Executive Summary

Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Niger's Agricultural Sector

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The Executive Summary is based on a Scientific Report and further complemented by a Policy Brief.

Setting the Scene

Climate change is already affecting the agricultural sector in Niger and its impacts will continue to increase in the future. This puts livelihoods and economic growth at risk and shows the urgent need for effective adaptation strategies.

This summary provides decision-makers and implementers in Niger with **localised information on current and future climate risks for the agricultural sector** including information on future crop yields**.** It presents **four suitable adaptation strategies** which enable farmers to cope with these climate risks and stabilise their crop yields. Additionally, this summary makes **suggestions to strengthen an enabling environment** that supports all farmers in taking up adaptation strategies that are most suitable for their individual contexts.

Key Recommendations[1]

Agroforestry and farmer managed natural regeneration of trees (FMNR) is an adaptation strategy with low input requirements, high risk mitigation and high upscaling potential. We recommend a continuation of FMNR practices in areas that are already implementing FMNR (in Tahoua, Zinder and Maradi), and a wider upscaling to the other regions of Niger, especially where soil organic carbon is high.

Integrated Soil Fertility Management (ISFM) comprises various traditional practices (e.g. Tassa and halfmoons) that hold great potential for climate change adaptation, including significant sorghum yield increases in the southern parts of the country, namely in Maradi and the southern parts of Zinder. Moreover, ISFM results in very positive effects for societies and environment, such as decreased surface runoff and soil loss, decreased wind velocity and increased soil moisture and plant diversity. Additionally, ISFM can lead to an increase in farmers' income and have a positive impact on food production. We therefore recommend policies towards sustainable land use intensification, rehabilitation of degraded soils and the necessary mechanisms to implement and evaluate these.

Irrigation for counter-season agriculture has the potential to mitigate climate risks in Niger as well as to help diversify diets and ensure food security. However, the provision of support services is necessary to avoid over-exploitation of already scarce water resources in the long-term. Raising awareness about water-saving irrigation management is crucial to ensure a long-term responsible use of natural resources. We therefore recommend low-cost irrigation options with low maintenance requirements across Niger, where water resources are sufficient.

Improved fodder and feed management for livestock leads to securing and increasing fodder availability in the face of climate change and thus presents a high-risk mitigation potential with a short pay-back period. It also results in additional positive effects, like economic benefits through the sale of fodder surplus, soil protection and rehabilitation from plant cover. We recommend the use of improved varieties of sorghum, as well as irrigated alfalfa cultivation and mowing. Careful planning for the use of land and water resources, as well as institutional support for access and maintenance of equipment are needed.

[1] Further information on the four adaptation strategies is detailed in sections "Adaptation Strategies" and "Policy Recommendations for an Uptake of Adaptation Strategies".

The Study Area

The Climate Risk Analysis focuses on the Republic of Niger, a landlocked country in Western Africa in the Sahel. Niger can be divided into five agro-ecological zones (AEZ) (Figure 1): the Sahara zone, covering two-thirds of the territory in the north, is characterized by arid climates of grassy steppe and has typically less than 200 mm precipitation per year. The Sahara-Sahelian zone experiences a gradual increase in annual precipitation which amounts at 200–300 mm. The Sahelian zone is a light savannah with an amount of 300–400 mm precipitation per year. The Sahelo-Soudanian zone which includes Niamey has a comparably high crop production potential, with precipitation amounts between 400–600 mm per year. Finally, the Soudanian zone at the southern tip of the country, with >600 mm precipitation per year holds even higher yet vastly unexploited cropping potential (RECA, 2004)[2].

