are projected to experience increases, such as most of Niger, Nigeria and Cameroon. In the western Sahel, the picture is different: Mauritania, Senegal and north-eastern Mali are all projected to see decreases in the number of heavy precipitation events. For example, in north-western Mauritania, the number of days with heavy precipitation is projected to decrease from seven days in the year 2000 to five days in 2080 (see Figure 12).

7 A heavy precipitation event is defined as a day on which the precipitation sum exceeds the 98th percentile of the daily precipitation sums of all wet days from 1861 to 1983, where a wet day is a day with a precipitation sum of at least 0.1 mm. Projections show national averages of the annual number of heavy precipitation events.

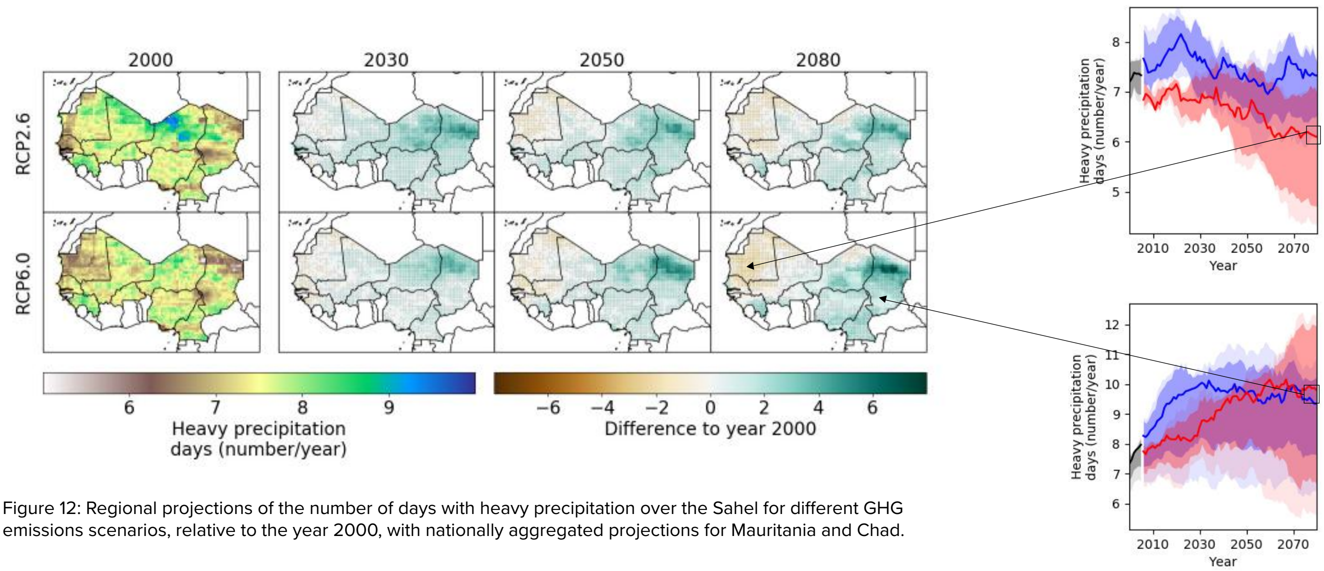


Figure 12: Regional projections of the number of days with heavy precipitation over the Sahel for different GHG emissions scenarios, relative to the year 2000, with nationally aggregated projections for Mauritania and Chad.

Water Resources

Water is the medium through which climate change most directly affects the lives of people and ecosystems. In general, the Sahel has abundant renewable water resources, of which less than 1 per cent is being extracted (UNCCD, 2019). However, at present, the Sahel's water supply is unevenly distributed, difficult to access due to poor hydraulic supply systems and challenging to manage due to the transboundary nature of water resources. For instance, total renewable water resources per capita range from 745,600 m^3/year in Burkina Faso to 6,818,000 m^3/year in Mali.

The majority of the IPCC CMIP5 model ensemble applied for climate and groundwater modelling projections by the Walker Institute indicate that, by the end of the century, most of West Africa will have a wetter climate under RCP8.5, with an increase in surface run-off and potential consequences for groundwater recharge. Moreover, the remaining multi-decadal climate variability, as well as land use, will have a significant influence on groundwater levels. Those projections, however, are subject to considerable uncertainties (Hausfather & Peters, 2020).

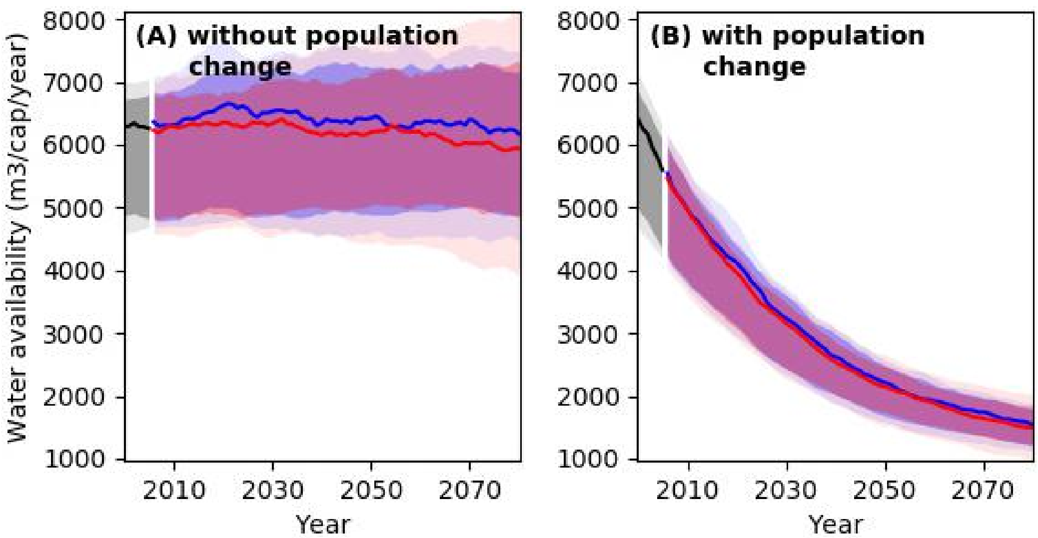


Figure 13: Projections of water availability from precipitation per capita and year with (A) national population held constant at year 2000 level and (B) changing population in line with SSP2 projections for different GHG emissions scenarios, relative to the year 2000.

Projections of water availability per capita based on a sub-sample of four CMIP5 models suggest a slight decrease until the end of the century of 2 per cent under RCP2.6. and 5 per cent under RCP6.0 (a less dramatic climate change scenario than the RCP8.5 mentioned in the paragraph earlier) assuming a constant population level (see Figure 13 A). Those projections, however, are also subject to high levels of modelling uncertainty and there is little agreement on the sign of the change among the projections.

Given the high levels of population growth in the Sahel, it is worthwhile to take socioeconomic factors into consideration when projecting water availability. Accounting for population growth according to SSP2 projections, per capita water availability for the Sahel is projected to decline more dramatically, i.e. by 76 per cent under RCP2.6 and 77 per cent under RCP6.0 by 2080 relative to the year 2000 (see Figure 13 B).

Over the last 30 years, increasing demand for water supply has resulted in 25 to 60 per cent reductions in flows, causing increasingly low water levels (USAID, 2017). Similarly, Lake Chad has seen a significant reduction in its surface area since the 1960s. Estimates attribute 50 per cent of the decrease to increased water use and the other 50 per cent to changing rainfall patterns and rising temperatures, which has led to increasing disputes over access to water, fishery and land ownership. Dams are often constructed for water storage during dry seasons in order to reduce uncertainties and water shortages and to produce hydroelectric power, thereby reducing reliance on fossil fuels and fuelwood (USAID, 2017). Yet, these benefits come at the cost of downstream water shortages, nutrient contamination and, in some cases, conflicts over the use of and access to water resources (UNCCD, 2019).

The predicted temperature increases, extreme weather events and changes in water availability will also have an impact on water quality (Kerres et al., 2020). The global temperature increase stimulates the growth of algae and bacteria in the water, while the oxygen solubility of the water decreases. In addition, a decrease in water levels reduces the dilution capacity of water with regard to pollutants. Taken together, this has negative consequences for the ecological integrity of aquatic systems and thus for the communities that depend on them. Water quality is also negatively affected by extreme weather events such as floods and landslides. Furthermore, climate change has a variety of indirect negative effects on water quality, for example through increased irrigation as a result of droughts.

Conclusion

The presented climate and climate impact projections show how the climate in the Sahel is projected to change. Depending on the scenario, temperatures in the Sahel are projected to rise between 2.0 to 4.3°C by 2080, compared to pre-industrial levels, with higher temperatures and more temperature extremes projected for the northern part of the region. Precipitation trends are uncertain and vary across the region, with projections indicating an overall increase in annual precipitation of up to 16 mm by 2080. Future dry and wet periods are likely to become more extreme. Per capita water availability will decline by 2080 mostly due to population growth. As will be discussed in more detail in the following chapters, the projected climatic changes will have significant impacts on key economic sectors in the Sahel and pose a threat to the well-being of the Sahelian population.


Photo: UNDP Burkina Faso

2.2 Food Security

In the Sahel, agriculture is the most important economic sector, involving between 60 and 80 per cent of the population and contributing to around 40 per cent of the GDP (Doso Jnr, 2014; UNISS, n.d.). As Sahel economies are highly reliant on crop farming and pastoralism, livelihoods and food security are intimately linked with weather trends and environmental conditions (Crawford, 2015).

Agriculture in the Sahel is characterized by limited water availability. Up to 50 per cent of rainfall evaporates before it reaches the crops. Onset variability of the rainy season, dry spells and droughts are the primary reason for crop failures, especially when they occur during essential phases of crop growth (Rockström & Falkenmark, 2015). Use of irrigation is rare due to insufficient water for extraction from wells or rivers making irrigation impractical in large areas of the Sahel (Doso Jnr, 2014; Rockström & Falkenmark, 2015). This makes agricultural production, and subsequently food security, in the Sahel highly dependent on rainfall patterns and thus vulnerable to climate change (Sissoko et al., 2011).

The northern Sahel is drier than its southern counterpart due to its proximity to the Sahara, consisting mostly of marginal lands (Rockström & Falkenmark, 2015). It is thus dominated by transhumant pastoralism and some farming of drought-resistant sorghum and millet crops (Doso Jnr, 2014). A quarter of the population in the northern Sahel is engaged in animal husbandry and livestock herds are an integral part of local cultural practices, determining social status and livelihoods. However, overgrazing and land clearing to promote growth of more palatable grasses, caused by high livestock densities and the expansive needs of a rapidly growing population, are common issues leading to land and soil degradation (Doso Jnr, 2014). Potential for agricultural expansion and intensification is low (Sedano et al., 2019). This increasing pressure on land resources in combination with no formal land titles and weak institutional and governance structures makes this region prone to land conflicts. Agriculture in the southern part of the Sahel is more diversified including subsistence crops such as cassava, maize, millet and sorghum, and cash crops, such as cocoa beans, cowpeas, groundnuts and

Photo: RSS Secretariat

rice (according to FAOSTAT area data, Doso Jnr, 2014; FAO, 2021), as well as extensively used forest and parkland areas comprised of natural vegetation (Doso Jnr, 2014; Sedano et al., 2019). As rainfall amounts are higher in the southern Sahel, soil quality is a prominent yield-limiting factor due to low nutrient and water-holding capacity (Doso Jnr, 2014).

In the past years, land pressure due to rapid population growth, agricultural intensification, overgrazing and deforestation have resulted in land degradation and desertification, which in turn reduce the productive capacity of soils and strongly affect subsistence farmers (Doso Jnr, 2014). It is estimated that some 100,000 hectares of arable land are being lost due to water erosion following heavy rainfall every year in Niger. Together with changing weather patterns, these developments have contributed to severe food insecurity that continues to threaten millions of Sahelians, while sparking competition over resources (Day & Caus, 2019). Between March and May 2022, around 26.5 million people in the Sahel were in a phase of crisis or worse (phase 3-5) regarding their acute food and nutrition insecurity, with the highest numbers in Nigeria (14.5 million), followed by Niger (3.3 million), Cameroon (2.9 million) and Burkina Faso (2.3 million) (Cadre Harmonisé, 2022a).[8] That represents an increase of 8.3 million people compared to the same period in 2021 (Cadre Harmonisé, 2021).

8 The IPC Acute Food Insecurity classification provides a differentiation between different levels of severity of acute food insecurity, classifying units of analysis in five distinct phases: (1) Minimal/None, (2) Stressed, (3) Crisis, (4) Emergency, (5) Catastrophe/Famine.

Large parts of the Sahelian population affected by food insecurity currently have limited capacity for agricultural intensification or adoption of adaptation strategies due to low incomes, low education levels and a lack of market infrastructures (Bjornlund et al., 2020; Sissoko et al., 2011).

Projected climate impacts on agriculture and food security[9]

The Sahelian countries are among the world's most vulnerable to climate change, which presents major challenges to the region (University of Notre Dame, 2021). Repeated cycles of droughts, desertification and floods make it increasingly hard for the local population to sustain subsistence agricultural practices. Projections of agricultural production show that this trend will intensify.

In the short term (i.e. June to August 2022), projections indicate that food insecurity will be at emergency levels in certain parts of the Sahel, for instance, in the Liptako-Gourma sub-region, around the Lake Chad Basin (see Figure 14).

For longer-term projections, the high uncertainty of projections regarding water availability (see Figure 13) currently translates into high uncertainty of drought projections. According to the median over all models employed for this analysis, the national crop

9 If not otherwise stated, the climate impact projections are based on climate data and climate impact simulations carried out in phase 2b of the ISIMIP project (ISIMIP2b; see www.isimip.org and Frieler et al., 2017. For more information see Chapter 2.1. or Annex A. The climate impact projections were published as part of the Climate Risk Profile conducted by PIK for the Sahel PA project (see Tomalka et al., 2021).

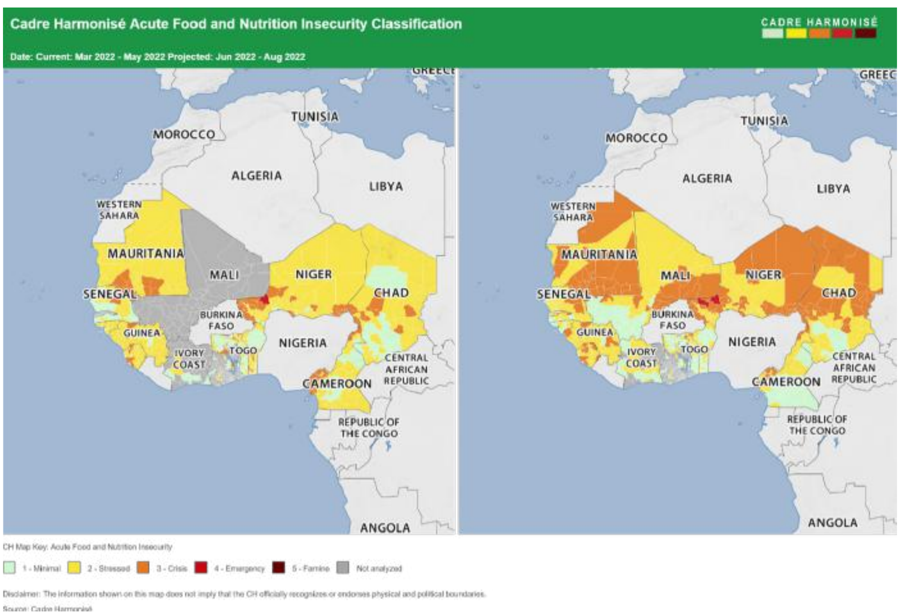


Figure 14: Current (left, March to May 2022) and projected (right, June to August 2022) food insecurity outcomes for Central and Western Africa (Source: Cadre Harmonisé, 2022b).

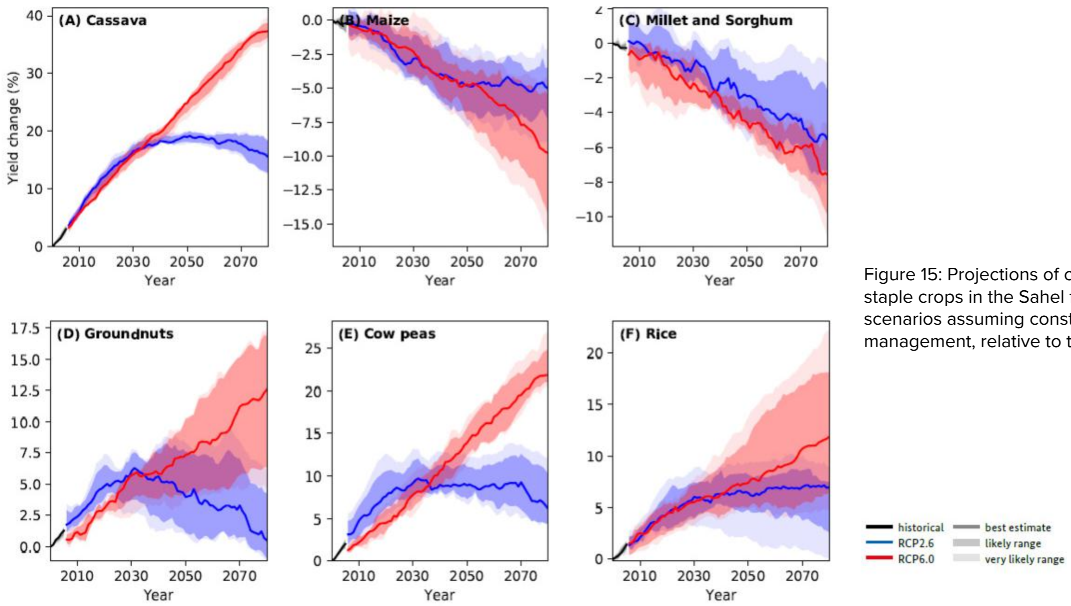


Figure 15: Projections of crop yield changes for major staple crops in the Sahel for different GHG emissions scenarios assuming constant land use and agricultural management, relative to the year 2000.

land area exposed to at least one drought per year will decrease from 2.3 per cent in 2000 to 2.0 per cent in 2080 under RCP2.6. Under RCP6.0, the proportion of exposed crop land will go up to 3.2 per cent in 2080. Under RCP6.0, the likely range of drought exposure of the national crop land area per year widens from 0.6–4.2 per cent in 2000 to 0.9–14.0 per cent in 2080. The very likely range widens from 0.2–15.7 per cent in 2000 to 0.3–32.1 per cent in 2080. This means that some models project a doubling of drought exposure over this time period.

Projections under a scenario without an ambitious climate policy (RCP6.0) indicate a decline in yields of major food crops. On average, maize is projected to decrease by -9.8 per cent and millet and sorghum by -7.6 per cent throughout the Sahel by 2080 and compared to the year 2000. However, some crop yields are projected to benefit from higher CO2 concentrations under RCP6.0, including cassava (+37.3 per cent), cow peas (+21.9 per cent), groundnuts (+12.6 per cent) and rice (+11.9 per cent) (see Figure 15).

Figure 15: Projections of crop yield changes for major staple crops in the Sahel for different GHG emissions scenarios assuming constant land use and agricultural management, relative to the year 2000.
While some yield changes may appear rather small at the regional level, there will be more pronounced changes at the sub-regional level. For example, projections for sorghum and millet show moderate declines in yields at the regional level, whereas the sub-regional analysis reveals a decrease in yields of up to 17 per cent for south-western Mali and an increase of up to 55 per cent for the eastern part of the country, as well as for parts of southern Niger (see Figure 16).

These longer-term climate change impact projections resonate with climate variability-related anomalies in crop water balances, as water availability largely affects

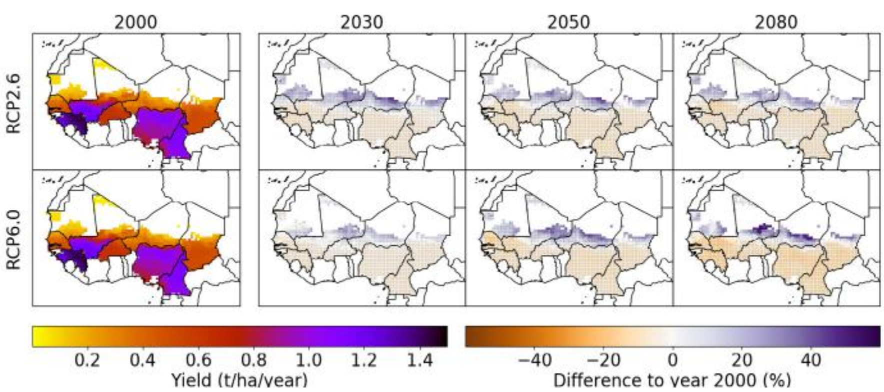


Figure 16: Millet and sorghum yield projections in the Sahel, relative to 2000, under RCP2.6 and RCP6.0.

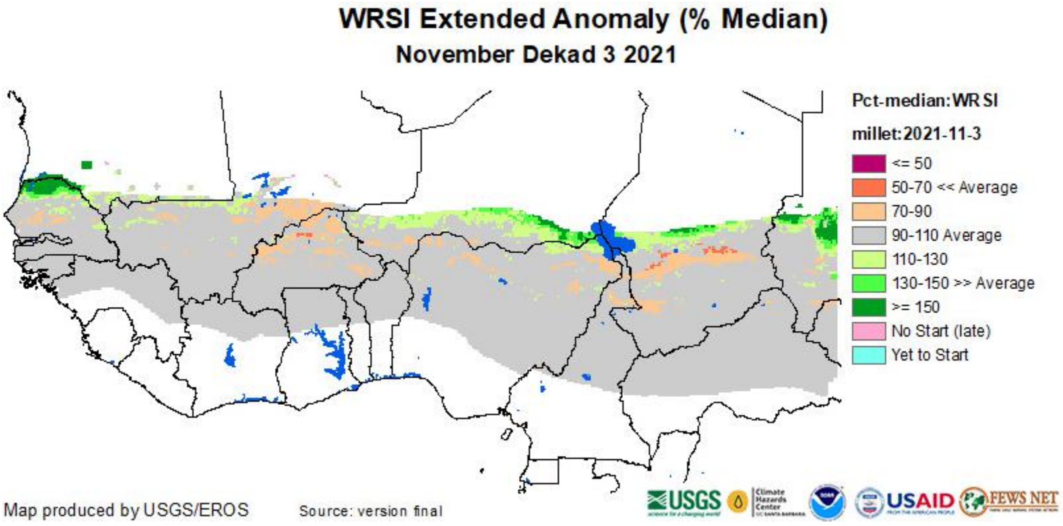


Figure 17: Extended Water Requirement Satisfaction Index (WRSI) for the time period from November 2021 until the end of the growing season for millet.

agricultural outcomes in the region. The Water Requirement Satisfaction Index (WRSI) assesses the percentage of the water need of crops that are met by available water from either rainfall or soil moisture. Figure 17 depicts a forecast of the WRSI for the period from November 2021 to the end of the growing season. During this time period, most above average anomalies (i.e. more available water than required by the plant) were projected for the northern part of the (geographical) Sahel region. Outcomes below average (i.e. less available water than required) are shown further to the south (except for Mali). In particular Burkina Faso and Chad showed anomalies below average.

Case study: Sorghum production in Burkina Faso[10]

Sorghum is the main cereal grown in Burkina Faso. Along with millet, it is the staple food for rural communities. Crop models[11] show that in most areas in Burkina Faso the suitability to grow sorghum will remain stable, as precipitation is either expected to increase or remain unchanged. However, as shown in Figure 18, some areas might become more (green) or less (red) suitable for sorghum production in future depending on the time horizon and the scenario. While the overall suitability in Burkina Faso to produce sorghum will remain stable, the changes at local level will have major implications on the livelihoods of affected smallholder farmers, who will need to adapt to those changes to ensure continued agricultural production and food security.

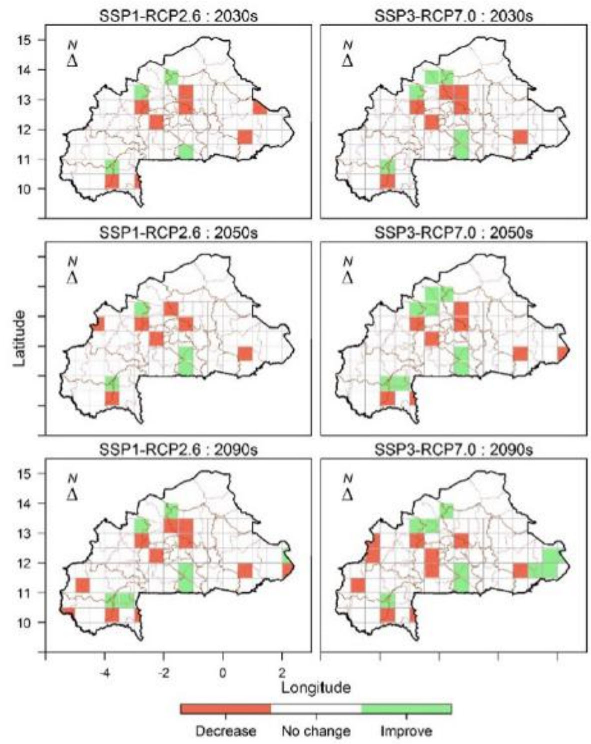


Figure 18: Maps showing the modelled changes in climatic suitability for sorghum in Burkina Faso for the 2030s (upper), 2050s (middle) and 2090s (lower) under the SSP1-RCP2.6 (left column) and SSP3-RCP7.0 scenarios.

In addition to the suitability analysis, sorghum was used as a case study to analyse yield changes. At the national level, sorghum yields are projected to remain nearly unchanged until the end of the century. However, changes in sorghum yields will vary between regions, models suggest increasing yields in a few northern regions (Sahel, Nord and Centre-Nord; up to +30 per cent under the low emissions scenario and up to +20 per cent under the high emissions scenario) and a decreasing trend in the south (Cascades, Haut-Bassins and Sud-Ouest; down to -30 per cent under the low emissions scenario

10 Taken from Röhrig et al. (2021), please refer to the publication for more information on the analysis.
11 The eXtreme Gradient Boosting (XGBoost) machine learning approach (T. Chen & Guestrin, 2016) was used to model suitability.

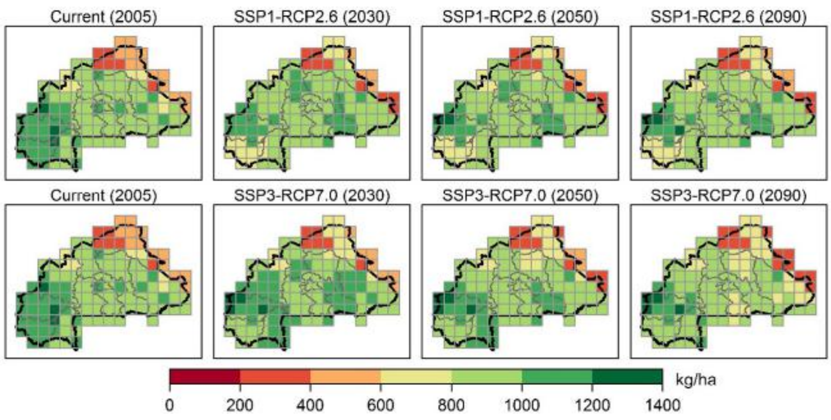


Figure 19: Current and projected future sorghum yield levels (kg/ha) in Burkina Faso at 0.5° grid spacing under SSP1/RCP2.6 (top row) and SSP3/RCP7.0 (bottom row) for the years 2005 ("current"), 2030, 2050 and 2090.

and down to -20 per cent under the high emissions scenario) (see Figure 19).

Conclusion

In recent years, land pressures due to rapid population growth, agricultural intensification, overgrazing and deforestation have resulted in land degradation and desertification. Together with changing weather patterns, these developments have contributed to severe food insecurity that continues to threaten millions of Sahelians, while sparking competition over resources. Currently, as showcased by Famine Early Warning Systems Network (FEWS NET) food security classification data, large parts of the Sahel already experience crisis levels of food insecurity, with some parts reaching emergency levels. PIK climate impact projections show how climate change will intensify food insecurity in the long term: yields of maize, millet and sorghum are projected to decline. Yields of cassava, cow peas, groundnuts and rice, on the other hand, are projected to benefit from CO2 fertilization. While an overall trend is visible, those impacts are expected to vary greatly across the region. Considering that agriculture represents the main economic activity in the Sahel and that the food security of the majority of the population depends on it, climate change adaptation in agriculture will be key to promoting resilience.

Despite the described challenges, which have been further aggravated by COVID-19, there are some promising changes in sight, which have been analysed by experts from the Initiative Prospective Agricole et Rurale (IPAR). Government initiatives prioritizing the agricultural sector in public interventions, large (although insufficient) investments by the private sector and the commitment of smallholder farmers and their organizations to cope with adverse weather conditions are reasons for satisfaction. Consequently, more and more smallholders are coming out of survival strategies and are considering agricultural production as a real business. Likewise, agri-food systems are moving away from self-subsistence tendencies and towards commercial agriculture centred on consumer preferences. Despite these notable changes, colossal long-term efforts are still needed to achieve the transformation towards productive and resilient agricultural systems.

2.3 Conflict

Armed conflicts lead to profound long-term consequences that impede the full realization of sustainable development. Beyond the immediate direct deaths from violence, they have been shown to impede economic growth (Collier, 1999; Collier & Hoeffler, 2004; Mueller, 2017) and to significantly increase mortality and morbidity rates relative to similar but peaceful countries and locations (Garry & Checchi, 2019; Jawad et al., 2020; Le & Nguyen, 2020; Wagner et al., 2018). Their effects typically persist for many years after the conflicts end (Garry & Checchi, 2019; Ghobarah et al., 2003). In addition to effects on displacement and mobility,[12] conflicts also reduce local and national resilience to disasters, climate change and health crises, rendering the immediate and secondary impacts of these crises, and the trends discussed in the previous chapters, even more severe.

