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Working Paper 200

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Niger - Land, climate, energy, agriculture and development

A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security

ISSN 1864-6638 Bonn, January 2021

PARI

ZEF Working Paper Series, ISSN 1864-6638
Center for Development Research, University of Bonn
Editors: Christian Borgemeister, Joachim von Braun, Manfred Denich, Till Stellmacher and Eva Youkhana

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Niger – Land, climate, energy, agriculture and development

A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security

Rabani Adamou, Boubacar Ibrahim, Abdou Latif Bonkaney, Abdoul Aziz Seyni, Mamoudou Idrissa.

Abstract

The Sahel is one of the most vulnerable regions to climate change in the world. Located in the central part, Niger is facing many complex and interconnected challenges which strongly hinder the achievement of the key sustainable development goals (SDGs). The high population growth rate (3.8% per year), weak infrastructure capacity, shortage of essential resources (including water, energy, food) coupled with the adverse impacts of variability and climate change threaten the population and reduce the country's economic growth efforts. With more than 77% of landmass area receiving less than 150 mm of precipitation yearly, and about 80% of the population depending on rainfed agriculture, water scarcity and dryness constitute serious constraints for the agriculture and livestock sectors. In addition, the unequal distribution of agricultural land and livestock worsens the poverty incidence among households, which is characterized by a GINI coefficient of 0.46 and 0.68 for land and livestock respectively. Access to drinking water remains very poor with high disparities between urban (64%) and rural areas (48%). Water sanitation amounting to only 2% in rural and 38% in urban areas, respectively, also remains a great issue. Elsewhere, several drought and flood episodes have negatively impacted agricultural productivity, causing recurrent famines and livestock losses. The situation is exacerbated by the impacts of land degradation, the advancement of desertification and also by climate change and variability threats, which are projected to increase in magnitude, intensity, duration and number over the country under all climate change scenarios. The country's high potential of renewable and non-renewable groundwater resources can be used for residential, agricultural and industrial purposes to overcome negative climate change impacts. Regarding the energy sector, the country is currently in an undesirable state, with very limited modern energy services (2% of the population), low electricity access (average rate of 18%, with around 10% in rural areas) and high dependency on traditional biomass (77% of primary energy consumption). However, the country is fortunate to have a tremendous amount of energy resources, including fossil fuels (oil, coal and gas) and renewables (solar, hydropower, and wind), that can be used to overcome many of the observed challenges and thereby contribute significantly in the achievement of various SDGs, including those related to affordable and clean energy, no poverty, and zero hunger. Indeed, in addition to resources for electricity production, Niger has a large surface water potential in the Niger River, with an average discharge of 6000 m^3/s and length of about 550 km, which can be mobilized for irrigation to enable food security. Therefore, socioeconomic development requires an integrated approach that brings all the key sectors into a common framework in order to solve the aforementioned challenges. Hence, in key development areas, several development policies and strategies from government, NGOs, and technical and financial partners have been initiated and implemented for inequality and poverty reduction to improve livelihoods in the country.

Keywords: Sahel, energy, climate change, land degradation, innovation, policy

JEL codes: O30, Q24, Q25, Q42, Q54, Q55, Q58

Acknowledgments

The study was funded by the “Program of Accompanying Research for Agricultural Innovation” (PARI), which is funded by the German Federal Ministry of Economic Cooperation and Development (BMZ).

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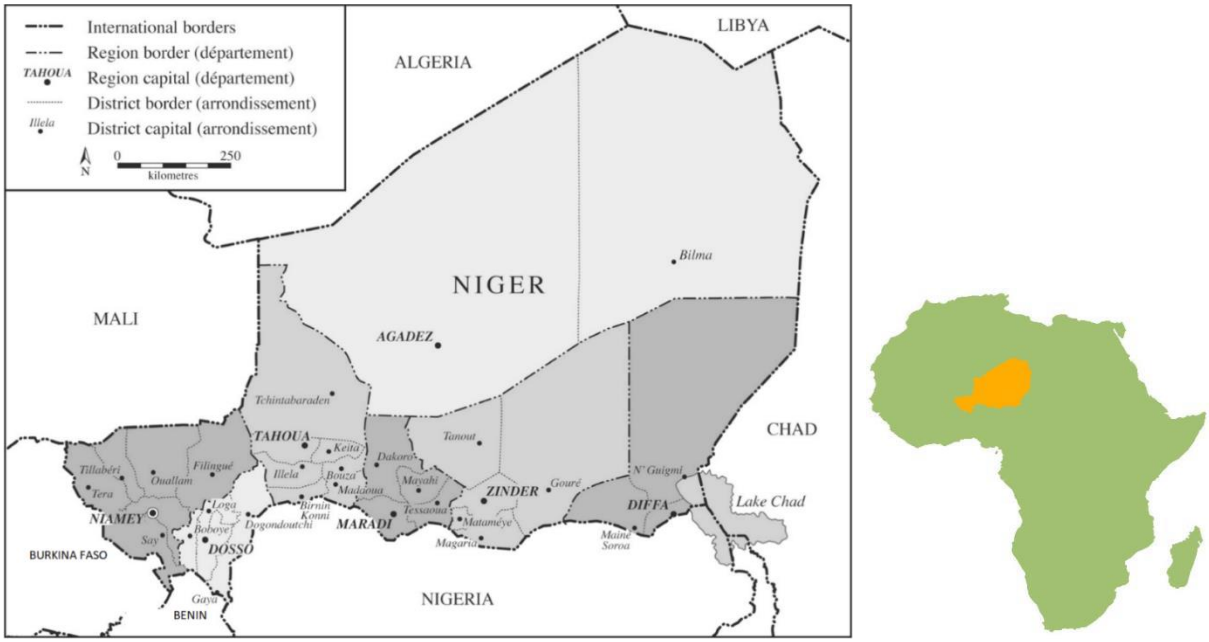
1 Introduction

Niger is a landlocked country situated in West Africa, with a total landmass of 1,267,000 km^2 (Figure 1). The country is divided into eight main administrative regions: Agadez, Diffa, Zinder, Maradi, Tahoua, Dosso, Tillabey and Niamey. It is very arid, and three fourths of the country are desert (Sahara) and mountains, with 77% of the country receiving less than 150 mm/year of precipitation. Temperatures are high throughout the year and range from 20-48°C in the dry season and 28-33°C in the wet season during the period 1976-2012 (Ndiaye et al., 2016; Mahamadou et al., 2018; Bonkaney et al., 2019). Niger is a Sahel country facing many complex and interconnected challenges (Bull, 2013) which strongly hinder the achievement of the key sustainable development goals (SDGs). In order to cope with the different challenges, many studies have been undertaken on the country.

The aim of this document is to describe the main characteristics of the country (land, climate, energy, agriculture and development) and to present the main finding of some studies and experiences.

Figure 1: Administrative subdivision of Niger

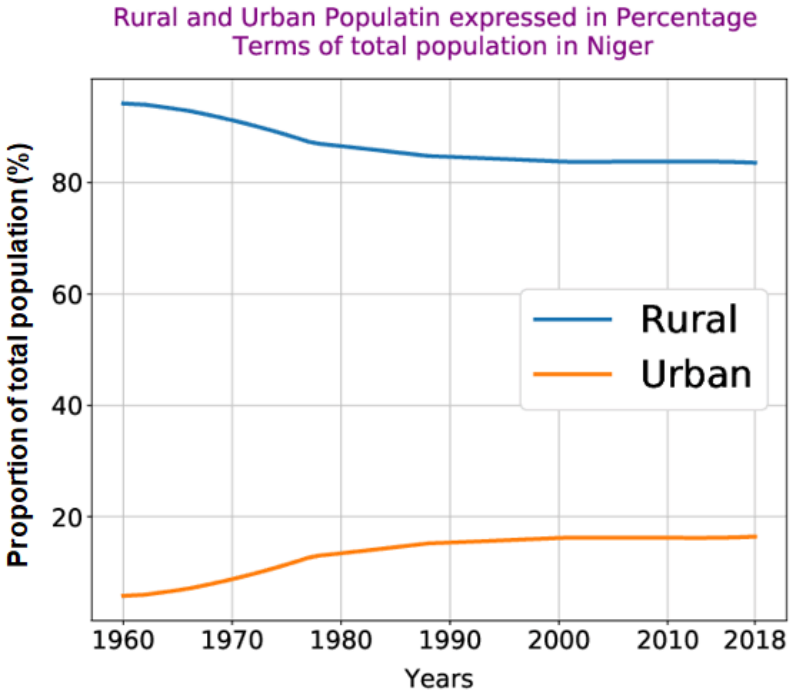


Source: Rossi (2015).

1.1 Key features of the economy and demographics, employment situation, recent poverty trends, status of the agriculture sector, access to water and energy, and food security

Niger presents a yearly population growth rate of 3.9%, it is among the fastest growing population rates in the world (World Bank, 2017). According to the World Bank (2017), the total population is estimated to be about 23.31 million inhabitants (in 2019), which is predicted to be 30--35 million by 2030 and could reach 67-78 million by 2050. Currently, more than 80% of this population is living in rural areas (Figure 2).

Figure 2: Evolution of the percentage of rural and urban population in Niger



Source: derived from World Bank Indicators API database.

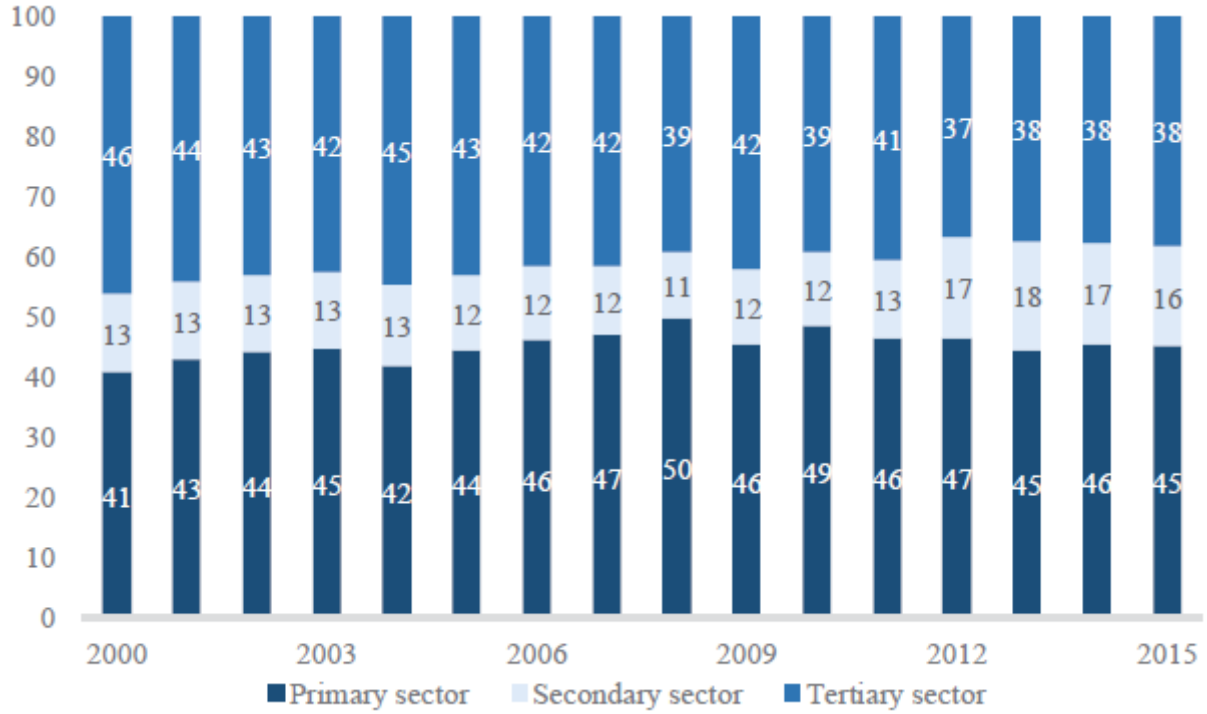
The rapid population growth combined with uncontrolled urbanization could seriously slow down the country's development efforts if a way to curb these trends is not found. The World Bank (2017) stated that the country's economy is driven by the informal sector, which contributes to about 61% of the national Gross Domestic Product (GDP).

The economy is dominated by the primary sector which contributes to about 45% of national GDP while secondary and tertiary sectors contribute respectively to about 16 and 38% of the national GDP (Figure 3). The main activities in the secondary sector includes manufacturing (6% of GDP), construction and public work (3%) and electricity, gas and water production (1 % of GDP) are small and relatively underdeveloped.

The relatively high contribution of the tertiary sector is not the result of the development of a more modern section of the economy but the reflection of the importance of import and export trade and the cost of transportation. Trading, transport and the public sector represent the most important activities in the tertiary sector with a share of 12% of GDP (World Bank, 2017).