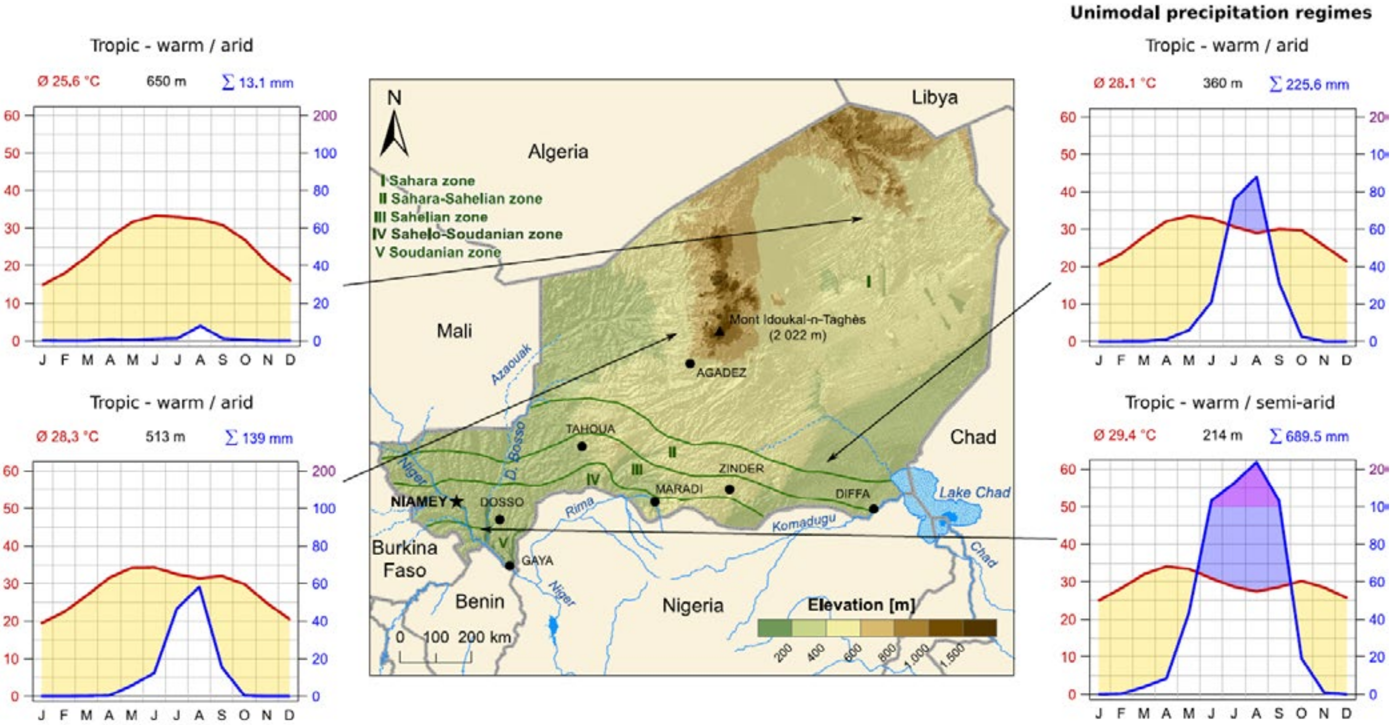

Figure 1: Topographical map of Niger with agro-ecological zones, and climate diagrams displaying the annual distribution of precipitation and temperature

The climate of Niger is characterised by a mean annual temperature of 23–30 °C, with higher values in the south of the country, namely in Tillabery, Dosso and Tahoua, and substantially cooler values in the mountainous regions (Aïr Mountains). The total amount of annual rainfall is between 10 and 800 mm, with very scarce precipitation north of 15 °N. The rainy season occurs between May and October, with a peak in August (Figure 1). The amount of rainfall as well as the rainy season onset and length show high year-to-year variability in all parts of Niger, with increasing variability towards the north.

Climate trends and impacts on crop and livestock production ought to be examined closely, since these two sectors are seminal for the national economy as well as for the food and nutrition security of the country. Niger has the highest annual demographic growth rate (3.8% (World Bank, 2020)) in Africa, so food demand is expected to further increase. The agricultural sector employs around 80% of the workforce, and generates 38.4% of the Nigerien GDP (République du Niger, 2020). The Nigerien livestock sector is prominent, given that the country has one of the largest cattle populations in the Sahel region (more than 15 million cattle). The agricultural sector relies on rainfed crop and pastoralist livestock production, which makes it extremely vulnerable to climatic changes. **Robust science-based adaptation planning in Niger is required to improve the resilience of those farming communities**.

[2] It should be noted that there are different classifications of AEZs in Niger. We focused on a commonly used classification of five zones.

Past and Projected Future Climate Changes

Table 1: Overview of changing climatic conditions for Niger.

Climate Impact	Past Trend	Future Trend	Certainty[3]
Mean annual temperature	Increasing	Increasing (both emissions scenarios)	Very high
Number of very hot days & tropical nights	Increasing	Increasing (both emissions scenarios)	Very high
Heavy rainfall intensity & frequency	No clear trend	Increasing (high emissions scenario)	Very high
		No clear trend (low emissions scenario)	Medium
Mean annual rainfall sums	Increasing since the 1980s	Increasing (high emissions scenario)	Very high
		No clear trend (low emissions scenario)	Medium
Rainy season onset	No clear trend	Increasing (high emissions scenario)	Medium
		No clear trend (low emissions scenario)	Low

Past climate changes

Temperature has increased in the last decades in Niger, along with the number of very hot days (maximum temperature above 35 °C) and tropical nights (minimum temperature above 25 °C). with an average **rise of 0.43 °C in the annual mean temperature between 1988 and 2006**. The highest increase of mean annual temperature was observed in Agadez region, especially near its capital Agadez (Figure 2). Niger is **recovering from decades of drought** (1970–80s) with mean annual **rainfall sums, heavy rainfall intensity and frequency having increased since then**. However, rainfall amounts are still below those of the mid-20th century and are characterised by high year-to-year variability and regional differences. Higher absolute increases were observed in the wetter south (Figure 3).

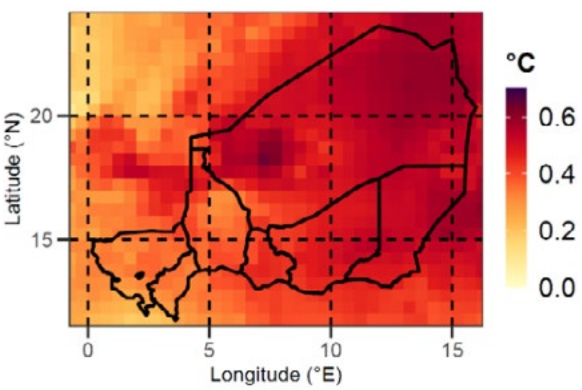

Figure 2: Difference in mean annual temperature in °C over Niger from 1988 to 2006