The importance of monitoring and forecasting armed conflict is highlighted in Gilmore et al. (2021). This study estimates the effects of armed conflict on long-term growth, in order to incorporate its impact in income

12 For a discussion on the link between conflict, migration and displacement, see Chapter 2.4.

projections for the entire 21st century. Most authoritative projections, such as the Organisation for Economic Co-operation and Development's (OECD) ENV model[13], simply ignore the adverse effects of conflicts and poor governance – an assumption that is obviously implausible in most regions of the world, and in particular the Sahel. The impact of this is illustrated by Figure 20, which shows the OECD-ENV projections for West Africa (including most countries of the Sahel) for the five SSPs[14] as dotted lines, and the conflict-corrected projections from Gilmore et al. (2021) as solid lines.

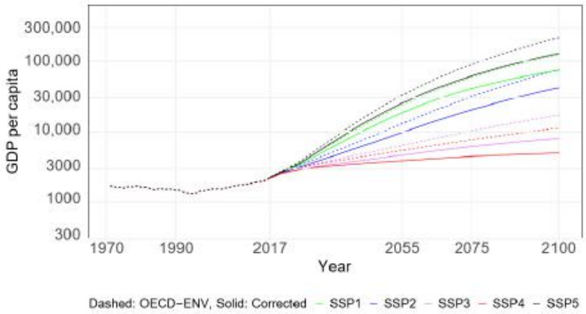


Figure 20: Conflict-corrected projections of GDP per capita in West Africa, for each of the five SSPs (Source: Gilmore et al., 2021).

Note: GDP per capita projections from the OECD-ENV model (Dellink et al., 2017) (dashed lines) and conflict-corrected projections (solid lines), for each of the five SSPs, averages for West Africa.

The correction due to conflict is substantial, in particular for the most pessimistic SSP scenarios. Under SSP4 (inequality scenario), Dellink et al. (2017) projects average GDP per capita for the region to increase from about $2,000 in 2017 to over $10,000 by the end of the century. When correcting for the negative impact of armed conflict, income is expected to increase much more slowly, to about $5,000 by the year 2100. This means that West Africa to a large extent will remain stuck in a 'conflict trap' (Collier et al., 2003) unless the conflict drivers are adequately addressed. The capacity of the region to adapt to and mitigate climate change will thus be much weaker than frequently assumed (Andrijevic et al., 2020). Monitoring the occurrence and risk of armed conflicts in the Sahel will therefore be crucial to accurately assess and anticipate the vulnerability of the region.

13 The OECD-ENV model (Dellink et al., 2017) is based on a macroeconomic model developed for OECD countries. It provides and serves as the basis for numerous projections of other important societal aspects such as energy and land use (Popp et al., 2017; Riahi et al., 2017), food prices (Popp et al., 2017), quality of governance (M. Andrijevic et al., 2020) and armed conflict (Hegre et al., 2016).
14 For a discussion of the SSPs, see O'Neill et al. (2014) and Gilmore et al. (2021).

Forecasting armed conflict in the Sahel

The forecasts presented in this section were generated by ViEWS and PREVIEW as part of the Sahel PA project.

The Violence Early-Warning System[15] is a research project based at Uppsala University and Peace Research Institute Oslo (PRIO). It provides monthly updated and publicly available assessments of the risk of armed conflict events across the Sahel and all of Africa, drawing on decades of peace research. The ViEWS findings presented below are based on the forecasting system presented in Hegre et al. (2019) and Hegre et al. (2021), coupled with an expansion developed in collaboration with the UN Economic and Social Commission for Western Africa (ESCWA). The outcomes predicted by the system – different levels of state-based, non-state and one-sided violence[16] – are defined and recorded by the Uppsala Conflict Data Program (UCDP).

PREVIEW is based at the German Federal Foreign Office. On a five-point scale, it estimates the likely change in the number of fatalities in armed conflict, and the likely change in the number of security-related incidents.[17] The forecasts are presented at the province (Admin 1) level for a selection of countries in the Sahel, here displayed in relation to observed violence in the second quarter of 2021 (Q2). The PREVIEW analysis and outcomes are based on the Armed Conflict Location & Event Data (ACLED) project (Raleigh et al., 2010). It overlaps considerably with the UCDP data and definitions above, but includes a broader range of political violence events, such as deaths in protests and riots. For the most lethal violence, however, the two datasets broadly agree on the most intense cases of conflict.[18]

15 ViEWS has been developed as part of the research project ERC-AdG 694640, funded by the European Research Council and Uppsala University. Visit https://viewsforecasting.org.
16 State-based conflict refers to conflicts over government or territory that is set between two or more armed actors, at least one of which is government of a state (e.g. fighting between the Government of Syria and ISIS). Non-state conflict is fighting between armed groups, neither of which is a government of a state (e.g. the PKK and PUK in Turkey and Iraq). One-sided violence, in turn, refers to fatal violence exerted by an armed actor against unarmed civilians, such as terror attacks targeting civilians. Full definitions are available at https://www.pcr.uu.se/research/ucdp/definitions/. Please see https://ucdp.uu.se and Gleditsch et al.(2002), Sundberg and Melander (2013), and Pettersson and Öberg (2020) for more information about the UCDP dataset.
17 While excluded from this report, PREVIEW also generates predictions for changes to the number of protest events and riots. No changes are expected in the Sahel over the first half of 2022.
18 To learn about the methodology behind the two projects, please see Annex B.

Please note that the PREVIEW forecasts show expected change in the overall number of conflict fatalities as recorded by ACLED, whereas the ViEWS forecasts show probabilities of the three types of political violence that the UCDP records. The predictions presented in this chapter are therefore complementary and not directly comparable. Below, we discuss the findings from each project and show that their assessments are in broad agreement.

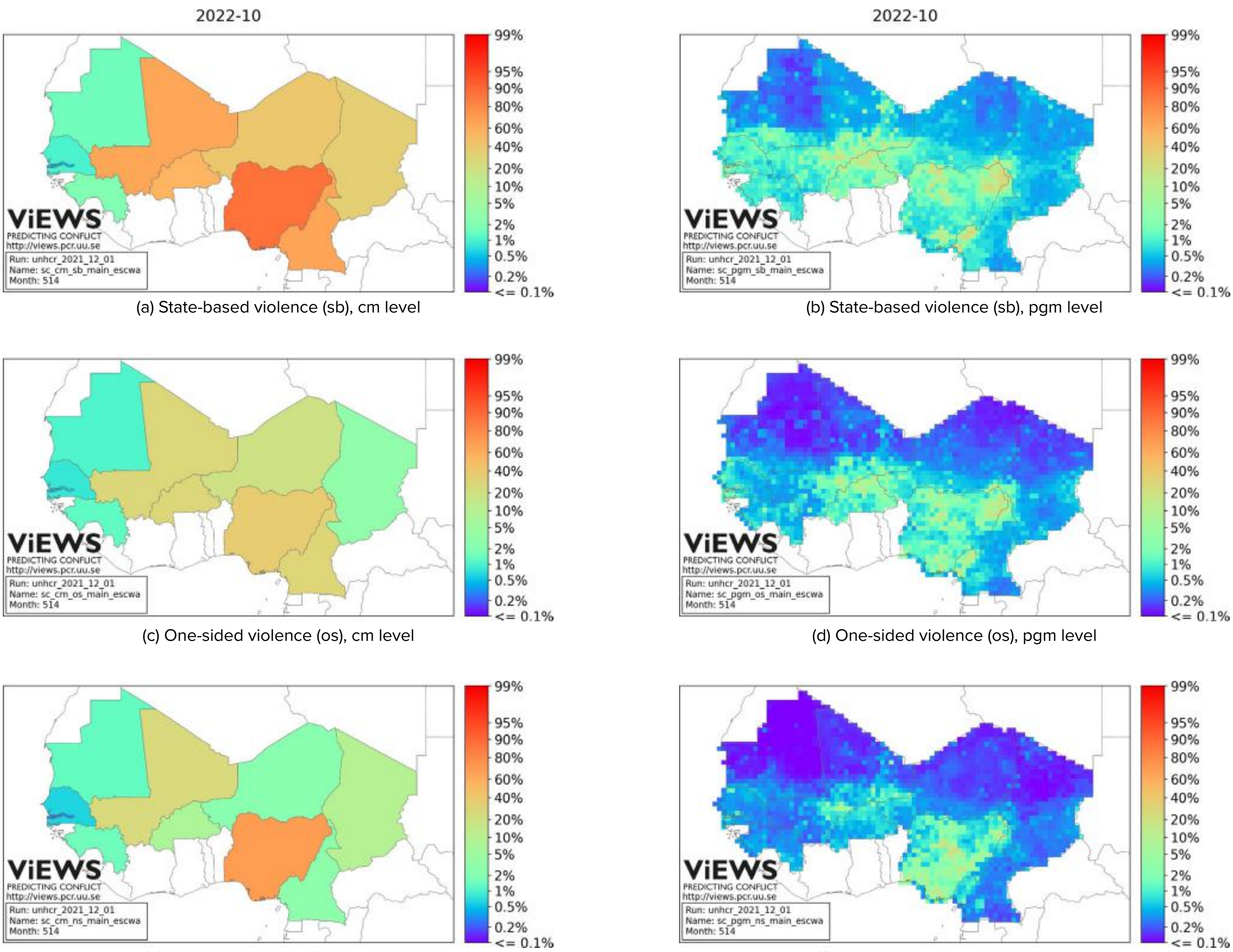
Short-term forecasts

Country-level forecasts: The ViEWS model projects a very high risk of conflict set between governments and armed groups (state-based violence) in half of the Sahel countries through 2022, as can be seen from the bright red or orange colours in Figure 21a. In Nigeria, Mali, Burkina Faso, Cameroon and Niger, the risk of 25 or more fatalities per month is higher than 50 per cent throughout the first three quarters of the year. Such levels of violence have been occurring frequently in all five countries in recent years (see Figure 3a[19]). The model also alerts to a high risk of state-based conflict in Chad.

The forecasts for fatal violence inflicted by a government or an armed group against unarmed civilians (one-sided violence, see Figure 21c) are similar. While the risks of one-sided violence are generally lower than for state-based conflict,[20] the same countries (and geographic locations) are highlighted by the model. This correlation is not a coincidence – most attacks against civilians occur in conflict contexts, and armed actors that deliberately

19 Unless otherwise stated, all fatality counts and details on conflict events related to the ViEWS forecasts in this report are derived from the database on UCDP Candidate Events (Hegre et al., 2020; Pettersson & Öberg, 2020; Sundberg & Melander, 2013). Fatality counts listed correspond to the 'best estimate' records.

20 The risks of at least 25 battle-related deaths per country and month by October 2022 nevertheless reach as high as 30–50 per cent in the ViEWS forecasts for half of the UNISS countries of the Sahel in Figure 21 c (Nigeria, Mali, Burkina Faso, Cameroon and Niger).



(a) State-based violence (sb), cm level

(b) State-based violence (sb), pgm level

(c) One-sided violence (os), cm level

(d) One-sided violence (os), pgm level

(e) Non-state violence (ns), cm level

(f) Non-state violence (ns), pgm level

Figure 21: Predicted probability of political violence in October 2022 (Source: ViEWS, December 2021).
Note: Predicted probability of state-based, one-sided and non-state violence in the Sahel in October 2022, 12 months into the future relative to the last month of data informing the forecasts. Figures a, c, e show the predicted probability of at least 25 battle-related deaths per type of violence, country and month (the country-month, or cm level). Figures b, d, f, show the predicted probability of at least one battle-related death per type of violence, PRIO-GRID cell (0.5x0.5 decimal degrees) and month (the PRIO-GRID-month, or pgm level).

attack civilians are largely the same as those involved in state-based conflict.[21]

Conflicts between non-state armed groups (non-state conflicts) is the third UCDP conflict outcome forecasted by ViEWS. For the majority of countries in Africa, the probability of reaching 25 or more deaths per month from non-state violence by October 2022 is lower than 10 per cent (seen for the Sahel from the blue or green colours in Figure 21e). Nigeria is the main exception, being plagued by recurring episodes of intercommunal violence, clashes between farmers and herders, banditry and cultist violence across the north-western and southern regions and by militant Islamist operations in the north-west. The geographic distribution of these risks is illustrated by the subnational forecasts – contrary to most other countries in the region, nearly all of Nigeria is at high risk of fatal non-state violence by October 2022 (see Figure 21f). Although this form of violence is not the most lethal in the region, non-state violence is projected to remain a serious security risk, particularly in sparsely populated regions.

Projections conducted as part of the PREVIEW project (see Figure 22-23) point to similar trends with regards to the overall number of fatalities from political violence in the Sahel, as recorded by ACLED. The quarterly fatality counts are expected to remain at largely the same level as in Q2 2021 ('neutral' change) in most of the corresponding countries of the Sahel,[22] albeit some considerable provincial variations are expected. These local variations are discussed below.

Subnational forecasts: The correlation between recent violence and future conflict risks becomes particularly evident when comparing the subnational forecasts from the two projects with maps of the recent history of conflict (Figure 24).

21 The correlation is not a given, though. One-sided violence, according to UCDP's definitions, does not necessarily take place in countries where armed conflict is ongoing. For a discussion of the determinants of one-sided violence, see Eck and Hultman (2007).
22 The PREVIEW maps and model projections do not include Guinea, Senegal, Nigeria and Cameroon and are thus excluded from comparison here.

Figures 21b, 21d and 21f present the subnational forecasts from ViEWS at a resolution of approximately 55x55km. Figures 22 and 23, in turn, present the PREVIEW forecasts at the provincial (Admin 1) level. Amongst the group of countries captured by both models, the figures suggest that Mali will remain violent over 2022, as well as much of Burkina Faso and the part of Niger that borders the aforementioned countries. The ViEWS model suggests that most of Mali will remain at a notable risk of fatalities from both state-based and one-sided violence, except for some sparsely populated regions in the north-west. The PREVIEW model, in turn, highlights a likely escalation of the number of conflict fatalities in north-eastern

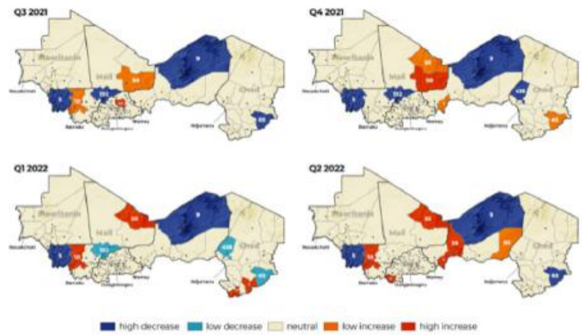


Figure 22: Estimated change in conflict fatalities in the Sahel from Q3 2021 to Q2 2022, relative to Q2 2021 (Source: PREVIEW, 2021).

Note: Estimated change in conflict fatalities, as recorded by ACLED, relative to Q2 2021. A 'high increase' suggests a rise in the number of conflict fatalities by a factor of more than 2.0, a 'low increase' a change by a factor of 1.5–2.0, 'neutral' no change, 'low decrease' a reduction by 0.66-0.5, and a 'high decrease' suggests that the number will be halved, if not more. Where changes are expected, the fatality counts observed in Q2 2021 are listed in white for reference.

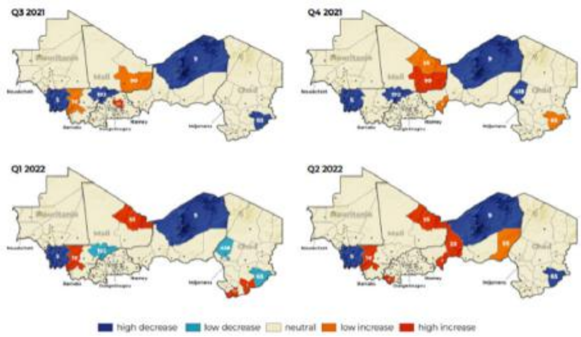
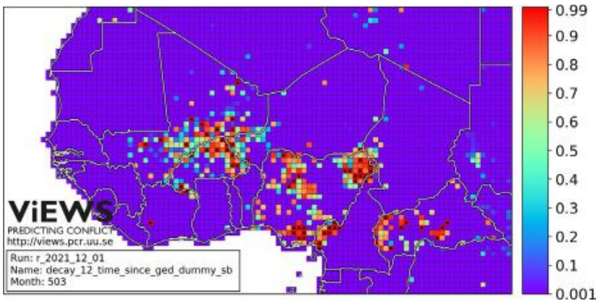
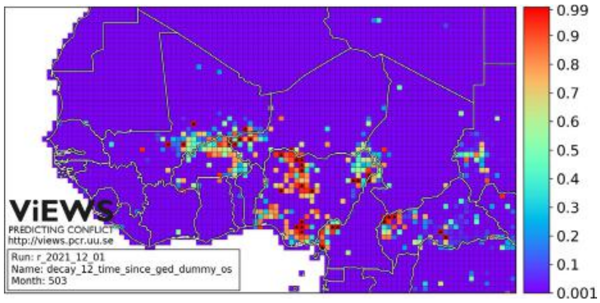


Figure 23: Estimated change in security-related incidents in the Sahel from Q3 2021 to Q2 2022, relative to Q2 2021 (Source: PREVIEW, 2021).

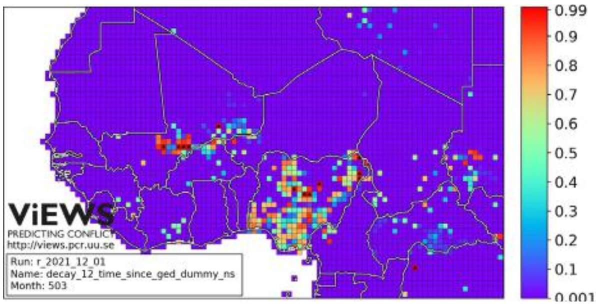
Note: Estimated change in security-related incidents, i.e. the ACLED event types 'battles', 'explosions/remote violence', and 'violence against civilians', relative to Q2 2021. A 'high increase' suggests a rise in the number of incidents by a factor of more than 2.0, a 'low increase' a change by a factor of 1.5–2.0, 'neutral' no change, 'low decrease' a reduction by 0.66-0.5, and a 'high decrease' suggests that the number will be halved, if not more. Where changes are expected, the event counts observed in Q2 2021 are listed in white for reference.



(a) State-based violence



(b) One-sided violence



(c) Non-state violence

Figure 24: Conflict history by location and time since the last event.
Note: The recent history of fatal political violence. Red cells observed such incidents in October 2021 (distinguished by a black marker) or September 2021. Purple cells have not experienced such incidents for many years. Based on data up until and including October 2021. Source: UCDP Candidate Events Dataset (UCDP Candidate) version 21.0.3 (global), adapted for the report.

Mali (Gao and Kidal) and western (Koulikoro) Mali (see Figure 22), further projecting that the number of security-related incidents – including one-sided violence – is expected to escalate almost exclusively in Mali over the same period (see Figure 23). The border region between Mali, Burkina Faso and Niger, however, is projected to stay at the same high level of violence compared to the reference period Q2 2021.

Both models see a clear danger of spill-over of violence from north-eastern Nigeria and northernmost Cameroon into south-eastern Niger and eastern Chad, respectively. The PREVIEW model also alerts to a probable escalation of conflict fatalities in southern Chad over Q1 2022.

Within the countries captured only by the ViEWS model, other high-risk areas include Zamfara, Katsina and Kaduna state in Nigeria (which have been particularly prone to banditry in recent months and years), and the Anglophone region of Cameroon (having seen a recent escalation of the Ambazonia insurgency).

Last, the ViEWS model flags some geographic locations that have not been highly affected by conflict over the past decades. Senegal, Guinea and the Gambia all show locations at a non-negligible probability of state-based violence, and partially also of one-sided violence (see Figures 21b–21d) over 2022. In these three cases, the risk assessments are driven by a combination of drought occurrence during the growing season, heavy dependence on agriculture and poor efficiency in water management.

Long-term forecasts

The Sahel was traditionally a region with few conflicts – up to the late 1990s, it was rare that more than two countries had conflict. Since then, this has become the norm. In 2015-16, Cameroon, Chad, Mali, Niger and Nigeria were in conflict. Figure 25 shows the likely proportion of Sahelian countries in conflict[23] for the next decades as generated by ViEWS, based on the simulations in

23 Conflict is here defined as a UCDP state-based armed conflict with at least 25 direct, battle-related deaths annually.

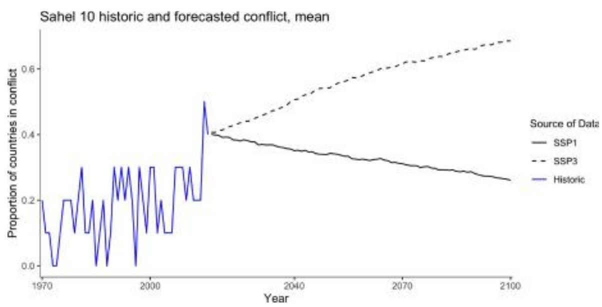


Figure 25: Observed and predicted proportion of the Sahel countries to experience armed conflict in 1970–2100, by SSP.
Note: Observed (1970–2016) and predicted (2017–2100) proportion of countries in the Sahel with at least 25 battle-related deaths from state-based armed conflict per year. Source: Gilmore et al. (2021).

Gilmore et al. (2021) and given two of the SSPs.[24]

The two black lines show the predicted share of Sahelian countries that will find themselves in conflict according to this model, when taking the two diverging socioeconomic pathways into account. Under optimistic SSP1 (which assumes that population growth will reduce over the next couple of decades, and that education levels and average income will increase considerably), the model suggests that the share of the Sahelian countries that will remain in conflict will decrease slowly to about 30 per cent at the end of the century. Niger and Nigeria are forecasted to observe conflict in most years by this time, while the risk is considerably lower in the other countries in the Sahel.

Under the pessimistic SSP3 (which assumes that populations will continue to increase rapidly, education levels will remain at today's levels and that incomes will increase at a very slow rate), close to 70 per cent of the region will be in conflict in any given year. Only Mauritania and the Gambia are likely to avoid regular conflicts according to these simulations.

24 The projections are based on a statistical model that captures that there are more frequent conflicts in large countries that have low income and education levels, and where there is a pre-existing history of conflict. Moreover, given these predictors, the model assumes that the geopolitical climate is similar to the past decade, with the prevailing tendency for foreign inference and relative lack of willingness to intervene to prevent conflict compared to the first decade of this century.

Conflict drivers

Reducing the risk of conflict is not straightforward – the causes of armed conflict are multifaceted and closely interlinked. However, four key themes of drivers of conflict in the region can be identified by the ViEWS and PREVIEW models: (1) conflict legacy, (2) demographic dynamics and socioeconomic factors, (3) poor governance and (4) challenges to livelihoods and food security due to societal vulnerability to climate extremes.

The sombre climate-related challenges discussed in the previous chapters of this report are thus just one small, albeit important, piece of the puzzle.

Conflict legacy

Violence breeds violence through several processes. First, weapons flow in and militarized organizations are built up, increasing the ability and willingness to continue to use violence. Wars often take a long time to settle, with protracted conflict becoming more prevalent throughout the region. Moreover, human and financial capital flees the region, reducing the incentives for keeping peace for economic reasons, and

Photo: RSS Secretariat

increasing the relative strength of actors specializing in violence. In some parts, government armies retreat from the scene, creating a vacuum filled by violent non-state actors. The PREVIEW model captures how past violence and terrorism further weakens state capacity and spreads across border regions into previously unaffected countries. Widespread organized crime may have similar effects.

To observers familiar with existing conflict patterns in the Sahel, it should therefore come as no surprise that past conflict prevails as the most important predictor of future violence in the region, especially for a short forecasting horizon. Both the ViEWS and PREVIEW models show that future conflict is predominantly expected in, or in close proximity to, countries and locations with a recent history of violence. To illustrate this in relation to the forecasts presented in the previous section, we show the number of fatalities per country as recorded by the UCDP over the past decade in Figure 3 in the introduction to this report. The geographical distribution of deaths up to 2021 is found in Figure 24.[25]

It is readily apparent from the figures that the Sahelian countries differ significantly both in terms of recent history of violence and the risk of future conflict. The countries that have observed the highest number of fatalities in recent years across all three UCDP categories of violence – Nigeria, Mali, Burkina Faso, Niger, Cameroon and Chad – are projected to be at the highest risk of future conflict in the ViEWS forecasts (Figure 21). Senegal, Guinea, Mauritania and the Gambia, which have been relatively peaceful over the past years, are in turn projected to be at a significantly lower risk of conflict over the next few years.

Demographic dynamics and socioeconomic factors

Demographic dynamics (population size and population growth in particular) and socioeconomic factors are two other key themes of conflict drivers in the Sahel. The reasons are manifold and closely intertwined. First, conflicts tend to be more deadly when occurring in large populations. This is mostly a scaling factor – large countries and densely populated areas are more likely to see a high number of fatalities than their smaller or more sparsely populated counterparts, even if the per capita risk of death is the same. This presents a substantial concern for the region in light of recent population growth projections that indicate the Sahelian population will rise to 455 million in 2030 and 712 million by 2050 (see Chapter 1). For vulnerable regions, large and growing populations are particularly worrisome as they increase the risk of economic instability, poverty and scarce resources.

Poverty, in turn, increases markedly when conflict erupts, and conflict prevents the development of knowledge-based and diversified economies that have decreased the incentives for war in other parts of the world. Accordingly, poverty indicators such as rate of undernourishment, financial insecurity, unemployment and infant mortality rates, are all associated with high risks of conflict. The high-risk countries of Mali and Niger, for example, present among the highest rates of infant mortality on the African continent. Clearly, the prevalence of conflicts in these areas hinder development and increase infant mortality rates, contributing to ‘development in reverse’. A high reliance on natural resource extraction (including agriculture), also emerges as a key driver of conflict in the region.[26]

Moreover, low-income countries, in which assets cannot be moved and the costs of capital flight are low, are more likely to attract violent competition for the control of rent-generating resources (Boix, 2008; Gat, 2006). This is exacerbated by challenges to livelihoods and food security that follow from societal vulnerability to climate extremes. Conflicts over increasingly scarce resources (firewood, water, livestock, arable land, minerals etc) also run the risk of aggravating existing ethnic tensions and fractionalization.

Note: Indices for civil liberties, political corruption, equal distribution of resources, women’s empowerment and rule of law averages for Sahel region, 1970–2016
Source: Varieties of Democracy (Coppedge et al., 2020).

25 Note that the UCDP only includes fatalities that are reported in news or intergovernmental organization (IGO) reports in their monthly reporting (the UCDP-Candidate Events Dataset), but include various other reports in their final, annual dataset (the UCDP-GED). It should also be noted that the strict documentation standards of the UCDP result in the number of deaths often being under-estimated. See Pettersson and Öberg (2020) and Hegre et al. (2020) for a detailed description of the data, and https://ucdp.uu.se for more information on the project.

26 For studies on poverty and conflict, see Collier et al. (2003), Fearon and Laitin (2003), Collier and Hoeffler (2004), and Boix (2008). For a review of literature on education, development and conflict, see Gat (2006) and Pinker (2011), and Hegre (2018).

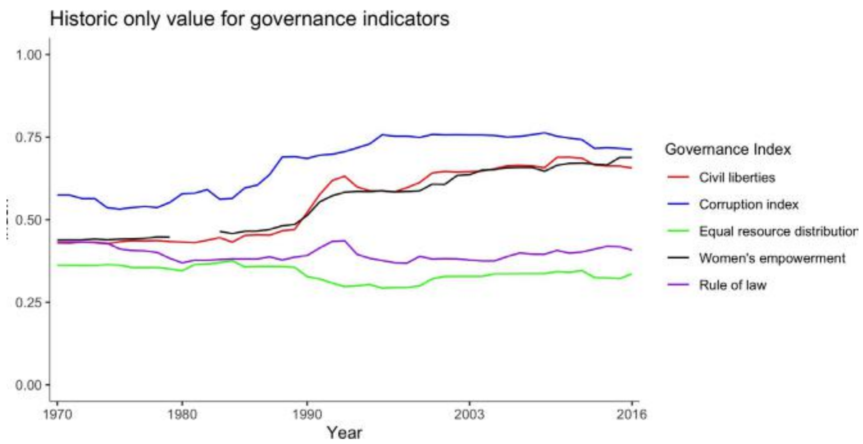


Figure 26: Historical governance indices for the Sahel, 1970–2016.

Poor governance

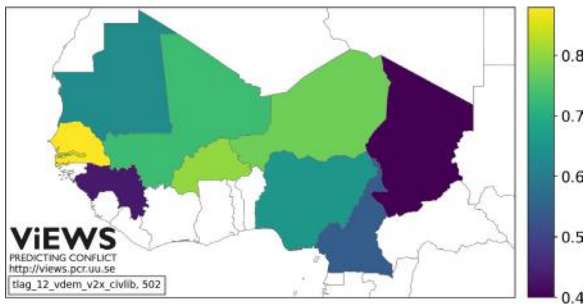
Poor governance is another key driver informing the conflict forecasts above, both in the short and long-term.[27] Figure 26 shows how the Sahel region has developed in terms of five key indices of governance – civil liberties, corruption, equal distribution of resources, women's empowerment and rule of law.[28] The figure shows that political corruption was increasing steadily in the region up to the late 1990s and has remained stable since then. Civil liberties and women's empowerment, in turn, have improved considerably over the past 30 years with minor periods of reversal, but the degree of rule of law and the equal distribution of resources have not changed much. Moreover, the Sahel region continues to score poorly on these and other governance issues even compared to other African countries.