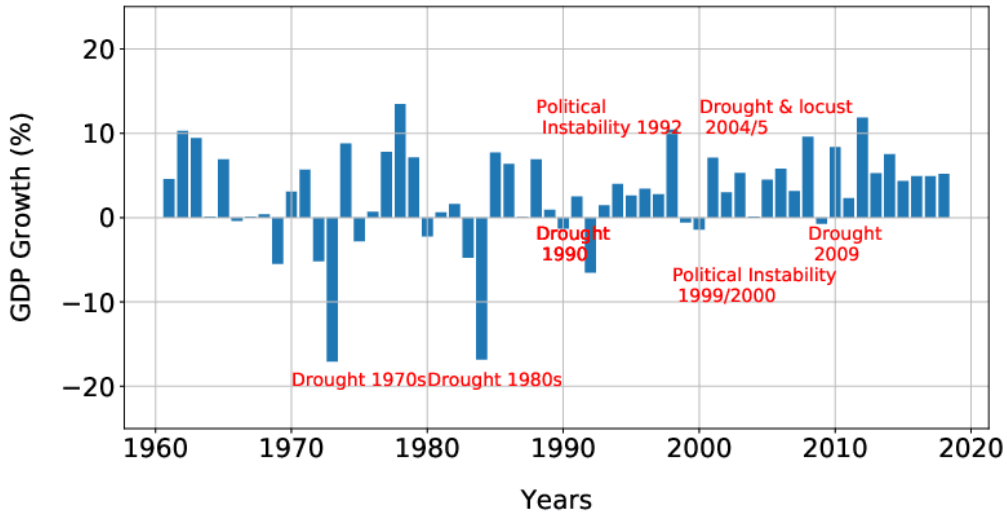
Altogether, it is worth noting that the GDP growth in Niger has been influenced by drought and political instabilities since the independence period. Economic growth increased from 4.9% to 6.5% between 2017 and 2018 (Figure 4). These rates surpassed the estimated potential growth rate of 4.8% projected by the World Bank. This increase is primarily due to the sound performance of the agricultural sector and sustained activity in the construction and services sectors.

Figure 3: Relative share of sectors in the GDP of Niger



Source: World Bank (2017).

Figure 4: GDP growth from 1961 to 2018

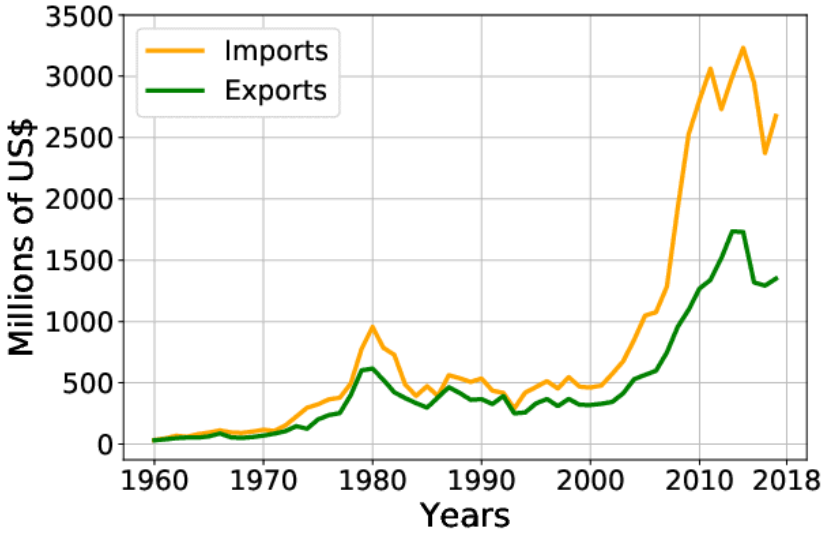


Source: derived from World Bank Indicators API database.

At the same time, the secondary sector is marginal and has a downward trend, and the main market of exported raw materials (uranium and oil) is facing unprecedented fluctuations (Ministère du plan, 2017).

For instance, in 2017, Niger exported 1.35B USD and imported 2.68B USD, resulting in a negative trade balance of 1.33B USD (Figure 5). Hence, during the last five years, the exports of Niger have decreased at an annualized rate of -16.2%, from 1.73B USD in 2012 to 1.35B USD in 2017.

Figure 5: Evolution of imports and exports from 1960 to 2017 in Niger

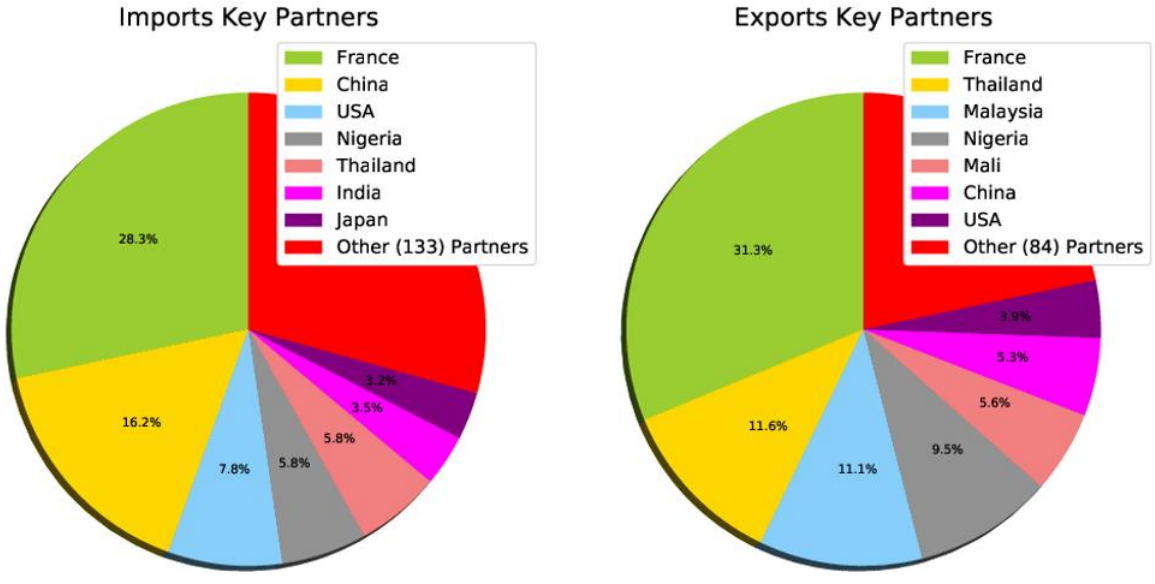


Source: derived from World Bank Indicators API database.

In 2017, the top exports of Niger were uranium (329M USD), refined oil (96.2M USD), other oil seeds (93.3M USD), gold (28.8M USD), and petrol gas (20.2M USD). The top export destinations are France (269M USD), Mali (96.6M USD), China (94.1M USD), South Korea (64.5M USD), and Switzerland (28.6M USD) while the top import origins are France (167M USD), India (113M USD), Ghana (104M USD), China (97.6M USD), and Belgium-Luxembourg (64.7M USD) (OEC, 2018). Figure 6 shows the key trade partners of Niger and their relative shares.

Consequently, the external current account deficit worsened, from 15.7% of GDP in 2017 to 18.2% in 2018, owing to significant infrastructure projects under way financed primarily by development partners, and to a lesser degree by foreign direct investment (FDI). Indeed, most of the equipment and building materials are imported due to the weak industrial sector development in the country.

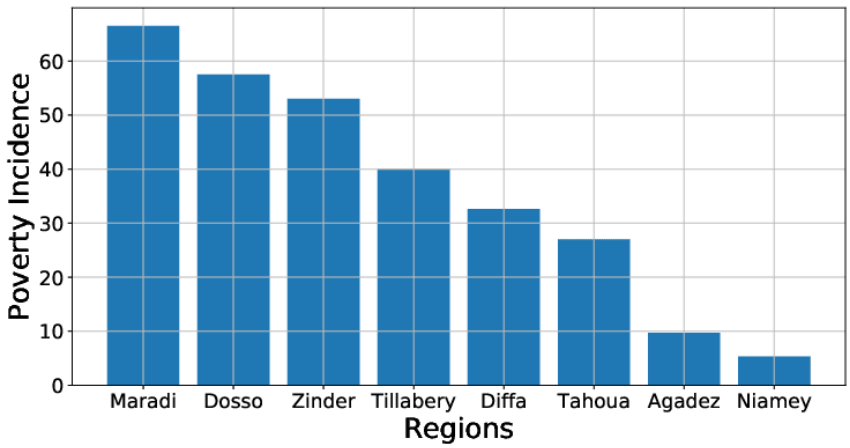
Figure 6: Key partners of imports and exports of Niger



Source: derived from World Bank Indicators API database.

However, Niger has made notable progress in reducing inequalities in recent years. For instance, according to the World Bank, the GINI index, a measurement of the extent to which the distribution of income among individuals or households within an economy deviates from a perfectly equal distribution, has significantly reduced, from 44.4% in 2005 to 34.3% in 2014. In addition, the poverty rate also decreased significantly from 81.4% (1994) to 41.5% (2019), though it still remains very high. The poverty rate differs from one region to the other. Indeed, the Maradi and Dosso regions are where the poverty incidence is very high (>50%) while Niamey and Agadez represent the regions with the lowest poverty incidence (<10%). Figure 7 shows the poverty incidence of the various regions of the country.

Figure 7: Poverty incidence for different regions in Niger in 2014



Source: data from INS (2015).

The overall unemployment rate has risen from 13% in 2011 to 17% in 2014 (ENISED, 2016). The incidence of unemployment is higher among women than men, with levels of 28.9% and 4.4% respectively in 2014. It is also more marked among young people, with an unemployment rate of 23.7% for the 15-29 age group. Underemployment affects 68.4% of the active population (ECVMA, 2014). It is mainly prevalent in rural areas, affecting 70.4% of the working population (MP, 2017a).

Agriculture is the principal source of livelihood for over 80% of the country's population and is the most important contributor in the economy with about 41% of the national GDP. This rain-fed agriculture remains little mechanized and very vulnerable to climate shocks (CNEDD, 2006; World Bank, 2018). Only 8% of the territory receives more than 400 millimeters of rain per year, which allows for satisfactory agriculture. In 2016, total agricultural land represented about 36.06% of the total land area while arable land (field crops, market gardening, permanent crops, fodder crops, artificial meadows ...) was only 13.26% (World Bank, 2018). Irrigated agriculture represents about 0.21% of the total agricultural land according to 2011 estimates (MA, 2018).

However, in the last decades, frequent droughts, low and variable rainfall and extreme events (floods and heatwaves) often reduced crop and livestock yields consequently leading to food shortages (RISE II-USAID, 2018). One-third of Nigerien households face moderate and severe food insecurity, experience seasonal food deficits and have poor dietary diversity (CILSS, 2018). According to the United Nations estimates, more than 50% of children under 5 years of age are chronically undernourished and acute malnutrition rates regularly exceed the WHO's threshold of serious concern of 10% (RISE II-USAID, 2018).

In the energy sector, Niger's energy balance shows an overwhelming predominance of biomass (essentially wood fuel), followed by oil, gas and electricity. With 93% of the balance of primary energy consumption in 2012, this value reduced to 77.6% in 2014 as a result of oil production in the country

which started in 2012. Other energy sources (oil, gas, electricity, etc.) represent only 22.4% of the total balance sheet, with an insignificant renewable contribution (less than 1%).

The household sector is the main end user of energy consumption and represents 90% of the total energy consumption, followed by transport with 8% and industry which accounts for 2%. National electricity production is mainly from thermal sources (57.62% for oil and 41.62% for coal) while the renewable sources contribute only 0.75%.

The country has significant untapped renewable energy potential (solar, wind and hydro). The monthly solar average values observed vary from 5 to 7 kWh/m^2/day, for an insolation duration of 8 to 10 hours/day (Tanimoune, 2018). The average wind speed in the north is also relatively important (5 m/s). The Niger River, with an average flow of 6,000 m^3/s, is an important hydropower resource, crossing the country on more than 550 km.

As for the water sector, adverse climatic conditions, rapid population growth (3.9%) and significant urbanization (4.2%) impose high pressure on water resources in Niger. Also, the lack of adequate infrastructure makes it difficult to access clean water. For instance, the percentage of population having access to clean water is 64% and 48% in urban and rural areas respectively (PMI, 2017). Moreover, the significant lack of water sanitation in both urban and rural areas (62% and 98%, respectively), enables the transmission of some diseases (cholera, diarrhea, dysentery, hepatitis A, typhoid and polio) and is also responsible for mosquito proliferation and related endemic malaria, which accounts for 28% of all illness and 50% of all recorded deaths in the country (PMI, 2017).