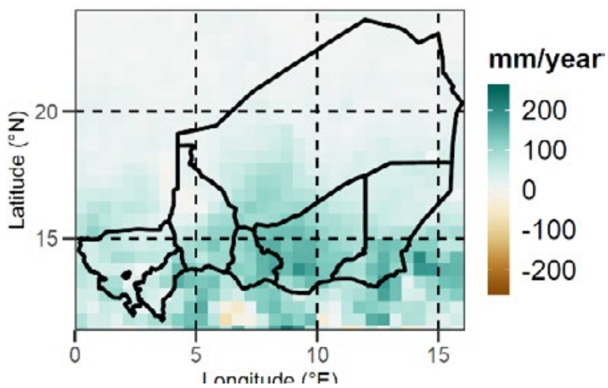

Figure 3: Difference in mean annual precipitation in mm over Niger from 1988 to 2006

[3] The confidence level of future climate projections is determined by the percentage of models agreeing on the trend (with significance level of 0.05) (compare IPCC, 2014). ≥ 90%: very high; ≤ 80%: high; ≥ 50%: medium; ≤ 50%: low.

Future Projections

Future projections of temperature show an overall continuation of the increasing trend (Figure 4). **Mean annual temperature is projected to increase between 1.3 °C (low emissions scenario) and 1.9 °C (high emissions scenario) by 2050**, compared to 2004. Further increases until the end of this century will occur under high future emissions. Additionally, **extreme temperatures**, namely **the number of very hot days** and **tropical nights, will increase** in all parts of the country under both emissions scenarios, the strongest increases being expected in the south (below 15 °N). The high emissions scenario projects 276 very hot days and 212 tropical nights per year for the end of the century.

Future rainfall projections are subject to modelling **uncertainty**, especially under the high emissions scenario. In case of low global efforts in climate mitigation (i.e. high emissions scenario), **mean annual rainfall sums** (Figure 5) and **heavy precipitation intensity might increase throughout the century**. Should there be strong climate change mitigation (i.e. low emissions scenario), Niger would see slight increases in the mean annual rainfall sums during the next decades, followed by a slight decline from mid-century, while having no or little changes in heavy rainfall intensity. The year-to-year variability is likely to decrease slightly in the first half of the century and increase at the end of the century. As for the rainy season, models hint at an earlier onset under both emissions scenarios until 2030. Afterwards, the trends are diverging with a projection of a later onset under SSP1-RCP2.6 and an earlier onset under SSP3-RCP7.0, with also regional differences.

To account for uncertainties in future emissions, one high emissions scenario (SSP3-RCP7.0) and one low emissions scenario (SSP1-RCP2.6) were used. Thereby, the high emissions scenario is built upon the assumption of continuously high future emissions, while the low emissions scenario assumes high mitigation efforts and aims to keep global warming likely below 2 °C above pre-industrial temperatures.

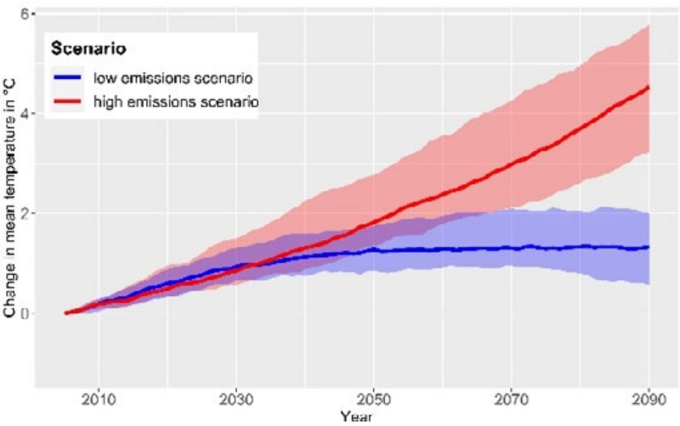

Figure 4: 21-year running mean of change in mean annual temperature in Niger under the low emissions scenario (blue) and the high emissions scenario (red).

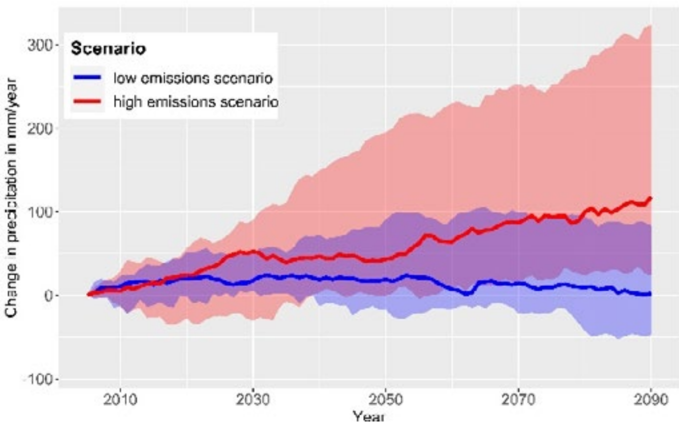

Figure 5: 21-year running mean of change in mean annual rainfall sum in Niger under the low emissions scenario (blue) and the high emissions scenario (red).

Past and Projected Future Hydrological Changes

Hydrological changes, and therefore water availability changes, are important to evaluate, given the fact that Niger's primarily rural population is heavily reliant on rain-fed agriculture in the face of arid climate conditions with scarce and highly variable precipitation. Past and future hydrological changes have been simulated using a semi-distributed hydrological model that is driven by emissions scenarios and global climate models' outputs.