The role of these indicators as potential drivers of conflict in the Sahel is highlighted by the ViEWS model. Results suggest that countries in which citizens enjoy extensive civil liberties (Figure 27a) run much lower risk of armed conflict than where these rights are restricted. Chad, Guinea, and to some extent Cameroon, for example, score low on this indicator. The former two also score very poorly on rule of law; the extent to which countries' laws are enforced effectively and impartially (see Figure 27b)[29], suggesting that the latent risk of armed conflict in Chad and Guinea is considerable. Also, Mauritania and Cameroon display poor rule of law compared to other countries in the region. The other three governance indicators affect the conflict forecasts along the same lines – in general, corruption is low where rule of law is well established, while women's empowerment is closely related to civil liberties and the equal distribution of resources.

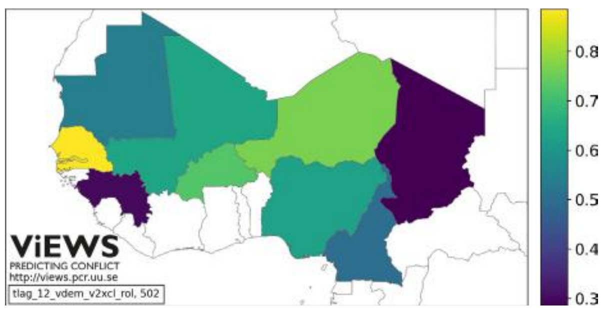
27 The role of governance is explicitly shaping the ViEWS forecasts, and probably implicitly through socioeconomic features in the PREVIEW model.

28 The corruption index has a high value where there is widespread bribery and embezzlement, in either the legislative or the executive branch of government or in implementing agencies. To score highly on the equal distribution of resources index, countries must provide universalistic public goods rather than particularistic ones, and thereby provide good public services with respect to, for instance, health or education. There is rule of law when laws are enforced transparently, independently, predictably, impartially and equally. The civil liberties index has a high value when there is absence of physical violence committed by government agents and absence of constraints of private liberties and political liberties by the government. Women's political empowerment exists when women have greater choice, agency and participation in societal decision-making, as well as fundamental civil liberties and representation in formal political positions. The data are from the V-Dem project that base their scores on assessments by more than 3,500 country experts.

29 Rule of law is defined by the V-Dem project as the extent to which laws are transparent and rigorously
enforced and public administration impartial, and to what extent citizens enjoy access to justice, secure property rights, freedom from forced labour, freedom of movement, physical integrity rights and freedom of religion.



(a) V-Dem civil liberties



(b) V-Dem rule of law

Figure 27: Current levels of governance.
Note: Input data from two of the best performing indicators of levels of governance in the ViEWS system – measures of civil liberties and the rule of law, both with a 12-month lag. The December 2021 forecasts are informed by data up until and including October 2021, while the 12-month lagged data in the figures above show the level of governance as of October 2020. Indices range from 0 (no rights) to 1 (full rights). Source: Coppedge et al. (2020), adapted for the report.

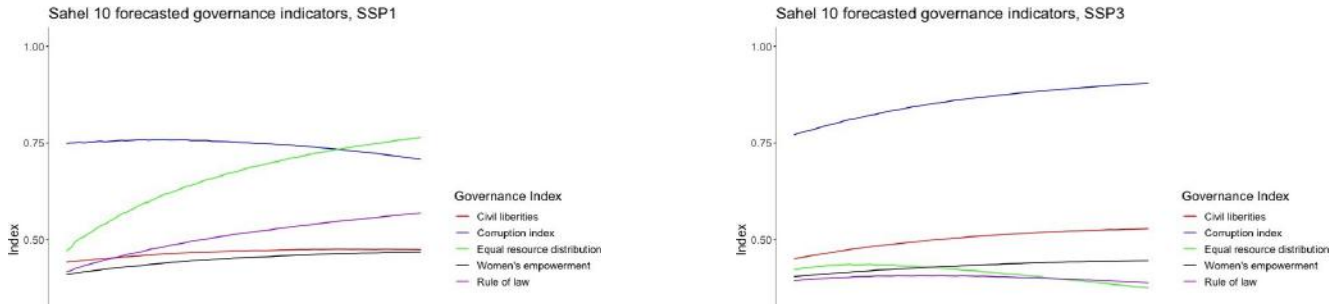


Figure 28: Projected quality of governance in the Sahel under SSP1 and SSP3.
Note: Expected quality of governance in the Sahel in terms of five indices under the optimistic, climate-friendly scenario SSP1, and the pessimistic SSP3. The projections were computed for this report based on the income projections of Gilmore et al. (2021). Source: ViEWS 2022, based on Gilmore et al. (2021).

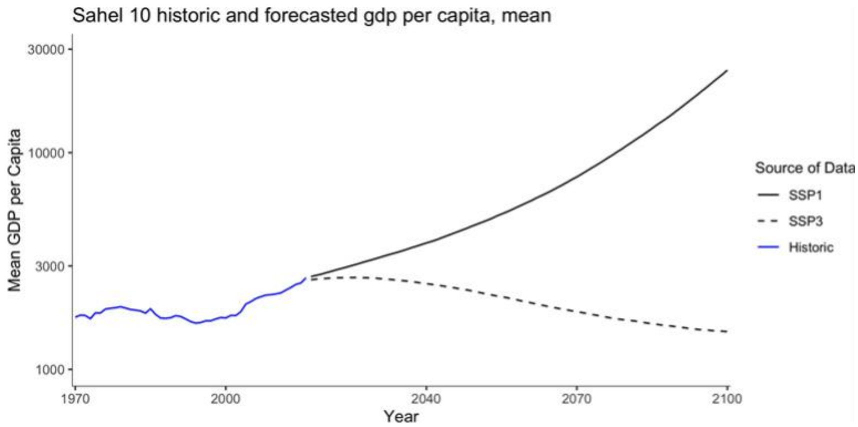


Figure 29: Historical and projected average income for the Sahel region.
Note: Historical and projected average income for the Sahel region, computed for this report based on the income projections of Gilmore et al. (2021). Source: ViEWS 2022, based on Gilmore et al. (2021).

Figures 26 and 27 illustrate the importance of promoting good governance in the region. Based on the projections in Gilmore et al. (2021), the figures show how the five governance indicators (Figure 28) as well as average income (Figure 29) are expected to develop in the Sahel over the coming decades, under the scenarios of SSP1 and SSP3.[30]

Under the optimistic scenario (SSP1, in which population growth will decline, education levels improve, and per capita income steadily rises as conflict levels decline and economies modernize), governance is likely to improve across all five indicators. In particular, findings suggest that better education, lower fertility rates and higher average income will improve the equal distribution of resources. This is particularly important as the ViEWS model suggests that resource management plays an important role as a driver of conflict in the Sahel, as further discussed below.

Under the pessimistic scenario on the other hand (SSP3, in which populations will continue to grow at a fast rate and education levels barely change, leading to declining income and increased reliance on subsistence agriculture), the quality of governance will decline from current levels across most indicators.

Two other governance indicators that are flagged by the ViEWS model are the extent to which citizens enjoy freedom of movement and physical integrity – freedom from political killings and torture by the government. These freedoms also decline during war and protracted conflicts and reinforce the expectation of continued violence in countries already suffering from such conflicts. Two UNISS countries that have been relatively peaceful over the past decade score very well on these governance indicators in the ViEWS analysis – Senegal and the Gambia. Good governance and civil liberties thus contribute to the low predicted risk of conflict in both countries.

Societal vulnerability to climate extremes

The final category of conflict drivers in the Sahel relate to societal vulnerability to environmental and climatic changes and other exogenous shocks, iterated by

30 The projections in Figures 29-30 were computed by ViEWS as part of the Sahel PA project, based on the results in Gilmore et al.(2021). The governance projections were generated under the assumption that quality of governance is primarily a function of socioeconomic development, as well as non-observed country characteristics. If key development indicators such as average income and education levels improve, governance also improves.

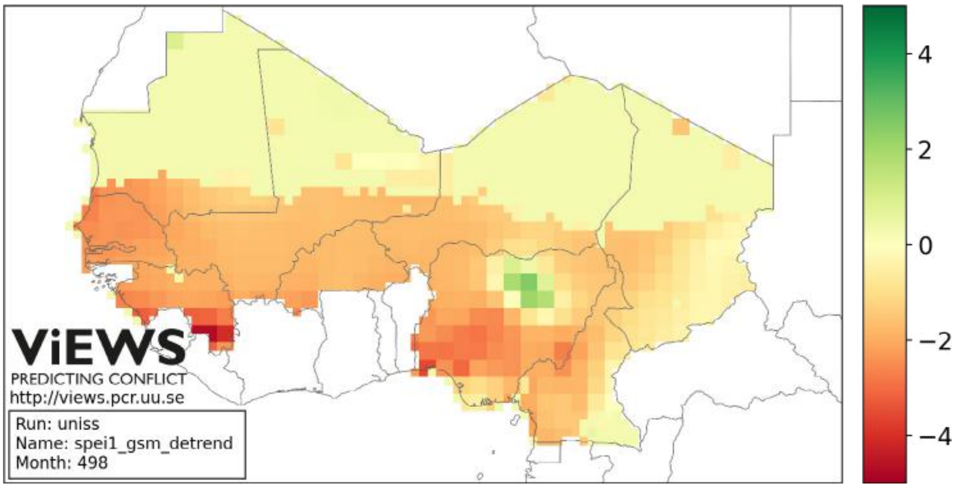


Figure 30: Drought occurrence during the growing season in 2021.
Note: Red and orange colours indicate the occurrence of a severe drought during the main crops' growing season. Yellow corresponds to average conditions; green shades correspond to intense rainfall and floods during the growing season. Values are based on the Standardized Precipitation Evapotranspiration Index (SPEI), an indicator of soil moisture that combines temperature and precipitation data on the ground. Data as of June 2021. Source: SPEI (Vicente-Serrano et al., 2010), adapted for this report

both the ViEWS and PREVIEW analyses.[31] Societal vulnerability is particularly dire where agricultural dependence is high, as households that rely on crop production as their primary income become more vulnerable to climate shocks and related crop failures and threats to herds. Studies have for example shown that climatic shifts have driven recruitment into Boko Haram and other extremist groups, as instability and weak government responses to communities' needs have disenfranchised marginalized people (Bøås, 2018; Crawford, 2015; Heinrigs, 2010). Economies that are heavily dependent on agriculture are also more associated with illiteracy and other sources of vulnerability at the individual level and poor governance and rent-seeking elites[32] at the country level.

Consequently, forecasting models like ViEWS have consistently assigned an increased probability of conflict to locations that have a relatively high share of cultivated land, and a high percentage of people employed in agriculture. Even in countries where the probability of violence has been relatively low or stable (e.g. Mauritania and Guinea), the likelihood of violence during 2022 is at risk of becoming "non-negligible" due to a combination of poor governance, low state capacity, severe droughts during the main crops' growing season and heavy dependence on agriculture.

As Figure 30 shows, the central-north of Nigeria was the only area that experienced abundant rainfall in June 2021, while the rest of the UNISS countries of the Sahel were affected by very dry conditions. Extremely intense droughts in turn hit the south-east of Guinea and the south of Nigeria, particularly the area of Lagos and Ibadan. Effects from these data on the risk of future conflict can be seen in the subnational forecasts from the ViEWS model and are particularly clear in the sub-model forecasts presented by Hegre et al. (2022).

Comparing the occurrence of droughts with the results from the ViEWS model also revealed some other interesting trends. While many of the drought-hit areas, such as Nigeria and Guinea, are assigned a moderate to high probability of conflict, these are not assigned to the areas that were affected by the most intense drought; rather, high levels of violence are predicted to occur in neighbouring locations. This is consistent with studies finding that droughts may trigger movement away from affected areas, as deprived people move in a quest for better livelihood conditions. As will be further outlined in the next sub-chapter, climate impacts are expected to feature more prominently as a

31 Please note that the drivers discussed in this chapter are based on the findings from the ViEWS and PREVIEW projects, more specifically on trends identified from evaluations of historic forecasts (see Annex B to learn more). Machine-learning techniques, such as those applied by the two projects, can be very useful for identifying the most promising predictors from a large number of candidate features, even when the relationship is non-linear. These techniques are however limited in that they cannot determine the direction of casual relationships, nor whether the variables at hand serve as core predictors in themselves, as proxies for other factors, or as moderating factors (see e.g. Uexkull et al. (2021) for an overview of the climate-conflict literature). More on the limitations of machine-learning techniques can be found in Hegre et al. (2022).
32 Political elites seeking to gain personal wealth through the political arena without reciprocal contributions, exemplified by e.g. bribery and corruption. See Tullock (1967) and Krueger (1974) for the origin of the term.

conflict driver for pastoralists, whose identity is closely tied with their livelihood and livestock, particularly if no sufficient adaptive measures are taken. Indeed, there is already evidence that desertification and shifting rainfall patterns have altered the routes of cattle herding communities, bringing them across farmland during, rather than after, the harvest season, contributing to the so-called "farmer-herder conflicts" (see Chapter 2.4).

Moreover, inflows of migrants and displaced persons can change the ethnic and socioeconomic dynamics in receiving areas, trigger competition for scarce resources and increase community tensions. Displacement, is projected to continue to increase in the Sahel from approximately 7.5 million in 2021 to 8.9 million by the end of 2023 as a result of conflict, climate change and environmental degradation (see Chapter 2.4). These dynamics may further shape human mobility patterns in the future, potentially exacerbating social tensions that contribute to conflict drivers. Moreover, conflicts can hinder the ability of pastoralists to move along traditional routes, bringing additional uncertainties to the table (see Chapter 2.4). Given the concerning climate projections presented in the previous chapters, we can expect the complex human mobility-conflict nexus to be of increasing importance in the future.

Lastly, while the dangers of a dry growing season contribute greatly to the conflict predictions for drought-affected locations in both the ViEWS and PREVIEW forecasts, recent findings from ViEWS suggest that conflict legacy and socioeconomic conditions are stronger predictors of future violence than droughts alone. While emphasis on climatic drivers is key to preventing violence, vulnerable societies are less able to recover from the adverse impacts of climate change and exogenous shocks and thus exhibit a higher risk of conflict, reiterating the importance of a holistic approach to conflict prevention and mitigation.

Conclusion

This chapter has presented the conflict forecasts for the Sahel from the ViEWS and PREVIEW projects. The findings point to a persistent conflict situation in the region. The countries that have observed the highest number of conflict fatalities in recent years – Nigeria, Mali, Burkina Faso, Niger, Cameroon and Chad – are projected to remain at a very high risk of conflict throughout 2022. A particular emphasis is placed on Gao, Kidal and Koulikoro (in north-eastern and western Mali, respectively), by the PREVIEW model, where the number of fatalities is expected to approximately double over Q1-Q2 2022, relative to Q2 2021. However, Senegal, Guinea, Mauritania and the Gambia, which have been relatively peaceful in recent years, are assigned a significantly lower risk of conflict over the next year. The implications of predictions presented in the chapter are sombre: violence in the Sahel will persist unless we see radical change in the complex and interconnected drivers of conflict. Four key groups of drivers have been identified: conflict legacy, demographic dynamics and socioeconomic factors, poor governance and societal vulnerability to climate extremes and other exogenous shocks. This suggests that measures aimed at immediate conflict reduction in the most affected areas may offer a temporary respite. However, any efforts to promote a durable peace in the Sahel must address the structural challenges that the region faces and invest in capacity-building for societal resilience to climate extremes, a topic further discussed in Chapter 3.

2.4 Migration and displacement in the context of climate change

Reflecting the wider Sahelian context, patterns of migration and displacement in the region are complex and related to multiple drivers of movement, whether as a last resort out of crisis conditions and away from harm or as a proactive strategy to reduce risk and access opportunities elsewhere. As touched upon in Chapters 1 and 2.3, migration and displacement trends are closely intertwined with diverse social, economic, political, demographic and environmental factors that influence why and when people leave their homes, where they are likely to move to and from, and the positive and negative consequences of these dynamics over space and time. In this chapter, we particularly highlight the relationship between human mobility and climate change, explore related population movements in the Sahel, provide examples of predictive analytics that give insight into short- and long-term trends, and reflect on differential migration and displacement outcomes.

BOX 2

Sources of data and knowledge use a range of methodological approaches to describe, measure and analyse population movements and situations, providing insights into trends from a variety of perspectives. At the same time, data on population movements is unevenly generated across the world and in the Sahel. Significant gaps remain where data and analysis are unavailable or insufficient for risk-informed, needs-led and inclusive policy and programming. A further challenge to users of human mobility data and analysis is that they bring different and unreconciled objectives, concepts, definitions and assumptions. Care is required, therefore, in the interpretation of findings as evidence for policy and planning. When multiple sources are brought together, as in this report, this becomes even more important for legal and policy applications as well as operational programming.

For the purposes of this report, the terms "population movements" and "human mobility" are used as umbrella terms encompassing different forms and situations of people on the move, including a differentiation between (voluntary) migration and (forced) displacement. While some apply "migration" as a general umbrella term, which encompasses all forms of population movement (notably the International Organization of Migration, development actors and migration scholars), others differentiate (voluntary) migration from (forced) displacement (notably UNHCR, humanitarian actors and forced displacement scholars), while recognizing situations where it may be difficult to draw a line between these concepts. Across them, the common concern for humanitarian, development and peacebuilding actors is to ensure that analysis allows for migrants and displaced people in vulnerable situations to be included, protected and prioritized in policy and measures as appropriate to the evolving dynamics and their needs.

Some examples of internationally agreed definitions are helpful to note, including for the purpose of displacement and migration statistics and the inclusion of human mobility issues in climate change policy and action. The harmonization of concepts and definitions related to (forced) displacement for statistical purposes has progressed under the United Nations Statistical Commission (UNSC) through the adoption in 2018 and 2020 of International Recommendations on Refugee and Internally Displaced Persons Statistics (IRRS and IRIS).[33] UNDESA (1998) defines an "international migrant" as "any person who changes his or her country of usual residence".[34] In the realm of climate change policy, "human mobility" has become the preferred terminology with reference to the United Nations Framework Convention on Climate Change (UNFCCC, 2011) Cancun Climate Change Adaptation Framework (2011) where human mobility refers to three forms of population movement: i) displacement – the primarily forced movement of persons; ii) migration – the primarily voluntary movement of persons and iii) planned relocation – process of settling persons or communities to a new location.

33 More information IRRS and IRIS here: https://egrisstats.org/recommendations/
34 The UNDESA definition excludes movements that are due to "recreation, holiday, visits to friends and relatives, business, medical treatment or religious pilgrimages" (UNDESA, 1998).

Our understanding of the multiple, complex and systemic ways that climate change is influencing trends in population movement has expanded over the past decade, as highlighted in knowledge of regional climate change impacts on people, biodiversity, and ecosystems in Africa, presented by the Intergovernmental Panel on Climate Change (IPCC, 2022). The scientific consensus presented by the Working Group II contribution to the IPCC's 6th Assessment Report highlights that climate and weather extremes, such as abnormally heavy rainfall, prolonged drought, heatwaves and cyclones, will increasingly drive displacement in the medium to long term and are exacerbating vulnerabilities (IPCC, 2022; Grolle, 2015). For example, increasing unpredictability, frequency and intensity of hazardous weather events and extreme climatic conditions will have impacts on the habitability of home areas, affecting food, livelihood insecurity and health, and contribute to conditions under which conflict or violence may be exacerbated or triggered (see Chapter 2.3).

It is widely agreed that rather than acting independently, climatic factors tend to work in combination with various drivers of migration and displacement (Black et al., 2011; Tacoli, 2009). Vulnerabilities created by pre-existing sociopolitical, economic and demographic factors are critical in this relationship, leaving individuals, families and communities residing in some geographic areas more susceptible to gradual changes and sudden shocks than others (see Chapter 2.1). A myriad of technical, socioeconomic, psychological, and cultural factors, including age and gender, inform risk perception and risk-taking behaviours, influence how likely people are to move as individuals, households or communities and resulting patterns of movement (Coxhead et al., 2015; De Jong, 2000; Morrow, 2009; Rogers & Castro, 1981). Human mobility may be undertaken as a household adaptation strategy to gradual changes (Jaeger et al., 2010), though outcomes may not always be positive for those moving and staying behind. Effects can also differ between men and women (Vinke & Harper, 2020; Vinke et al., 2021). Age, gender and socioeconomic status also influence the timing and modality of movements following sudden-onset hazard events. For example, poorer households tend to be less likely to have adequate access to information about storm severity, evacuations and sites where humanitarian assistance may be accessed (Gemenne, 2011; Morrow et al., 2015). Individual- and family-level considerations can also influence willingness to take part in government-led emergency evacuations (Oakes, 2014).

Subjective perceptions of climate change influence behavioural responses, and human perceptions of the environment do not always match observations measured by modern instruments (De Longueville et al., 2020; Schmidt-Verkerk, 2010). Research in Burkina Faso showed that, between 1988 and 2007, residents perceived an increase in temperature which matched with available studies, but their perceptions of worsening rainfall conditions were inconsistent with the trends observed in rainfall data (De Longueville et al., 2020). Another challenge is that traditional methods of weather forecasting are rendered less applicable as climate change disrupts weather patterns, while access to weather forecasts and modern early warning systems is limited. Some local coping strategies currently support local adaptation, such as traditional techniques of water harvesting and reforestation (Haglund et al., 2011). In the longer term, climatic impacts on food security and shifting rainfall patterns (see Chapters 2.1 and 2.2) are likely to lead to further climate-related migration and displacement across the region without adequate alternative forecasting methods, scaled-up adaptation responses and additional sources of income (Clement et al., 2021).

In western Africa, the vast majority of international migrants are from other countries in the region (UNDESA, 2020). Current estimates from mid-2020 suggest 90 per cent of migrants in West Africa remain within the region, but COVID-19 travel restrictions influenced this number; previous estimates were closer to 60 per cent (Blocher et al., 2015). Areas of limited statehood, where governmental control is weak, have allowed non-state armed groups to gain power in several Sahelian states (Bøås & Strazzari, 2020). These difficult boundary conditions translate into a high vulnerability to climate change. The lack of social protection regimes, as well as the absence of crop and livestock insurance, mean that a single extreme event can foster population movements through the loss of income. Many nomadic pastoralists and subsistence farmers have few resources to adapt to climate impacts. When hydroclimatic extremes cause cattle deaths and crop yield losses, the affected populations are often immediately faced with existential livelihood crises, as they have too few monetary or other resources to offset their losses. In turn, these events can prompt migration responses in order to secure income or access to fertile land. For uninsured smallholder farmers in particular, migration can be a crucial survival strategy when faced with environmental pressures (Weinreb et al., 2020).

Climate-related shocks and pressures such as drought-related food insecurity and freshwater scarcity are – besides violent conflict – a major driver of displacement in the Sahel. Many people in the Sahel also face the compounded challenge of simultaneous conflict and climatic shocks. While the number of people displaced by conflicts has increased significantly in the Sahel and has more than doubled over the last decade in sub-Saharan Africa overall, Sahelian droughts and extreme rainy seasons have also induced large scale displacements. For example, at least 276,000 people across Niger and 32,000 people in Chad's capital N'Djamena were displaced in 2020 by flooding events (IDMC, 2021). Severe droughts in the 1970s and 1980s lead to millions of deaths and triggered large scale displacement. In the last decade, weather related hazards have induced an average of 820,000 new displacements of people from their homes each year in the 10 UNISS Sahel countries.[35]

While people displaced in the context of climate change and disasters most often stay within the borders of their respective country, some displaced people may cross borders in the search of safety, sometimes triggering the need for international protection.[36] The adverse effects of climate change are also likely to worsen the situation of people living in displacement and amplify protection concerns. They further limit the possibility for displaced communities to safely return to their areas of origin where vulnerability is high and capacity to reduce risk or adapt to a changing climate is limited.[37]

Understanding displacement in relation to climate change impacts in conflict-affected contexts is particularly challenging.

35 Based on IDMC data on new displacements caused by hazardous weather events between 2010 and 2020.
36 For more information on claims for international protection in the context of the adverse effects of climate change and disasters, see UNHCR's Legal Considers paper (UNHCR, 2020).
37 For more information, see UNHCR's Strategic Framework for Climate Action (UNHCR, 2021b).

Nevertheless, specific relationships between environmental factors and crisis conditions for displacement, including conflict and disasters, have been established. The literature stipulates that climate-related fragility and insecurity is often associated with agricultural dependency, in particular rain-fed agriculture, fragile State institutions, and ethnic fractionalization (Schleussner et al., 2016). Agricultural and pastoral growing seasons mark an especially vulnerable time, particularly for subsistence farmers and herders in States that do not possess the capacity to mitigate impacts of potential crop or livestock losses (Von Uexkull et al., 2016). This poses a serious challenge to the Sahel, given that agriculture is central to the Sahelian economy and provides the majority of jobs.

The shifting nature and scale of movements across the Sahel linked to climate change impacts are further intertwined with wider patterns of displacement (Kniveton et al., 2012). Secondary cities and towns constitute an important link between the urban and rural areas in the Sahel, including in a context of insecurity. While rural areas are the most exposed to insecurity, especially in border areas, secondary cities are experiencing an additional, even faster population growth with the massive arrival of IDPs and refugees. Coupled with the movement from the countryside, demographic growth is generating the expansion of small urban areas or secondary cities which results in a process of in situ urbanization. For example, in Niger between 1970 and 2015, the number of cities with a population between 10,000 and 30,000 increased from four to 51 and from one to 12 for cities with a population between 30,000 and 100,000 (World Bank, 2019b). In Burkina Faso, where 1.5 million people are internally displaced (CONASUR, 2021), the number of IDPs is higher than the number of host population in many secondary towns in the centre-north and Sahel regions. Lack of urban planning in secondary cities in Burkina Faso, Mali and Niger is being further exacerbated by lack of preparation for new arrivals of refugees and conflict-related IDPs, which is in turn contributes to increasing urban flood risk – another driver of displacement.

Photo: UNHCR Niger

Overall, substantial variation in the nature and distribution of climatic change, and the capacity of populations to adapt to those changes, is likely to exacerbate geographic disparities in migration and displacement trends in the coming decades (Gemenne, 2011; C. Raleigh et al., 2008). These trends may in turn have implications for demands on public infrastructure and basic service provision, such as food, water and energy distribution systems, as well as public health capacity. Additionally, changing patterns of movement and settlement are expected to fundamentally alter the distribution of climate exposure and vulnerability, reducing risk in some places while enhancing or introducing new risk in others. The characteristics of migration and displacement matter, therefore, to both sending and receiving areas, and understanding the characteristics and vulnerabilities of populations on the move may inform which services are most critical and what new patterns of climate-related vulnerability might emerge.

One of the challenges to advancing knowledge in the area of human mobility and climate change is related to the timescales associated with climate change. Climate change impacts can involve cumulative effects that build over long periods of time, which may reach potential “tipping points” into major, sudden changes for natural and human systems that are difficult to predict. This requires different research methods and time-lags to capture (Bayar & Aral, 2019). People commonly live in unstable environments for many years and may only decide to leave as a last resort, for example, when a natural hazard event hits after the coping capacities of people are already eroded (Schutte et al., 2021). Research on the cumulative impact of shocks on human mobility demonstrates that multiple shocks to the household – both climatic and non-climatic – can contribute to an increase in migration propensities when studied over time (Blocher et al., 2021; Blocher et al., n.d.). This evidence of critical thresholds for human mobility particularly holds true for rural, agricultural households that are dependent on rain-fed agriculture. Uninsured households with a limited diversity of income sources are generally found to be less resilient, and the reactivity of their decision to move in response to climate conditions points to a lack of available alternatives. Taken together, these findings suggest that current mobility patterns may not be adequate indicators of future trends under climate change in some parts of the Sahel, where temperature increase and rainfall variability significantly affects the success of current livelihoods.

Transhumance and farmer-herder conflicts

The seasonal transhumance of nomadic pastoralists in the Sahel, which has developed as a means of securing resources like water and pasture under harsh environmental conditions, has shaped livelihoods and intercommunal relations over centuries. Labour migration linked to more sedentary occupations, on a seasonal and permanent basis, within and across countries, has enabled the diversification of livelihoods and remittances play a crucial role for development.

Pastoralism in the Sahel is facing a crisis that is structured around issues of mobility and the capacity of States to protect land for transhumant communities. This is a consequence of demographic developments, a drastic increase in the space allocated to agricultural land, as well as a trend toward the privatization of lands, often at the expense of pastoral lands and rights. Some countries, such as Niger, Mali and Burkina Faso, have adopted regulations to protect pastoral areas, but their application is far from automatic. The inclusion of a population in movement, often beyond their country of origin, in national and local governance mechanisms that have been built around a sedentary model is automatically a major challenge (Pellerin, 2021). This causes particular difficulties with regards to the consideration of pastoral needs and grievances. Moreover, in some contexts, it is also observed that policies have been developed to reduce the mobility of herders, further restricting their access to natural resources and the flexibility of their movements to adapt to increasing rainfall variability.

Pastoralism, in particular transhumant pastoralism, is not only a major contributor to the region’s GDP, but provides livelihoods for many social groups. Transhumant pastoralism typically corresponds to ethnic ties and is often practiced by groups that are predominantly marginalized within their respective society (UNOWAS, 2018). This pre-existing marginalization makes them particularly vulnerable to climate impacts and other shocks, such as the COVID-19 pandemic, which can have cascading effects. The projected increase in the frequency of droughts and flooding events will adversely affect pastoralist livelihoods and impact cooperation with farming communities (Schilling et al., 2010). For the most vulnerable nomadic herders, reduced access to pastoral resources results in the decapitalization of their herds. This can lead to underemployment and unemployment, disproportionately affecting young people. Within communities engaging in transhumant pastoralism, the practice not only provides a means for living but is deeply interwoven with cultural heritage (De Haan et al., 2016) representing values such as dignity and pride. This engenders challenges related to the adoption of alternative livelihoods as a means to adapt to climatic changes and contributes to existing grievances regarding state institutions and other communities. The inter-community dimension to the tensions in the Sahel is evident. In the Central Sahel, for example, pastoral grievances are exploited by various Jihadist groups that actively recruit in the region. To exemplify, Jihadists are reported to actively block common transhumance routes to force one member of a passing herder group to join their forces if the rest want to continue their journey.