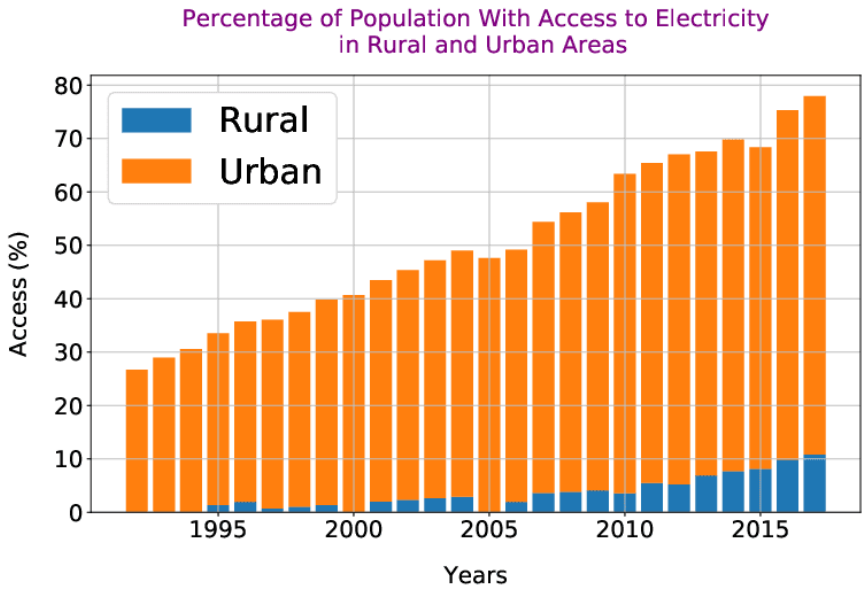
1.2 Problem definition showing how land degradation, energy use and climate change affect livelihoods and sustainable development goals in Niger

Deforestation, land degradation as well as climate variability and change represent the greatest adversities affecting livelihoods in the Sahel (Danida, 2008; Nkonya et al., 2016). In Niger, land degradation is caused by multiple forces, including extreme and erratic weather conditions, particularly drought and heat, and human activities (deforestation, overgrazing, continuous cropping and pollution) coupled with a lack of coherent environmental policies (Thiombiano and Tourino-Soto, 2007). Indeed, the desert is advancing by 200,000 ha each year and government reforestation programs to reclaim 215,000 ha each year face recurrent droughts and increasing demand for wood and farmland (CS-GDT, 2014). Since 1990, forest land has decreased by one third and covers only 1% of the country's area. The unprecedented population growth and urbanization trends contributed to the conversion of agriculture areas into barren land which drastically affects food production and the provision of other ecosystem goods and services (RARSUS, 2017-2019). Over the past 30 years, the country has experienced multiple food crises, largely induced by agricultural risks (such as droughts, floods, and locust infestations), which adversely affect household incomes and impose high welfare costs in terms of food availability, food affordability, and malnutrition (Prolinova, 2008). Under these conditions, addressing the SDGs, including 1 (no poverty), 2 (zero hunger), 3 (health and nutrition), 8 (sustainable economic growth) and 11 (sustainable cities and communities), remains a great challenge in the country**.**

Energy products and services play an important role in livelihood support. Unfortunately, the country has a very low access rate to electricity, which is around 18% at the national level in 2018 (https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=NE). However, disparities do exist between rural and urban areas. Indeed, the electrification rate in urban areas is around 67% while in rural areas it is only 10.8% (World Bank, 2019). Figure 8 shows the high disparity in electricity access between the urban and rural areas. Also, Niger imports about 70% of electricity from Nigeria (Figure 9). However, the huge potential of nuclear energy resources (uranium) and renewable energy,

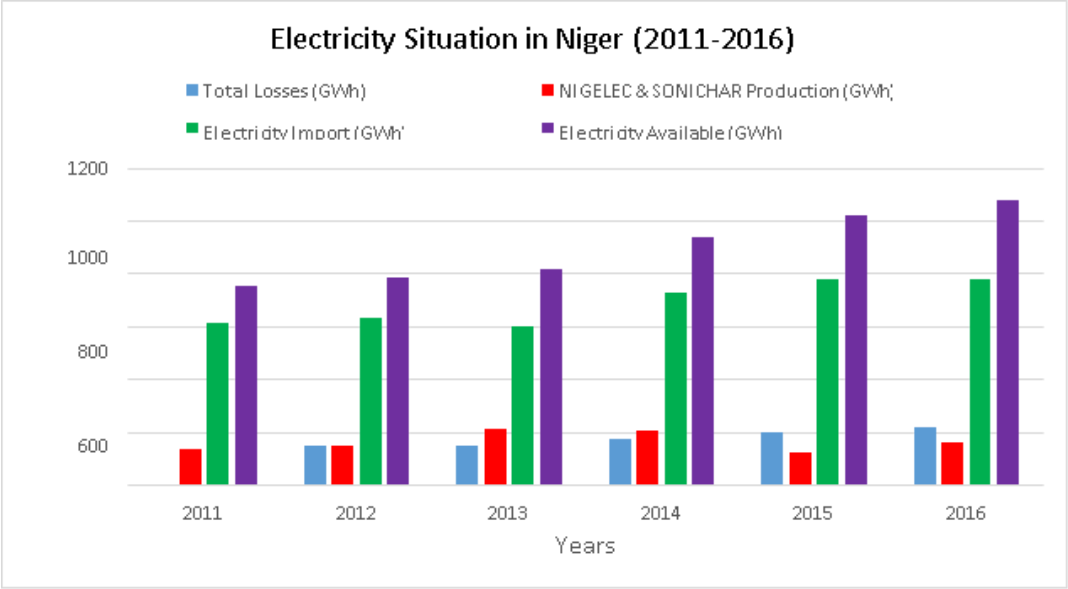
including solar, wind and hydropower, can be a great energy security opportunity for the country and the whole region (SDG 7: sustainable energy supply).

Figure 8: Access to electricity in rural and urban areas



Source: Bonkaney (2019).

Figure 9: Electricity situation in Niger



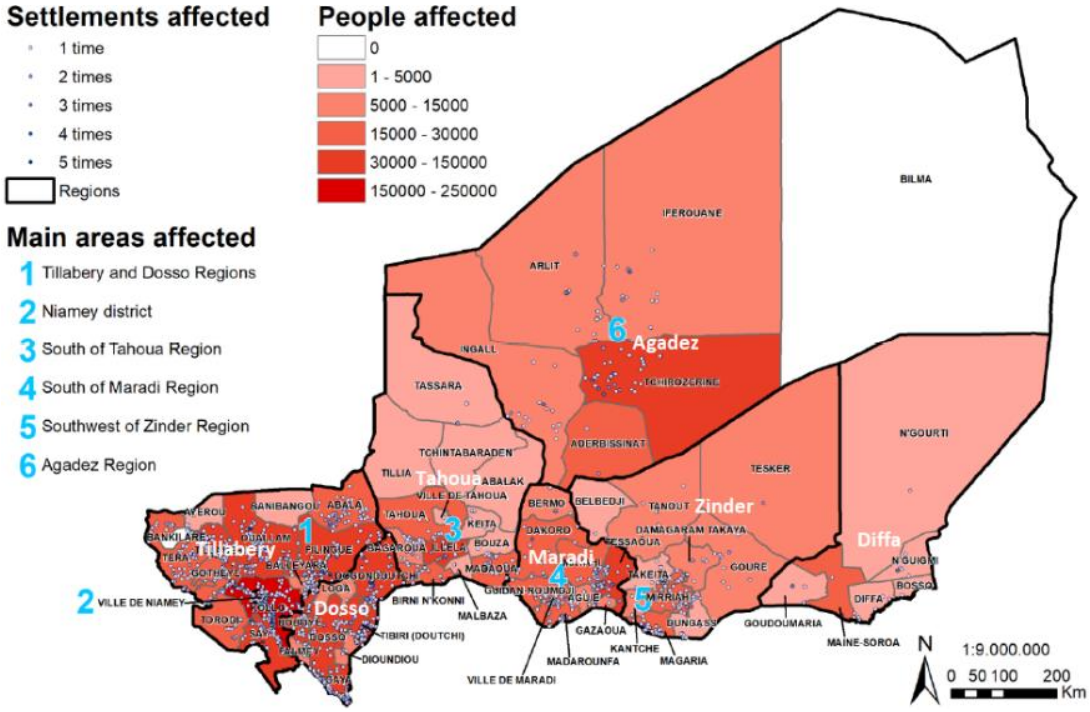
Source: Bonkaney (2019).

Climate change is a cross-cutting issue, affecting both land and energy, and highly influencing livelihoods. In the Sahel, the number of hot days during the 2000s is 2.5 to 3 times as high compared to the 1980s. In the same period, heatwave (consecutive hot days) frequency has increased and its duration reached 5 to 6 days in Niamey (Ndiaye et al., 2017). Climate change impacts extend beyond an increase in temperature, impacting ecosystems and communities. Electricity consumption has increased and shortfalls of the grid and water distribution systems has become more frequent. It has also been noted that there are more deaths of children and elderly persons as a result of the increase of heatwaves in frequency and number coupled with unmet power demand. Indeed, according to

national health authorities, around 500 deaths (elders and children) have been recorded at the National Hospital of Niamey in April 2010, when maximum temperatures rose to 45-46 °C.

Furthermore, several flood episodes have been noted in the country, along with their devastating effects. Indeed, during the period 1998-2015, about 4000 settlements and 1.7 million people were affected by floods in the country (Fiorillo et al., 2018). The observed trend has increased since 2010. The Tillabery and Dosso regions were the most exposed to floods and account for 61.1% and 54.4% of the total affected localities and population respectively (Figure 10). Therefore, climate change contributes to land degradation, affects agricultural yield, and disturbs electricity production and distribution.

Figure 10: Settlements and people affected per department in the 1998-2015 study period



Source: Fiorillo et al. (2018).

Overall, Niger is facing many development challenges in the key areas of the sustainable development goals like no poverty (SDG1), zero hunger (SDG2), clean water and sanitation (SDG6), affordable and clean energy (SDG7), reduced inequalities (SDG10), and, under variability and a changing climate context, SDG 13 (climate action). Moreover, the rapid population growth in the country has contributed to increased demand for goods and services, mainly food and energy, which in turn has increased pressures on natural resources and ecosystems leading to their over-exploitation and degradation. The purpose of this work is to establish the current situation and to investigate, in the context of climate change, an integrated approach that captures all these key development issues and their interlinkages. Methodology, criteria for literature search

The methodology applied in this report has three components:

- Preliminary literature review based on scientific products (research papers, scientific articles and reports, theses, communications) and national, regional and international strategy documents and guidelines (technical reports and policies), conducted by a multidisciplinary expert team;
- Interviews with national and regional services and NGOs working in the areas of climate change, environment, agriculture, water resources and energy to improve and update the information collected from the literature review;

- The output of a finalization meeting between the multidisciplinary experts' staff and identified key stakeholders in related areas to complete the information collection process, to improve the document and to initiate the adoption of the resulting document by stakeholders.

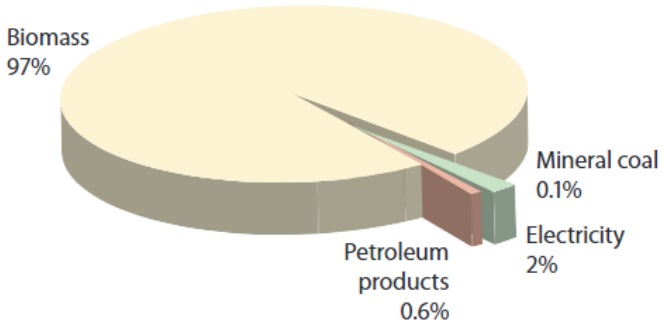
2 Situation and trends in rural energy and land use change

2.1 Energy use and associated challenges and opportunities

The development challenge of Niger in particular and the Sahel region in general is partly linked to a high level of energy insecurity exacerbated by rapid population growth and an unprecedented climate variability and change. The energy situation in Niger is typical of other least-developed countries and is characterized by low access to modern energy systems and high dependence on unsustainable traditional energy use.

Traditional biomass is used by 97% of households in Niger (Figure 11). Biomass energy sources are essentially wood (firewood and charcoal), crop residues (straw, rice husk, cotton stalks, millet, sorghum and maize, etc.) and livestock manures. Wood consumption is about 0.6 kg/day/person for large urban centers, 0.7 kg/day/person for average cities and 0.8 kg/day/person in rural areas (Bello, 2012). This situation has created large-scale deforestation and has contributed to increasing desertification. In the 1970s, wooded areas were estimated at 16,096,400 ha composed of forest and marginal or non-forested forest land located in the southern part of the country. After 30 years, the estimated surface area of natural forest formations was 5,741,917 ha (Hamadou and Gambo, 1999). Overall, the forest areas have decreased from 1,945,000 ha in 1990 to 1,129,500 ha in 2016 (Figure 13).