Table 2: Summary of the hydrological changes.

Impact	Trend past	Trend future	Confidence[4]
River discharge	Increasing	Increasing (decreases possible under the low emissions scenario)	Medium
Groundwater recharge	Increasing	Increasing (especially under the high emissions scenario)	Medium
Evapotranspiration	No major change	Slightly increasing	High
Flood peak discharge	Increasing since the 1990s	Increasing (but shifts in regime possible)	Medium

Past hydrological changes

Past hydrological changes in Niger are dominated by inter-annual and decadal variability: the 1950–60s were predominantly wet periods, followed by severe droughts in the 1970–80s (Conway et al., 2009; Descroix et al., 2012; Mahe et al., 2013). **Precipitation amounts and river discharge have recovered to long-term average conditions with an increasing trend since the late 1990s**. Besides, population growth has entailed changes in land use (non-agricultural bush and shrubland converted into cultivated land) in the southern part of the country since mid-20th century, thereby favouring higher rates of surface runoff as well as lower rates of infiltration. Groundwater recharge has been further impeded by higher rates of groundwater abstraction as extraction has become more mechanised.

Projected hydrological changes

In line with increasing precipitation, the **annual average of river discharge** is projected to **increase generally, although not under all emissions scenarios and global climate models**. Niger River, the largest river of the country, is projected to carry 8% and 12% more annual discharge within the next two decades (2021–2040) under the low emissions scenario and the high emissions scenario, respectively, compared to the reference period (1995–2014). The discharge is then likely to further increase by 25% (low emissions scenario) and 9% (high emissions scenario) towards the middle of the century, and eventually decline to −3% (low emissions scenario) and 0.5% (high emissions scenario) at the end of the century. As for the Dallo Bosso catchment, increases are expected throughout the century, ranging from 30% to 45% (low emissions scenario), from 30 to 145% (high emissions scenario, 145% being noted for the end of the century). These changes for Niger River and Dallo Bosso will be reflected in the monthly discharges, mainly between July and December.

The increases in precipitation amounts partially also translate to **greater annual rates of groundwater recharge mainly under the high emissions scenario** in large parts of the Niger basin, especially in the south. Under the low emissions scenario, models hint at increases, which are however not statistically significant, especially towards the end of the century.

Annual peak discharge, an indicator for the seasonal flood, is expected to increase in line with seasonal increases in discharge, increasing the likelihood of flooding.

Therefore, future projections of hydrological changes mainly show a continuation of the past trends but slight variations such as shifts in regime of flood peak discharge are possible.

[4] The confidence level of future climate projections is determined by the percentage of models agreeing on the trend (compare IPCC, 2014).
≥ 90%: very high; ≥ 80%: high; ≥ 50%: medium; ≤ 50%: low.

Climate Impacts on Agricultural Production

Table 3: Summary of climate change impacts on agricultural production showing overall trends at national level (for further information about regional differences, see the full Climate Risk Analysis).

Impact	Current situation	Future trend	Certainty
Weather influence in sorghum yields	Medium 54%	-	High
Sorghum suitability	Medium 6.9%	Increasing: +3.3. to +4.9% (low emissions scenario) Increasing: +5.7 to +8.9% (high emissions scenario)	High
Sorghum yields	Low 0.24–0.5 t/ha	Increasing: +15 to +17% (low emissions scenario) Increasing: +10 to +14% (high emissions scenario)	Medium
Weather influence in millet yields	Medium 49%	-	High
Millet suitability	Medium 6.4%	Increasing: +3.5 to +3.8% (low emissions scenario) Increasing: +4.5 to +11.9% (high emissions scenario)	High
Weather influence in maize yields	High 83%	-	High
Maize suitability	Low to medium 1.7%	Relatively stable: +1.0 to +2.7% (low emissions scenario) Relatively stable: +1.2 to +1.8% (high emissions scenario)	High
Weather influence in cowpea yields	Medium 55%	-	High
Cowpea suitability	Medium 9.8%	Relatively stable: +1.2 to +1.5% (low emissions scenario) Relatively stable: +2.0 to +4.0% (high emissions scenario)	High

Using statistical and process-based crop models, the impacts of climate change on the following four staple crops were analysed: the **annual grain crops sorghum, millet** and **maize** as well as the **annual legume cowpeas**. These four crops were selected based on their importance for food security in the country, stakeholders' priorities, data availability and suitability for the crop models.

Sorghum is an annual grass species cultivated for its grain. The crop takes 90–300 days to mature. Sorghum is adapted to warm days and night temperatures above 22 °C throughout the growing season and requires about 500–1000 mm of rainfall for optimal growth.

- **Current suitability:** Under current climatic conditions, **6.9% and 6.1% of Niger is considered optimally and moderately suitable for sorghum production**, respectively. The suitable areas are found in all provinces, except for the Agadez region, where only a few areas in the south are marginal suitable.