Transhumant pastoralism can serve as a viable example of adaptation in challenging dryland environments like the Sahel. Traditional knowledge has aided pastoral communities in these demanding settings. Nonetheless, due to socioeconomic marginalization, pastoralist groups possess limited capacity for adaptation to a rapidly changing climate. Despite that, efforts to adapt already include diversification of income, seasonal labour migration and changes in spatial and temporal aspects of annual transhumance routes. As the onset of the rainy season is becoming increasingly uncertain, herders are adapting the start of their annual journey accordingly. This temporal component can lead to herders arriving too early in the receiving farming communities, which may disturb growing and harvesting season and thereby cause tensions. Furthermore, pastoralist routes are altered in order to locate higher quality pastures, avoid regions particularly hard-hit by drought and gain access to markets (Cepero et al., 2021). This has negative consequences for intercommunal ties, as pastoralists can no longer rely on the more established relations along their former routes. This contributes to uncertainties for herding communities, as well as farming communities, and can lead to grievances on both sides. Hence, efforts to adapt may not always be successful and indeed lead to maladaptation.

While more established conflict drivers such as fragile state institutions, marginalization of certain ethnic groups and the presence of foreign or domestic armed actors are still considered to be the stronger indicators of armed conflict, climate impacts are putting stress on ecosystem-services and are thereby reducing resource availability (Benjaminsen & Ba, 2019; Cepero et al., 2021; Schleussner et al., 2016). This can lead to increased competition among the different user groups. Additionally, the economic losses put further financial pressure on already fragile state institutions, further weakening them. These dynamics create a downward spiral with respect to intercommunal relations and greatly affect pastoralist livelihoods (Brottem & Mcdonnell, 2020). While transhumance as a form of human mobility can pose challenges, e.g. regarding land tenure, education and provision of health services, these should not serve as a way to legitimize state-side pressures to sedentarize (Cepero et al., 2021). Forced sedentarization may transform into a source of further grievances.

Halima Boubacar says: “Before we used to take our herds to Nigeria to graze our animals, but now I don’t want to go back, Nigeria for me is a place where people are killed. The problem is that we host people while we lack resources ourselves, so our animals sometimes have to go to farming areas and this creates tensions with the farmers that can sometimes go as far as violence“. She ends with: “For me climate change is things that other people are doing elsewhere that impact us here“.

Immobility

Despite migration and displacement garnering most of the attention in public discourse on climate impacts on demographics and population movements, it is crucial to also address the topic of immobility (Black et al., 2013). There is a distinction to be made between non-movement, which is regarded to be voluntary, and trapped populations (Geddes et al., 2012; Government Office for Science, 2011). The voluntary and involuntary "immobility" of certain households and household members is an emerging area of study for which insights have been taken from several case studies in the Sahel and coastal West Africa.[38]

Socioeconomic impacts of climate change can lead to a further increase in the number of trapped people. For example, studies show that severe, protracted droughts in Burkina Faso dampen migration (Henry et al., 2003). Women are especially at risk of being trapped (Vinke et al., 2021). Trapped households and communities are usually marked by high vulnerability to climate impacts. They experience high exposure to climate change-related biophysical changes but have low adaptive capacities to respond. While desiring to move out of harm's way, they are unable to do so, for social, economic or health reasons. In other words, they simply lack the means or the social network to attempt relocation (Cepero et al., 2021). Climate impacts and other shocks further diminish these households' capacity to adapt and can contribute to further marginalization. Therefore, policy on human mobility and adaptation to climate change must also address the needs of trapped people because of a lack of means and/or armed conflict. At the same time, providing adaptation options for those who choose to stay is necessary.

Migration and displacement outcomes: resilience and vulnerability

Migration, relocation, resettlement and local integration of people are commonly discussed solutions for people moving in response to slow and sudden climate impacts. However, as with refugee populations, a number of considerations must be made to maximize the resilience-building potential of migration and minimize the negatives. A growing body of literature reinforces evidence that migration can be a positive, transformational force for the migrant themselves, their communities of origin and their communities of destination (Gemenne et al., 2017). In particular, migration of some family members can help others to remain through financial and social remittances.[39] For example, one study found that financial and social remittances from Senegalese migrant fishermen in Mauritania enabled households to relocate away from areas threatened by coastal erosion (Zickgraf et al., 2016).

Yet, the expectation that migration will lead to a better standard of living is not always realized. Depending on the prior conditions of the household, migration and displacement has been known to erode household resources and well-being (Warner & Afifi, 2014). The household's overall adaptive capacities reflect the availability of alternative choices and the degree of agency in decisions to migrate, as discussed above, and hence can be an indicator of the likely outcome of migration. Moreover, recurring climate related and non-climatic shock can reduce a household's ability to migrate in a safe and orderly manner. In Nigeria, for example, a study employing panel data of agricultural residents in the Sudano-Sahelian Ecological zone from 2010-2018 concluded that repeated environmental shocks limited capacities to respond to further shocks and diminished the ability of ageing populations and poorer households to migrate (Makanju & Uriri, 2021). The researchers observed that adaptive capacities increased between 2015 and 2018, accompanied by a greater ability of these disadvantaged groups to take mobility decisions.

In a number of contexts, migrants and displaced people – including whole communities relocated away from climate hazards - sometimes face a range of more critical new issues, such as the disruption of their traditional livelihoods (Fernando et al., 2010). Migrants and displaced people in urban areas in the Sahel, in particular, often face difficulties in the socially and environmentally fragile cities and resort to settling in informal settlements and under exploitative labour conditions (Zickgraf et al., 2016).

38 For reviews of available evidence, see Gemenne et al. (2017), Zickgraf et al. (2016).

39 According to Levitt (1998) Social remittances are: "the ideas, behaviours, identities and social capital that flow from receiving to sending country communities. The role that these resources play in promoting immigrant entrepreneurship, community and family formation, and political integration is widely acknowledged."

Moving from Reaction to Action - Anticipating Vulnerability Hotspots in the Sahel 58

Moreover, tensions between migrant, displaced or relocated communities and host communities may arise in certain situations. Political shifts, poverty and conflicts in the region in recent history have influenced discriminatory and anti-migrant sentiment, sometimes leading to violent flare-ups (Adepoju, 2003; Badewa & Dinbabo, 2021). For example, economic downturn and unemployment among young people in Cote d'Ivoire in the 2000s, together with a shift in government policy towards involuntary return of migrants, contributed to anti-foreigner sentiments and attacks that prompted many people to return to neighbouring countries (Adepoju, 2003).

Projecting population movements

From a policy and planning perspective at regional, national and local levels, the value of predictive modelling of displacement and migration is largely in understanding trends, rather than in the production of precise, quantitative estimates. Where this knowledge can be grounded in data for specific locations, it may inform the strategic allocation of resources for adaptation and preparedness in support of people facing the greatest risks. This would include the identification of places likely to be areas of origin/return, transit/hosting and temporary or permanent settlement for large numbers of migrants and displaced people.

This chapter summarizes the findings from three different models using three different methodologies applied to the Sahel region:

1. **Foresight Model (DRC):** Projects conflict-related internal and cross-border displacement 1 - 3 years into the future at the national level, incorporating environmental factors such as weather-related hazards, access to water, agricultural stress and food security next to the economic situation, violence, governance and sociodemographic factors.
2. **West Africa Context Analysis and Foresight Initiative model (WACAFI) model (DRC):** Projects internal displacement at subnational level 3 - 4 months in advance, also taking environmental factors into account (see above).
3. **INCLUDE Model (Jones et al. 2016):** Projects sub-national changes in the distribution of residential population occurring as a function of known drivers of population movement over five-to-ten-year intervals until 2050, including environmental and climate-related drivers and conflict. This is then used to infer medium- and longer-term internal migration patterns.[40]

It should be noted that comparison between the models is limited by differences in their methodologies, including timescales, data used, definitions and types of population movements that they capture.

Short-term forecasting of displacement

The Danish Refugee Council (DRC) has developed two models to forecast displacement at the country and subnational level based on a machine learning approach. The Foresight model is focused more narrowly on predicting internal and cross-border displacement, defined as asylum-seekers, refugees and persons internally displaced by conflict one to three years into the future at the national level. The Foresight model is used in combination with the WACAFI model (see methodological information in Annex C). The latter is a model built to estimate the number of IDPs at Admin 1 level in Burkina Faso, Mali and parts of Niger three to four months in advance.[41]

The results from the model have shown that the relationship between conflict and displacement is quite strong, but some periods/regions do see changes in displacement without also experiencing a high level of conflict locally. This can potentially be explained by violence in neighbouring regions and anticipatory displacement. The findings also highlight how both food security and vegetation health can impact future displacement in the Sahel region.

40 The results of the INCLUDE model display the distribution of residential population over time. This implies that the model cannot make an explicit distinction between people that migrate and those that are forced to flee. The projected numbers therefore might also include displacements, especially in earlier time intervals. Nevertheless, the term internal climate migration is the most adequate, as the model does not explicitly consider other forms of mobility including cross-border migration, displacement and planned relocation, as well as immobility, nor does it reflect shorter-term, seasonal or cyclical migration. While the differentiation between migration and displacement is crucial for protection, existing data does not allow to project displacement over longer timeframes.

41 The short-term forecast models, while considering aspects related to climate change, food security and conflict, do not account for different scenarios nor build on the forecasts and data inputs for how these different variables will evolve in the short or longer-term, as presented in the previous chapters.

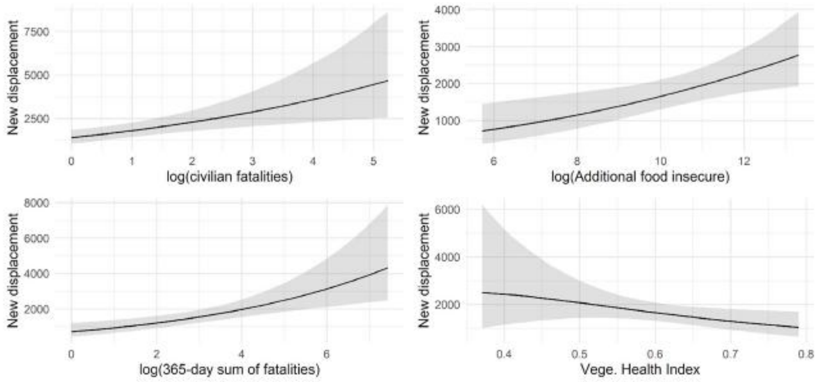


Figure 31: Relationship between new displacement and key underlying drivers in the Liptako-Gourma Triangle.

The current results from the Foresight model for 2022 and 2023 suggest that displacement caused by conflict and persecution[42] will continue to increase in the Sahel, from approximately 7.5 million people displaced in 2021 in the region to 8.9 million by the end of 2023. The increase will be driven by the major displacement crises in Nigeria, Cameroon and Burkina Faso, but also significant growth in displacement in Mali, Niger and Chad.

The findings underscore the fact that the drivers of displacement – conflict, environment, governance, economy, etc. – are not going to fundamentally change for the better. It highlights that if the aims of UNISS - tackling the structural problems that make the region vulnerable to conflicts - are not achieved, then displacement is likely to continue to grow at an unprecedented scale.

Some of the challenges in terms of modelling displacement on a near-term and subnational basis are related to the reliability of the data. Even when reports come at a regular pace, the constant value of some of the displacement figures calls into question whether a count has really taken place or whether the last available data has been re-used (e.g. one region in one country has had the exact same number of IDPs since July 2019). For the national level modelling it is challenging to capture sudden, unprecedented surges in displacement, such as the initial displacement surge in Burkina Faso. As displacement is generally increasing, this is part of explaining why the WACAFI model also has a conservative bias. A total of 32 of the 42 forecasts so far for the Sahel/West Africa underestimated the level of displacement for the coming year, which is higher than in other regions where the model has been applied.

Long-term forecasting of internal migration

For this report, the INCLUDE model is exemplified as applied in (1) the latest update to the World Bank's Groundswell report series, and (2) for the more recent Sahel PA pilot study of five Sahelian countries.
The INCLUDE model[43] projects future spatially explicit subnational population change as a function of geographic, socioeconomic, demographic and environmental characteristics of the population and landscape. It is a gravity-based approach (commonly used in geographic models of spatial interaction, allocation and accessibility) that leverages the spatial regularities in the relationship between known drivers of migration and patterns of population change. Fit to historic data, the model estimates the empirical strength certain drivers display in either attracting or pushing out population. This information is then used in a scenario based (SSPs/RCPs) approach to estimate the impact of local/regional socioeconomic, geopolitical and environmental conditions, including climate impacts on economic livelihoods, on future changes in the spatial distribution on the population. Further detailed in the Annex C, the INCLUDE model estimates the potential impact of climate change on internal migration by comparing spatial population outcomes under climate change scenarios against futures that assume no change in current conditions.

Migration modelling over longer timescales faces somewhat similar challenges to

42 This is based on UNHCR's data on asylum-seekers and refugees, and Internal Displacement Monitoring Centre's (IDMC) data on conflict-induced IDPs. As such it does not take into account natural hazard induced displacement (captured as disaster displacement in the IDMC figures), but reflects when environmental factors interact with violence and persecution to induce displacement

43 See Jones and O'Neil (2013; 2016) as well as the World Bank Groundswell report series (Rigaud et al., 2018; 2021a, 2021b; and Clement et al., 2021).

displacement modelling with data inputs, mostly related to the uncertainties and low spatial resolution of reported census data in the region. Correct census data lays the foundations for modelling the future spatial distribution of population. Thereby the choice of the underlining census data significantly influences modelling results in the long-term.

Application of the INCLUDE model in the Groundswell Africa report

The Groundswell Africa: Internal Climate Migration in West African Countries report (Rigaud et al., 2021b) applied the model to project future internal climate migration for all of the West African countries from Niger and Nigeria westward. The work included climate impacts with the development scenarios in four combinations: a pessimistic scenario with high emissions and poor development prospects, a more inclusive development scenario with high emissions and more equitable development prospects, a more climate-friendly scenario with low emissions and poor development prospects, and an optimistic scenario with low emissions and equitable development. Figure 32 provides the combinations of RCPs and SSPs used in this work. Further details on the modelling methods can be found in the full Groundswell Africa report (Rigaud et al., 2021b).

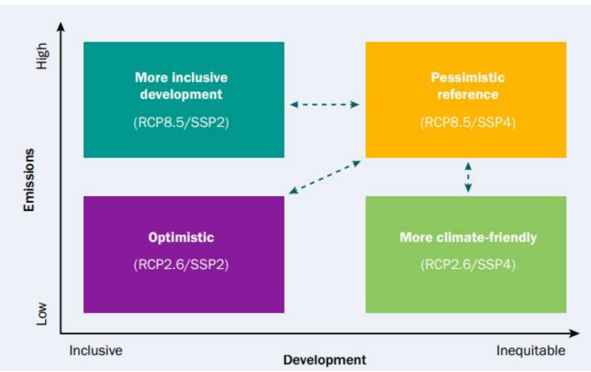


Figure 32: The four scenarios underlying the Groundswell Africa report (Source: Rigaud et al., 2021b).

For this report, the data for eight of the UNISS countries (Mauritania, Senegal, Gambia, Guinea, Mali, Burkina Faso, Niger and Nigeria) have been subsetted from the overall West Africa region. Chad and Cameroon were not included in the Groundswell Africa modelling work. Figure 33 presents internal climate migration projections up to 2050 under the four scenarios, beginning in 2010, which was the baseline for the population projections. The high end of the pessimistic scenario (RCP8.5/SSP4) shows that up to 30.7 million people could move within their countries as a result of climate impacts. However, mean values across scenarios range from 7.1 to 18.3 million, with percentages of the population ranging from 1.19 to 2.60% of the projected population in 2050. Given continued high fertility, total projected population for the UNISS region under SSP2 is 546.4 million, while under SSP4 it is 640.3 million, roughly double current population levels.

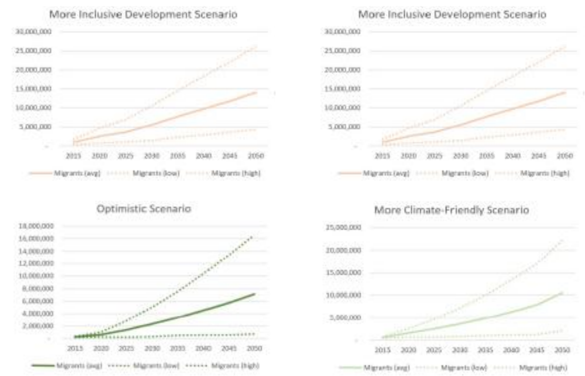


Figure 33: Climate migration projections by scenario (mean with high and low confidence intervals).

Compared to many other regions, the results for the Sahel have wide bands of uncertainty owing to differences in the climate impact signals up to 2050. Commenting on rainfall projections for the Sahel, Biasutti (2019) states, "while uncertainty in future projections remains, confidence in them is encouraged by the recognition that seasonal mean rainfall depends on large-scale drivers of atmospheric circulations that are well resolved by current climate models." The climate models (GCMs) employed for this work project drying in the western Sahel and wetting in the eastern Sahel. Climate projections are then fed into sectoral impact models[44] that estimate future changes in indicators measuring the health of important economic livelihoods e.g. crop yields, water stress. Despite the broad consistency in the GCMs used in this work, the actual water and crop sectoral impact models project differing patterns, often conflicting in the directionality of projected change, which contributes to uncertainty. The maps in Annex C (Figures 41-43), demonstrate that there is a great deal of spatial variation in the crop, water and net primary productivity (NPP)[45] results across the RCP2.6 and RCP8.5 based scenarios.

44 An index approach is used to assess deviations from the historical baseline.

45 NPP is only used to gap-fill areas not included in the crop model results, and extreme values in the Sahara and northern Sahel need to be discounted in part because of very low baseline values.

Figure 34 shows the hotspots of climate migration in the Sahel in 2050, defined as places likely to be large origin and host locations of migrants in the context of climate change. Climate migration hotspots for each scenario reflect areas at the top 5th and bottom 5th percentile in positive and negative population differences between climate and no climate scenarios, respectively. The maps reflect areas with high agreement across scenarios on the locations where the largest number of people will shift into (climate in-migration) or out (climate out-migration) of a grid cell over time.[46] Because hotspots are measured in terms of absolute differences in population under climate and no climate scenarios, more densely settled areas with higher population numbers are more likely to be hotspots.

Climate out-migration will occur in areas where livelihood systems are increasingly compromised by climate impacts, and climate in-migration will occur in areas with better livelihood opportunities. These reflect movements from less viable areas with lower water availability and crop productivity and from areas affected by rising sea level and storm surges to areas with better opportunities. Climate in-migration hotspots reflect better climatic conditions for agriculture, as well as cities able to provide better livelihood opportunities.

Major climate out-migration hotspots appear on the Mali-Mauritania border and in southern Niger. The shifts in Niger from southwest to eastern areas are mostly because of more favourable climatic conditions projected for the eastern portions of the Sahel, and should be viewed with caution, since the areas along the border with Chad are inhospitable. These maps also show that the coastal areas of Mauritania, Senegal and Nigeria are likely to see climate out-migration because of sea level rise and increasing flood hazard.

These hotspots occur against a backdrop of population increase and reflect amplified growth rates (climate in-migration) or reduced growth rates (climate out-migration) because of climate impacts. Given the rapid population growth in Sahelian countries, very few areas will decline in population numbers. So, though an area may represent an out-migration hotspot (in blue), that does not mean that its population will decline. Rather, these out-migration hotspots reflect shifts in population distribution away from certain areas because of habitability declines.

Changes in water availability and crop productivity (as well as net primary productivity where crops are not grown) result in a mix of in- and out-migration hotspots inland. Inland areas that see net climate in-migration (red spots) tend to be where the impact models project higher water availability and, in the northern Sahel, increases in NPP that would be advantageous for pastoralists. These include a few in-migration hotspots near borders, including the Mali–Burkina Faso border and the area north of Kano, Nigeria. While the climate projections may indicate that these areas will be favourable for future growth, recent conflict in these areas may mitigate that growth or, indeed, lead to displacement out of those regions.

46 Out-migration hotspots are places that will see a relative decrease in population in scenarios that account for climate impacts compared to a population projection that does not include climate impacts (no RCPs) and are therefore places that are net origin of internal migrants in the context of climate change. In-migration hotspots on the contrary will face a relative increase in population and are thus net hosts of internal migrants in the context of climate change.

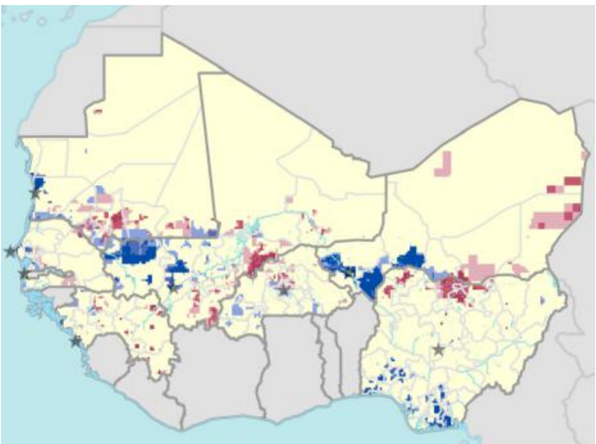


Figure 34: Hotspots of internal climate in- and out-migration for the Sahel region from the Groundswell Africa modelling work for 2050.

Application of the INCLUDE model for the Sahel PA project

Following up on Groundswell Africa, we modified and applied the INCLUDE model to a five-country area of the Sahel (Burkina Faso, Mali, Mauritania, Niger and Senegal) as a pilot study under the Sahel PA project. For this work, additional spatial data relevant to the region was added to the model (conflict data from the ViEWS project; groundwater recharge estimates from the International Atomic Energy Agency (IAEA), and LandSat derived, spatially explicit estimates of built-up land density). We then ran four new SSP/RCP scenarios (SSP2/RCP2.6, SSP2/RCP4.5, SSP3/RCP4.5, SSP5/RCP8.5) that span a range of socioeconomic and emissions outcomes. The two SSP2 scenarios allow us to compare the variation that occurs between a business as usual socioeconomic future in which (1) climate change is dramatically curtailed (SSP2/RCP2.6), and (2) in which climate change also roughly follows a business as usual scenario (SSP2/RCP4.5). The third scenario considers a worst-case socioeconomic future along with a business as usual climate outcome (SSP3/RCP4.5) which allows us to compare the variation that occurs across alternative socioeconomic futures (SSP2 vs SSP3) while holding climate constant (RCP4.5). Finally, we added a worst-case climate outcome (SSP5/RCP8.5) which must be coupled with SSP5 as the scientific community generally agrees this fossil-fuel driven world is the only plausible pathway to RCP8.5. It is worth noting that SSP5 represents a positive socioeconomic future for the region, with access to education and technological diffusion occurring rapidly, driving down birth-rates and leading to a shift in labour from primary to secondary and tertiary sector activities which results in rapid urbanization.

Table 1 presents likely trends on internal migration associated with the effects of climate change for the period 2025-2050 under each scenario. For the full five-country region, estimates of migration related to the effects of climate change range from upwards of 12 million (9.84 per cent of the regional population) under the SSP5/RCP8.5 scenarios on the high end, to just over 5 million (3.42 per cent of the population). Climate change impacts appear to be a significant factor in driving movement, as the proportion of the population uprooted doubles in the SSP2/RCP4.5 scenario relative to the more climate-friendly SSP2/RCP2.6 future. In absolute terms, the number of migrants under the SSP3/RCP4.5 scenario is similar to that driven by the worst-case climate outcome (SSP5/

Table 1: Projected climate migrants (and proportion of the total population) for the five-country study area.

	Climate-Induced Migrants						Portion of Population					
Burkina Faso	2025	2030	2035	2040	2045	2050	2025	2030	2035	2040	2045	2050
SSP2/RCP2.6	178,619	320,808	486,218	686,839	890,400	1,104,599	0.73%	1.18%	1.61%	2.07%	2.48%	2.86%
SSP2/RCP4.5	345,000	576,389	899,085	1,205,002	1,646,977	2,020,381	1.42%	2.11%	2.97%	3.64%	4.58%	5.23%
SSP3/RCP4.5	422,790	606,500	769,387	576,236	1,390,011	1,615,218	1.64%	2.05%	2.28%	1.52%	3.27%	3.43%
SSP5/RCP8.5	1,132,014	1,523,136	1,943,230	2,426,315	2,885,741	3,400,074	4.95%	6.14%	7.27%	8.52%	9.61%	10.87%
Mali	2025	2030	2035	2040	2045	2050	2025	2030	2035	2040	2045	2050
SSP2/RCP2.6	249,561	446,501	689,812	933,766	1,178,266	1,413,775	1.08%	1.73%	2.42%	3.00%	3.51%	3.94%
SSP2/RCP4.5	420,699	759,128	1,193,142	1,625,418	2,087,357	2,481,702	1.83%	2.94%	4.19%	5.22%	6.21%	6.91%
SSP3/RCP4.5	575,178	882,487	1,192,718	1,580,223	2,045,478	2,350,167	2.38%	3.19%	3.82%	4.53%	5.32%	5.60%
SSP5/RCP8.5	868,438	1,308,187	1,889,477	2,442,130	3,000,546	3,580,023	4.03%	5.58%	7.48%	9.08%	10.60%	12.16%
Mauritania	2025	2030	2035	2040	2045	2050	2025	2030	2035	2040	2045	2050
SSP2/RCP2.6	328	24,411	54,436	57,110	87,540	103,656	0.01%	0.49%	1.01%	1.00%	1.46%	1.65%
SSP2/RCP4.5	683	42,299	103,698	109,100	180,809	209,949	0.01%	0.84%	1.92%	1.91%	3.01%	3.35%
SSP3/RCP4.5	21,264	63,966	124,293	129,113	169,637	214,622	0.44%	1.21%	2.16%	2.08%	2.55%	3.03%
SSP5/RCP8.5	12,508	49,990	166,534	264,348	352,012	441,468	0.28%	1.05%	3.33%	5.08%	6.57%	8.07%
Niger	2025	2030	2035	2040	2045	2050	2025	2030	2035	2040	2045	2050
SSP2/RCP2.6	247,355	576,527	1,018,037	1,415,052	1,868,379	2,463,346	0.97%	1.93%	2.95%	3.57%	4.13%	4.84%
SSP2/RCP4.5	625,745	1,048,084	1,764,796	2,334,941	3,040,844	3,894,276	2.44%	3.52%	5.11%	5.88%	6.73%	7.64%
SSP3/RCP4.5	448,324	956,407	1,959,999	2,848,320	3,962,638	5,371,489	1.66%	2.94%	5.03%	6.16%	7.26%	8.42%
SSP5/RCP8.5	761,909	1,027,275	1,317,131	1,718,232	2,213,356	2,775,621	3.21%	3.86%	4.44%	5.26%	6.23%	7.27%
Senegal	2025	2030	2035	2040	2045	2050	2025	2030	2035	2040	2045	2050
SSP2/RCP2.6	63,542	69,912	148,541	202,449	224,333	241,566	0.37%	0.37%	0.73%	0.93%	0.97%	1.00%
SSP2/RCP4.5	230,198	265,997	701,654	841,799	1,054,161	1,157,355	1.34%	1.42%	3.45%	3.87%	4.57%	4.77%
SSP3/RCP4.5	448,117	522,317	926,508	1,270,179	1,331,449	1,772,642	2.40%	2.47%	3.91%	4.82%	4.59%	5.58%
SSP5/RCP8.5	355,076	668,078	993,260	1,274,281	1,641,079	1,874,215	2.23%	4.00%	5.71%	7.11%	9.00%	10.21%
Full Region	2025	2030	2035	2040	2045	2050	2025	2030	2035	2040	2045	2050
SSP2/RCP2.6	739,405	1,438,159	2,397,044	3,295,216	4,248,918	5,326,942	0.78%	1.35%	2.01%	2.51%	2.95%	3.42%
SSP2/RCP4.5	1,622,325	2,691,898	4,662,375	6,116,260	8,010,148	9,763,663	1.71%	2.52%	3.92%	4.65%	5.57%	6.26%
SSP3/RCP4.5	1,915,672	3,031,678	4,972,905	6,404,070	8,899,214	11,324,138	1.91%	2.61%	3.73%	4.22%	5.20%	5.91%
SSP5/RCP8.5	3,129,946	4,576,665	6,309,632	8,125,305	10,092,734	12,071,401	3.54%	4.75%	6.06%	7.31%	8.59%	9.84%

RCP8.5). However, in relative terms the proportion of the population on the move under SSP3/RCP4.5 is some 4 per cent lower. This is owing to the much larger population projected under SSP3 relative to SSP5, and the fact that the SSP5 future suggests more incentive for migration from rural to urban areas in response to climate, as economic conditions in urban areas are far better under the SSP5 future.

While the SSP5/RCP8.5 scenario leads to the highest number of migrants in most countries, the trend is not universal. In Niger, the models project significantly less movement under the SSP5/RCP8.5 future relative to both the RCP4.5 futures. In this instance, it is the socioeconomic futures associated with SSP2 and SSP3 that lead to a higher number of migrants than in the worst-case climate outcome. Given that Niger is currently characterized by a very low urbanization rate and large portions of the population engaged in agriculture and pastoralism (two of the most threatened livelihoods under any amount of climate change), the results suggest that emphasis on economic transitions and socioeconomic well-being are, in this case, even more important than climate action. That being said, investments into climate mitigation and adaptation remain of extreme importance.

Impacts of climate change and other drivers are not uniform across the region, so a spatial dimension is important. Figure 35 shows the potential development of hotspots of climate migration in the five-country region by 2050 based on the Sahel PA project modelling work. As in the application for the Groundswell Africa report outlined above, climate migration hotspots for each scenario reflect areas at the top 5th and bottom 5th percentile in positive and negative population differences between climate and no-climate scenarios, respectively. The maps reflect areas with high agreement across ensemble members and scenarios on the locations with the largest projected gains in populations (climate in-migration) and losses (climate out-migration).