Figure 11: Distribution of households' energy consumption by type of energy



Source: Gado (2015).

Indeed, the exploitation of wood for energy production in Niger devastates nearly 150,000 ha each year (Bello, 2012; Ali, 2010). For these reasons, the need for wood fuel is no longer satisfied by wood removal in the areas surrounding cities. For cities like Niamey, Dosso, Maradi, Zinder, and Diffa, wood fuel comes from remote areas in neighboring countries like Burkina Faso, Benin and Nigeria (Bello, 2012). Therefore, there is an urgent need to find a sustainable solution which could significantly help to reduce excessive pressure on plant cover.

The use of other biomass sources is low compared to wood. Crop residues are more used to feed animals or to build houses. As for animal manure, it is mostly used for land fertilization, so very few initiatives for biogas production were implemented. All applied strategies to date have not resulted in noticeable substitution of wood fuel in cooking. Indeed, the substitution of wood by oil and gas (LPG), which was around 3% in the 1990s, reached only 9% in the 2010s despite the production of oil and gas in the country since 2012 (ECCREE, 2014).

The use of charcoal as a source of energy is also very marginal in Niger compared to the neighboring countries of Mali and Burkina Faso. With the exception for a few localities in the extreme south of Dosso (Gaya district), no locality in Niger has professional charcoal producers. Charcoal is mainly imported from Burkina Faso and Benin. It is used by some professionals in the informal sector

(restaurants, jewelers, blacksmiths, launderers, etc.). However, charcoal consumption, with a growth rate of 2.8% per year, has gradually increased in the past years. The importation flow has doubled from 130,000 tons in the 2000s to 277,000 tons in the 2010s (Fonabes, 2016).

Large deposits of mineral coal exist in the north of the country at Anou Araren (Agadez region), where the reserves are estimated at about 15 million tons with a calorific value of 3,650 kcal/kg, and at Salkadamna (Tahoua region), where the reserves are estimated at about 70 million tons with a calorific value of 6,000 kcal/kg. Other signs of coal deposits were also discovered in Aïr (near Solomi). These resources remain under exploited as only 37MW of electricity has generated from coal in the north since 1982, mostly to respond to the needs of uranium mining companies in the region. Elsewhere, an unsuccessful carbonization initiative of 150,000 tons per year of improved coal to replace wood fuel in cooking was initiated in 2004 (IEA, 2016).

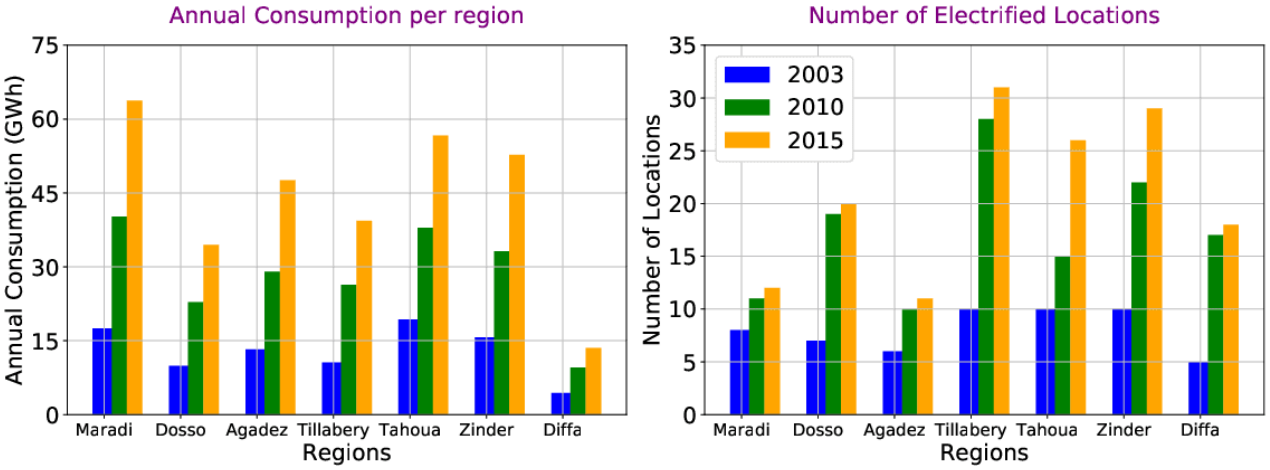
Niger also has a substantial oil potential in two major basins that cover 90% of the country's territory: the western basin (Lullemeden basin at the center of the country) and the eastern basin (Lake Chad basin). Most of the proven potential, estimated at 700 million barrels of oil and 14 billion cubic meters of gas, is in the eastern basin. The country has become an oil producer; it has exploited and refined 20,000 barrels/day since 2011. Significant oil reserves were found in 2017 in the Lullemeden basin, and this will permit production at 5 times the current capacity. The short-term objective fixed by the national authorities is to boost the oil sector to become the engine of the national economy by 2025. Thus, if investments in crude oil exports by pipeline are operational by 2021-2022, the oil sector could represent 24% of the national GDP by 2025 (compared to 4% in 2017), 45% of the fiscal revenues (compared to 19% in 2017), 68% of exports (compared to 16% in 2016), and 8 to 12% of formal wage employment (compared to 5 to 8% in 2012). The country planned the utilization of the produced oil to generate electricity through a thermal plant of 120 MW built close to Niamey at Goroubanda in 2017. Due to technical challenges during the project's implementation, a hybrid solution was chosen in the end which enhanced the installed 60 MW from the thermal source with additional photovoltaic solar power to reach the expected goal.

The country invests around 10% of its budget in the purchase of conventional energy (electricity, oil and gas). With a total installed capacity of less than 330 MW, the demand of electricity is much higher than the supply (Sessa, 2017; Tanimoune, 2018). During hot periods, the national power company (NIGELEC) is not able to meet the demand of about 150 MW in Niamey, while the total available supply is 120 MW, resulting in recurrent blackouts in the city these past years (Bonkaney et al., 2019). Electricity consumption in Niger is one of the lowest in the world, 51.44 kWh per capita in 2014, which slightly increased to 54.17 kWh per capita in 2016. The population rate using oil fuel and clean energy is estimated at 3.7% nationwide, with high disparities between urban and rural areas (RNV-ODD, 2018). National electricity production was mainly generated from fossil resources (fuel and coal) but has involved renewable energy (solar) in recent years. The share of generated electricity from fossil and solar sources is respectively 84% and 14%. The electricity sector situation for the period 2011 to 2016 shows an increase in the total available electricity which is not due to a significant improvement in national production, but mostly to the intensification of importation. Elsewhere, the global electricity loss has also increased during the same period due to decrepit generation and transport systems confronted by more frequent climatic extreme events (heavy rain and wind, flood, hot days and heatwaves). The huge potential of gas and oil provides the opportunity to increase the country's energy security by improving electricity generation at a relatively low cost.

Nevertheless, the annual electricity consumption (AEC) as well as the total electrified areas have significantly increased since 2003 for all regions, with significant improvement occurring in the Tillabery, Zinder and Tahoua regions. Indeed, electrified locations increased from 10 to 31 for Tillabery, 10 to 29 for Zinder and 10 to 26 for Tahoua during the period 2003-2015 (Figure 12). On the other hand, the total AEC has increased from 10 to about 40 GWh for Tillabery, 16 to 53 GWh for Zinder and 20 to 57 GWh for Tahoua during the same period. These trends can also be observed for the remaining regions. For the same time, the poverty rate in these regions has significantly reduced while livelihoods

improved (PDES, 2017). The observed trends show the importance of electricity in the wellbeing of local populations.

Figure 12: Evolution of annual electricity consumption and the number of electrified locations for the different regions of Niger



Source: Bonkaney (2019).

The share of renewable energy resources in the total electricity consumption is about 0.01% (MEP, 2015). Indeed, in 2017, the total installed capacity of electricity from renewable energy was estimated to 20 MW, produced mainly from solar photovoltaic. To date, no electricity is generated from hydropower (IRENA, 2019). However, the country's enormous renewable energy potentials (solar, hydro, wind and biomass) could provide affordable energy sources, especially in remote areas (Bonkaney, 2015; 2017; Diallo, 2018). This would help to diversify energy supply and to contribute to sustainable energy access (IRENA, 2013). Therefore, the energy transition of the country could occur via the valorization of renewable energies.

To drastically enhance the national electricity access rate, efforts must be made in rural areas. A national agency for rural electrification (ANPER in French) was created in 2013 (http://www.anperniger.ne/images/documents/Loi-ANPER.pdf). It aims at designing, implementing and monitoring programs for the development of rural electrification based on pure renewable energy systems implementation and hybridization of existing conventional systems. The strategic choice of renewable energy is guided by the country's ongoing economic and social development plan, PDES 2017-2021 (MP, 2017a). Indeed, the government of Niger intends in this plan to take advantage of the country's enormous potential of renewable energy (solar energy) to increase access to electricity in rural areas from 0.1 to 30% by 2030. Hence, significant resources were mobilized in 2018 from the World Bank (NESAP Project), the EU/AFD (Agadez solar power plant), and the African Development Bank (PEPERN project) in order to substantially improve the rate of access to energy services and to reduce the disparity between rural and urban areas.

In terms of renewable energy promotion, generation of 327 MW is planned, which is projected to reach 62% of the nationwide installed capacities by 2030 and to increase the injection of renewables into the national grid from 0% in 2015 to 54% in 2030 (RNV-ODD, 2018). Furthermore, it is projected that the country will invest about 6B USD by 2030 to meet the goal of sustainable energy for all (INDC, 2015).

2.2 Review of dynamics of land degradation, land use and land cover change over the last 30 years

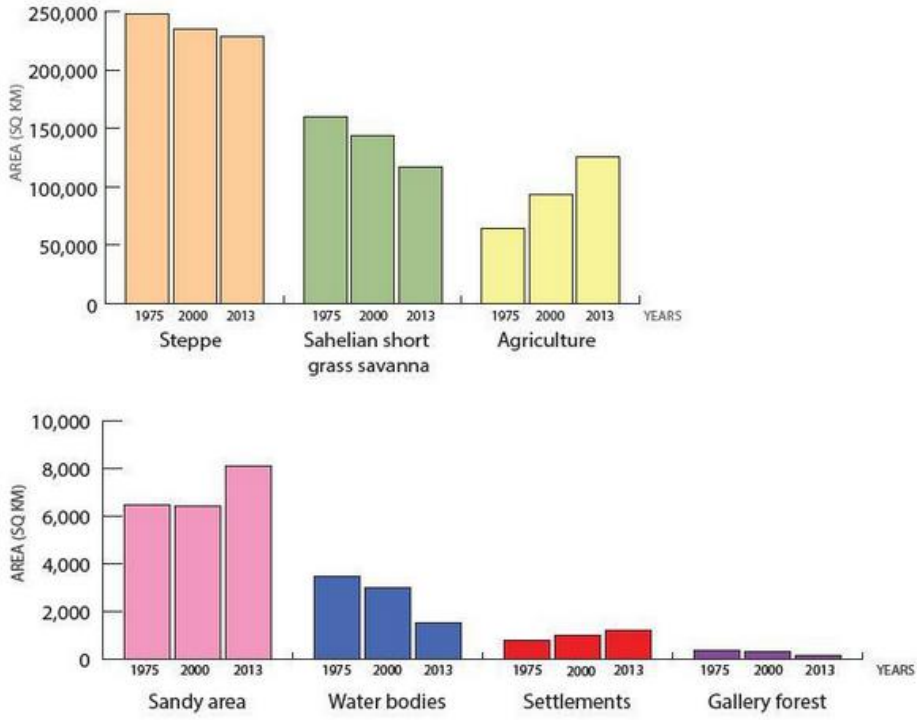
Land use and land cover changes are critical because they give rise to series of processes that lead to systematic effects on both local/regional and global climates. Rapid population growth and urbanization have exacerbated the pressure on land use for agricultural and settlement purposes. Hence, most vegetated areas are converted to croplands or settlements. In 1975, settlements represented 0.15% of the total land mass but this figure reached 0.23% in 2013, corresponding to a total increase of about 54% (Figure 13). The most dramatic change in Niger's landscape is due to agricultural expansion to meet the increasing food demand. For instance, over the period 1975-2013, cultivated area increased from 12.6 to 24.5% of the total agricultural land area, which represents a total increase of 94.2%. This expansion occurred mostly in productive sandy soils of the West (Tillaberi), where cropland is now continuously growing at the expense of pastoral lands. In addition, an increase of 50% in irrigated agriculture was also observed along all the Niger River. According to the ongoing government planning, including the Nigériens nourrissent Nigériens (3N) Initiative (3N, 2012), a supplementary 50,000 ha are needed to allow additional production of 500,000 to 600,000 tons of rice before 2023. In the east and central regions of the country (Zinder and Maradi), which were already heavily cultivated in 1975, the situation of land uses is now a wall-to-wall homogeneous agricultural landscape. Agriculture is still expanding eastward on the remaining short grass Sahelian savannas of the Manga zones (Diffa).