- **Projections:** Crop models show an overall northward shift and an increase in **suitability to grow sorghum** by 2030, 2050 and 2090 up to +4.9% under the low emissions scenario and up to +8.9% under the high emissions scenario. Mainly in the central southern parts of Zinder and Diffa an increase in areas with optimal suitability is projected. More significant changes in suitability are likely to occur under the high emissions scenario, at the end of the century. Decreases in suitability may be seen in some areas but are expected to be outnumbered by increases in other areas. In addition to the suitability analysis, sorghum was used as a case study to analyse yield changes using a process-based crop model. At the national level, sorghum yields are projected to increase in 2030, 2050 and 2090 up to approximately +17% under the low emission scenario. Under SSP3-RCP7.0, nationally averaged yields are also projected to increase by about 14% by 2030, but then decline again to an overall increase of about 11% by 2050 and 10% by 2090. However, changes in sorghum yields will vary between regions. **Models suggest increasing yields in Agadez** (up to approximately +60% under the low emissions scenario and up to +65% under the high emissions scenario), and to a lower extent in **Tahoua and Diffa**. **Decreasing trends are projected for Tillabery and Niamey.**

Millet is one of the main staple crops in Niger, cultivated as a food grain and a forage crop. It can grow under conditions considered as too harsh for other food crops, i.e. on soils that are low in fertility and receive relatively low amounts of rainfall. Millet takes 60 to 120 days to mature, and thrives under 25–35 °C and 400–900 mm of precipitation.

- **Current suitability:** Today, **6.4% of Niger is optimally suitable for millet production**, the largest suitable areas being located in the Tillabery region.
- **Projections:** Millet suitability is projected not to change in the greatest part of the country. Models suggest a **northward expansion in millet suitability**, with an increase up to +3.8% under the low emissions scenario and up to +11.9% under the high emissions scenario by 2090. It can be noted that the Tahoua region will likely know the most significant suitability gains, due to increasing rainfall amounts.

Maize is a vigorous annual grass and grain crop. Its maturing period depends on local conditions and can vary 65 to 365 days in Niger. Temperature and rainfall during the growth period should be between 18 °C and 33 °C, and 600 to 1200 mm respectively.

- **Current suitability:** Today, **only 2.7% and 1.7% of Niger is moderately suitable and optimally suitable for maize production respectively**. Maize suitability is the lowest among the four studied crops' suitability, under current climatic conditions.
- **Projections:** Although maize suitability is likely to remain relatively stable at the national level, regional differences should be heeded. Suitability is projected to **improve in Zinder and Maradi until mid-century, then decrease**, especially under the high emissions scenario, in the southern parts of these regions, which are today the major maize growing areas. **Decreases are also expected for the Tillabery and Dosso regions** from the 2030s onwards and under both emissions scenarios.

Cowpea is an annual legume that is adapted to semi-arid and hot climate and grows on sandy soils. Like most other legumes, cowpea can fix nitrogen in the soil leading to improved soil fertility. The crop takes 60 to 240 days to mature and needs 20–35 °C as well as 600–1500 mm of precipitation during the growing season.

- **Current suitability: 9.8% of Niger being optimally suitable for cowpea production** under current climatic conditions, cowpea has the highest potential to be cultivated in the country, when compared to the three other crops.
- **Projections:** Suitability to grow cowpea will increase in some areas and decrease in others by 2030, 2050 and 2090, remaining overall stable at the national level. Areas in **Tahoua and Tillabery regions will become more suitable**, whereas **Zinder is likely to face losses in cowpea suitability** throughout the century under both emissions scenarios.

Overall, the **areas suitable to grow sorghum and millet are projected to increase under climate change in Niger, while those for maize and cowpea will remain stable**. A **multiple crop suitability analysis** shows that currently less than 1% of the country is optimally suitable for producing all four crops and 2.7% are defined as moderately suitable. However, the potential for multiple cropping (4 crops) will decrease further under climate change (down to 0.2% under the high emissions scenario), especially in the Tillabery region. Nevertheless, areas optimally suitable for cultivating three crops are projected to increase, particularly under the high emissions scenario. This indicates some potential for diversification, which increases food security and provides economic benefits through cultivation of multiple crops.

Climate Impacts on Livestock Production

Table 4: Summary of climate change impacts on livestock production.

Impact	Trend past	Trend future	Confidence
Livestock number	Increasing	- no data -	-
Fodder availability, grazing potential	Decreasing	Decreasing in the south, increasing in the centre (low emissions scenario) Increasing towards the end of the century (high emissions scenario)	High

The impacts of climate change on grassland productivity and therefore grazing-based livestock production (goats, cattle, sheep) in Niger have been analysed using a process-based dynamic global vegetation model.

Currently, the grazing potentials are the highest in the Dosso region along the border with Benin, exceeding 2.5 tonnes dry matter per hectare per year. Grazing potentials decrease towards the north following the decreasing precipitation gradient across Niger. The lowest potentials are found in the Agadez region, with almost no potential for grazing in the desert regions.

Under the low emissions scenarios, model simulations point to a 3% grazing loss (by 2030), followed by a 6% increase (2050) and a 5% decrease (2090), taking 1995–2014 as a baseline. 20% (by 2030), 17% (2050) and 57% (2090) of increases, compared to the same reference period, are expected under the high emissions scenario. These projected changes are however national averages, and it should be noted that the changes will differ substantially between regions. Most positive trends are expected to be seen in Agadez, Diffa, Tahoua, Zinder, between 15 and 19 °N, whereas Dosso is the most likely to experience decreases in grazing potential, under both scenarios.