Similarities with Figure 34 in some more rural areas (the area surrounding Niamey in Niger and along the border of Mali and Mauritania to the northwest of Bamako) result from the common application of ISIMIP data in the model. However, it is notable that here we appear to have more local definition in the distribution of hotspots, particularly in and around urban areas, likely as a result of the additional spatial detail included in this application of the model. Most urban areas are projected to serve as in-migration hotspots, and the spatial detail regarding urban-rural dynamics around many larger cities (e.g. Bamako) are indicative of rural to urban migration as rural livelihoods falter. Rural areas projected to grow under climate change scenarios (e.g. the border between Niger and Nigeria north of Kano) generally coincide higher water availability.

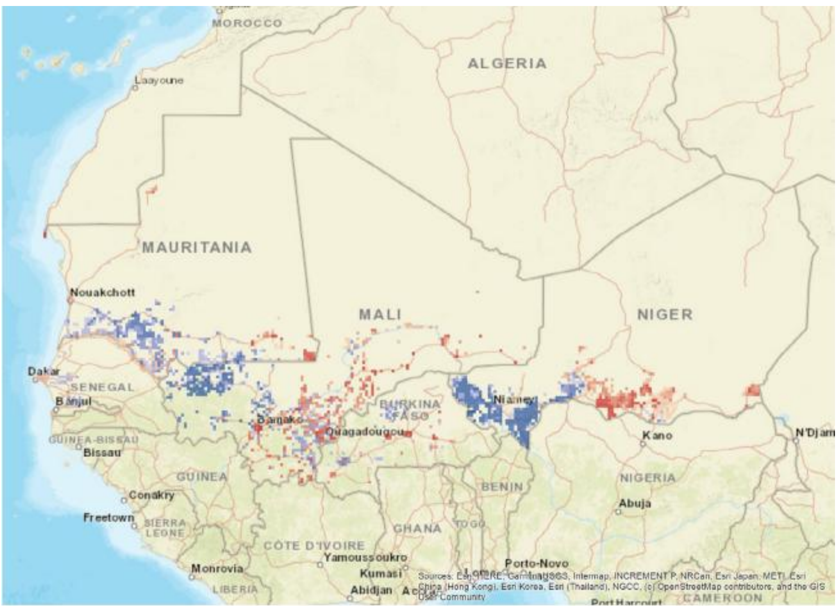


Figure 35: Hotspots of internal climate in- and out-migration for the Sahel PA modelling work, Sahel Region, for 2050.

Conclusion

Migration and displacement trends in the Sahel and their outcomes are complex and evolving. The literature reviewed in this chapter provides further understanding of the varied and complex nature of human mobility. It can, for example, be a positive response to climatic and other shocks and stresses. Migrating to where paid work opportunities are available can help to diversify household income and thereby absorb the adverse effects of crop yield losses due to extreme weather events (Vinke et al., 2021). Rural to urban migration, while not without potential challenges in both sending and receiving areas, can also be a way to address unemployment and underemployment, particularly for youth (de Brauw et al., 2014). At the same time, population movement may be triggered by the lack of alternative livelihood options as traditional rural livelihoods come under increasing stress, or dwindling resources may mean that undertaking regular or seasonal migration as a household coping strategy is beyond household means – leading instead to displacement or involuntary immobility.

Wherever displacement occurs in the context of conflict, disasters and adverse climate change impacts, displaced people should be adequately protected, whether they remain within their countries of residence or flee to other countries in search of safety. Cooperation among all actors is key if we are to avert, minimize and address the challenges associated with human mobility in the context of climate change and disasters in an integrated manner.

The different models highlighted in this chapter each bring together multiple sources of data, including on conflict, climate change and environmental degradation, to provide important insights into this complexity over different time scales and across a broad range of situations. Under all climate change scenarios, investment in the development of adaptive capacities – with voluntary migration as one option – is increasingly urgent, while climate in combination with multiple other factors are expected to drive a growing displacement trend.

While projected quantitative estimates of future movements should be handled with due care and attention to definitions, assumptions and limitations, those generated by these models help to provide a sense of scale. The short-term displacement forecasts made using the Danish Refugee Council's Foresight and WACAFI models find that conflict-related displacement may increase from approximately 7.5 million people displaced in the region in 2021 to 8.9 million by the end of 2023, i.e. an increase of nearly 20 per cent (1.4 million people) over the coming two years.

The two sets of longer-term projections of climate-induced internal migration produced using the INCLUDE model offer other findings: The first, taken from the Groundswell Africa report (Rigaud et al., 2021) forecasts between 7.1 and 18.3 million people (around 1.2 to 2.0 per cent of the total projected population) will migrate within their countries as a result of climate impacts by 2050. An updated version of the model for the Sahel PA project was applied to a five-country subregion (Burkina Faso, Mali, Mauritania, Niger and Senegal) found that 5.3 - 12.1 million people (nearly 3.5 per cent to 10 per cent of the total projected population) could be moving by 2050.

TOWARDS RESILIENCE IN THE SAHEL

STRATEGIC RECOMMENDATIONS

Photo: RSS Secretariat

The Sahel region emerges as a climate vulnerability hotspot, faced with an interplay of climate impacts, food insecurity, weak governance, conflict, migration and displacement.

Climate change projections show that the region will become gradually hotter. Extreme weather events, including droughts and floods, are expected to intensify in this context. Rainfall trends are more uncertain and vary across the region, but the overall trend shows a projected increase in rainfall in the future. Those changes, in combination with a growing population, could lead to aggravated resource scarcities, especially in rural areas. Short-term predictions highlight that large parts of the Sahel already experience crisis levels of food insecurity, with some parts even reaching emergency levels. In the long term, yields of maize, millet and sorghum are projected to decline due to climate change, putting even more pressure on already vulnerable rural populations. Yields of cassava, cow peas, groundnuts and rice, on the other hand, are projected to benefit from CO_2 fertilization. While these general crop-depending trends are visible, impacts are expected to vary greatly across the region, which highlights the need for location- and context-specific adaptation measures to promote resilient and productive agricultural systems.

Coupled with other factors, advancing anthropogenic climate change is depriving farmers and pastoralists of their livelihoods, increasing vulnerabilities and threatening human security in the Sahel. There are strong feedback loops between the adverse effects of climate change and other conflict drivers, in particular governance, which contribute to a downward spiral of violence. Armed conflict will continue to plague the region for years and most likely decades, unless radical change occurs. The cumulative impact of both climatic and non-climatic shocks on households makes them more prone to


Photo: UNDP Nigeria

recruitment by armed groups and contributes to migration and displacement. While migration can be a successful adaptation strategy, many who are forced to leave their homes face deteriorated living conditions and increased vulnerability.

Despite the negative trends mentioned above, the Sahel is endowed with abundant natural resources which, if managed equitably and sustainably, “could turn the region’s fortunes around” (UNECA, 2019). The overall development trend points to improvements, yet those are marginal (OSCDE, 2021). With some exceptions, GDP, GDP per capita and government spending have grown significantly although admittedly starting from very low bases. For the most part, peaceful coexistence and cooperation between community groups have prevailed, and customary laws have often resulted in peaceful resolutions of local conflicts, although there have been tensions over time, which in some cases have turned violent, as in recent years.

This analysis shows that it is possible to predict short-, medium- and long-term changes in climate, food security, conflict and displacement, which can help to identify existing and emerging risk hotspots across the Sahel region. **Better anticipating those risks is key if the region is to move away from humanitarian response towards proactive decision-making and resilient development.**

Based on the projections and analyses conducted as part of this report, drawing from the comprehensive data review process and in close consultation with various stakeholders and experts, various concrete policy recommendations were identified to improve anticipatory action and preparedness in the Sahel. Those recommendations can be clustered into three broad topics: (1) data availability and quality, (2) adaptation and (3) governance.


Photo: RSS Secretariat

3.1 Data availability and quality

Data access and availability is a core tenet of any predictive analytics project. Seeking to expand and improve current models, the members of the research consortium embarked on a comprehensive data review process as part of the Sahel PA project. Having reached out to 23 UN system entities and more than a dozen organizations from the public and private sector, then undertaking more than 50 individual discussions, a number of issues were identified.

First, the issue of **data availability and accessibility.** In addition to a lack of investment, ongoing conflict contributes to data scarcity in the Sahel. As an example, both factors have led to a 50 per cent decrease in data collected through weather balloons across the continent from 2015 to 2020 (WMO, 2020). This study further found that publicly available agricultural data in the Sahel is sparse and/or unreliable. Even though all countries are represented in the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) on agricultural yields and inputs, which go back to the 1960s for most crops, these data are only collected on a national level and consist of a mix of official data, imputations, calculated data and estimates. They are therefore of limited use for predictive modelling due to their unquantifiable uncertainties.

Accessibility is also hindered by the fact that many of the UN organizations do not own the data they use, nor do they have a monopoly on these data. Rather, they act as coordinators and intermediaries for data gathering and management. As such, it becomes difficult to share the data in its totality as every contributor would need to grant access to their input/country information. This is a major impediment to quantitative research which in turn severely hinders thorough data analysis.

Second, the issue of **gaps in temporal and spatial coverage** of available data. The UN system is uniquely placed to collect and manage invaluable high-quality data from the countries and missions in which it is engaged. Such data holds the potential to greatly assist future research and predictive analytics, which could help inform future policies and targeted interventions to the areas in which they are most needed. However, data collection is costly and has often been limited to specific regions and/or selected or irregular time periods, rendering the number of data points available highly restricted. While such data compilations are often sufficient to inform singular qualitative studies, predictive analytics projects require a large amount of data points with entries collected in a systematic and uniform manner in order to adequately train and calibrate forecasting models. One issue, for example, is the inconsistent categorization of spatial administrative units, with some countries (e.g. Niger) having changed their administrative divisions or others using unclear definitions based on local names and agricultural practice (e.g. Mauritania).

Third, the issue of lack of consistency in data gathering, particularly in terms of survey data. Even though several high-quality sources of survey data were identified during the data review phase of the project for conflict and displacement, the use of these sources was significantly limited by a lack of standardization. There are differences in survey methodologies and definitions across regions that make data difficult to collate and compare. Additionally, there is a lack of consistency in choice of region to cover. This means that some regions within a country are over-represented, thus making the given survey a poor model for the entire country.

Some of these issues will require administrative and governance solutions, such as a method for streamlining and simplifying data-sharing processes. Others will require methodological and organizational interventions in future data collection efforts, for example greater consistency in temporal and geographic coverage and methods used by various organizations. Such investments could allow us to make use of the invaluable knowledge contained within the silos found in governments and international organizations and enable objective predictive analytics to assist policymakers by providing a quality source of information. Efforts to improve data sharing and accessibility could build on ongoing initiatives, such as the guidance developed by the Inter-Secretariat Working Group on Household Surveys for the next decade or the work done by the Committee for the Coordination of Statistical Activities (CCSA).

SPECIFICALLY, WE RECOMMEND THE FOLLOWING:

- **Building a network of data-sharing (preferably digital) hubs to make existing data publicly available** is key to leverage the already available data sources and improve predictions.

- To improve the data landscape, statistical offices, meteorological agencies and ministries of the Sahel countries should be supported in **collecting data in a standardized manner and to facilitate timely exchanges,** gather additional subnational data and collate already acquired (public and non-public) data. To enhance climate data availability and quality, countries should be supported in building and maintaining weather stations and collecting weather data in a standardized manner. To improve agricultural predictions, standardized and regular crop yield data collection at plot, village and subnational level needs to be improved.

- Reliable displacement and conflict data is particularly hard to gather and **long-term commitments to such data collection** are crucial. This would, for instance, allow for **consecutive survey waves and consecutive qualitative data gathering to monitor developments over time** and make more accurate inferences about implications for the future. Depending on adequate privacy protection mechanisms, using modern technology, such as Big Data, could be one way to improve data availability.

- In this digital era, the Sahel is experiencing a **"technological dynamic",** supported by a large penetration of mobile devices. This could provide new opportunities for real-time data collection and sharing and allows for the inclusion of perspectives from marginalized communities. UNISS should consider piloting real-time data collection platforms focusing on variables of interest for predictive analytics.

- The **involvement of local experts and stakeholders in data collection, model development and scenario-building,** particularly in the early stages, will help to tap into the vast array of context-specific knowledge and skills on the ground and can help predictions and resulting adaptation measures to be more readily accepted by the local population planners and political decision makers.

- **Joint international research with institutions in the Sahel** should be supported. This includes online and in-person exchanges and training of researchers. Sahelian early-career researchers and practitioners should be supported to form a basis for better risk anticipation capacities in the countries in the future.

3.2 Adaptation

The climatic changes projected above can lead to widespread food insecurity and significant displacement within the region. In the face of rising temperatures, increasing food insecurity, declining access to crucial resources such as water, a growing population and increasing urbanization, the Sahel is at great risk of falling yet deeper into the 'conflict trap'. Even in the absence of overt conflicts, human security regarding dignity, safety and general well-being is at stake in situations of increasing resource scarcity and food insecurity. Vulnerable societies are less able to recover from the adverse impacts of climate change and disasters and may become more prone to displacement and conflict risks, which is why investment in adaptation is a crucial means to mitigate future disasters and reduce climate-related conflict risks in the region.

Resilience of communities is particularly crucial where agricultural dependence is high, as households that rely on crop production for their primary income become more vulnerable to climate shocks and related crop failures. Such vulnerabilities can contribute to communities' feelings of deprivation and enhanced grievances over a lack of basic rights. Vulnerabilities may also expand opportunities for militias to mobilize deprived individuals and create situations where people either choose to migrate or are forced to flee. Economies that are heavily dependent on agriculture are also more associated with illiteracy, higher levels of poverty, poor governance and rent-seeking elites at the country level.

While migration can be a successful adaptation strategy, many who are forced to move due to changing climatic conditions and extreme weather events are unable to maintain their living standards in their new settlements post migration (Vinke et al., 2020). Moreover, many people that migrate prefer to stay as close to their original homes as possible, therefore efforts to enable the population to safely and sustainably migrate or stay within their communities need to be increased. This reiterates the importance of investing in local capacity-building to support adaptation and societal resilience as a mitigator of future conflict and displacement. These challenges and the broad range of options to address them, illustrate the value of adopting a holistic approach to peacebuilding and conflict prevention.

Overall, **climate change adaptation measures need to be mainstreamed in local, national and regional policies and programmes,** as well as in international cooperation projects and efforts to implement the UNISS. There should be a focus on people in the most vulnerable situations, including displaced persons, as our research also revealed that refugee camps in the regions are increasingly affected by climate change impacts. Inclusiveness and policy coherence must be promoted, and it must be ensured that women are effectively involved in decision-making at all levels by providing resources, advocacy, capacity development, remuneration and other initiatives.

Photo: UNDP Mali

PRECISELY, WE RECOMMEND THE FOLLOWING:

- **Using participatory approaches and indigenous knowledge is key.** Local populations already have a vast array of knowledge on regional environmental conditions, as well as experience with adaptive strategies which can be used in climate adaptation and paired with insights from climate science. A participatory approach includes affected communities in the design of adaptation measures, also facilitating the acceptance of such measures among the local population. An example of such an approach is Participatory Scenario Planning (PSP) for seasonal climate decision-making.[47] However, with fast changing and more extreme climate conditions, innovative solutions and new technologies are also needed as part of a comprehensive adaptation strategy.

- Suitable adaptation strategies have been identified and tested across the region. Yet, considerable knowledge is neglected and structures that have been developed over the last decades continue to be severely under-resourced. **Leveraging lessons learned and best practices while building on and enhancing coordination across existing regional and national structures,** such as the Permanent Interstate Committee for Drought Control in the Sahel (CILSS), is key to scale up adaptation across the region. Integrated and area-based approaches must seek to bolster and gather support around those regional and national structures and identify best practice where it exists.

- Building and strengthening resilience to the impacts of climate change and **investing in national social protection systems** will, over time, help to reduce food insecurity and provide more stable and predictable means to address them.

- Investment in **disaster prevention and disaster risk reduction** is needed. Coverage by early-warning systems must be enhanced and access to these systems eased, especially for people in the most vulnerable situations.

- Improving **safe pathways for migrants and protecting the rights of people in all phases of movement** will help communities build resilience, leading to a reduction of displacement risk. Moreover, barriers to local integration of people in their area of refuge can be promoted through existing migration dialogues.

- There is a need to further **mobilize funding for displaced and trapped populations.** Options for resettlement from hazardous areas need to be assessed and implementation supported where necessary.

- **Access to domestic energy** is often not accounted for in planning schemes by governments but is absolutely essential. Especially in displacement settings, investments in gas and/or renewables should be a priority. This demands inter-agency coordination from the UN to ensure a holistic approach, including halting deforestation and investment in reforestation.

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47 PSP describes ''a process of collective sharing, learning, and interpretation of seasonal climate forecasts where multiple stakeholders, including meteorologists, community members, local government departments and local NGOs share knowledge and discuss to find ways to interpret the information into a form that is locally relevant and useful'' (Le et al., 2018)

With wood being the predominant energy source, deforestation around the areas of concentration of displaced people is becoming irreversible. Despite relatively proactive policies by governments to make gas affordable to people in the most vulnerable situations, the transition from wood to gas is slow. The weak presence of the private sector outside the major cities and the absence of strong demand due to the inability of vulnerable households to make the first investment are the main bottlenecks. **The establishment of a win-win partnership with the private sector to support both the supply and demand of gas** is essential. At the same time, renewable energy initiatives need to pay closer attention to the multitude of past interventions, many of which have faced challenges of scaling up and economic rationality. To have a better chance of success, interventions aimed at rehabilitation of degraded lands and reforestation should include a component related to the provision of wood alternatives for domestic energy.

Given that climate change is projected to have severe negative effects on the agricultural sector in the Sahel, and thereby on the livelihoods and food security of its population, there is a need for more agricultural support in terms of climate adaptation and resilience. The potential for ecological restoration, that is the return of biodiversity and productivity to lands, is great across the Sahel and already underway (UNCCD, n.d.).

In particular, emphasis should be given to providing technical support at the national level for relevant ministries (e.g. Ministries of Agriculture or Environment) to implement projects of the scale and ambition needed.

- **Resilient and sustainable agricultural production** (including traditional and new techniques) should be promoted capitalizing on the complementarity of agricultural and pastoral production systems. This includes increasing the funding of national agricultural research systems, **the provision of adequate agricultural technical and vocational education and training systems,** and building the skills of young people, marginalized population groups and women to seize the entrepreneurship opportunities offered in the agricultural sector. Finally, public policies must opt for the construction of a sustainable intensification around family farming systems, which should be further supported by the intervention of the private sector through inclusive business models and investments.

- **Community-led reforestation methods,** such as Farmer Managed Natural Regeneration, should be scaled up across the region, strengthening local climate adaptation through agroforestry and harnessing mitigation co-benefits. Reforestation efforts can also entail intercommunal environmental peacebuilding methods which support common resource management.

It is important to also give priority to climate change adaptation in other climate-sensitive sectors, such as infrastructure, energy and water. An increased investment to strengthen digital infrastructure for universal connectivity is also necessary. This way, economic diversification opportunities could be promoted which, together with broader regional economic integration and the free movement of people and goods across the Sahel, would help strengthen resilience in the long-term.

3.3 Governance

To tackle the interrelated risks outlined in the report, promoting good governance is of particular importance. Discussed in depth in Chapter 2.3, good governance is key to handling the challenges from climate change, demographic pressure and violent actors in the region. Violent conflict and military coups are much more prevalent in countries with political institutions that are non-representative and repressive and/or unable to produce good governance outcomes. Poorly governed countries with weak rule of law are poorly placed to promote economic growth and reduce poverty. Given the impact from climate change and population growth that will affect the Sahel more than any other region in the world, policies in the region must be very ambitious. To succeed in such policies without widespread social unrest, good governance, equal distribution of the impacts and the protection of civil liberties are essential.


Photo: UNHCR Niger

IN PARTICULAR, WE RECOMMEND THE FOLLOWING:

- **Strengthening both the rule of law,** particularly the coherence of rules that govern access to land and land tenure security, **and the inclusivity of public institutions and social networks** are important medium- to long-term measures in addressing conflict risks. In addition, it is important to improve access to dispute settlement mechanisms, for example through combined court and informal conflict resolution mechanisms. Strengthening people's trust in and access to official courts, as well as transitional justice, to address human rights violations after periods of conflict is also an important measure.

- It is important to **improve inclusiveness and ownership within governmental institutions** in order to foster greater representation of marginalized groups. Underrepresentation can cause grievances and can contribute to the proliferation of armed non-state actors, who tap into this dissatisfaction.

- **Strengthening collaboration with local elected officials through area-based approaches** at all stages of defining and implementing strategies and interventions is crucial. In parallel with support for national development plans, specific attention must be paid to **supporting policies of decentralization of competencies** from the central level to the regional and communal level. These policies have been underway since the 1990s but their issues, scope and mechanisms are still poorly understood by aid actors (UN system entities and NGOs). The increased responsibility of town halls and regional councils in essential sectors such as health, water, education, urban planning or natural resources management does not translate into increased collaboration between local elected officials and external actors. The lack of effort to include local elected officials in decision-making, coordination, exchange and planning weakens local governance. This is highly problematic given that strong local governance strengthens the trust between a state and its population, and is thereby a central element in the process of stabilizing or even overcoming a crisis.

- Considering that displacements are projected to rise, **improving intercommunal relationships,** particularly between displaced and local populations, can help reduce potential conflict. The same also applies to farmer-herder relations: fostering cooperation and complementarity between these groups is an important step towards achieving the first strategic orientation for the Sahel to "promote inclusive governance for better community living". One suggested way to do this is through **participatory land use planning and mapping.**

- **Addressing pastoral grievances.** The protection of pastoral routes, supportive infrastructure along the way and improved fodder are among the measures that could contribute to more peaceful relations between pastoralist communities and other user groups, in addition to the positive economic outcomes they could provide.

- **Community and vocational training centres** can help improve communication and ease intercommunal tensions. Joint training and skills development programmes for displaced and host communities can strengthen collaboration. Courses on climate adaptation and mitigation could serve the future needs of host and source countries alike. Measures need to support self-efficacy of refugee populations and invest in long-term skill development, besides urgently needed disaster relief.

- Impeding traditional freedom of movement has the potential to add to intercommunal tensions by adversely affecting transhumant pastoralism and potential income diversification though seasonal labour migration. It is therefore important to **improve intraregional freedom of movement** and revert back to the Economic Community of West African States (ECOWAS) protocols, while strengthening the rule of law. Regional mobility serves as a crucial measure in help to confront societal shocks such as climate change and the COVID-19 pandemic.

- Although peacekeeping is extremely challenging, research clearly shows that UN peacekeeping engagement can help to contain armed conflict, limit the amount of violence and mitigate the adverse consequences relative to a situation without peacekeeping engagement. Continued and expanded budget support and mandates for peacekeeping and peacebuilding is and will thus be instrumental to reducing the prevalence of political violence in the region.

- Strengthen the understanding of the climate and security nexus through the expansion of strategic positions, such as the recently created United Nations Climate Security and Environmental Advisor to Somalia, which specifically address the links between climate change, environment and conflict in the country. Evaluate lessons learned from this position and test applicability to different contexts in the Sahel. Monitoring the occurrence and risk of armed conflict will be essential to anticipating the challenges to human development, highlighting the costs of non-action and paving the way for the realization of the Sahelian and pan-African visions for the future.

While measures aimed at immediate conflict reduction may offer a temporary respite, any efforts to promote a sustainable peace must also address the structural challenges that the Sahel faces. It follows that more investment should be channelled towards capacity-building for societal resilience to climate extremes (see also Adaptation).

- Recognizing the high levels of population growth in the region, pro-youth policies and programmes should be promoted.

- Sahel economies are facing several challenges, including the low capacity to mobilize internal and external resources. Given the COVID-19 pandemic and its impact on the economies of Sahel countries, an economic recovery plan is urgently needed. The UN system can play a critical role in supporting resource mobilization strategies, e.g. in the form of grants, loans (concessional) and tools like debt service management initiatives and debt swap.

As the above underlines, reactive measures that address immediate needs at the expense of long-term investments in the Sahel will not suffice. To make a meaningful change towards durable peace and prosperity in the Sahel, governments and UN agencies must address the structural and slow-moving features that characterize countries over time, while making a concerted effort at local and national capacity-building to enhance societal resilience to climate extremes and other exogenous shocks.

CONCLUSION

Photo: RSS Secretariat

Increasing temperatures, intensified extreme weather events and high uncertainty regarding rainfall trends are paired with growing population numbers, laying the foundations for resource scarcities, declining yield trends of key staple crops and food insecurity in large parts of the Sahel. Given that most people in the region make a living from smallholder farming, such developments make many households highly vulnerable and raise concerns regarding human security and human mobility patterns. Where climate impacts clash with bad governance, violent conflict is often not far away. Without radical change, armed conflict will most likely remain prevalent in the Sahel for decades to come. Extremist recruitment will continue to find fertile ground where people are deprived of their livelihoods by climatic and non-climatic shocks, which further fuels armed conflict. As a consequence, migration and displacement will continue, rendering intercommunal tensions and grievances more likely and further increasing people's vulnerability to all four risk areas discussed in this report.

The disruptive nature of interrelated crises in the Sahel, such as displacement, food insecurity, conflict and climate-related extreme events, are a significant barrier to development and to achieving the goals set out in key regional planning initiatives (e.g. Agenda 2030, Sahel 2043, UNISS). Without immediate bold and collective action, the projected impacts of climate change on food security will continue to nourish instability, armed conflict and displacement in the region, thereby hindering the unfolding of the Sahel's manifold potential. To prevent this, it is vital to implement location- and context-specific adaptation measures that promote resilient and productive agricultural systems. Governments must address structural challenges that their countries are facing and enhance societal resilience to climate extremes and other exogenous shocks. This can be supported by cross-border cooperation and collaboration with local elected officials, inclusive growth and the empowerment of women and young people.

Photo: UNDP Nigeria

This report has contributed to a sound, data-based prediction of future economic, social, political and environmental trends in the Sahel to foster informed and anticipatory action. With the advent of new computational technologies (e.g. increased data storage, transfer and processing speeds, advanced high-level programming languages) and the greater availability of data, vulnerability hotspots might be better modelled and anticipated. This, in turn, could transform humanitarian responses, sustainable development and international protection from being primarily reactive to proactive and inform preventative, climate-smart and conflict-sensitive development planning.

Notwithstanding the above risks and bottlenecks, the Sahel is a promising region with considerable natural, cultural and human resources. Predictive analytics can play an instrumental role in supporting their sustainable use for human progress.

The Sahel sits on one of the largest aquifers in Africa. With appropriate investments, including solar powered pumps and enhanced water management, these significant groundwater resources could especially benefit water stressed rural populations. The region further holds great potential for ecological restoration. The process of regreening has already started and, according to the United Nations Convention to Combat Desertification (UNCCD), tree coverage has improved in many areas over the past years (UNCCD, 2021; UNCCD, n.d.). This is a clear sign of the vast potential to restore land productivity and biodiversity via resilient and sustainable agricultural and livestock practices. In addition, the Sahel has an immense productive potential for renewable energy including abundant solar energy capacity. Only 49 per cent of the Sahelian population has access to electricity and only 12 per cent access to clean cooking (IEA et al., 2021) which provides enormous opportunities not only for renewable energy markets but also to improve health, protection, education and livelihoods. Moreover, the region can profit from a dynamic young population that can serve as a vital vector for development. Around 64 per cent of the Sahelian population is less than 25 years old, making it one of the most youthful regions worldwide (UNDESA, 2021). This demographic dividend is and should be mirrored and considered in employment, education and training programmes in order to maximize young people’s potential, including their human agency, innovation and entrepreneurial spirit.

It is thus crucial to strengthen inter-agency cooperation and use the best available science to instil a new approach and make the change towards anticipation and preparedness that will build on these assets to guide the structural transformation and a new narrative in and for the Sahel. It is time to see the Sahel as a promising region of opportunities and for every organization with a part to play to work together to support unleashing these opportunities for the good of the population of the Sahel.