Erratic climatic conditions (drought and desertification) have increased negative anthropogenic impacts on land. Sandy areas and wetlands were respectively 1.26% and 1.27 USD in 1975. These land cover types, which showed a slight reduction in 2000 (1.24% for sandy land and 1.18% for wetlands), have increased in 2013 to reach 1.58% and 1.40%, for sandy land and wetlands respectively (Figure 13). The possible explanation could be that during the drought years of the 1970s, 1980s and 2010s, many of these dunes became active when vegetation cover was lost. In addition, wind erosion, overgrazing on low vegetation, and loss of woody cover from drought and deforestation often result in land degradation and enhance the process of desertification.

Elsewhere, a general decline is observed for steppe, Sahelian short grass (grass), water bodies, gallery forests as well as savanna. Across the whole country, between the different vegetation types, steppes remain the dominant land cover class and have remained more or less stable (about 45% of the mapped area). The more productive natural vegetation, however, suffered a sharp decline. The area of Sahelian short grass savanna (usually present on sandy soils) contracted by 26.7% from 1975 to 2013. Gallery forests, representing the densest and most biologically diverse vegetation in Niger, have also significantly declined. Their total area has always been low (about 470 km^2 in 1975) but significantly decreased (66%) in the 38-year period. Indeed, these forests mainly occupy narrow valleys, which are now heavily cultivated.

About 100,000 to 120,000 ha of forest area disappears each year (CNEDD/UNDP, 2006). However, the rate of decrease of the forest area between 1990 and 2000 is higher than that of 2000-2016. This might be attributed to government policies to combat deforestation while promoting reforestation.

Figure 13: Evolution of the different land cover types in Niger



Source: CILSS (2016).

In response to high deforestation, the Niger government and its development partners have invested more than 200 billion FCFA (304,878,048€) since the early 1980s to promote Sustainable Land Management (SLM) and other activities to reduce poverty and vulnerability of local communities (World Bank, 2009). Overall, more than 50 programs have promoted SLM in Niger. Despite large investments in SLM programs, their impacts on land management, agricultural production, poverty, and other outcomes are not well known due to the lack of appropriate evaluation systems. A few studies have documented impacts of particular projects and land management practices in selected locations. However, although these studies provide valuable insights, they are limited in scope and by the methods used. A common problem is the absence of suitable counterfactual observations or inadequate definitions of the counterfactual used to compare outcomes for communities and households participating in programs or using particular land management practices with communities and households that do not encounter themselves in a treatment condition (Warren et al., 2011; FAO, 2018).

2.3 Causes and impacts of land degradation on dimensions of sustainable development such as poverty reduction, food security, access to energy, and gender empowerment

Land is a vital asset for producing food and other ecosystems goods and services (Nkonya, 2016; GIZ, 2012; Adams, 2000). Productive land is the most important natural capital asset that human beings possess. Therefore, its degradation will negatively affect the livelihoods of people, especially those living in the developing world (Nkonya, 2016; Adams, 2000). Land degradation is a global problem that particularly impacts poor rural inhabitants of low- and middle-income countries, because land provides among others key resources such as food, energy and shelter. Therefore, land degradation constrains the supply of these ecosystems services and negatively impacts household income and consumption, thereby worsening poverty and widening inequalities.

Land degradation is present on about 30% of the total global land area and more than 3 billion people in the world are settled on degraded land. The annual global cost is estimated at about 300 billion USD, with Sub-Saharan Africa accounting for the largest share (about 22% of the global cost of land degradation). Land Use/Cover Change (LUCC) accounts for 78% of the total global cost of land degradation (Nkonya et al., 2016). In Niger, the cost of land degradation due to LUCC is about 0.75 billion USD in 2007, which accounts for 11% of the national GDP (6.773 billion USD) (Moussa et al., 2015).

The causes of land degradation are multiple and differ from one location to the other (Thiombiano and Tourino-Soto, 2007). In Niger, land degradation might come from expansion of crop- and grazing land, unsustainable agricultural and forestry practices, urban expansion, population growth and infrastructure development, limited availability of land associated with poor land management, deforestation, overexploitation of wood cover, extractive industry, strong rains and winds, floods, and other climate change impacts (Bonnassieux, 2015; Andres, 2015; Birungi, 2008; CNEDD/UNDP, 2006).

Many studies have demonstrated that land degradation is one of the key constraints on poverty reduction in many developing countries (Birungi, 2008; Kirui and Mirzabaev, 2015). In Niger, where more than 80% of the population is dependent to rain-fed agriculture, land degradation due to harsh climatic events (drought, flood, desertification) and poor land management induces regular declines of agricultural productivity which results in increased poverty in communities (Danida, 2008; Prolinova 2008). Moreover, in the west and east parts of the country (Tillaberi and Diffa), which are the main agricultural and breeding regions, land degradation coupled with insecurity and related population migration have deteriorated local communities' living conditions. The restriction of fishing, irrigated agriculture and breeding along Lake Chad, the Yobe River and the pastoral zones have increased poverty and endanger livelihoods in these regions (AFD, 2018).

Land degradation and resulting consequences, climate change and growing insecurity raise concerns over attaining the sustainable development goals in the country especially SDG1 (poverty reduction) and SDG2 (zero hunger). Food security is one of the main challenges that Sahel countries are facing. Niger has experienced severe hunger and food crises. Food insecurity in the country is mainly caused by drought, floods and soil infertility. However, in addition to land degradation, rapid population growth will also play a part in threatening food security in Niger. The analysis of different projections has demonstrated that food security is far from assured in the future, because there is a clear gap between food needs and continuous population growth in the country. Under the influence of demographic pressure, the gap could in the long run be an exponential trend with the consequence of a strong unbalance between demand and production (TNC, 2016).

Land degradation through deforestation and desertification impacts Niger's communities that are highly dependent on fuel wood, i.e. 97% of the households (Gado, 2015). In light of ongoing desertification trends, the country's already low energy access rate through fuel wood will worsen even further if an alternative sustainable solution is not found. In addition, soil erosion and floods threaten the country's energy production each year, causing perturbations in the electricity distribution system and frequent shortfalls of the grid during the rainy season, which will increase under climate change. Hence, urgent actions need to be taken in order to find alternative energy sources for rural inhabitants and also to restore the already degraded land. These alternatives include improved cooking stoves, carbonized mineral coal, biofuel energy generation, GPL, solar cooking stoves and the use of renewable energy sources for electricity production.

It is also well known that land degradation in developing countries affects men and women differently (UNCCD, 2018). Indeed, due to unequal economic, social, political, and cultural positions, land degradation has disproportionate impacts on women's livelihoods, health, food and nutrition security, access to water and energy, as well as coping capabilities. Women, especially in rural communities, play a key role in natural resource management and achieving food security. Indeed, they often grow, process, manage and market food and other natural resources. They are generally responsible for small

livestock, vegetable gardens and collecting fuel, fodder and water, as well as for carrying out their traditional reproductive roles. In Niger, men have usually been responsible for decision-making and planning of farming activities, but in some areas, they have been increasingly leaving degraded lands to look for jobs in urban areas, leaving women to assume new roles and responsibilities on farms. Therefore, in dry land areas, women have to deal with environmental stresses and shocks and their aftermath, which significantly increase their burden of unpaid care work. In addition, land degradation increases the workload of managing the land by reducing land productivity as well as increasing time spent collecting water and wood for fuel. Gender roles in resource management vary from setting to setting, and over time within the same setting, especially as new environmental challenges are faced. New challenges allow men and women to negotiate their extra work burden and thus attain more balanced division of labor in a redefinition of roles. Increased access and more equal control over resources also help women and men make up for detrimental environmental impacts because male and female farmers can select from a wider range of ways to deal with degradation. In turn, women's particular efforts to combat desertification (land reclamation, reforestation, and irrigation systems) may lead to increased self-confidence as well as improved natural resource management, financial management and negotiating skills (FAO, 2011).

3 Observed and projected impacts of climate change

Climate change seems to be the most significant environmental challenge of our time as it poses serious threats to sustainable development in the world especially developing nations. The effects on our ecosystems are already severe and widespread (Christopher, 2013). These include, but are not limited to, temperature rise, spatio-temporal misallocation of annual rainfall, increased frequency of severe storms, land cover change, increased natural disasters, changes in the geographic distribution of wildlife and flora and the appearance of so-called climate-sensitive diseases. The Sahel region is one of the most vulnerable areas to climate change in the world.

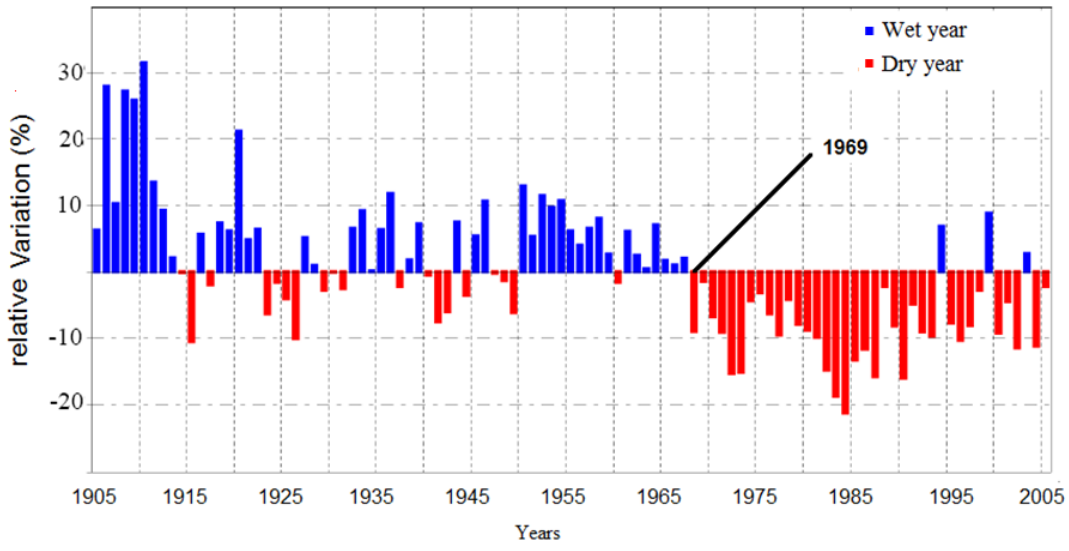
3.1 Observed and projected trends in extreme weather events (droughts, heavy precipitation, floods and heatwaves)

Rising global average temperature and resulting climate variability and change, extreme weather events such as dryness, heavy precipitation and floods, hot days and heatwaves are likely to become more frequent and more intense.

3.1.1 Drought

In West Africa in general and in the Sahel in particular, rainfall variability, increased dryness and prolonged drought, with regional variability, are recurrent phenomena since the 1970s (Figure 14). One of the main consequences of multiyear drought periods in Niger is severe famine, such as the ones associated with droughts (MHA, 2017) in the 1970s, 1980s, 1990s, and 2000s, which have caused many casualties and important socio-economic losses. Most of the time, drought is accompanied by other hazards. For example, in 2009, drought was compounded by locust infestation, which led to 4% decline in per capita GDP and stark losses in the herding subsector as 2.7 million head of livestock perished, resulting in approximately 805 million USD in losses, which corresponded to 30% of the GDP (World Bank, 2017). The water sector is also strongly impacted by prolonged drought conditions due to limited water storage infrastructure. This situation heavily impacted the population and the wildlife.

Figure 14: Relative variation of the annual rainfall amount in Sahel (with regard to 1961-1990 average)



Source: Mahe and Paturel (2009).

3.1.2 Heavy precipitation and floods

Despite the significant decrease in annual rainfall, Niger as well as the whole Sahelian region is experiencing an increase in intensity and frequency of extreme rainfall and related consequences. The increase in surface flow despite the drop in precipitation (Mahé et al., 2005), called the "Sahelian paradox", is a phenomenon that has been observed in many watersheds in the region. This phenomenon could be considered as positive at first given the local climate and recurring droughts, but in practice it mainly results in an increase in floods, intense erosion of agricultural land and a silting of many reservoirs, water bodies and streams. Many high-cost reservoirs are rapidly losing their storage capacity and can no longer perform their function of providing water for irrigated agriculture in the dry season (MHA, 2017; Fowe et al., 2015). The Niger River is in an undesirable state due to the additional influx of sediments from its tributaries, leading to more frequent flooding, reduced navigability and degradation of river ecosystems, which in turn has repercussions on fishing and commercial activities (Okpara et al., 2013). The intensive leaching of agricultural land leads to a decline in soil fertility and a loss of arable land as a result of gully erosion. In fact, there is general evidence over the West Sahel of an increased number of heavy (precipitation above 10 mm/day) and very heavy precipitation events (precipitation above 20 mm/day) (Oguntunde et al., 2018).