Climate change impacts go beyond the changes in grazing potentials: national security in Niger appears to be intertwined with the livestock sector. Existing tensions, such as conflicts between farmers and pastoralists over land use, cattle raiding and recruitment by extremist groups are likely to be further aggravated under climate change.

Adaptation Strategies

Well designed and implemented adaptation strategies can not only **reduce present and future yield losses** induced by climate change, but also have various **positive economic, social and environmental co-benefits.**

Based on the projected climate change impacts and stakeholder interests, **four adaptation strategies** were analysed regarding their suitability under changing climate conditions in Niger:

Agroforestry and farmer managed natural regeneration of trees (FMNR): Agroforestry, defined as "the integration and use of trees in crop fields, farms and agricultural landscapes" (Dinesh et al., 2017), helps to re-green areas that were once semi-desert and to restore marginal production areas. Promoted in the aftermath of the 1970–80s droughts, FMNR is the most common agroforestry practice in Niger, notably in Tahoua, Maradi and Zinder. It involves identification, active protection and regrowth of wild tree and shrub stumps in fields, rather than tree seedlings planting (Reij & Garrity, 2016). This low-cost land restoration technique can, for example, help diversify agricultural products, create a favorable microclimate in fields, recharge groundwater levels, and act as a windbreak, thus holding great potential for increasing the resilience of local livelihoods to climate change.

Integrated Soil Fertility Management (ISFM): ISFM is a set of traditional soil fertility management practices adapted to local conditions, including the use of fertiliser, organic inputs and improved germplasm (Vanlauwe et al., 2010). Tassa (also known as Zaï), half-moons, stone bunds, filter bunds, grass strips, mulching and bocage system are all ISFM practices that help to prevent land degradation and improve soil fertility. They have already been implemented by some Nigerien farmers since the 1980s with considerable land restoration achievements.

Irrigation for counter-season agriculture: Precipitation is increasingly erratic and food security is at stake particularly during the dry season, which runs from October to May. Irrigation can help farmers to bridge potential food shortages during the dry season thereby securing income and livelihoods. In 2017, only 33% of the total irrigable land area in Niger were irrigated (AQUASTAT, 2017). Today, irrigation is mainly practised along the banks of the Niger River using state-led irrigation systems (overseen by the Office National des Aménagements Hydro-Agricoles) for rice cultivation, as well as through off-season irrigation systems, which were set up by the Nigerien government as a response to the 1980s droughts, primarily for vegetable crops (onions, tomatoes, chili peppers among others). Besides, low-cost but labour-intensive small-scale irrigation, initiated and managed by farmers themselves, are conducted in addition to common runoff collection practices such as Tassa and half-moon.

Brought out in several national policies and initiatives including the 2015 Strategy of Small-Scale Irrigation (Ministère de l'Agriculture et de l'Élevage, 2015) and the 3N Initiative (République du Niger, 2015), irrigation has been defined as a priority for agricultural development in Niger.

Improved fodder and feed management for livestock: Providing feed resources in adequate quantity and quality is essential to ensure livestock systems' productivity. As livestock main feed sources, crop residues and natural pasture lands, are decreasing, improved fodder management as well as alternative options are needed.

Hay and silage making, which aims to preserve fodder and crop residues, are recommended. Fodder crops such as bourgou, fodder sorghum, cowpea and alfalfa have been promoted by the Nigerien government. The Irhazer, Tamesna and Aïr Agricultural Development Support Project (PADA/ITA) led for instance to a wider cultivation of alfalfa in Agadez.

Cost-Benefit Analysis

A **farm-level cost-benefit analysis** (CBA) was carried out for four different adaptation strategies in the district most suitable for the strategy. Two indicators were used to give detailed insights into the economic potential of the different strategies: (1) the benefit-cost ratio (BCR) which represents the ratio between discounted benefits and costs of a strategy and is greater than 1 for economically beneficial strategies and (2) the net present value (NPV), which represents the discounted net benefit for a strategy applied on one acre (approximately 4 050 m²). Uncertainties based on future emissions and economic developments among other factors were included in the results whenever possible. Given that the assumptions differ slightly between adaptation strategies, the results should be compared with caution.

Table 5: CBA of four adaptation strategies with values for BCR and NPV.

Adaptation strategy	Benefit-cost ratio in 2050	Net present value per acre
Rainfed millet and cowpea intercropping with agroforestry and FMNR	1.71 (low emissions scenario) 1.99 (high emissions scenario)	842,000 CFA (low emissions scenario) 1,174,000 CFA (high emissions scenario)
Rainfed millet and cowpea intercropping with ISFM (Tassa technique)	4.79 (low emissions scenario) 5.29 (high emissions scenario)	4,999,000 CFA (low emissions scenario) 5,656,000 CFA (high emissions scenario)
Vegetables and crops production with off-season irrigation	1.05 (low emissions scenario) 1.02 (high emissions scenario)	1,479,000 CFA (low emissions scenario) 550,000 CFA (high emissions scenario)
Irrigated alfalfa fodder production	2.44 (low emissions scenario) 2.38 (high emissions scenario)	35,813,000 CFA (low emissions scenario) 34,350,000 CFA (high emissions scenario)

The indicated values for BCR and NPV display positive economic returns (after 5 years for agroforestry, 1–2 years for ISFM, 24–27 years for irrigated counter-season vegetables and crop production, 1–2 years for irrigated alfalfa production) for all strategies irrespective of the emissions scenario (high or low) or future economic development pathway (negative or positive). Thus, **all four analysed strategies were found to be economically beneficial under the current as well as the projected future climate** compared to business-as-usual agricultural practices. More specifically, the results indicate that for our case studies, **ISFM for millet and cowpea intercropping has the most positive return on a rather small-scale investment**, followed by irrigated alfalfa fodder production, agroforestry for millet and cowpea intercropping, and vegetables and crops production with off-season irrigation.