References

Adepoju, A. (2003). Migration in West Africa. Development, 46(3), 37–41. https://link.springer.com/article/10.1177/10116370030463006

Andrijevic, M., Cuaresma, J., Muttarak, R., & Schleussner, C. (2020). Governance in socioeconomic pathways and its role for future adaptive capacity. Nature Sustainability, 3(1), 35–41. https://doi.org/https://doi.org/10.1038/s41893-019-0405-0

Andrijevic, M., Crespo Cuaresma, J., Muttarak, R., & Schleussner, C.-F. (2020). Governance in socioeconomic pathways and its role for future adaptive capacity. Nature Sustainability, 3(1), 35–41. https://doi.org/10.1038/s41893-019-0405-0

Badewa, A. S., & Dinbabo, M. (2021). Irregular Migration and Regional Security Complex in the Sahel-Lake Chad Corridor: A Human Security Discourse. Ìrìnkèrindò: A Journal of African Migration. https://africamigration.com/issue/nov2021/IJAM_12_IRREGULAR_MIGRATION_WEB.pdf

Bayar, M., & Aral, M. (2019). An Analysis of Large-Scale Forced Migration in Africa. International Journal of Environmental Research and Public Health. https://doi.org/10.3390/ijerph16214210

Benjaminsen, T. A., & Ba, B. (2019). Why do pastoralists in Mali join jihadist groups? A political ecological explanation. The Journal of Peasant Studies, 46(1), 1–20. https://doi.org/10.1080/03066150.2018.1474457

Bertaud, A.,& Malpezzi, S. (2004). The Spatial Distribution of Population in 48 World Cities:Implications for Economies in Transition. https://www.academia.edu/48428283/The_spatial_distribution_of_population_in_48_world_cities_Implications_for_economies_in_transition

Biasutti, M. (2013). Forced Sahel rainfall trends in the CMIP5 archive. Journal of Geophysical Research D: Atmospheres, 118(4), 1613–1623. https://doi.org/10.1002/jgrd.50206

Biasutti, M. (2019). Rainfall trends in the African Sahel: Characteristics, processes, and causes. WIREs Climate Change, 10(4). https://doi.org/10.1002/wcc.591

Bjornlund, V., Bjornlund, H., & Van Rooyen, A. F. (2020). Why agricultural production in sub-Saharan Africa remains low compared to the rest of the world – a historical perspective. International Journal of Water Resources Development, 36(sup1), S20–S53. https://doi.org/10.1080/07900627.2020.1739512

Black, R., Arnell, N. W., Adger, W. N., Thomas, D., & Geddes, A. (2013). Migration, immobility and displacement outcomes following extreme events. Environmental Science & Policy, 27, S32–S43. https://doi.org/10.1016/J.ENVSCI.2012.09.001

Black, R., Bennett, S. R. G., Thomas, S. M., & Beddington, J. R. (2011). Migration as adaptation. Nature, 478(7370), 447–449. https://doi.org/10.1038/478477a

Blocher, J., Gharbaoui, D., & Vigil, S. (2015). West Africa: a testing ground for regional solutions. Forced Migration Review, 49, 3. https://www.fmreview.org/climatechange-disasters/blocher-gharbaoui-vigil

Blocher, J. M., Vinke, K., Schellnhuber, H. J., Gleixner, S., Gornott, C., George, N. B., Kileli Leyani, E. O., Laudien, R., Lobanova, A., Ludescher, J., & Weisz, H. (2021). Assessing the Evidence: Climate Change and Migration in the United Republic of Tanzania. https://publications.iom.int/books/assessing-evidence-climate-change-and-migration-united-republic-tanzania

Blocher, J. M., Hoffmann, R., & Weisz, H. (n.d.). Evidence of Erosive Effects of Multiple and Cumulative Household-reported Livelihood Shocks on Migration in Tanzania.

Bøås, M. (2018). Rival Priorities in the Sahel - Finding the Balance between Security and Development. https://reliefweb.int/sites/reliefweb.int/files/resources/Policy Note on Sahel_Final Version.pdf

Bøås, M., & Strazzari, F. (2020). Governance, Fragility and Insurgency in the Sahel: A Hybrid Political Order in the Making. The International Spectator, 55(4), 1–17. https://doi.org/10.1080/03932729.2020.1835324

Boix, C. (2008). Economic Roots of Civil Wars and Revolutions in the Contemporary World. World Politics, 60(3), 390–437. https://doi.org/10.1017/S0043887100009047

Brottem, L., & Mcdonnell, A. (2020). Pastoralism and Conflict in the Sudano-Sahel: A Review of the Literature. https://www.researchgate.net/publication/347465818_Pastoralism_and_Conflict_in_the_Sudano-Sahel_A_Review_of_the_Literature

Cadre Harmonisé. (2021). Résultats de l'analyse de l'insécurité alimentaire et nutritionnelle aiguë en mars-mai 2021 et en juin-août 2021. Au Sahel, en Afrique de l'Ouest et au Cameroun. . https://www.ipcinfo.org/fileadmin/user_upload/ipcinfo/docs/ch/CH_Regional_Acute_Food_and_Nutrition_Insecurity_2021MarAug.pdf

Cadre Harmonisé. (2022a). Résultats de l'analyse de l'insécurité alimentaire et nutritionnelle aiguë courante en mars-mai 2022 et projetée en juin-août 2022 1. Au Sahel, en Afrique de l'Ouest et au Cameroun. https://www.ipcinfo.org/fileadmin/user_upload/ipcinfo/docs/ch/Fiche_comunicaion_R%C3%A9gion_SAO_MARS2022_VF_.pdf

Cadre Harmonisé. (2022b). CH Map Key: Acute Food and Nutrition Insecurity March 2022 - August 2022. https://www.ipcinfo.org/cadre-harmonise

Carleton, T. A., & Hsiang, S. M. (2016). Social and economic impacts of climate. Science, 353(6304). https://doi.org/10.1126/SCIENCE.AAD9837

CASCADES. (2021). Scenarios on possible future impacts of climate change in the Central Sahel.

Cepero, O. P., Desmidt, S., Detges, A., Tondel, F., Ackern, P. Van, Foong, A., & Volkholz, J. (2021). Climate Change, Development and Security in the Central Sahel. https://www.adelphi.de/de/publikation/climate-change-development-and-security-central-sahel

Christidis, N., Mitchell, D., & Stott, P. A. (2019). Anthropogenic climate change and heat effects on health. International Journal of Climatology, 39(12), 4751–4768. https://doi.org/10.1002/joc.6104

Clark, Colin. (1951). Urban Population Densities. Journal of the Royal Statistical Society. Series A (General) 114(4), 490. https://doi.org/10.2307/2981088

Clement, V., Kanta Kumari, R., de Sherbinin, A., Jones, B., Adamo, S., Schewe, J., Sadiq, N., & Shabahat, E. (2021). Groundswell Part 2 : Acting on Internal Climate Migration. https://openknowledge.worldbank.org/handle/10986/36248

Collier, P. (1999). On the economic consequences of civil war. Oxford Economic Papers – New Series, 51, 168–183. https://www.jstor.org/stable/3488597

Collier, P., Elliott, V. L., Hegre, H., Hoeffler, A., Reynal-Querol, M., & Sambanis, N. (2003). Breaking the Conflict Trap: Civil War and Development Policy. A World Bank policy research report. https// doi.org/10.1086/503614

Collier, P., & Hoeffler, A. (2004). Greed and grievance in civil war. Oxford Economic Papers, 56(4), 563–595. https://www.jstor.org/stable/3488799

CONASUR. (2021). Enregistrement des Personnes Deplacees Internes du Burkina Faso. https://reliefweb.int/sites/reliefweb.int/files/resources/Tableau de bord général sur l%27enregistrement des PDI au 31 Décembre 2021.pdf

Coppedge, M., Gerring, J., Knutsen, Carl Henrik Lindberg, S. I., Teorell, J., Altman, D., Bernhard, M., Fish, M. S., Glynn, A., Hicken, A., Lührmann, A., Marquardt, K. L., McMann, K., Paxton, P., Pemstein, D., Seim, B., Sigman, R., Skaaning, S.-E., Staton, J., Cornell, A., ... Zibla, D. (2020). V-Dem Codebook v10. Varieties of Democracy (V- Dem) Project. http://doi.org/10.2139/ssrn.3557893

Coxhead, I., Nguyen, C. V., & Vu, L. H. (2015). Migration in Vietnam: New Evidence from Recent Surveys (Issue ID 2752834). https://doi.org/10.2139/ssrn.2752834

Crawford, A. (2015). Climate change and state fragility in the Sahel. Fundación Para Las Relaciones Internacionales y El Diálogo Exterior (FRIDE) Policy Brief, 205, 1-6. https://www.iisd.org/publications/climate-change-and-state-fragility-sahel

CRED & UNDRR. (2020). Human Cost of Disasters. An Overview of the Last 20 Years 2000-2019. https://www.undrr.org/publication/human-cost-disasters-overview-last-20-years-2000-2019

Day, A., & Caus, J. (2019). Conflict Prevention in the Sahel: Emerging Practice across the UN. United Nations University. https://collections.unu.edu/view/UNU:7536

De Brauw, A., Mueller, V., & Lee, H. L. (2014). The role of rural-urban migration in the structural transformation of Sub-Saharan Africa. World Development, 63, 33–42. https://doi.org/10.1016/j.worlddev.2013.10.013

De Haan, C., Dubern, E., Garancher, B., & Quintero, C. (2016). Fragility, Conflict and Violence Cross-Cutting Solutions Area - A Road to Stability? Pastoralism Development in the Sahel. http://hdl.handle.net/10986/24228

De Jong, G. F. (2000). Expectations, gender, and norms in migration decision-making. Population Studies, 54(3), 307–319. https://doi.org/10.1080/713779089

De Longueville, F., Ozer, P., Gemenne, F., Henry, S., Mertz, O., & Nielsen, J. Ø. (2020). Comparing climate change perceptions and meteorological data in rural West Africa to improve the understanding of household decisions to migrate. Climatic Change, 160(1), 123–141. https://doi.org/10.1007/s10584-020-02704-7

Dellink, R., Chateau, J., Lanzi, E., & Magné, B. (2017). Long-term economic growth projections in the Shared Socioeconomic Pathways. Global Environmental Change, 42, 200–214. https://doi.org/10.1016/j.gloenvcha.2015.06.004

Dong, B., & Sutton, R. (2015). Dominant role of greenhouse-gas forcing in the recovery of Sahel rainfall. Nature Climate Change 2015 5:8, 5(8), 757–760. https://doi.org/10.1038/nclimate2664

Doso Jnr, S. (2014). Land degradation and agriculture in the Sahel of Africa: causes, impacts and recommendations. Journal of Agricultural Science and Applications, 3, 67–73. https://www.researchgate.net/publication/284364313_Land_degradation_and_agriculture_in_the_Sahel_of_Africa_causes_impacts_and_recommendations

Eck, K., & Hultman, L. (2007). One-Sided Violence Against Civilians in War. Journal of Peace Research, 44(2), 233–246. https://doi.org/10.1177/0022343307075124

Faleg, G., & Mustasilta, K. (2021). Salafi jihadism in Africa - A winning strategy. European Union Institute for Security Studies (EUISS). https://www.jstor.org/stable/resrep32285

FAO. (2021). AQUASTAT Database. Food and Agriculture Organization of the United Nations. http://www.fao.org/nr/water/aquastat/data/

Faye, C., Gomis, E., & Dieye, S. (2019). Current Situation and Development of Water Resources in Senegal. Ecological Engineering and Environment Protection, 5–16. https://doi.org/10.32006/eeep.2019.1.0516

Fearon, J. D., & Laitin, D. D. (2003). Ethnicity, Insurgency, and Civil War. American Political Science Review, 97(01), 75–90. https://doi.org/10.1017/S0003055403000534

Fernando, N., Warner, K., & Birkmann, J. (2010). Migration and Natural Hazards: Is Relocation a Secondary Disaster or an Opportunity for Vulnerability Reduction? In T. Afifi & J. Jäger (Eds.), Environment, Forced Migration and Social Vulnerability (pp. 145–156). Springer. https://doi.org/10.1007/978-3-642-12416-7_11

FEWS NET. (2021). Afrique De L'ouest. Perspectives sur la sécurité alimentaire. Novembre 2021 à Mai 2022. https://fews.net/node/25766

Frieler, K., Lange, S., Piontek, F., Reyer, C. P. O., Schewe, J., Warszawski, L., Zhao, F., Chini, L., Denvil, S., Emanuel, K., Geiger, T., Halladay, K., Hurtt, G., Mengel, M., Murakami, D., Ostberg, S., Popp, A., Riva, R., Stevanovic, M., … Yamagata, Y. (2017). Assessing the impacts of 1.5 °C global warming – simulation protocol of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b). Geoscientific Model Development, 10(12), 4321–4345. https://doi.org/10.5194/gmd-10-4321-2017

Garry, S., & Checchi, F. (2019). Armed conflict and public health: into the 21st century. Journal of Public Health, 42(3), e287–e298. https://doi.org/10.1093/pubmed/fdz095
Gat, A. (2006). War in Human Civilization. Oxford University Press.

Geddes, A., Adger, W. N., Arnell, N. W., Black, R., & Thomas, D. S. G. (2012). The Implications for Governance of Migration Linked to Environmental Change: Key Findings and New Research Directions. Environment and Planning C: Government and Policy, 30(6), 1078–1082. https://doi.org/10.1068/c3006c

Gemenne, F. (2011). Why the numbers don't add up: A review of estimates and predictions of people displaced by environmental changes. Global Environmental Change, 21, S41–S49. https://doi.org/10.1016/j.gloenvcha.2011.09.005

Gemenne, F., Blocher, J., Longueville, F. D. E., Diaz, S. V., Zickgraf, C., Gharbaoui, D., & Ozer, P. (2017). Changement climatique, catastrophes naturelles et déplacements de populations en Afrique de l'Ouest. Climate change, natural disasters and population displacements in West Africa. Geo-Eco-Trop: Revue Internationale de Géologie, de Géographie et d'Écologie Tropicales, 22. https://orbi.uliege.be/bitstream/2268/218730/1/Gemenne%20et%20al_Geo-Eco-Trop_Final.pdf

Ghobarah, H. A., Huth, P. K., & Russett, B. M. (2003). Civil wars kill and maim people – long after the shooting stops. American Political Science Review, 97(2), 189–202. https://www.jstor.org/stable/3118203

Gilmore, E., Hegre, H., Olafsdottir, G., & Petrova, C. (2021). The 'conflict trap' reduces economic growth in the Shared Socioeconomic Pathways.

Gleditsch, K. S., & Ward, M. D. (1999). A revised list of independent states since the congress of Vienna. International Interactions, 25(4), 393–413. https://doi.org/10.1080/03050629908434958

Gleditsch, N. P., Wallensteen, P., Eriksson, M., Sollenberg, M., & Hegre, H. (2002). Armed Conflict 1946-2001: A New Dataset. Journal of Peace Research, 39(5), 615–637. https://doi.org/10.1177/0022343302039005007

Government Office for Science. (2011). Migration and Global Environmental Change - Final Project Report. https://www.gov.uk/government/publications/migration-and-global-environmental-change-future-challenges-and-opportunities

Grolle, J. (2015). Historical case studies of famines and migrations in the West African Sahel and their possible relevance now and in the future. Population and Environment, 37, 181–206. https://doi.org/10.1007/s11111-015-0237-4

Haglund, E., Ndjeunga, J., Snook, L., & Pasternak, D. (2011). Dry land tree management for improved household livelihoods: Farmer managed natural regeneration in Niger. Journal of Environmental Management, 92(7). https://doi.org/10.1016/j.jenvman.2011.01.027

Hausfather, Z., & Peters, G. P. (2020). Emissions – the 'business as usual' story is misleading. Nature, 577(7792), 618–620. https://doi.org/10.1038/d41586-020-00177-3
Hegre, H., & Nygård, H. M. (2015). Governance and Conflict Relapse. Journal of Conflict Resolution, 59(6), 984–1016. https://doi.org/10.1177/0022002713520591

Hegre, H. (2018). Civil Conflict and Development. In N. van de Walle & C. Lancaster (Eds.), Oxford University Press Handbook on the Politics of Development. Oxford University Press. https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199845156.001.0001/oxfordhb-9780199845156-e-9

Hegre, H., Allansson, M., Basedau, M., Colaresi, M., Croicu, M., Fjelde, H., Hoyles, F., Hultman, L., Högbladh, S., Jansen, R., Mouhleb, N., Muhammad, S. A., Nilsson, D., Nygård, H. M., Olafsdottir, G., Petrova, K., Randahl, D., Rød, E. G., Schneider, G., … Vestby, J. (2019). ViEWS: A political violence early-warning system. Journal of Peace Research, 56(2), 155–174. https://doi.org/10.1177/0022343319823860

Hegre, H., Bell, C., Colaresi, M., Croicu, M., Hoyles, F., Jansen, R., Leis, M. R., Lindqvist-McGowan, A., Randahl, D., Rød, E. G., & Vesco, P. (2021). ViEWS 2020 : Revising and evaluating the ViEWS political Violence Early-Warning System. Journal of Peace Research, 58(3), 599–611. https://doi.org/10.1177/0022343320962157

Hegre, H., Buhaug, H., Calvin, K. V, Nordkvelle, J., Waldhoff, S. T., & Gilmore, E. (2016). Forecasting civil conflict along the shared socioeconomic pathways. Environmental Research Letters, 11(5), 054002. https://doi.org/10.1088/1748-9326/11/5/054002

Hegre, H., Croicu, M., Eck, K., & Högbladh, S. (2020). Introducing the UCDP Candidate Events Dataset. Research & Politics, 7(3), 205316802093525. https://doi.org/10.1177/2053168020935257

Hegre, H., Lindqvist-McGowan, A., Vesco, P., Jansen, R., & Rakhmankulova, M. (2022). Forecasting armed conflict in the Sahel: Forecasts for November 2021–October 2024. http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-464571

Heinrigs, P. (2010). Security Implications of Climate Change in the Sahel Region: Policy considerations Club Secrétariat du.

Heinrigs, P. (2011). Security Implications of Climate Change in the Sahel Region: Policy considerations. Organisation for Economic Co-Operation and Development (OECD), 1–32.

Henry, S., Boyle, P., & Lambin, E. F. (2003). Modelling inter-provincial migration in Burkina Faso, West Africa: the role of socio-demographic and environmental factors. Applied Geography, 23(2), 115–136. https://doi.org/10.1016/j.apgeog.2002.08.001

IDMC. (2021). GRID 2021 Displacement in A Changing Climate. https://www.internal-displacement.org/global-report/grid2021/

IEA, IRENA, UNSD, World Bank, WHO. (2021). Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC. https://trackingsdg7.esmap.org/data/files/download-documents/2021_tracking_sdg7_report.pdf

IPCC. (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. https://doi.org/10.1017/CBO9781107415324

IPCC. (2022). AR6 Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. In Press. https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_FinalDraft_FullReport.pdf

Jaeger, D. A., Dohmen, T., Falk, A., Huffman, D., Sunde, U., & Bonin, H. (2010). Direct evidence on risk attitudes and migration. Review of Economics and Statistics, 92(3), 684–689.

Jawad, M., Hone, T., Vamos, E. P., Roderick, P., Sullivan, R., & Millett, C. (2020). Estimating indirect mortality impacts of armed conflict in civilian populations: panel regression analyses of 193 countries, 1990–2017. BMC Medicine, 18(1), 266. https://doi.org/10.1186/s12916-020-01708-5

Jones, B., & O'Neill, B. C. (2013). Historically grounded spatial population projections for the continental United States. Environmental Research Letters, 8(4), 044021. https://doi.org/10.1088/1748-9326/8/4/044021

Jones, B, & O'Neill, B. C. (2016). Spatially explicit global population scenarios consistent with the Shared Socioeconomic Pathways. Environmental Research Letters, 11(8), 084003. https://doi.org/10.1088/1748-9326/11/8/084003

Kandji, S. T., Verchot, L., & Mackensen, J. (2006). Climate Change and Variability in the Sahel Region: Impacts and Adaptation Strategies in the Agricultural Sector.https://doi.org/10.12691/ajwr-7-4-5

Kerres, M., Servos, M., Kramer, A., Hattermann, F., Tänzler, D., Pilz, T., & Mueller, A. (2020). Stop Floating, Start Swimming. Water and climate change – Interlinkages and prospects for future action. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://www.everydrop-counts.org/imglib/pdf/

Water Climate Report 2020.pdf

Kniveton, D. R., Smith, C. D., & Black, R. (2012). Emerging migration flows in a changing climate in dryland Africa. Nature Climate Change, 2(6), 444–447. https://doi.org/10.1038/nclimate1447

Koné, H. (2020). Where do Sahel terrorists get their heavy weapons? Institute for Security Studies (ISS), ISS Today. https://issafrica.org/iss-today/where-do-sahel-terrorists-get-their-heavy-weapons

Krueger, A. O. (1974). The Political Economy of the Rent-Seeking Society. American Economic Review, 64(3), 291–303. https://econpapers.repec.org/RePEc:aea:aecrev:v:64:y:1974:i:3:p:291-303

Lange, S., Volkholz, J., Geiger, T., Zhao, F., Vega, I., Veldkamp, T., et al. (2020). Projecting Exposure to Extreme Climate Impact Events Across Six Event Categories and Three Spatial Scales. Earth's Future, 8(12). https://doi.org/10.1029/2020EF001616

Le, K., & Nguyen, M. (2020). Armed conflict and birth weight. Economics & Human Biology, 39, 100921. https://doi.org/10.1016/j.ehb.2020.100921

Le, T. T., Luu, T. T. G., Simelton, E., Carter, A., Le, D. H., & Tong T. H. (2018). Guide to Participatory Scenario Planning (PSP): Experiences from the Agro-Climate Information Services for women and ethnic minority farmers in South-East Asia (ACIS) project in Ha Tinh and Dien Bien province, Vietnam. CGIAR Research Program on Climate Change, Agriculture and Food Security Southeast Asia (CCAFS). https://ccafs.cgiar.org/resources/publications/guide-participatory-scenario-planning-psp-experiences-agro-climate

Levitt, P. (1998). Social Remittances: Migration Driven Local-Level Forms of Cultural Diffusion. International Migration Review, 32(4), 926. https://doi.org/10.2307/2547666

Makanju, A. O. M., & Uriri, A. E. (2021). Aging, Resilience, and Migration in the Sudano-Sahelian Ecological Belt in Nigeria. African Human Mobility Review, 7(3), 7–25. https://www.sihma.org.za/journals/AHMR 7:3 Sep-Dec 2021 ONLINE VERSION OK.pdf#page=9

McLeman, R., Wrathall, D., Gilmore, E., Thornton, P., Adams, H., & Gemenne, F. (2021). Conceptual framing to link climate risk assessments and climate-migration scholarship. Climatic Change, 165(1–2), 24. https://doi.org/10.1007/s10584-021-03056-6

Meinshausen, M., Smith, S. J., Calvin, K., Daniel, J. S., Kainuma, M. L. T., Lamarque, J.-F., Matsumoto, K., Montzka, S. A., Raper, S. C. B., Riahi, K., Thomson, A., Velders, G. J. M., & van Vuuren, D. P. P. (2011). The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. Climatic Change, 109(1–2), 213–241. https://doi.org/10.1007/s10584-011-0156-z

Mo Ibrahim Foundation. (2020). Ibrahim Index of African Governance (IIAG) Data Portal. https://iiag.online/data.html

Montgomery, J. M., Hollenbach, F. M., & Ward, M. D. (2012). Improving predictions using ensemble Bayesian model averaging. Political Analysis, 20(3), 271–291. http://doi.org/10.1093/pan/mps002

Morrow, B. H. (2009). Risk Behavior and Risk Communication: Synthesis and Expert Interviews. https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/climate-communications/messaging-climate-change/Morrow.-2009.-Risk-Behavior--Risk-Communication.pdf

Morrow, B. H., Lazo, J. K., Rhome, J., & Feyen, J. (2015). Improving Storm Surge Risk Communication: Stakeholder Perspectives. Bulletin of the American Meteorological Society, 96(1), 35–48. https://doi.org/10.1175/BAMS-D-13-00197.1

Mueller, H. (2017). How Much Is Prevention Worth? Background paper for United Nations–World Bank Flagship Study, Pathways for Peace: Inclusive Approaches to Preventing Violent Conflict. http://hdl.handle.net/10986/29380

Nett, K., & Rüttinger, L. (2016). Insurgency, Terrorism and Organised Crime in a Warming Climate Analysing the Links Between Climate Change and Non-State Armed Groups. Climate Diplomacy, Adelphi, 1–76. https://climate-diplomacy.org/sites/default/files/2020-10/CD%20Report_Insurgency_170724_web.pdf

New, M., Hewitson, B., Stephenson, D. B., Tsiga, A., Kruger, A., Manhique, A., Gomez, B., Coelho, C. A. S., Masisi, D. N., Kululanga, E., Mbambalala, E., Adesina, F., Saleh, H., Kanyanga, J., Adosi, L., Bulane, L., Fortunata, L., Mdoka, M. L., & Lajoie, R. (2006). Evidence of trends in daily climate extremes over southern and west Africa. Journal of Geophysical Research D: Atmospheres, 111(D14). https://doi.org/10.1029/2005JD006289

Niang, I., Ruppel, O., Abdrabo, M., Essel, A., Lennard, C., Padgham, J., & Urquhart, P. (2014). Africa. In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1199-1266). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781107415386.002

Nicholson, S. E., Some, B., & Kone, B. (2000). An Analysis of Recent Rainfall Conditions in West Africa, Including the Rainy Seasons of the 1997 El Niño and the 1998 La Niña Years. Journal of Climate, 13(14), 2628–2640. https://doi.org/10.1175/1520-0442(2000)013<2628:AAORRC>2.0.CO;2

Nsaibia, H. (2020). State atrocities in the Sahel: the impetus for counterinsurgency results is fueling government attacks on civilians. https://acleddata.com/2020/05/20/state-atrocities-in-the-sahel-the-impetus-for-counter-insurgency-results-is-fueling-government-attacks-on-civilians/

Nsaibia, H., & Duhamel, J. (2021). Sahel 2021: communal wars, broken ceasefires, and shifting frontlines. https://acleddata.com/2021/06/17/sahel-2021-communal-wars-broken-ceasefires-and-shifting-frontlines/

Nyce, C. (2007). Predictive analytics white paper. http://www.the-digital-insurer.com/wp-content/uploads/2013/12/78-Predictive-Modeling-White-Paper.pdf

OSCDS. (2021). Rapid Assessment of United Nations (UN) investments in the Sahel (2016 – 2020). https://unis-sahel.org/2021/10/29/rapid-assessment-of-united-nations-un-investments-in-the-sahel-2016-2020-reflections-on-un-and-partner-investments-in-the-region/

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., van Ruijven, B. J., van Vuuren, D. P., Birkmann, J., Kok, K., Levy, M., & Solecki, W. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Global Environmental Change, 42, 169–180. https://doi.org/10.1016/j.gloenvcha.2015.01.004

O'Neill, B. C., Kriegler, E., Riahi, K., Ebi, K. L., Hallegatte, S., Carter, T. R., Mathur, R., & van Vuuren, D. P. (2014). A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Climatic Change, 122(3), 387–400. https://doi.org/10.1007/s10584-013-0905-2

Oakes, R. (2014). Using Q method and agent based modelling to understand hurricane evacuation decisions. University of Sussex. https://core.ac.uk/download/pdf/30609708.pdf

Oyebande, L., & Odunuga, S. (2010). Climate Change Impact on Water Resources at the Transboundary Level in West Africa: The Cases of the Senegal, Niger and Volta Basins. The Open Hydrology Journal, 4, 163–172. https://doi.org/10.2174/1874378101004010163

Page, S. E. (2007). The difference: how the power of diversity creaetes better groups, firms, schools, and societies. Princeton University Press. https://doi.org/10.2307/j.ctt7sp9c

Pellerin, M. (2021). ntendre la voix des éleveurs au Sahel et en Afrique de l'Ouest : quel avenir pour le pastoralisme face à l'insécurité et ses impacts ? https://fr.peacenexus.org/wp-content/uploads/2021/12/Rapport-Synthetique-Patoralisme-et-Insecurite-au-Sahel-et-en-Afrique-de-lOuest-RBM.pdf

Pettersson, T., & Öberg, M. (2020). Organized violence, 1989–2019. Journal of Peace Research, 57(4), 597–613. https://doi.org/10.1177/0022343320934986

Pinker, S. (2011). The Better Angels of Our Nature. Why Violence has Declined. Viking. https://www.jstor.org/stable/24542853

Popp, A., Calvin, K., Fujimori, S., Havlik, P., Humpenöder, F., Stehfest, E., Bodirsky, B. L., Dietrich, J. P., Doelmann, J. C., Gusti, M., Hasegawa, T., Kyle, P., Obersteiner, M., Tabeau, A., Takahashi, K., Valin, H., Waldhoff, S., Weindl, I., Wise, M., … Vuuren, D. P. van. (2017). Land-use futures in the shared socio-economic pathways. Global Environmental Change, 42, 331–345. https://doi.org/10.1016/j.gloenvcha.2016.10.002

Raineri, L. (2018). If victims become perpetrators: Factors contributing to vulnerability and resilience to violent extremism in the central Sahel. https://www.international-alert.org/publications/if-victims-become-perpetrators-violent-extremism-sahel/

Raleigh, C., Jordan, L., & Salehyan, I. (2008). Assessing the impact of climate change on migration and conflict (Paper Commissioned by the World Bank Group for the Social Dimensions of Climate Change Workshop). https://www.researchgate.net/publication/255519298_Assessing_the_Impact_of_Climate_Change_on_Migration_and_Conflict

Raleigh, C., Linke, A., Hegre, H., & Karlsen, J. (2010). Introducing ACLED: An Armed Conflict Location and Event Dataset. Journal of Peace Research, 47(5), 651–660. https://doi.org/10.1177/0022343310378914

Riahi, K., van Vuuren, D. P., Kriegler, E., Edmonds, J., O'Neill, B. C., Fujimori, S., Bauer, N., Calvin, K., Dellink, R., Fricko, O., Lutz, W., Popp, A., Cuaresma, J. C., KC, S., Leimbach, M., Jiang, L., Kram, T., Rao, S., Emmerling, J., … Tavoni, M. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Global Environmental Change, 42, 153–168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

Rich, D.C. (1980). Potential Models in Human Geography. Concepts and Techniques in Modern Geography (No. 26). Norwich, Norfolk: Geo Abstracts. https://archive.org/details/potentialmodelsi0000rich

Rigaud, K.K., de Sherbinin, A., Jones, B., Adamo, S., Maleki, D., Abu-Ata, N., Casals Fernandez, A., Arora, A., Chai-Onn, T., & Mills, B. (2021a). (b) Groundswell Africa: Internal Climate Migration in the Lake Victoria Basin. World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/36403

Rigaud, K.K., de Sherbinin, A., Jones, B., Adamo, S., Maleki, D., Abu-Ata, N. E., Casals Fernandez, A. T., Arora, A., Chai-Onn, T., & Mills, B. (2021b). (a) Groundswell Africa: Internal Climate Migration in West African Countries. World Bank, Washington, DC. http://hdl.handle.net/10986/36404

Rigaud, K.K., de Sherbinin, A., Jones, B., Bergmann, J., Clement, V., Ober, K., Schewe, J., Adamo, S., McCusker, B., Heuser, S., & Midgley, A. (2018). Groundswell: Preparing for Internal Climate Migration. World Bank, Washington, DC. https://doi.org/10.1596/29461

Rockström, J., & Falkenmark, M. (2015). Agriculture: Increase water harvesting in Africa. Nature 2015 519:7543, 519(7543), 283–285. https://doi.org/10.1038/519283a

Rogers, A., & Castro, J. L. (1981). Model Migration Schedules. IIASA Research Report. https://doi.org/10.2307/1532474

Röhrig, F., Gloy, N., von Loeben, S., Arumugam, P., Aschenbrenner, P., Baek, H.-R. L., Bado, I., Chemura, A., Habtemariam, L., Kaufmann, J., Koch, H., Laudien, R., Liersch, S., Lüttringhaus, S., Murken, L., Neya, O., Noleppa, S., Ostberg, S., Sanfo, S., … Wortmann, M. (2021). Climate Risk Analysis for Identifying and Weighing Adaptation Strategies for the Agricultural Sector in Burkina Faso.