Several flood episodes have been observed in Niger (MHA, 2017) during the last decades causing many injuries to the affected population and impacting the national economy. Indeed, owing to the low quality of water drainage systems as well as low soil infiltration capacity, high precipitation is usually followed by floods causing fatalities and losses. During the last rainy season, life was badly affected in many regions including Niger's capital Niamey and Maradi due to heavy rainfall in 2019, which was exacerbated by inappropriate land use and land degradation. Most traditional clay houses became unusable, and about 100,000 people were affected by the flood. At least 2,000 people became homeless and more than 50 people lost their lives due to flooding. Thousands of animals also died. During the period 1999 to 2015, the first scientific investigation conducted by national technical services and ANADIA (Italian cooperation) regarding flood damage and impacts in Niger, noted considerable flood impacts, including losses to about 4000 settlements and 1.7 million people affected (Edoardo, 2018). The analysis has also shown a sudden increase in flood impacts since 2010. Population increase, land uses, and climate variability and change are the primary causes. Therefore, there is an urgent need to take measures to address flooding issues in Niger, because it is projected that the monthly average rainfall will increase by 2025 compared to normal over the 1961-1990 period, with the exception of the Tillaberi and Niamey stations, which will experience a decrease (SCN-2008).

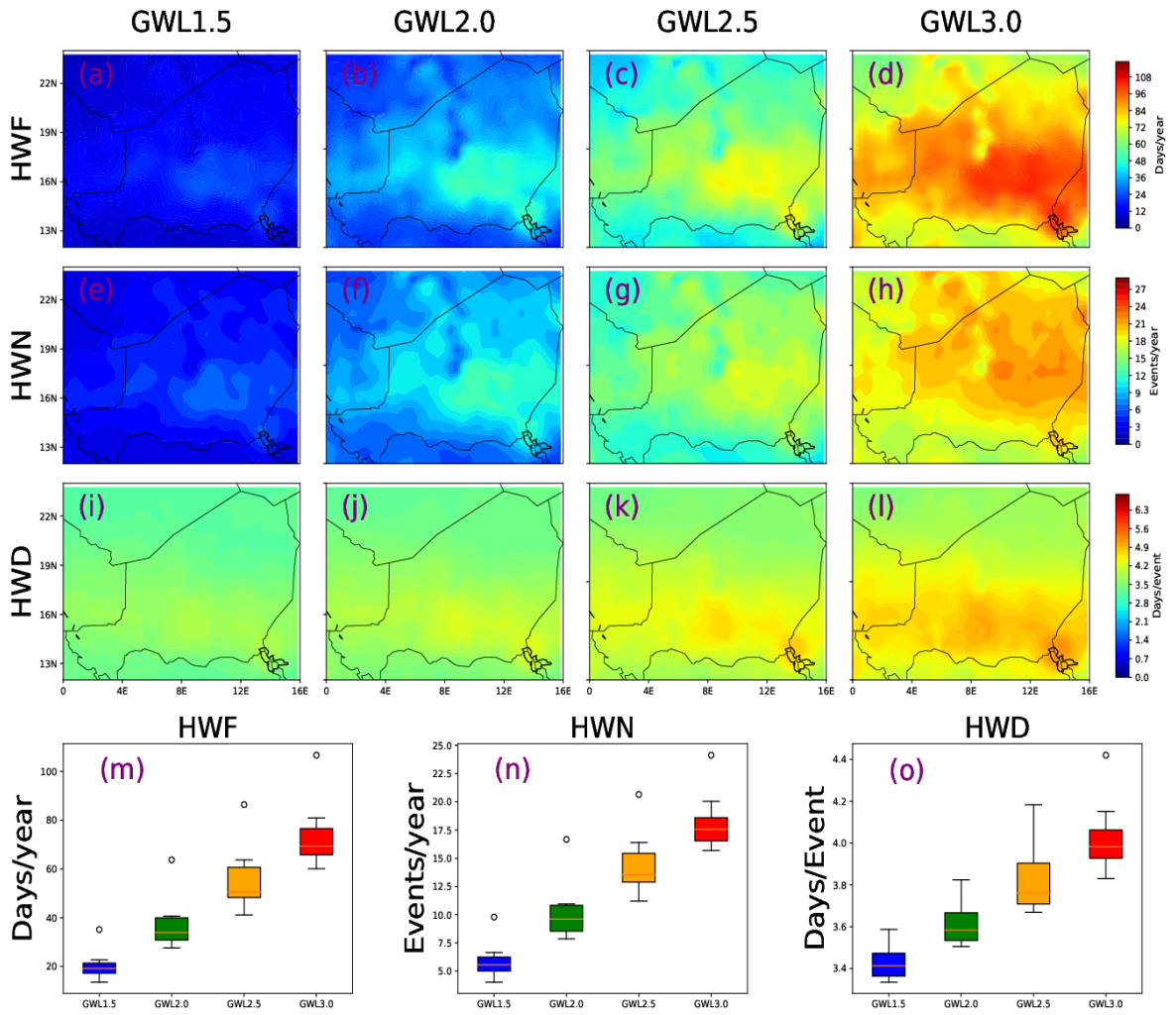
3.1.3 Hot days and heatwaves

Regarding hot days and heatwave events, Niger is considered as an area with high risk in terms of extreme temperatures. Indeed, heatwaves observed during the last decades have caused many deaths in the country. There has been an increase in heatwave characteristics such as heatwave number, heatwave frequency, and heatwave duration in Niamey during the last decades (Ndiaye et al., 2017). Moreover, it is projected that climate change will further increase these characteristics. The magnitude of increase will be higher at Global Warming Level GWL2.0 than that of GWL1.5 (Figure 15) (Bonkaney, 2019). This will increase the vulnerability of the population to these extreme temperatures. According to conducted climate projections, the Sahel will be confronted with a rise in temperatures associated with a high variability of rainfall and a tendency toward extreme events (Ndiaye et al., 2017, Bonkaney, 2019). It was reported that by the year 2030, average temperatures in Niger may increase by 1^0C to 2.75^0C (Butt et al. 2002; Ndiaye, 2017), with precipitations declining slightly.

The signs of global warming in Niger are indisputable. The climate scenarios generated at the country's nine main synoptic stations (Agadez, Birni N'Konni, Gaya, Mainé Soroa, Maradi, Niamey, Tahoua, Tillabéri, Zinder) show that the maximum and minimum temperatures will be rising (TCN-2016). Analysis of the observational climatic data of the period 1976 – 2011 has shown a significant increase

of annual mean temperatures (around 2.2±0.1°C). The surface temperature seasonal cycle has two hot periods (March-April-May and September-October-November), ranging between 35 and 45°C (Ndiaye et al., 2017).

Figure 15: Projected changes in heatwaves characteristics (HWN, HWF, and HWD) in Niger at specific global warming level (GWL1.5, GWL2.0, GWL2.5, and GWL3.0)



Source: Bonkaney (2019).

3.2 Observed and projected impacts on agriculture productivity, disease vectors and health, biodiversity, livelihoods and incomes, food security, conflicts and migration

There is ample evidence that climate change is having serious effects on agricultural production, disease vectors and health, and the livelihoods of millions of farmers. Climate variability, land degradation and other natural events have changed rural landscapes nationwide. Among climatic variations, rainfall variation is one of the main factors of habitat degradation and loss of biological diversity in Niger. The country is extremely sensitive to changes in rainfall (CNEDD, 2009). As the population lives mainly from rainfed agriculture, the decrease in average annual rainfall since the 1970s, combined with great interannual variability and rapid population growth, have led to several food crises requiring international assistance. This was the case for the years 1968, 1973, 1981, 1984, 1987, 1990, 2000, 2004 and 2009 (Biasutti and Giannini, 2006; DMN, 2009).

Drought, combined with human actions, has led to desertification and degradation of natural resources. The continuing degradation of agricultural and pastoral lands by drought and desertification has led to a series of bad years, particularly in terms of agropastoralism, with all the socio-economic consequences that ensued (Thébaud and Batterbury, 2014). It is becoming increasingly clear that not only droughts but other extreme events will occur regularly in the future, and their magnitude and frequency may be exacerbated by climate variability and change. Extreme events like floods and high temperatures will also have more harmful effects on wildlife (CNEDD/UNDP, 2006). High temperatures will cause the death of more animals and will slow the reproduction of certain species such as reptiles and birds. In another note, more dryness will increase biodiversity loss through the disappearance of some species, and will increase bushfires which will destroy wildlife and their habitat causing genetic erosion of some species.

The issue of food security is a major challenge given the many climatic risks including drought, flooding and changing precipitation patterns. Precipitation has continued to decline along the Sahelian belt and the rainy season has changed through the years. The consequences are catastrophic, with a significant drop in agricultural production yields, especially food crops (maize, millet and sorghum). According to CNEDD/UNDP (2006), agricultural production, until the beginning of the 1970s, only covered 86% of food needs, and at the end of the 1980s it became structurally deficient mainly because of climate change, including recurrent droughts. It was noted that the cereal balance was particularly negative from 1989 to 1996. More recently, 1.5 million people in Niger were affected by food insecurity in 2017. Another 1.5 million are estimated to be chronically food insecure, and millions more experience transitory shortages during the lean season. Nearly 20% of the population cannot meet their food needs because of factors such as inadequate agricultural production, climatic and security constraints and high demographic growth. This figure rises to nearly 30% during periods of poor rainfall. Furthermore, climate change could further reduce crop yields. It is projected that the yield of millet and sorghum in Niger will decline by 20% with a global warming level of 2°C by 2050. In Gaya a further increase in temperature of 3°C will decrease the yield of sorghum on clay soil by 17% for the wet and by 18% for the dry scenario respectively while in Konni the decrease will be around 1% and 17%, respectively. The Tillabery and Tahou regions will also experience a decline of about 13% for the wet and 2% for the dry scenario respectively (CNEDD, 2012).

The consequences of climate change on livestock are closely linked to the sensitivity and vulnerability of livestock systems (CNEDD/UNCP-AAP, 2011). Thus, according to CNEDD/UNDP (2006), years of drought have caused huge livestock losses. In terms of sheep, 5% losses were recorded against 22% in terms of goats in 1974. Losses in the first year after 1984's drought amounted to 33% for goats and 35% for sheep. Camels recorded the lowest loss rates: 18% in 1974 and 19% in 1984. As for floods, according to the damage report published by the SAP/GC (national early warning system agency) in its bulletin n°37 in 2005, the death of 7,798 heads of cattle was reported nationwide for that year.

In a context of widespread and entrenched gender inequality, food insecurity affects women disproportionately, especially in rural areas. Persistent gender disparities continue to challenge development and have an impact on food and nutritional security. These challenges will be accentuated under the ongoing global warming trends. Studies have also shown strong links between climate-related disasters and female mortality, with women, boys and girls more than 14 times more likely than men to die during a disaster (Peterson, 2007; DFID, 2013). Women often have more limited rights than men, limited mobility and less access to resources, information, and decision-making. Consequently, they are significantly more vulnerable to the impacts of climate change and have fewer capacities to adapt and diversify their livelihood options. These gender inequalities will increase as a result of climate change (Nellemann et al., 2011). .

In Niger, the impacts of climate change on health mainly concern climate-sensitive diseases such as malaria, meningitis and measles (PN/CC, 2012). Indeed, drought combined with high temperatures increases risks of certain diseases such as measles, while heavy rains and floods, in turn, increase the proliferation of certain endemic diseases like malaria, which is the most dangerous. Indeed, it is

projected that climate change will increase the amount of people exposed to malaria by 0-20% by 2100 (Tanser et al., 2003). As far as cholera and the incidence of meningitis are concerned, it is also projected that climate change will increase these two diseases by 2050 (CNEDD, 2012).

Sand and/or dust storms, combined with the extremes of certain climatic variables such as temperature and relative air humidity, greatly exacerbate respiratory diseases and cause eye irritation. They can also be associated with the spread of meningitis. Nutritionally, drought has led to famine, which is one cause of malnutrition and fragility of vulnerable groups, including pregnant women, breastfeeding women and children. In terms of exposure to animal diseases, the increase in temperature will lead to a geographical redistribution of certain vector-borne infectious diseases including Rift Valley fever, bluetongue and West Nile virus to higher altitudes and latitudes.

In Niger, migration can be linked to the consequences of climate change (Di Bartolomeo, 2011; INS, 2015). Indeed, the decrease in agricultural production or the decimation of livestock and hunger force people to migrate to large cities or to foreign countries in the hope of finding more favorable places for their livelihoods. The 1970s and 1980s droughts were followed by a significant migration to coastal countries (INS, 2015).