Policy Recommendations for an Uptake of Adaptation Strategies

The four adaptation strategies were specifically analysed in terms of their biophysical risk mitigation potential as well as soft-assessment indicators including **co-benefits, potential negative outcomes, barriers for implementation and the potential to reduce climate risks as well as existing inequalities**. These results lead to policy recommendations that can support the sustainable uptake of individual adaptation strategies by maximizing potential co-benefits and minimizing negative consequences.

STUDY RESULTS & POLICY RECOMMENDATIONS

Agroforestry and Farmer Managed Natural Regeneration (FMNR) practices are beneficial for local livelihoods, contributing to **climate resilience, income diversification, favourable soil properties**, as well as improvements in women's and children's **health and nutrition**. They can **increase yields of staple crops** like sorghum, up to +150% in the south of Niger (Maradi, Zinder), where soil fertility is already high. Furthermore, FMNR holds a **high upscaling potential** since Niger is part of the intervention zones of the "Great Green Wall" initiative. Although **FMNR can easily be applied** by smallholder farmers as almost no external inputs are required, **institutional support to clarify land tenure status, establish rural wood markets or strength women's organizations is needed to reap the greatest benefits**. Implementing agroforestry systems can therefore be recommended across Niger for their various socio-economic and environmental benefits.

Policy recommendations

- Investments and policies related to the "Great Green Wall" initiative could be leveraged to promote further FMNR practice.
- Women should be involved in the establishment of agroforestry systems, as their health, workload and economic situation are impacted positively by them. Strengthening the capacity of women's organizations can have a great impact on environmental protection and especially on promoting agroforestry and FMNR.
- Tree species and density should be carefully chosen and agroforestry should be planned according to the local context, including land use competition.
- Access to tree seedlings, equipment for planting and financial resources should be ensured for local smallholder farmers.
- Land tenure status needs to be overhauled, including the recognition of customary rules and authorities through more institutional support.
- Awareness raising about FMNR can be expanded for instance through information material for various target groups, e.g. farm radio programs, and the establishment of rural wood markets.

Integrated soil fertility management (ISFM) holds great potential for climate change adaptation as it **contributes to improved water use efficiency, prevents erosion, and restores degraded lands**. The study shows that the adoption of Tassa can entail for example **significant increases in sorghum yields** over all regions of Niger, especially in the southern regions (Maradi and Zinder), by on average 300–600% under both emissions scenarios. The highest yield increase is 1500% and is mainly found in Maradi. **Food production and therefore food security can be enhanced, in addition to employment rate** as more people are likely to be hired for the implementation of such farming practices. Despite these substantial benefits, as well as its **high-risk mitigation potential and its high cost-effectiveness**, the **uptake of ISFM can be difficult due to its strenuous manual labour requirements as well as its potential to fuel conflicts between farmers and herders**.

Policy recommendations

- Education and empowerment campaigns are key for the dissemination ISFM. Considering that ISFM is an approach indigenous to the region, its promotion should build on and leverage existing knowledge.
- Awareness raising of the advantages of ISFM, in particularly the long-term socio-economic and environmental benefits through e.g. trainings and information days can help to increase the adoption of the adaptation strategy.
- To fully benefit from the yield increases caused by ISFM, farmer cooperatives (“warrantage” systems) are a good way for farmers to organise themselves and to ensure stable produce prices.
- Policies that incentivise credit and loan schemes and subsidy programmes to produce organic inputs could address the lack of access to equipment and input.
- Policies towards sustainable land use intensification, rehabilitation of degraded soils and necessary mechanisms to implement and evaluate these can help to promote the uptake of ISFM.

Irrigation can mitigate climate risks in Niger and help diversify diets and ensure food security by **(1) supplying water needed during dry spells in the rainy season**, thereby mitigating the impact on staple crops and by **(2) enabling farmers to cultivate irrigated high-value crops** such as vegetables **during the dry season**, for both household consumption and (market) sales.
However, this requires high investments, maintenance costs, technical knowledge, as well as institutional support, and is likely to put additional pressure on water resources and land. Provided that irrigation is developed in a planned and equitable manner, **the adaptation strategy** has the potential to **strengthen the livelihoods of farming and non-farming households**. **Employment opportunities are created especially in the dry season**, as labour is required for the construction, operation and maintenance of irrigation facilities. In return, these opportunities can reduce rural exodus, and help households to pay for education and health-related expenses among others. **Irrigation facilities such as small dams and reservoirs can also act as protective infrastructures to control seasonal floods**.