Sarr, A. B., Diba, I., Basse, J., Sabaly, H. N., & Camara, M. (2019). Future evolution of surface temperature extremes and the potential impacts on the human health in Senegal. African Journal of Environmental Science and Technology, 13(21), 482–510. https://doi.org/10.5897/AJEST2019.2757

Schilling, J., Scheffran, J., & Link, P. M. (2010). Climate Change and Land Use Conflicts in Northern Africa. Nova Acta Leopoldina NF, 112(384), 173–182.

Schleussner, C.-F., Donges, J. F., Donner, R. V., & Schellnhuber, H. J. (2016). Armed-conflict risks enhanced by climate-related disasters in ethnically fractionalized countries. Proceedings of the National Academy of Sciences, 113(33), 9216–9221. https://doi.org/10.1073/pnas.1601611113

Schmidt-Verkerk, K. (2010). “Buscando la vida” - How Do Perceptions of Increasingly Dry Weather Affect Migratory Behavior in Zacatecas, Mexico? In T. Afifi & J. Jäger (Eds.), Environment, Forced Migration and Social Vulnerability. Springer. https://doi.org/10.1007/978-3-642-12416-7

Schutte, S., Vestby, J., Carling, J., & Buhaug, H. (2021). Climatic conditions are weak predictors of asylum migration. Nature Communications, 12(1), 2067. https://doi.org/10.1038/s41467-021-22255-4

Sedano, F., Molini, V., & Azad, M. (2019). A Mapping Framework to Characterize Land Use in the Sudan-Sahel Region from Dense Stacks of Landsat Data. Remote Sensing, 11(6), 648. https://doi.org/10.3390/rs11060648

Sissoko, K., van Keulen, H., Verhagen, J., Tekken, V., & Battaglini, A. (2011). Agriculture, livelihoods and climate change in the West African Sahel. Regional Environmental Change, 11(S1), 119–125. https://doi.org/10.1007/s10113-010-0164-y

Sundberg, R., & Melander, E. (2013). Introducing the UCDP Georeferenced Event Dataset. Journal of Peace Research, 50(4), 523–532. https://doi.org/10.1177/0022343313484347

Tacoli, C. (2009). Crisis or adaptation? Migration and climate change in a context of high mobility. Environment and Urbanization, 21(2), 513–525. https://doi.org/10.1177/0956247809342182

Tollefsen, A. F., Strand, H., & Buhaug, H. (2012). PRIO-GRID: A unified spatial data structure. Journal of Peace Research, 49(2), 363–374. https://doi.org/10.1177/0022343311431287

Tomalka, J., Birner, J., Dieye, A. M., Gleixner, S., Harper, A., Hauf, Y., Hippe, F., Jansen, L., Lange, S., Laudien, R., Rheinbay, J., Vinke, K., von Loeben, S., Wesch, S., Zvolsky, A., & Gornott, C. (2021). Climate Risk Profile: Sahel. https://agrica.de/wp-content/uploads/2021/11/PIK_Climate-Risk-Profile-Sahel_09.pdf

Tullock, G. (1967). The Welfare Costs of Tariffs, Monopolies, and Theft. Economic Inquiry, 5(3), 224–232. https://doi.org/10.1111/j.1465-7295.1967.tb01923.x

Udeh, C. (2018). How climate change is provoking clashes between herdsmen and farmers in Nigeria. Cambridge Climate Lecture Series. https://theecologist.org/2018/feb/22/how-climate-change-provoking-clashes-between-herdsmen-and-farmers-nigeria

UN Envionment Management Group. (2021). Mid-Term Technical Segment of the 27th Senior Officials Meeting. Nexus Dialogue: Rethinking the UN Approach on Strategic Foresight for Environmental Action. https://unemg.org/wp-content/uploads/2021/06/04a-Concept-Note-Strategic-foresight-for-environmental-action.pdf

UNCCD. (2019). The Global Land Outlook, West Africa. https://www.unccd.int/resources/publications/global-land-outlook-west-africa-thematic-report-land-degradation-neutrality

UNCCD. (2021). Drought, Desertification, and Regreening in the Sahel. https://catalogue.unccd.int/1715_Drought_desertification_regreening_Sahel_Eng_Final.pdf

UNCCD. (n.d.). The Sahel: Land of Opportunities, Land with a Future. https://knowledge.unccd.int/knowledge-products-and-pillars/unccd-e-library/sahel-land-opportunities-land-future

UNDESA. (1998) Recommendations on Statistics of International Migration, Revision 1. https://unstats.un.org/unsd/publication/seriesm/seriesm_58rev1e.pdf

UNDESA. (2019). World Population Prospects 2019, Online Edition. https://www.un.org/development/desa/pd/news/world-population-prospects-2019-0

UNDESA. (2020). International Migrant Stock 2020. https://www.un.org/development/desa/pd/content/international-migrant-stock

UNDESA. (2021). Index of Least Developed Countries (LDCs). https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/ldc_list.pdf

UNDP. (2020). Human Development Data Center. In Human Development Report. http://hdr.undp.org/en/data

UNECA. (2019). Sahel 2043: Towards a resilient, inclusive and prosperous Sahel region. In ECA Printing and Publishing Unit. https://repository.uneca.org/handle/10855/43654

UNFCCC. (2011) Decision 1/CP.16 Cancun Climate Change Adaptation Framework. https://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf

UNHCR. (2020). Legal Considerations Regarding Claims for International Protection Made in the context of the Adverse Effects of Climate Change and Disasters. International Journal of Refugee Law, 33(1), 151–165. https://doi.org/10.1093/ijrl/eeab026

UNHCR. (2021a). Refugee data finderl. United Nations High Commissioner for Refugees (UNHCR). https://www.unhcr.org/refugee-statistics/download/

UNHCR. (2021b) Strategic Framework for Climate Action. Uhttps://www.unhcr.org/604a26d84/strategic-framework-for-climate-action

UNISS. (n.d.). Agriculture, sowing hope. https://unis-sahel.org/news/1625/

United Nations. (2018). UN Support Plan for the Sahel. Working Together for a Prosperous and Peaceful Sahel. https://www.un.org/africarenewal/sahel/documents/un-support-plan-sahel-working-together-prosperous-and-peaceful-sahel

United Nations. (2021). The Sahel: Land of Opportunities. United Nations Africa Renewal. https://www.un.org/africarenewal/sahel

University of Notre Dame. (2021, July). ND-GAIN Country Index. https://gain.nd.edu/our-work/country-index/

UNOWAS. (2018). Pastoralism and Security in West Africa and the Sahel. https://unowas.unmissions.org/sites/default/files/rapport_pastoralisme_eng-april_2019_-_online.pdf

USAID. (2017). Climate Change Risk Profile. West Africa Sahel. https://www.climatelinks.org/sites/default/files/asset/document/2017 April_USAID ATLAS_Climate Change Risk Profile - Sahel.pdf

Van Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G. C., Kram, T., Krey, V., Lamarque, J.-F., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S. J., & Rose, S. K. (2011). The representative concentration pathways: an overview. Climatic Change, 109(1–2), 5–31. https://doi.org/10.1007/s10584-011-0148-z

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index. Journal of Climate, 23(7), 1696–1718. https://doi.org/10.1175/2009JCLI2909.1

Vigil, S. (2017). Climate Change and Migration : Insights from the Sahel. In Out of Africa. Why People Migrate (pp. 51–71). Torrossa. https://www.torrossa.com/en/catalog/preview/4312251

Vinke, K., Bergmann, J., Blocher, J., Upadhyay, H., & Hoffmann, R. (2020). Migration as Adaptation? Migration Studies, 8(4), 626–634. https://doi.org/10.1093/migration/mnaa029

Vinke, K., & Harper, A. (2020). Climate Change and the Future of Safe Returns. https://www.unhcr.org/5fb28b504.pdf

Vinke, K., Rottmann, S., Gornott, C., Zabre, P., Nayna Schwerdtle, P., & Sauerborn, R. (2021). Is migration an effective adaptation to climate-related agricultural distress in sub-Saharan Africa? Population and Environment. https://doi.org/10.1007/s11111-021-00393-7

Von Uexkull, N., Croicu, M., Fjelde, H., & Buhaug, H. (2016). Civil conflict sensitivity to growing-season drought. Proceedings of the National Academy of Sciences of the United

States of America, 113(44), 12391–12396. https://doi.org/10.1073/pnas.1607542113

Wagner, Z., Heft-Neal, S., Bhutta, Z. A., Black, R. E., Burke, M., & Bendavid, E. (2018). Armed conflict and child mortality in Africa: a geospatial analysis. The Lancet, 392(10150), 857–865. https://doi.org/10.1016/S0140-6736(18)31437-5

Ward, M., & Beger, A. (2017). Lessons from near real-time forecasting of irregular leadership changes. Journal of Peace Research, 54(2), 141–156. https://doi.org/10.1177/0022343316680858

Ward, N., & Conway, D. (2020). Applications of interannual-to-decadal climate prediction: An exploratory discussion on rainfall in the Sahel region of Africa. Climate Services, 18, 100170. https://doi.org/10.1016/j.cliser.2020.100170

Warner, K., & Afifi, T. (2014). Where the rain falls: Evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. Climate and Development, 6(1), 1–17. https://doi.org/10.1080/17565529.2013.835707

Warntz, W., & Wolff, P. (1971). Breakthroughs in Geography. New York: New American Library. https://archive.org/details/breakthroughsing0000unse

Weidemann, N. B., Kuse, D., & Gleditsch, K. S. (2010). The geography of the international system: The CShapes dataset. International Interactions, 36(1), 86–106. https://doi.org/10.1080/03050620903554614

Weinreb, A., Stecklov, G., & Arslan, A. (2020). Effects of changes in rainfall and temperature on age- and sex-specific patterns of rural-urban migration in sub-Saharan Africa. Population and Environment, 42(2), 219–254. https://doi.org/10.1007/s11111-020-00359-1

World Bank. (2019a). Mortality Rate, under-5. https://databank.worldbank.org/reports.aspx?source=2&series=SH.DYN.MORT.FE&country=#

World Bank. (2019b). Niger Urbanization review : Supporting Niger' Modern Oases. https://openknowledge.worldbank.org/handle/10986/35197

World Bank. (2021a). GDP per capita (current US$) - Burkina Faso, Cameroon, Chad, Gambia, The, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal | Data. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=BF-CM-TD-GM-GN-ML-MR-NE-NG-SN&most_recent_value_desc=false

World Bank. (2021b). Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population) | Data. https://data.worldbank.org/indicator/SI.POV.DDAY

WMO. (2020). The gaps in the Global Basic Observing Network (GBON). https://library.wmo.int/doc_num.php?explnum_id=10377

Zickgraf, C., Vigil, S., de Longueville, F., Ozer, P., & Gemenne, F. (2016). The Impact of Vulnerability and Resilience to Environmental Changes on Mobility Patterns in West Africa (No. 14). https://www.knomad.org/publication/impact-vulnerability-and-resilience-environmental-changes-mobility-patterns-west-africa

Annex: Methodologies

Annex A: Climate change and food security models

Intersectoral Impact Model Intercomparison Project (ISIMIP)

The climate and food security projections in Chapters 2.1 and 2.2 are largely based on climate data and climate impact simulations carried out in phase 2b of the Intersectoral Impact Model Intercomparison Project (ISIMIP2b; see www.isimip.org and Frieler et al., 2017). The ISIMIP impact model simulations are based on the same harmonized input data including climate data from four global climate models (GCMs).

Data base

These four GCMs were selected from the larger CMIP5 (phase 5 of the Coupled Model Intercomparison Project) ensemble, based on criteria including data availability, model performance and climate sensitivity (Frieler et al., 2017).

Future climate impact projections in ISIMIP2b were made for two RCPs under the SSP2 socioeconomic pathway[48]. RCP2.6 represents the low emissions scenario in line with the Paris Agreement, whereas RCP6.0 represents a medium to high emissions scenario.

Models

The following overview lists the number of models whose output data was used to carry out simulations of the different indicators presented in more detail in Section 3.

- 4 Global Climate Models (GCMs)
  IPSL-CM5A-LR, GFDL-ESM2M, MIROC5, HadGEM2-ES
  GCMs simulate the physical, chemical and biological dynamics of the climate system.
- 6 Global Hydrological Models (GHMs)
  CLM45, H08, LPJmL, MPI-HM, PCR-GLOBWB, WaterGAP2
  GHMs simulate the hydrological cycle at the land surface of continental-scale river basins.
- 3 Global Gridded Crop Models (GGCMs)
  GEPIC, LPJmL, PEPIC
  GGCMs simulate crop growth at the grid scale for a selected number of crop functional types.

48 SSPs outline a narrative of potential global futures, including estimations of broad characteristics such as country-level population, GDP or rate of urbanization (more info see box Chapter 1). SSP2 represents the "middle of the road" pathway.

- 3 Global Vegetation Models (GVMs)
  LPJ-GUESS, LPJmL, ORCHIDEE

GVMs simulate the dynamics of terrestrial vegetation and soil as well as the associated carbon pools and fluxes.

- 2 Global Species Distribution Models (GSDMs)
  BioScen1.5-SDM-GAM, BioScen1.5-SDM-GBM
  GSDMs simulate species distribution based on known locations of a species and information on environmental conditions.
- 1 Temperature Related Mortality Model (TRMM)
  TRM-Tsukuba
  TRMMs simulate excess mortality attributable to non-optimal temperature based on statistical relationships between temperature and mortality.

Indicators

This overview provides detailed information about each indicator with the type and number of models indicated in brackets. Climate projections used in this analysis are based on data from the GCMs and shown at the 0.5 ° grid-cell level, which corresponds to approx. 50 x 50 km near the equator.

Temperature (4 GCMs):

Temperature change projections are based on daily mean near-surface air temperature data from the GCMs. Changes are averaged over the whole country.

Very hot days (4 GCMs):

Very hot days refer to days with a maximum near-surface air temperature above 35 °C.

Precipitation (4 GCMs):

Precipitation change projections are based on daily precipitation sums from the GCMs and shown as averages over the whole country.

Heavy precipitation events (4 GCMs):

The precipitation event analysis is based on daily precipitation sums from the GCMs and national averages. A heavy precipitation event is defined as a day on which the precipitation sum exceeds the 98th percentile of the daily precipitation sums of all wet days from 1861 to 1983, where a wet day is a day with a precipitation sum of at least 0.1 mm.

Projections show national averages of the annual number of heavy precipitation events.

Water availability (4 GCMs, 6 GHMs):
Water availability at the national level is projected using the Falkenmark Water Stress Indicator (FWSI) and total run-off from the GHMs. The FWSI represents the annual amount of water from rainfall that is available to each person. It is computed by first summing up run-off over the entire country and year and then by dividing the amount of water by the national population. FWSI projections are provided including and excluding the effects of population change. For this purpose, SSP2 population projections from the ISIMIP2b database are used. A country is said to be under water stress (face water scarcity) when water supplies drop below 1,700 (1,000) cubic metres per person per year.

Run-off (4 GCMs, 6 GHMs):
Run-off is defined as the amount of water discharged through surface and subsurface streams, including all precipitation, snow melt and irrigation water that is neither absorbed by the soil nor evaporated. Projections are based on total run-off from the GHMs. Total run-off is computed as the sum of surface run-off and subsurface run-off. Projections are shown at the 0.5° grid-cell level.

Exposure to droughts (4 GCMs, 6 GHMs):
For projections of the crop land area exposed to drought at least once a year, a drought index based on soil moisture projections from the GHMs is used (Lange et al., 2020). A grid cell is considered to be exposed to drought in a given year if monthly mean soil moisture drops below monthly threshold values for at least seven consecutive months, with at least four of those months belonging to the given year. The monthly threshold values are the 2.5th percentiles of monthly mean soil moisture under pre-industrial climate conditions. Land use patterns from ISIMIP2b are then used to compute the crop land area exposed to drought. Constant land use patterns representing conditions from 2005 are used. The profiles show the fraction of the national crop land area that is exposed to at least one drought in a given year.

Crop yield (4 GCMs, 3 GGCMs for maize, rice, soy, wheat, 1 GGCM otherwise):
Crop yield projections are based on the GGCMs and constant year 2005 level land use patterns and agricultural management (irrigation, fertilizer use, growing seasons). Two of the GGCMs (GEPIC and PEPIC) only provide crop yields for maize, rice, soy and wheat. This means that for all other crops, yield projections are based on one GGCM only (LPJmL). All GGCMs simulate effects of CO2 fertilization. The profiles show projected changes in national production for all relevant crop types covered by these models.

Annex B: Conflict models

The ViEWS model

Coverage, scope, and levels of analysis

ViEWS currently generates monthly probabilistic assessments of the risk of fatal political violence across Africa and the Middle East during each month in a rolling three-year forecasting horizon. The forecasts are produced separately for three different types of political violence, as defined by the Uppsala Conflict Data Program (UCDP):[49] (1) state-based violence (sb) involving at least one government of a state, such as fighting between the government of Syria and ISIS, (2) non-state violence (ns) between armed groups, neither of which is a government of a state, such as the PKK and PUK in Turkey and Iraq, and (3) one-sided violence (os) exerted by armed actors against unarmed civilians, for example terror attacks targeted at civilians.

The predictions are presented at two spatial resolutions, both using the calendar month as the temporal unit of analysis: the country and subnational PRIO-GRID level. At the country level, the system generates separate forecasts for the probability that 25 or more people will lose their lives to each type of violence per country and month (henceforth referred to as the country-month, cm level).[50] At the subnational level, the system produces separate forecasts for the probability that at least one life will be lost to each type of violence per approximately 55x55 km location and month (henceforth referred to as the

49 Full definitions are available at https://www.pcr.uu.se/research/ucdp/definitions/. Please see https://ucdp.uu.se and Gleditsch et al. (2002), Sundberg and Melander (2013), and Pettersson and Öberg (2020) for more information about the UCDP dataset.
50 The spatial coverage of each country conforms with the latest version of the CShapes dataset. The CShapes dataset is presented in Weidmann, Kuse, and Gleditsch (2010). The list of countries included in the dataset is in turn determined in Gleditsch and Ward (1999), with subsequent updates.

PRIO-grid-month, pgm level).[51]

Input Data
The ViEWS model draws upon decades of peace research on the complex and interconnected causes of conflict and the causes of peace. It is informed by publicly available historical time-series data on an extensive suite of conflict predictors that have been assembled from this research, covering the time from 1989 up until and including two months prior to each monthly release of the ViEWS forecasts. The conflict predictors pertain to themes including, but not limited to, conflict history, the strength of political institutions and measures of democracy, socioeconomic conditions, food prices and food security, climate variability, societal vulnerability, natural and social geography, and social and political unrest. At the country level, the forecasting system is informed by and trained on global data, while at the subnational level, it is trained on the African continent and the Middle East. This means that forecasts for the Sahel region are informed by patterns learnt from other places as well. This not only guarantees more data availability for the forecasts, and thus an increase in their accuracy, but also teaches the system to infer patterns and trends that are observed broadly across space and can be usefully applied to predict violence in the region of interest.

Algorithms and the modelling set-up
The collected data are split into three subsets: a 'training' set used to train the forecasting models on the historical data to infer the conditions and patterns that are conducive to conflict, a 'calibration' set used to readjust the forecasts in a such a way that the mean predicted value matches the average of the real observations, and a 'test/forecasting' set for which the forecasts are produced.

Once split into the three subsets, the data are fed into several so-called random forest algorithms that learn from historical observations in order to forecast future conflict. Random forest is a machine-learning algorithm based on multiple decision trees, and it has been shown to perform very well for forecasting tasks of the type discussed here. When training a model, the random forest uses some data points to identify combinations of a handful of predictors that are particularly good at predicting armed conflict for another set of data points. It repeats this many times and "votes up" predictors[52] that always produce good predictions. It is therefore very useful for identifying the most promising predictors from a very large number of candidate features. It also works well when the relationship between a predictor and the outcome is non-linear, or when the effect of a predictor varies in association with the value of another, which may often be the case when trying to predict conflict.

Several different sub-models are trained, calibrated and tested, by means of the procedure above, each based on data pertaining to a relevant theme or group of conflict predictors. Each of these thematic sub-models allow the forecasting system to address the forecasting problem from a different angle. Sub-models informed by a theme related to water, for example, reflect the effect of availability of and access to water on the risk of conflict in the location at hand. While sub-models informed by a theme of natural and social geography offer insights into the role of terrain or the proximity to natural resources in setting the scene for the onset, or continuation of, conflict in the same location.

As a final step, the outputs from each of the thematic sub-models are combined into two composite main models that produce the final forecasts: one that is trained to generate predictions at the country-month level, and one that is trained to produce the subnational PRIO-GRID-month conflict forecasts. This procedure of combining broad collections of sub- models is known as 'ensemble modelling' and is one of the main pillars of the ViEWS system.[53] Much like a crowd is wiser than the single individuals comprising it, overarching models that collect forecasts from a suite of smaller thematic sub-models are known to achieve more accurate predictions. This aspect of the system not only improves

51 The subnational level is delimited by the PRIO-GRID, a grid structure that divides the world into squared cells corresponding to an area of approximately 55x55 kilometers at the equator, or 0.5x0.5 decimal degrees. The PRIO-GRID system is presented at https://grid.prio.org/ and in Tollefsen, Strand, and Buhaug (2012)

52 A partition of historic data is used to identify variables that are particularly good at predicting the outcome of interest in another partition of the data. The procedure is repeated many times and the variables that have been "voted for" or "flagged" the most are prioritized/given the greatest weight when producing forecasts for the future.

53 The two main models are therefore also known as 'ensembles' or 'ensemble models'.

how well the prediction system performs, but also helps in understanding how individual predictors contribute to the risk assessments described below.[54]

Another feature of the modelling set-up is that each thematic sub-model is optimized for a different number of months into the forecasting horizon. The system produces different predictions when predicting three months into the future than when predicting three years ahead. Generally, structural conditions such as institutional characteristics and development factors are more useful in predicting conflict in the long-term, while rapidly changing conditions or shocks, such as food price peaks, might prove more relevant to predict violence in the short-term. Through a sophisticated system of weights, sub-models that for example include data on recent conflict events are therefore given more emphasis in short-term predictions, whereas structural sub-models informed by institutional factors that change slowly over time are preferred when forecasting several years into the future. Analyses of forecasts for different periods into the future can serve as a valuable resource in designing policy interventions with varying targets e.g. short-term relief or remedies, as compared to long-term investments in infrastructure or strengthening of political institutions.

The PREVIEW model

Baseline – PREVIEW's Conflict Prediction Model

The regional escalation prediction model at subnational level (ADM1) used for this Central Sahel report builds on PREVIEW's[55] previous work in the field of predictive analytics, namely the PREVIEW Quartile Conflict Model (hereafter referred to as PREVIEW QM). It serves as one baseline data-driven input for the quarterly, interministerial German Early Warning Policy Process, for which it identifies countries with increased conflict and/or escalation potential with a short and mid-term horizon of up to 24 months into the future. In the later process, such data-driven analytical insights are then contextualized by qualitative information and expert assessments. Subsequently, policy recommendations are being developed.

Characteristics of the regional prediction model

The new regional prediction model applied for this report extends the above logic to subnational level (ADM1) and shows methodological advancements in terms of the choice of the dependent variable which is based on the latest VIEWs (University Uppsala) Prediction Competition (2021).[56] Its aim is to predict the log-change and thus escalation or de-escalation of the aforementioned variables (number of fatalities, security-related incidents and protests).

The applied PREVIEW regional model for the Central Sahel region at subnational level has the following characteristics:

- Data Sets: It uses ACLED as the core conflict data set for Africa implying that the applied dependent variables and features are also distinct. These data are well-suited to be applied to regions on the African continent.
- Spatial Aggregation: PREVIEW's model aggregates its predictions results at province (ADM1) level. This allows for the identification of cross-border conflicts and precise localization of internal conflicts.
- Temporal Aggregation: PREVIEW's model aggregates results in quartiles.
- Scope: PREVIEW's regional model only focuses on the Central Sahel region.
- Measurement: As a measure for the dependent variables (number of conflict related deaths; number of security-related incidents, such as violence against civilians, battles, remote violence; number of protests and riots), the logarithmic change (basis exp.) in comparison to the basic period (T0) is used. A change e.g. by a value of approximately 0.7 implies a doubling of the respective dependent variable's value.
- Features: Structural Risk features have been derived from the World Bank's World

54 See Hegre et al., 2019; Montgomery et al., 2012; Page, 2007 and Ward & Beger, 2017.

55 PREVIEW is the German Federal Foreign Office's capability for data-driven crisis early warning and prediction, information management and actionable visualizations, informing and guiding policymakers and practitioners across the German government. Its global and regional conflict prediction models inform Germany's quarterly interministerial early warning process by identifying countries / regions at high conflict risk and making recommendations for in-depth qualitative analysis by policy and country experts and regional delegations. Recently, PREVIEW has developed prediction models at subnational level for precise localization of conflicts, both within countries and across borders. The Central Sahel and Lake Chad Basin have thereby been the first use cases of particular relevance with respect to the climate-security relationship.

56 The invitation can be found here: https://www.pcr.uu.se/research/views/news/?tarContentId=844492

Development Indicators, as well as the International Monetary Fund's (IMF) World Economic Outlook. 1,100 features have been included in the initial models for each province based on the ACLED data; about 100 features were used from the World Development Indicators Database and IMF-WEO. A subsequent recursive feature elimination cut the number of features down to between approximately 60 and 110 of the most relevant (see features below).

- Evaluation: The applied prediction model has been evaluated by comparing the model's predictions based on a Q2 2020 training cut-off time and an out of sample validation period for the quartiles Q3 2020 – Q2 2021, with the actual conflict dynamics already known in retrospect. All applied performance metrics (Mean Squared Error, Mean Absolute Error und Targeted Absolute Distance with Direction Augmentation)[57] have achieved a better result than a No-Change Model.
- Data Availability: When focusing on a single model region it is easier to find high-quality data, than for a model with a global scope. In particular, socioeconomic data vary significantly in their availability at subnational level across countries and over time. Currently no socioeconomic indicators with a spatial resolution lower than ADM0 (=country level) and temporal resolution in a higher frequency than year are used in the model.

Features

List of top 30 features (out of 60 kept features) for the final model logchange (FATALITIES)

- ACLED_LOGCHANGE_FATALITIES_SRZ__mean
- ACLED_LOGCHANGE_FATALITIES_T-2
- ACLED_LOGCHANGE_FATALITIES_T-1
- ACLED_LOGCHANGE_FATALITIES_SRZ__sum_values
- ACLED_LOGCHANGE_FATALITIES__sum_values
- ACLED_LOGCHANGE_FATALITIES__mean
- ACLED_LOGCHANGE_FATALITIES__quantile__q_0.25
- ACLED_LOGCHANGE_FATALITIES_SRZ_T-7
- ACLED_LOGCHANGE_FATALITIES_SRZ_T-1
- ACLED_LOGCHANGE_FATALITIES_SRZ_T-2
- ACLED_LOGCHANGE_FATALITIES_SRZ_T-3
- ACLED_LOGCHANGE_FATALITIES_SRZ_T-4
- ACLED_LOGCHANGE_FATALITIES_SRZ_T-6
- ACLED_LOGCHANGE_FATALITIES_SRZ_T-5
- ACLED_LOGCHANGE_FATALITIES_T-5
- ACLED_LOGCHANGE_FATALITIES_T-4
- ACLED_LOGCHANGE_FATALITIES_SRZ__median
- ACLED_LOGCHANGE_FATALITIES_SRZ__minimum
- ACLED_LOGCHANGE_FATALITIES_SRZ__quantile__q_0.25
- ACLED_LOGCHANGE_FATALITIES_SRZ__quantile__q_0.75
- ACLED_LOGCHANGE_COUNT_SRZ__sum_values
- ACLED_LOGCHANGE_FATALITIES_T-3
- ACLED_LOGCHANGE_FATALITIES__maximum
- ACLED_LOGCHANGE_FATALITIES__quantile__q_0.75
- ACLED_FATALITIES__linear_trend__attr_"slope"
- ACLED_LOGCHANGE_FATALITIES__median
- ACLED_LOGCHANGE_FATALITIES__minimum
- ACLED_LOGCHANGE_COUNT_SRZ__mean
- ACLED_LOGCHANGE_COUNT_SRZ__minimum
- ACLED_FATALITIES_SRZ__mean_change

List of top 30 features (out of 111 kept features) for the final model logchange (COUNT_SRZ)

- ACLED_LOGCHANGE_COUNT_SRZ__quantile__q_0.25
- ACLED_LOGCHANGE_COUNT_SRZ__mean
- ACLED_LOGCHANGE_COUNT_SRZ_T-3
- ACLED_LOGCHANGE_COUNT_SRZ_T-1
- ACLED_LOGCHANGE_COUNT_SRZ_T-2

57 The Targeted Absolute Distance with Direction Augmentation accounts for both the sign and the magnitude of the predictions versus the actual change and was designed for the ViEWS prediction competition. ϵ was set to a value of 0.048 for all comparisons. The score is calculated as followed:

$$TADDA^{(M)} = \frac{\sum_{i=1}^{N} |y_{\Delta,i} - f_{\Delta,i}| + |f_{\Delta,i}| I\left[y_{\Delta,i}^{(\pm)} \neq f_{\Delta,i}^{(\pm)}\right] I\left[|y_{\Delta,i} - f_{\Delta,i}| > \epsilon\right]}{N}$$

The details are to be found in the following article (still under review): Hegre, H., Colaresi, M., Vesco, P. (2022). United they stand. Findings from an escalation prediction competition. In: International Interactions (forthcoming, still under review).