Several studies have shown a link between climate change, environmental degradation and conflict at the global, regional and even local scale (Campbell et al., 2007; Mabey, 2008; Burke et al., 2009). Previous conflicts have already emerged as a consequence of water scarcity, encroachment of agricultural land into grazing land, as well as damage of crops by livestock. Indeed, a case study in Niger by Turner et al. (2011) showed that the expansion of croplands in the four study areas resulted in an increased proximity of grazing livestock to cropped fields. Hence, since climate change is expected to reduce agricultural productivity, the cropped areas are expected to expand which may result in potential conflicts between farmers and pastoralists.

4 Technological, socio economic and policy actions for sustainable land management and climate change adaptation and mitigation

Niger, as well as other areas in the West African Sahel, have recorded high impacts of climate change on natural resources during the past decades (CNEDD/UNDP, 2006). Land degradation and rainfall deficits have brought many challenges to the agriculture and water resources sectors, which have led local populations to develop many strategies in order to cope (World Bank, 2017; Nkonya, 2016; Adams, 2000). Land provides vital environmental functions and ecosystem services, including provisioning, regulating, supporting and cultural services, which support production of food, feed, fuel, and fiber to society, regulate risks of natural hazards, and provide cultural and spiritual services for human well-being (Save the Children, 2009).

Sustainable Land Management (SLM) represents a holistic approach to achieving long-term productive ecosystems by integrating biophysical, socio-cultural and economic needs and values (FAO, 2017). SLM is one of the main mechanisms to achieve Land Degradation Neutrality.

4.1 Technological responses categorized by land use types

Technologies and techniques developed by technical services and local populations depend on the type of land and its intended uses. The main objectives of these measures are:

- Increase land productivity
- Enhance water-use efficiency
- Restore and conserve soil fertility
- Improve livelihoods
- Improve ecosystems, be environmentally friendly
- Prevent, mitigate and rehabilitate land degradation
- Improve biodiversity
- Exploit the opportunities which may be presented by climate change.

The technologies are related to croplands, rangelands and forests, woodlands and shrublands.

4.1.1 Croplands

The country's agroforestry parklands (AP) occupy approximately 90% of agricultural land (Abasse, 2000). These parklands are managed to fit environmental conditions (mitigate climate change) and also to fulfil specific functions related to production diversification in croplands. The major crops in the country are millet (43.9%), cowpea (33%), and sorghum (22.4%). The density within the park is generally low as well as species composition. This implies that there has been decrease in both richness and abundance of trees and shrubs (FAO, 2007). The most dominant parkland species in the country are: *Faidherbia albida* (Del.) A. Chev (syn. *Acacia albida: Mimosoideae*), baobab (*Adansonia digitata* L: *Bombacaceae*), locust bean (*Parkia biglobosa* (Jacq.) Benth: *Mimosaceae*) and *Tamarindus Indica*. These are the most preferred species by farmers due to their potential economic value. Since the droughts of the 1970s, the government has created many strategies in order to reduce the impacts of rainfall shortages on agricultural production. These strategies aim to improve food production during the dry season through irrigation, increase crops yield, recover degraded lands and prevent desertification.

4.1.2 Expanding of irrigation

Since the agricultural sector is highly dependent on low-productivity rainfed cultivation systems (94%), it has not yet been able to cover the food demand. Agriculture will remain the main source of growth in Niger in the coming years and irrigation, despite constraints, will play a key role. Niger's population has been practicing subsistence or economic irrigation for many years and with potential irrigable land estimated at 270,000 ha or about 2% of the cultivable area, only 76600ha have yet been exploited (AFTAR, 2009) (Tables 1).

Irrigated agriculture in Niger is more extensively practiced in seven main regions of the country (Table 1). The largest concentration is in the Tahoua region, with about 20,000 ha of currently irrigated land producing mostly onions and tomatoes. The Niger Valley has about 17,500 ha of irrigated areas where rice predominates but where onions and fruits are also cultivated. The Maradi region, with about 13,000 ha, offers a wide range of market garden crops. In Zinder, the irrigated 8,000 ha are mainly dedicated to sugar cane.

Table 1: Irrigation situation by region (ha)

Natural Regions	Irrigation potential	Irrigated areas	Public Irrigation	Private irrigation	Administrative region	speculations
River Niger	142,000	17,500	8,295	9,205	Tillabery, Niamey, Dosso	Rice, onion and fruits
Dallols Bosso and Maouri	39,000	5,000	84	4,916	Tillabery, Dosso	Rice, onion and fruits
Ader Doutchi, Magia and Basse	35,200	20,000	4,280	15,720	Tahoua	Onion and tomato
Tarka valley						
Komadougou, lac tchad and cuvettes	20,000	10,000	283	9,717	Diffa	Black pepper
Goulbi Valley and N'kaba	10,400	13,000	512	12488	Maradi	horticultures
Koramas	10,000	8,000	-	8,000	Zinder	Sugar cane, horticulture
Air valley and Oiasis	10,000	3,100	-	3100	Agadez	Onion and potato
Total	270,000	76,600	13,454	63,146	Niger	Rice, onion, fruits, horticulture products, potato, sugar can, black pepper

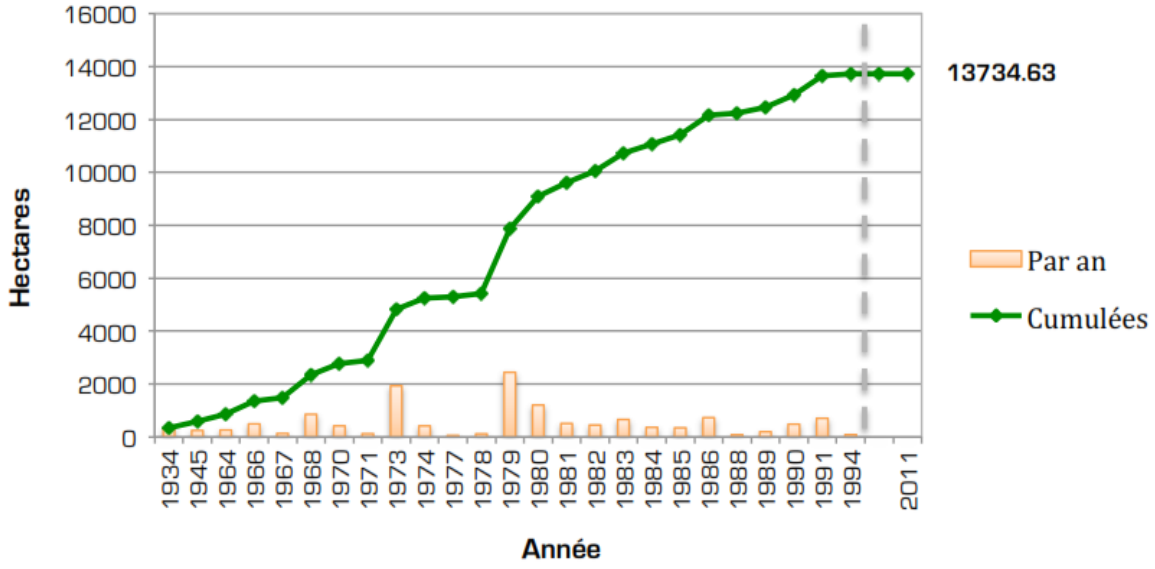
(CEIPI, 2011)

Niger's irrigation sub-sector is diverse, including both public and private investments and varying degrees of water control and productivity. Irrigated crops are mainly rice for home consumption and for the local market, along with a range of horticultural products for local and export markets. Although irrigated perimeters represent only a tiny part of the total area of arable land, they contribute largely

to the national economy. Irrigation development and improved productivity of irrigated agriculture are therefore major national priorities. However, Niger is at first sight in a paradoxical situation, as it is an arid area where irrigated agriculture remains limited despite the significant water resources (MHA, 2017), particularly the Niger River which flows through 550 km of the country. In total, the country's water resources amount to about 30 billion m^3 of surface water per year plus 2.5 billion m^3 of renewable groundwater per year and about 2000 billion m^3 of non-renewable groundwater.

The government has designated four intervention zones as "strategic agricultural areas" because of their "relatively" favorable conditions for the development of private irrigation (renewable water resources, access to land, good soil quality, access to markets and financial services). The areas chosen are: the valley of the Niger River, the Bosso and Maouri dallols, goulbis of Maradi and Kaba, the koramas of Zinder. As in many regions in Africa, surface irrigation is the most developed in Niger. Surface irrigation involves the application of water by gravity flow to the surface of the field. However, since 2000, an increase in drip irrigation is observed in the country (Figure 16) (CEIPI, 2011). Many farmers are adopting drip irrigation by using a small solar pumping system. The use of sprinkler irrigation is very low.

Figure 16: Evolution of the equipped irrigated area with AHA

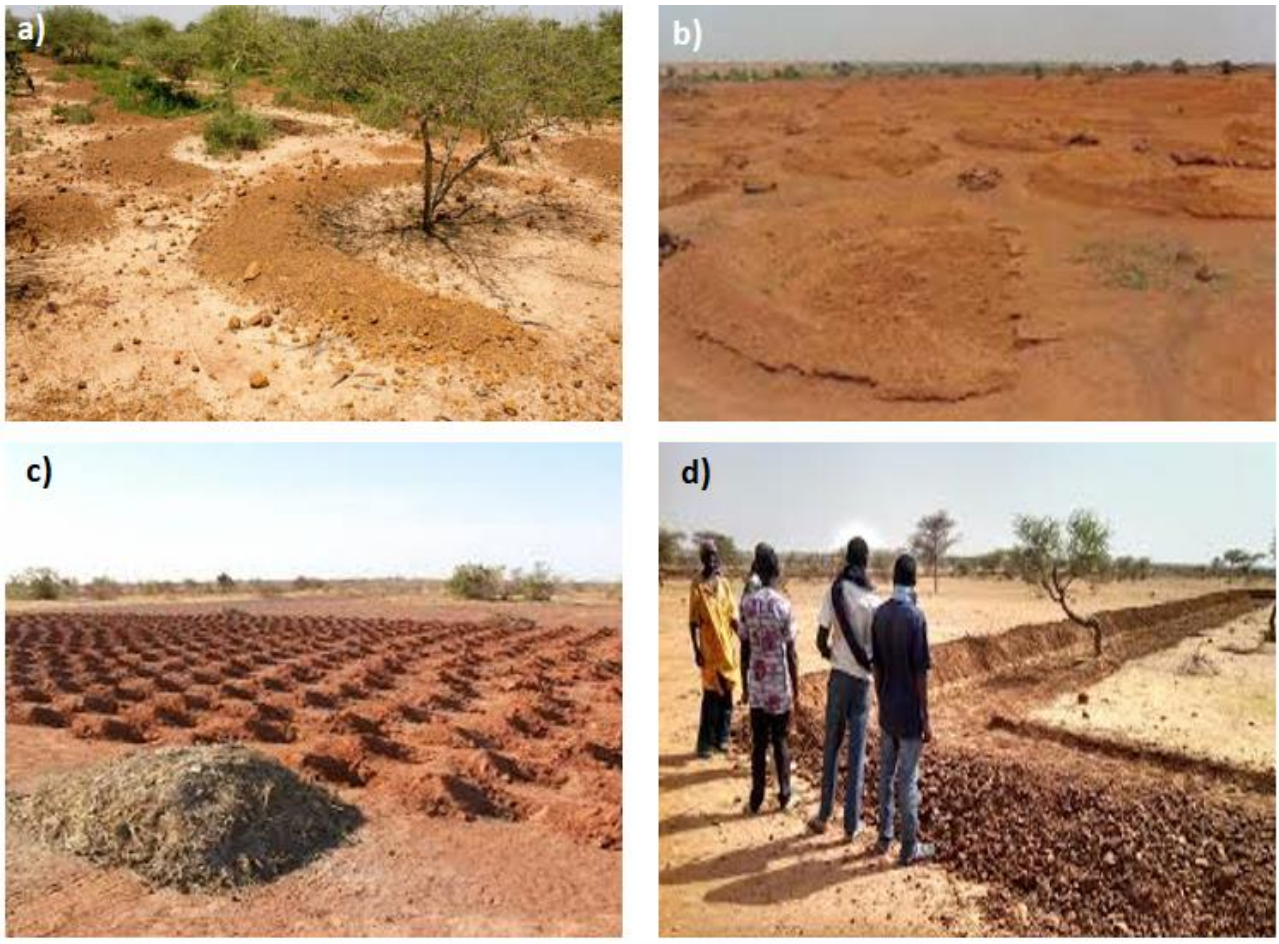


Source: CEIPI (2011).