Policy recommendations

- Low-cost irrigation options with low maintenance requirements can be promoted across Niger, where water resources (for instance surface water) are available.
- Awareness raising about water-saving irrigation management is crucial to ensure a responsible long-term use of natural resources.
- Irrigation may only be recommended as a long-term adaptation strategy due to its high investment and depending on local water availability as well as traditional farming practises.
- Ideally, water saving equipment such as drip irrigation, smart irrigation systems or other innovative irrigation systems are promoted and supported by extension services to encourage farmers to use sustainable and environmentally responsible techniques.
- Provision of support services is needed to ensure the ability of farmers to operate the technology by themselves and take care of their maintenance.
- The development of financing mechanisms, such as access to loans or credits, can support the accessibility for irrigation equipment.
- For upscaling irrigation, all user interests in water and energy should be carefully considered. Dispute settlement mechanisms could be implemented to address potential conflicts between upstream and downstream users.

Improved fodder and feed management for livestock, with the options of improved varieties for sorghum production, irrigated alfalfa production and mowing, is a promising adaptation strategy which presents a **high-risk mitigation potential and various positive outcomes**. The use of the improved sorghum variety Fadda would entail **higher crop yields**, up to +250% in the north of Niger under both emissions scenarios. Irrigated alfalfa production is a very cost-beneficial strategy that becomes profitable already from the second year on, as well as providing an inexpensive **source of protein** and contributing to **soil fertility** through nitrogen fixation. Mowing, combined with storage, offers an opportunity to increase fodder availability during the dry season. Moreover, improved fodder and feed management does not only help to strengthen resilience to climate change and livelihoods of farmers, but also comes with **employment opportunities for women,** who tend to be more involved into fodder production and management than men. Nonetheless, **costs related to the irrigation, packaging and transportation of fodder crops can hinder the uptake of the adaptation strategy**. **Proper application** and **careful planning as well as institutional support** are required for successful implementation.

Policy recommendations

- The choice of appropriate varieties and crop rotation as well as the number of cuttings (with regard to the adaptation strategy mowing) depends on local conditions and is important in order to ensure a sustainable and successful fodder crop production.
- Providing innovative and low-cost equipment, with low maintenance for fodder storage and production, to municipalities and farmer cooperatives can improve the problematic packaging and transportation of fodder crops.
- Pilot plots of sufficient coverage conducted for instance by local authorities can foster acceptance of farmers for improved varieties or new management techniques such as irrigated crop production.
- Women empowerment through awareness raising across gender can help to sensitize about the participation of women in decision making, which in turn presents an important opportunity to improve the sustainability of fodder management.
- It is also important to highlight the value of local landraces as they are a pillar for safeguarding local traditions, agronomic practices, and accompanying knowledge. Safeguarding of seeds and practices could be institutionalized by in-situ conservation projects, local seed banks, corporations with national or international gene banks and diversity fairs.
- A better communication and interaction of seed sector stakeholders can help to improve seed and knowledge dissemination on a local, regional, and national level.

All four adaptation strategies have a **high potential to improve the livelihoods of smallholder farmers under current and projected future climate conditions** in Niger. By increasing the resilience of rural communities, they can also help to fight instability, conflict and terrorism. Particularly, ISFM appears the most promising adaptation strategy, resulting in very positive effects for societies and environment, including substantial yield increases in the southern parts of the country. Improved fodder and feed management for livestock should be considered to further support the valuable livestock sector in Niger, keeping in mind that it can lead to competitive demands for the use of land and water resources. Agroforestry can also be recommended for smallholder farmers for its low-barrier implementation and its high upscaling potential. Lastly, irrigation has a high potential to improve livelihoods especially in northern Niger, but is also complex, costly and support-intensive adaptation strategy that needs to always ensure a sustainable use of already scarce water resources.

The Study Approach

To provide localised information on current and future climate risks as well as recommendations on suitable adaptation strategies for the agricultural sector, an impact-action-uncertainty chain was followed (Figure 6). As a first step, the current and future changing climate conditions as well as hydrological changes were analysed. Secondly, the resulting future impacts of climate change on crop production and livestock fodder management were modelled. Then, the results were fed into an action dimension to assess different adaptation strategies with regard to their risk reduction potential, cost-effectiveness, and other socio-economic evaluation criteria, such as potential maladaptive outcomes and development co-benefits. Finally, the uncertainty attached to the results was critically discussed and recommendations targeting decision-makers were given.

Figure 6: The impact-action-uncertainty chain of the climate risk analysis

The analysis utilised data from global climate models[5], different process-based models and a farm level cost-benefit analysis in collaboration with the Humboldt Forum for Food and Agriculture (HFFA) Research GmbH. Information from expert interviews and literature complemented the findings.

Figure 7: Stakeholder engagement followed throughout the study process

Relevant stakeholders from Niger's local and national governmental institutions, civil society, academia, the private sector, practitioners and development partners were engaged throughout the study process. In two workshops (a kick-off workshop and a validation workshop in Niamey) and a household survey conducted by the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), key stakeholders at the regional and national level contributed with conceptual inputs, technical expertise as well as local insights which shaped and validated the study design and results (Figure 7).

[5] The global climate models have been downscaled to 55 km × 55 km for a higher spatial resolution and bias-corrected with observed climate data in Niger.

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For more information and further study results, please visit www.agrica.de. Any questions can be addressed to Christoph Gornott (gornott@pik-potsdam.de) or Nele Gloy (nele.gloy@pik-potsdam.de).

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