- ACLED_LOGCHANGE_COUNT_SRZ_T-4
- ACLED_LOGCHANGE_COUNT_SRZ__median
- ACLED_LOGCHANGE_COUNT_SRZ__minimum
- ACLED_LOGCHANGE_FATALITIES__mean
- WDI_T-1_RESEARCH_AND_DEVELOPMENT
- ACLED_LOGCHANGE_COUNT__quantile__q_0.25
- ACLED_LOGCHANGE_FATALITIES_SRZ_T-2
- ACLED_LOGCHANGE_FATALITIES__sum_values
- ACLED_LOGCHANGE_COUNT_T-1 4
- IMF_GGXCNL_T-4
- ACLED_LOGCHANGE_COUNT_SRZ__sum_values
- ACLED_LOGCHANGE_COUNT__sum_values
- ACLED_T0_POPULATION_TOTAL
- ACLED_LOGCHANGE_COUNT__minimum
- ACLED_LOGCHANGE_COUNT__mean
- ACLED_COUNT_Battles__first_location_of_maximum
- ACLED_LOGCHANGE_FATALITIES__minimum
- ACLED_LOGCHANGE_FATALITIES_SRZ_T-5
- ACLED_LOGCHANGE_FATALITIES_T-1
- ACLED_LOGCHANGE_FATALITIES_SRZ__mean
- ACLED_LOGCHANGE_FATALITIES_T-2
- ACLED_LOGCHANGE_FATALITIES__quantile__q_0.25
- ACLED_ACTOR_COUNT__absolute_sum_of_changes
- ACLED_LOGCHANGE_COUNT_SRZ__quantile__q_0.75
- WDI_T0_INDIVIDUALS_USING_INTERNET

<u>List of top 30 features (out of 54 kept features) for the final model logchange (COUNT_PRO)</u>

- ACLED_LOGCHANGE_COUNT_PRO__mean
- ACLED_LOGCHANGE_COUNT_PRO__quantile__q_0.75
- IMF_GGX_NGDP_T-3
- ACLED_LOGCHANGE_COUNT_PRO_T-3
- ACLED_LOGCHANGE_COUNT_PRO_T-2
- ACLED_COUNT_Riots__mean_change
- ACLED_LOGCHANGE_COUNT_PRO__median
- ACLED_LOGCHANGE_COUNT_PRO__quantile__q_0.25
- WDI_T0_ACCESS_TO_ELECTRICITY
- WDI_T-1_GOVERNMENT_EFFECTIVENESS_ESTIMATE
- ACLED_LOGCHANGE_COUNT_PRO_T-1
- ACLED_LOGCHANGE_COUNT_PRO_T-8
- IMF_PPPSH_T-2
- IMF_NGSD_NGDP_T5
- ACLED_LOGCHANGE_COUNT_PRO_T-4
- WDI_T-1_NET_OFFICIAL_DEVELOPMENT
- WDI_T0_ACCESS_TO_ELECTRICITY
- IMF_GGXCNL_T-3
- ACLED_COUNT_Riots_T0
- WDI_T-1_MILITARY_EXPENDITURE
- WDI_T0_POLITICAL_STABILITY_ESTIMATE
- IMF_GGX_T1
- ACLED_COUNT_Strategic developments_T-3
- WDI_T0_POPULATION_TOTAL
- ACLED_LOGCHANGE_COUNT_PRO__maximum
- WDI_T0_FIRMS_EXPECTED_TAX_OFFICIALS
- WDI_T0_GDP_CURRENT_USD
- ACLED_LOGCHANGE_COUNT_PRO_T-5
- ACLED_LOGCHANGE_COUNT_PRO__minimum
- ACLED_LOGCHANGE_COUNT_T-2

Annex C: Population movement models

Foresight model

This model looks at forced displacement as a result of the underlying macro-level conditions related to a number of dimensions:

1. **Economy.** Covers the economic well-being and equality in a given country
2. **Violence:** Covers the level of violence, the different types of violence and fatalities
3. **Governance:** Covers aspects related to the legitimacy of the state, public service provisions and human rights
4. **Environment:** Covers aspects related to climate disasters, access to water, agricultural stress and food security
5. **Sociodemographic:** Covers aspects related to marginalized groups, urbanization, size and composition.

The data used in the model is all derived from open source. The main data sources are the World Bank development indicators, the Armed Conflict Location & Event Data Project (ACLED), the Uppsala Conflict Data

Program (UCDP), EM-DAT, UN agencies (UNHCR, the World Food Programme, The Food and Agriculture Organization), Internal Displacement Monitoring Center (IDMC), etc. In total, the system aggregates data from 18 sources and contains 148 indicators. The data on forced displacement depend wholly on the numbers from UNHCR and IDMC.

The machine learning model employed is an ensemble. An ensemble model works by leveraging several constituent models to generate independent forecasts that are then aggregated. Here we employ two gradient boosted trees to generate the point forecasts. The average margin of error in the model is evaluated by comparing historical projections from the last five to 10 years to actual displacement. This is further compared to the planning figures for displacement being used in the Humanitarian Response Plan (HRP) as a benchmark. The results show that the model generally performs well in the Sahel, ranging from an average margin of error down to 11 per cent in Mali to 34 per cent in the case of Burkina Faso. The highest and lowest errors are both found in Niger where the 2015 forecast was 91 per cent off the actual displacement, while the 2017 forecast was 0.09% off the actual displacement (in absolute numbers the forecast was 140 people off). 16 of the 42 forecasts so far have been less than 10 per cent off the actual level of displacement. The forecasts generally improve over time and in 2021 the estimated margin of error on the forecasts is below 2 per cent for three of the six countries. Comparing the model to the HRP planning figures it shows that in five of the six countries covered in the Sahel/West Africa, the model performs with a higher degree of accuracy.

WACAFI model

The WACAFI model uses dataset on internal displacement at Admin 1 level which has been constructed from reports from UNHCR, OCHA, national offices, etc. Data on internal displacement are not available on a consistent and regular basis, which meant that either the data had to be interpolated to a regular structure or the model had to be capable of handling irregular time spans. WACAFI is built with the latter strategy to not distort the connections between development in the outcome and the explanatory variables. Data on internal displacement at Admin 1 level is available in different time periods for the three countries.

At the Admin 1 level, changes in displacement are happening intermittently, and some locales will have longer stretches of time with no change. For that reason, the statistical model chosen is a zero-inflated model that can produce predictions of no change in the number of internally displaced. The explanatory variables were selected mostly among data sources that could vary on monthly and subnational scale. Most yearly and national level data, that were experimented with, were found to be too crude to assist in estimating on a monthly and subnational basis. This has so far ruled out some of the predominantly national indicators on governance and economy, though the use of these in the modelling is still a work in progress.

For conflict, the WACAFI model leverages data from ACLED which is aggregated to a list of variables at the Admin 1 level: all fatalities, fatalities from violence against civilians, number of conflict events, fatalities in neighbouring regions, conflict events in neighbouring regions and a 365-day rolling sum of fatalities. Additional conflict variables have also been tested, but they did not add significantly to the predictions.

Food security is firstly captured by using Cadre Harmonisé data on current and projected population in levels of food insecurity at the Admin 1 level. Since the data already incorporates the displaced population in their evaluation, the model constructs a variable estimating the additionally food insecure, i.e. the difference between the population in food security phase 3-5 and the previous displaced population.
Secondly, the three-month average of the Vegetation Health Index from Global Information and Early Warning System on Food and Agriculture (GIEWS) is used also as a variable indicating food security.

In terms of estimating displacement, the model outperforms both a naïve “previous value as next forecast” and a slightly more elaborate model with a linear trend of the recent year’s displacement development. The average margin of error on the forecasts is 14 per cent.

The model set-up allows the regional office to produce a likely scenario for the future that is then used in the model to project key variables to estimate the future conditions and the future displacement.

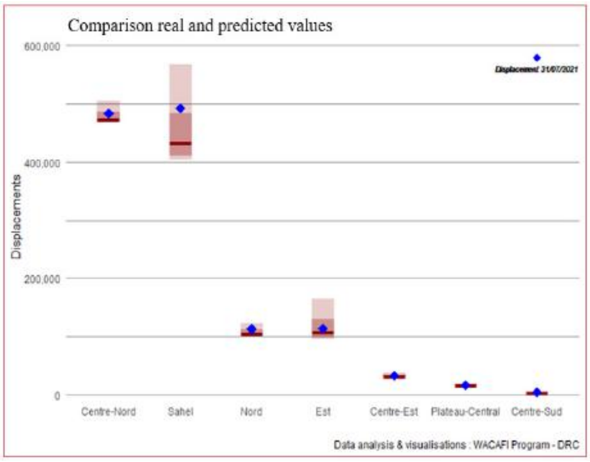


Figure 36: Comparison between real and predicted values of displacement in Burkina Faso.

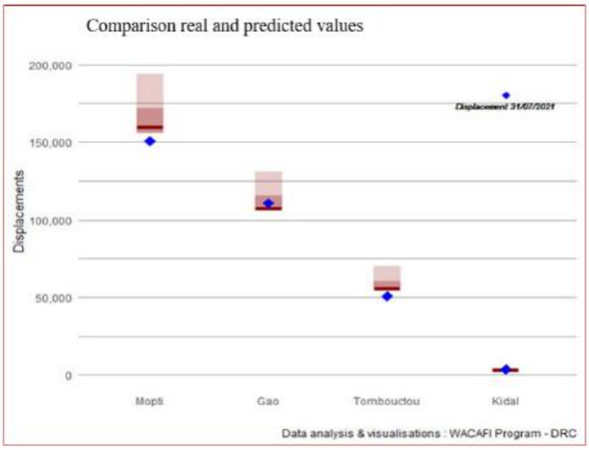


Figure 37: Comparison between real and predicted values of displacement in Mali.

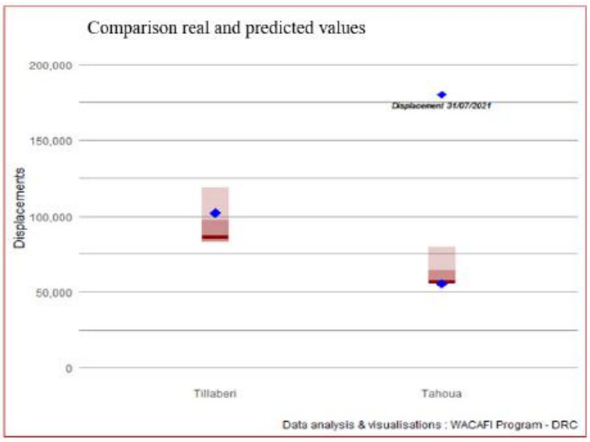


Figure 38: Comparison between real and predicted values of displacement in Niger.

The INCLUDE model

The INCLUDE model projects future spatially explicit subnational population change at varying spatial and temporal resolution, to-date varying from 1 to 15 km (30 arc seconds to 7.5 arc minutes) and five to 10-year intervals. The following text addresses methods used in the UNHCR-sponsored modelling work for the Sahel PA project using the INCLUDE model. Though the methods are similar, those desiring further methodological details for the work underpinning the World Bank's Groundswell Africa report are encouraged to review the methods chapter and technical appendices in that report (Rigaud et al., 2021).

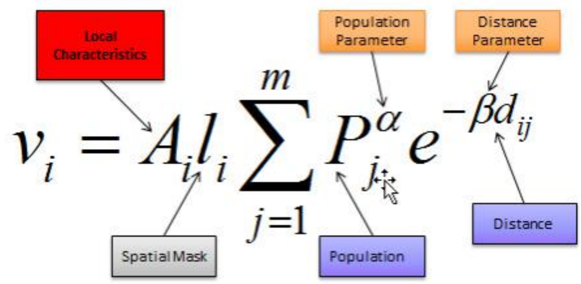
The INCLUDE model uses a modified form of population potential, a distance-weighted measure of the population taken at any point in space that represents the relative accessibility of that point (for example, higher values indicate a point more easily accessible by a larger number of people). Population potential can be interpreted as a measure of the influence that the population at one point in space exerts on another point. Summed over all points within an area, population potential represents an index of the relative influence that the population at a point within a region exerts on each point within that region. It can also be considered an indicator of the potential for interaction between the population at a given point in space and all other populations (Rich, 1980). Population potential will typically be higher at points close to large populations, thus it is also an indicator of the relative proximity of the existing population to each point within an area (Warntz & Wolff 1971). Historically, population potential is often considered as a proxy for attractiveness, under the assumption that agglomeration is indicative of the various socioeconomic, geographic, political, and physical characteristics that make a place attractive.

For this assessment, the calculation of potential is modified by adding variables that describe local/regional conditions, including climate impacts on economic livelihoods, and weighting the attractiveness of each location (grid cell) as a function of the historic relationship between these variables and observed population change. Population potential is, conceptually, a relative measure of agglomeration, indicating the degree to which amenities and services are available and that certain livelihoods are viable. In the INCLUDE model, this value shifts over time as a function of the population distribution, assumptions regarding spatial development patterns (e.g. sprawl vs. concentration) and of certain geographic characteristics of the landscape. The Groundswell approach expanded the model by considering the local impact of climate on certain key sectors. In this further expanded version of the model, the agglomeration effect is enhanced or muted as a function of additional local characteristics that aid in differentiating between places.

Beginning with a current (base-year) gridded population distribution for each country, the model estimates changes in the spatial population distribution (including the impact of climate change) in five-year time steps by (1) calculating a population potential surface (a distribution of values reflecting the relative attractiveness of each grid cell) and (2) allocating population change to grid cells proportionally based on potential. To generate estimates of internal migration under climate change, we then run scenarios for each of the relevant SSPs that exclude the impacts of climate change. That is, we hold the values for all variables that are influenced by climate change constant at current day values (crops, water, NPP, drought likelihood and sea-level). The differences in the spatial population distribution between the two scenarios that include climate drivers and this no-climate scenario are attributed to migration induced by changing conditions, as the only variables that have changed are those impacted by a shifting climate. Figure 39 provides a full flowchart of the modelling steps.

Figure 39: Flowchart of modelling steps (adapted from Rigaud et al., 2018).
Note: * The counterfactual population projection simply scales the population distribution in 2010 to country-level population totals appropriate to each SSP.

In this application version of the INCLUDE model, population potential (vi) is calculated as a parametrized negative exponential function:



$$v_i = A_i l_i \sum_{j=1}^{m} P_j^{\alpha} e^{-\beta d_{ij}}$$

Eq. 1

where spatial mask (l) prevents population from being allocated to areas that are protected from development or unsuitable for human habitation, including areas that will likely be affected by sea- level rise between 2015 and 2050. P_j is the population of grid cell j, and d is the distance between two grid cells. The population and distance parameters (α and β) are estimated from observed patterns of historical population change. The β parameter is indicative of the friction of distance or the cost of travel that generally determines the shape of the distance–density gradient in and around urban areas (e.g. sprawl vs. concentration). The α parameter captures returns on agglomeration externality, interpreted as an indicator of the characteristics that make a place more or less attractive.

Importantly, the SSPs include no climate impacts on aggregate total population, urbanization or the subnational spatial distribution of the population. The INCLUDE approach was modified by incorporating additional spatial data including the ISIMIP sectoral impacts, projections of the mean drought index availability and sea-level rise. The index A_i is a weight on population potential that is calibrated to represent the influence of these factors on the agglomeration effect that drives changes in the spatial distribution of the population. All of the data are incorporated into the model as 1 kilometre gridded spatial layers. The value A_i is calculated as a function of these indicators. Numerically, it represents an adjustment to the relative attractiveness of (or aversion to) specific locations (grid cells), reflecting current water stress, crop yields, ecosystem services and the likelihood of drought relative to normal conditions.

Calibrating the model

The model is calibrated over two decadal periods (1990–2000 and 2000–2010 for Groundswell Africa; 2000-2010 and 2010-2020 for the UNHCR projections) of observed population change relative to observed conditions. As noted above, the value A_i is calculated as a function of these different climatic/socioeconomic indicators and acts as an adjustment to relative attractiveness. In order to carry out the procedure, model estimates of the α and β parameters are necessary, and A_i must be calibrated. Two separate procedures are employed.

The α and β parameters are designed to capture broad-scale patterns of change found in the distance-density gradient, which is represented by the shape/slope of the distance decay function from Equation 1. The negative exponential function described by Equation 1 is very similar to Clark's (1951) negative exponential function, which has been shown to accurately capture observed density gradients throughout the world (Bertaud & Malpezzi, 2004). To estimate α and β, the model in Equation 1 is fitted to the 1990-2000 and 2000-2015 population change from GHS-Pop, and we compute the values of α and β that minimize the sum of absolute deviations:

$$S(\alpha,\beta) = \sum_{i=1}^{n} \left| P_{i,t}^{mod} - P_{i,t}^{obs} \right|$$

Eq. 2

where $P_{i,t}^{mod}$ and $P_{i,t}^{obs}$ obs are the modelled and observed populations in cell i, and S is the sum of absolute error across all cells. We fit the model for two-time steps (1990-2000 and 2000-2015) and take the average of the α and β estimates.

In this modified version of the population potential model, the index A_i is a cell-specific metric that weights the relative attractiveness of a location (population potential) as a function of environmental and/or socioeconomic conditions. The modelling approach requires that the relationship between A_i and the different local indicators is estimated, which are hypothesized to impact population change. When α and β are estimated from historic data (e.g. observed change between 2000 and 2015), a predicted population surface is produced that reflects optimized values of α and β, such that absolute error is minimized. Figure 40 includes a cross section (one dimension) of grid cells illustrating observed and predicted population for 10 cells. Each cell contains an error term that reflects the error in the population change projected for each cell over a five-year time step. It is hypothesized that this error can at least partially be explained by a set of omitted variables, including environmental/sectoral impacts. To incorporate these effects, we first calculate the value of A_i such as to eliminate ε_i for each individual cell (which is labeled observed A_i):

$$\Delta P_{i,t}^{obs} = A_i * \Delta P_{i,t}^{mod}$$

Eq. 3

where $\Delta P_{i,t}^{obs}$ and $\Delta P_{i,t}^{mod}$ are the observed and modelled population change for each cell i and A_i is the factor necessary to equate the two.

The second step is to estimate the relationship between observed index A_i and the different potential drivers of spatial population metrics by fitting a spatial lag model:

$$A_{i,t} = \rho W A_{i,t+} \beta_1 C_{i,t} + \beta_2 H_{i,t} + \beta_3 N_{i,t} + \cdots \beta_n D_{i,t} + \varepsilon_{i,t}$$

Eq. 4

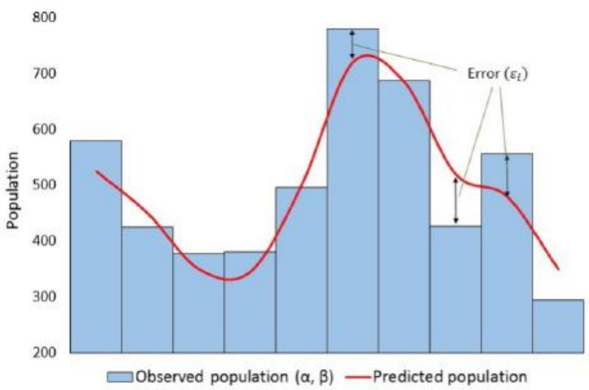


Figure 40: Cross section of grid cells illustrating observed and projected population distributions. The error term is used to calibrate the index A(i).

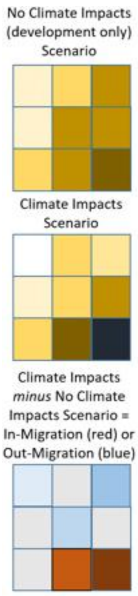
Where C,H and N are the five-year deviations from the historic baseline on crop yield, water availability and net primary production, respectively, and D represents an additional set of drivers which for Groundswell Africa includes age and sex structure, flood risk and ACLED conflict fatalities. For the UNHCR projections, groundwater recharge and built-up land, and the ACLED data were replaced by ViEWS short-term probability of conflict. Together these variables and their respective coefficients constitute the set of explanatory variables that go into producing index A_i. Note that for any grid cell in which C (crop yield) is a non-zero value, the value of N (net primary production) is automatically set to zero, so that only one of the two variables is contributing to the index A_i. Finally, ρ is the spatial autocorrelation coefficient and W is a spatial weight matrix. From this procedure, a set of cell specific A values is estimated.

For future projections, projected values of each independent variable are used, along with their respective coefficient estimates from Equation 4, to estimate spatially and temporally explicit values of A_i . To produce a spatially explicit population projection for each time step, estimates of α and β from the historic data (which reflect the business as usual nature of SSP2) are applied to produce estimates of the agglomeration effect, to which the spatio-temporally variant estimates of A_i for the RCPs described above are applied. Finally exogenous projections of national urban and rural population change are incorporated and the model applied as specified above.

Past testing of the model indicated that cells meeting certain criteria should be excluded from the calibration procedure. First, cells that are 100 per cent restricted from future population growth by the spatial mask (I, Equation 1) are excluded, as the value of v_i in these cells (0) renders the observed value of A_i inconsequential. Second, the rural and urban distributions of observed A_i were found to include significant outliers that skewed coefficient estimates in Equation 4. In most cases, these values were found to correspond with very lightly populated cells where a small over/under prediction of the population in absolute terms (e.g. 100 persons) is actually quite large relative to total population within in the cell (e.g. large percentage error). The value of A_i (the weight on potential), necessary to eliminate these errors, is often proportional to the size of the error in percentage terms, and thus can be quite large even though a very small portion of the total population is affected. Including these large values in Equation 1 would have a substantial impact on coefficient estimates. To combat this problem, the most extreme 2.5 per cent of observations are eliminated on either end of the distribution.

Estimating internal climate migrants

Gravity models do not directly model internal migration. Instead, internal migration is assumed to be the primary driver of deviations between population distributions in model runs that include climate impacts and the model runs that do not account for climate impacts (development-only (the “no climate” models) that only include the non-climate related drivers). Migration is a fast demographic variable compared with fertility and mortality; it is responsible for much of the decadal-scale redistributions of population (Rigaud et al. 2018). Without significant variation in fertility/mortality rates between climate-migrant populations and non-migrant populations, it is fair to assume that differential population change between the climate impact scenarios and the development-only scenarios occur as a function of migration. Thus, for each grid cell we consider the impact of climate change to be the difference between the climate and no-climate scenario (e.g. SSP3/RCP4.5 vs. SSP3/No-Climate). To estimate total internal migration under any scenario, we sum the positive differences at the grid-cell level between any scenario and its corresponding no-climate scenario.



The figure to the left reflects the process for a hypothetical model run for one of the scenarios, in which higher population densities in 2050 are reflected by darker shades. Future population projections without climate impacts are subtracted from population projections with climate impacts to yield a map of population differences. Positive differences are assumed to reflect net in-migration and negative differences are assumed to reflect net out-migration due to climate change impacts.

An advantage of the INCLUDE modelling approach, when compared to other modelling approaches, is the application of readily available and globally consistent population grids, global climate models, climate impact models and other inputs. Gaps in migration data and extensive, context-specific socioeconomic data required to parameterize most other models means that those can largely only be applied at local scales. That said, it needs to be acknowledged that global data sets may contain inaccuracies or poorly represent local-scale dynamics, and so this remains a trade-off.

ISIMIP index values

Here, the projections for the water, crop and ecosystem models out to 2050–2100 are presented that were used for the INCLUDE model. It uses the index in which the historical baseline value is subtracted from the projected value and then divided by the historical baseline value. Positive index values are capped at 2, which represents a tripling of the baseline value (whether it be water availability, crop production or ecosystem productivity).

Photo: UNDP Burkina Faso

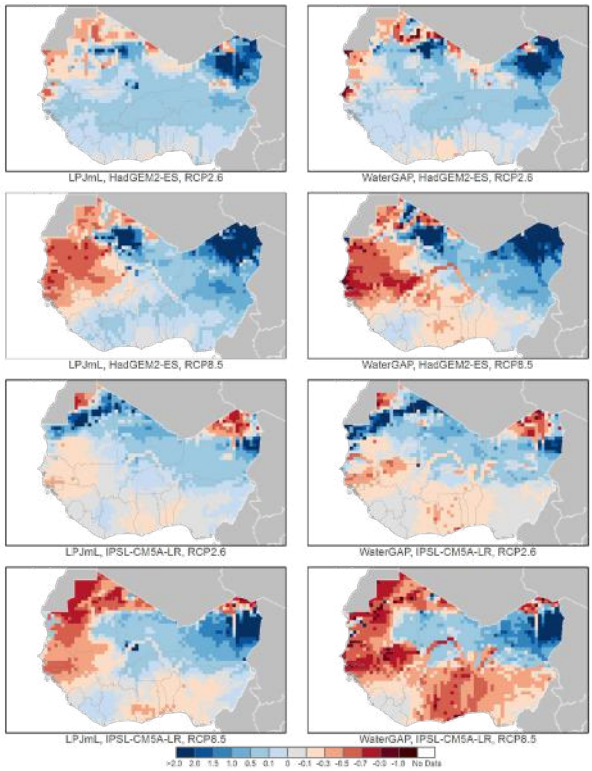


Figure 41: ISIMIP Average Index Values against 1970–2010 Baseline for Water Availability, West Africa, 2050–2100.
Note: Data compiled from LPJmL/water (panel a) and WaterGAP (panel b), forced with the HadGEM2-ES climate model (top four maps) and IPSL-CM5A (bottom four maps) under RCP2.6 and RCP8.5. Blue areas indicate wetting relative to the historical baseline, and gray and tan areas indicate drying.

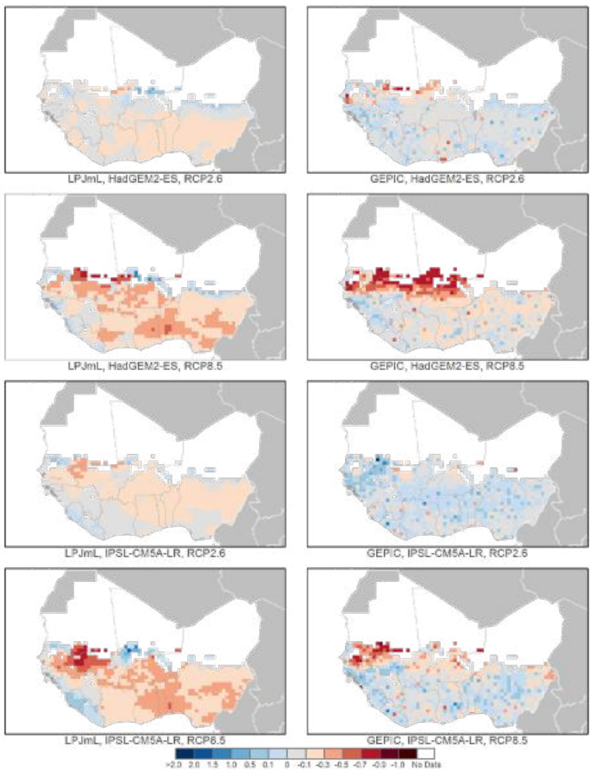


Figure 42: ISIMIP Average Index Values against 1970–2010 Baseline for Crop Production, West Africa, 2050–2100.
Note: Data compiled from LPJmL/crop (panel a) and GEPIC (panel b), forced with the HadGEM2-ES climate model (top four maps) and IPSL-CM5A (bottom four maps) under RCP2.6 and RCP8.5. Blue areas indicate wetting relative to the historical baseline, and tan to red areas indicate drying. White areas do not grow the four major crops.

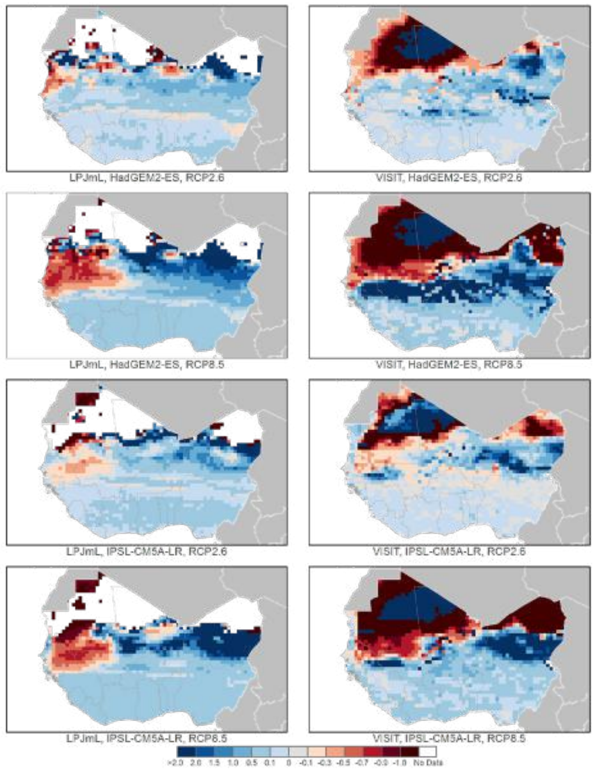


Figure 43: ISIMIP Average Index Values against 1970–2010 Baseline for Ecosystem NPP, West Africa, 2050–2100.
Note: Data compiled from LPJmL (panel a) and VISIT (panel b), forced with the HadGEM2-ES climate model (top four maps) and IPSL-CM5A (bottom four maps) under RCP2.6 and RCP8.5. Blue areas indicate higher NPP relative to the historical baseline, and tan to red areas indicate lower NPP. NPP = net primary productivity.

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