4.1.3 Rainwater harvesting

Rainwater harvesting is developed in Sahelian areas through the implementation of some techniques of water conservation and soil restoration (CES/DRS). These CES/DRS techniques (Figure 19) allow populations to manage their ecosystems and improve their agricultural production. These techniques help to better prepare the population for environmental changes (changes in climate and land degradation) and shocks, including drought. The CES/DRS techniques are well developed in regions where the annual rainfall amount is lower than 600 mm, which includes more than 90% of the country's total landmass. These techniques serve several purposes at once: (i) better water management, (ii) increased water productivity for agriculture, forestry and pastoral areas and (iii) environmentally sustainable management. Depending on topography, the main techniques are: trays arrangement (half-moons, Nardi Trenches, benches), slope arrangement (manual trenches, filtering dykes), landscaping of glacis (stony cords, filtering dykes, Zaï), and development of the lowlands (thresholds for water spreading, micro-dams) (Figure 17). These techniques have helped to recover important land and they can also help to increase crop yields up to 200% (GIZ, 2012).

Figure 17: Common rainfall harvesting techniques applied in Niger



Note: a) Sylvo-pastoral half-moon, b) Agricultural staggered half-moons, c) Zaï, d) Nardi trenches.

Source: Botoni (2013).

4.1.4 Crop diversification

In rainfed production systems, crop diversification consists of farming systems that combine cash crops and food crops. In Niger, this practice varies across agro-ecological zones and ethnic groups. The main functions of crop diversification are to reduce agriculture failure, to restore soils (use of green cover or legume species), and to harvest early maturing crops as a food security adaptation strategy. Given the climate constraints in the country, most farmers opt for crop production systems based on the associated cultivation of millet, sorghum and cowpea (African bean, *Vigna unguculata*). All these systems have low potential yields, but they are adapted to low rainfall. Intercropping also makes it possible to mitigate production risks by combining crops with different seasonal growth characteristics. For example, in a year of early drought, millet or sorghum will overtake cowpea, while cowpea can become more important in years where late planting rains occur and cereal growth is insufficient. This form of diversification also helps to stabilize incomes and to expand the use of the little water in the soil by working during the planting and the early weeding. There is evidence that with good crop association and appropriate seedling density, this type of intercropping can increase yields, eliminate weeds and boost nitrogen levels in the soil (BM, 2013). The benefits of this strategy are offset by the poor performance of these three crops that dominate production. Together, they account for 85 to 90% of the total area under cultivation, leaving less space for other high-yield crops and greater diversification. Although many other crops are produced (groundnut, rice, maize, fonio, sorrel, okra, sesame and nutmeg), the area devoted to each of them is relatively small. Groundnuts

account for 4% of the total area under cultivation, and most other crops account for less than 1%. Also, many initiatives are taken by rural communities to mitigate the challenges they face since 1970s (Luxereau, 2014). The evolution of representations of nature favours the development of long neglected areas, such as the lowlands that are increasingly coveted for market gardening. Degraded agricultural areas are reforested in the Ader and in the Zinder region. The development of arboriculture and nurseries has also been observed. Soil remediation actions undertaken with the support of projects in certain areas allow recovery of their fertility. The involvement of farmers' organizations in the management of irrigation schemes along the Niger River has led to an improvement in rice yields. Agricultural products, including onions, market garden products, sesame seeds, and nutsedge, which are the subject of significant demand at the national level and in countries of the sub-region, are progressing. The modernization of technical practices, such as the development of small-scale irrigation and the existence of well-structured commercial networks, favours their production. In the regions concerned, rural exodus is decreasing. Revenues from marketed products are used to buy food, improve equipment, and increase livestock (Bonnassieux, 2015). Altogether, production of high value crops (market gardening) in the dry season is one more way to increase and diversify farm income. It provides substantial revenues and nutritional benefits to the households that engage in it (BM, 2013).

4.1.5 Adoption of drought-tolerant crops and crop varieties

Since the 1970s famines, Sahelian countries have engaged in the development of new varieties of crops which are more drought tolerant. In Niger, IRD, ICRISAT and INRAN have conducted extensive research activities in this sector (Ouendeba and Siaka, 2014). Millet is the most cultivated crop in Niger. In terms of area, it occupies 63% of the land planted with cereal crops. Its production varies with the agro-climatic conditions of the growing areas. Many studies have been conducted in order to find a variety that is more tolerant to drought and to the rainy season's shortening. Field trials coordinated by ROCAFREMI (Réseau Ouest et Centre Africain de Recherche sur le Mil) were set up from 1991 to 1996 in Niger to identify performing varieties with an appropriate cycle. Sixteen improved varieties were tested in the Sahelian zone (14) and in the Sudanian zone (2); 100 farmers were involved in carrying out these tests in the production areas. Four varieties, ZATIB, CT6, GR-P1 and SOUNA III were selected by producers in the Sahelian zone (400-600 mm) and 3 varieties H80-10-GR, HKP3 and HKP were selected in the northern zone of the country (with annual rainfall <400 mm) (Ouendeba and Siaka, 2014). Similar research studies have been conducted for other crops such as maize, sorghum, bean, groundnut, etc.

4.1.6 Conservation agriculture

Conservation agriculture plays a crucial role in the cropping systems of dryland regions such as Niger. It aims to produce high crop yields while reducing production costs, maintaining soil fertility and conserving water. According to a 2013 estimate, about 13% of total agricultural lands are applying conservation agriculture (RECA, 2013). Some of the key conservation agriculture practices in Niger are:

- Minimum soil disturbance via maintaining soil cover, mixing and rotating crops
- Minimum soil disturbance through zero tillage, minimum tillage and animal traction
- Maintaining soil cover via mulching (crop residues, pruning, and other plant materials)
- Establishment of crop cover through intercropping, relay cropping, sequential cropping, and the use of animal droppings
- Cultivation of wild species for food production or medicinal purposes according to Moussa (2013), which revealed the use of wild species such as legume species *Cassia obtusifolia* and *Senna occidentalis* as part of crop diversification.

4.1.7 Agroforestry

Agroforestry, which consists of land-use systems that combine the use of trees, animals and crops in cropping systems, is practiced in Niger. Agroforestry improves livelihoods in smallholder cropping systems because it results in multiple socio-economic services such as firewood, timber, forage, medicine, shade, etc. and ecological services such as the use of tree species as fertilizers, atmospheric carbon dioxide reduction and biodiversity conservation (Moussa et al., 2016). Agroforestry parklands constitute one of the most dominant vegetation types in Niger while also playing a great role in fighting land degradation such as desertification. To overcome this environmental threat, the government initiated several afforestation and reforestation programs in urban and rural areas. For instance, the creation of the Niamey Green belt in 1965, which covers 2,500 ha with neem tree plantations, was a response to land degradation threatening the capital (MCE, 2010). In addition, Niger Independence Day (3rd of August each year) was declared in 1975 as National Tree Day (Fête Nationale de l'Arbre). Furthermore, in 1980, Operation Green Sahel Program was created with emphasis on the use of exotic and local plants in agroforestry and urban forestry. This green space constitutes a carbon bank as demonstrated by Moussa et al. (2019) who found that urban forests in Niamey and Maradi cities are carbon sinks and botanical gardens for native tree species conservation (green Sahel au Niger). An average of 5 tons of carbon were sequestered per hectare (NDC, 2015). In addition, agroforestry in the regions of Maradi and Zinder improved quality of life for women by reducing time allocated to gathering firewood and has also increased food security of local communities by providing substantial nutritive elements (such as fruits, grains, leaves).

4.1.8 Rangelands

In Niger, livestock plays a major role in the socio-economic life of the population (Alhassane et al., 2017). The country's herds are estimated to contain about 36 million heads, all breeds combined, with a market value of 2000 billion FCA, which contributes more than 15% to the household budget and nearly 11% to the national GDP (MEL, 2012). However, the sector's contribution to the country's economy is below its potential; due to the insufficient quantity and quality of feed resources that come mainly from natural rangelands subjected to strong pressures by cultivation and overgrazing. The result is an overgrazing of pastures which leads to a modification of the diversity of flora and decrease of primary production, which in the long term can cause biodiversity loss. Biodiversity loss has its own consequences, including homogenization of vegetation and decrease in performance of livestock zootechnics (Heitschmidt and Stuth, 1991). The reduction in quantity and quality of forage supply makes feeding conditions difficult and exposes pastoral communities to poverty and food insecurity, thus undermining the pastoral economy (Alhassane et al., 2017). Rangeland production systems vary with ethnic groups in Niger in terms of livestock rearing across urban and rural areas (Duteurtre and Faye, 2009). However, in rural areas, rangelands production systems face several challenges such as expansion of agricultural lands into rangeland, urbanization, plastic pollution, species invasion such as *Sida cordifolia* (Moussa, 2013), floods, droughts, insecurity, and banditries with stealing of animals.

4.1.9 Rotational grazing

In Niger, the term "pastoralism" is generally associated with the use of common property resources subject to certain group agreements, rather than "open access" (Studer, nd). "Ranching", on the other hand, involves individual, private ownership of land. Pastoralism is based on open pastures of savannahs, meadows, steppes, and shrub areas managed by nomadic herders (Studer; nd). Pastoralists follow the resources of pastures/meadows and water, and they destock in times of drought (often de facto through the mortality of livestock rather than by their sale). However, these breeders have rapid response strategies for restocking after drought (high reproduction rates in local sheep and goats). There are many types and degrees of pastoral mobility, which vary according to environmental conditions or the given situation of households (e.g. conflicts).

Rotational grazing is a management system based on the subdivision of pastures into several enclosures and on the successive grazing of these paddocks or parks by animals according to a rotation so that no veld (grazing area) is grazed simultaneously (JGRC, 2001). Therefore, rotational grazing allows higher stocking rates than continuous grazing. The main principles of rotational grazing are as follows: (1) control the frequency with which grazing is used and adjust the rotation cycle to ensure good forage quality in each park. Grazed plants (including the preferred and therefore overexploited species) are made available with a recovery or rest period following grazing; (2) control the intensity at which the pasture plants are consumed by controlling the number of animals grazing in each park and their duration of occupation, and (3) reduce the extent of selective grazing by confining a relatively large number of animals on a small part of the veld, which leaves them little possibility of selection and avoids the domination of undesirable species (invasive plant species).

The grazing intensity is adapted to the climatic conditions: in dry periods, the recovery periods are longer due to the limited recovery potential of the plants and their high sensitivity to misuse and degradation. The ratio between the periods of occupation and the periods of absence determines the yield and the vigor of the plants: the shorter the period of occupation of the park, the higher the yield of the veld will be: a second consumption of "regrowth" is avoided and the recovery period is therefore at least equal to the period of absence. However, the shorter the period of occupation and the longer the period of absence, the greater the number of plots required in a rotating grazing system.

The authorities define the passage corridor which is a track or path assigned to the movement of animals between two or more localities, countries or pastoral areas (Hammel, 2001; Gagnol and Afane, 2010). The pasture area is a space with a pastoral vocation located in the pastoral zone (unlike pastoral enclaves, which are spaces with a pastoral vocation located in an agricultural zone). The corridors, pasture areas and pastoral enclaves are defined for a given period. In some regions of Niger, their positions are changed in order to allow rotation between agriculture and livestock.

4.1.10 Addressing invasive bush encroachment

Today, natural resources are confronted with continuous degradation in particular due to climatic hazards, anthropic pressure and invasive plants (Amani and Barmo, 2010). The economic and environmental impacts of these invasions are very high, hence there is a renewed interest in these plants. Invasive species have been the subject of several definitions. There are seven invasive plants in Niger including four in drained areas (*Prosopis juliflora, Sida cordifolia, Calotropis procera* and *Pergularia tomentosa*) and three in aquatic environments (*Mimosa pigra, Eichornia crassipes* and *Typha australis*). The invasion of these plants gives rise to conflicting opinions. Some stand for their complete elimination others for their conservation because they could bring certain benefits. It is a fact that in regions with arid climates such as Niger, where vegetation cover is low and declining, the eradication of these species does not seem to be a good option. One possible solution would be to contain invasive species in areas where they are currently forming high concentrations. These plants can be valorized in several ways: dune fixation and riverbank protection, livestock feeding, fish breeding, production of biofuel, and also human food (Amani and Barmo, 2010).

4.1.11 Forests, woodlands and shrublands

Niger is home to species and plant formations represented by several biogeographic stages. There are four main phytogeographical sectors in Niger (Saadou, 1998):

- Northern Sudan, with vegetation consisting of tree and shrub savannas
- South Sahelian sector, consisting of thickets, tree steppes and shrubs
- Northern Sahelian vegetation consisting of Acacias shrub steppes
- Saharan sector, a desert area where vegetation contracts in humid depressions and oases (contracted steppes).

The flora in Niger, all groups combined, contains about 2,124 species of which one is endemic (*Rhyncosia airica*) in Aïr (Saadou, 1998). Added to this, there are 487 species of algae discovered by Djima (2013), which means there are 2,761 total plant species (CNEDD, 2014). The lower groups (viruses, bacteria, fungi and lichens) have not been the subject of further investigation.

Overall plant formations are estimated at 109,950,548 ha, of which 3,962,862 ha are in the south Sudanese savannah formations, 35,983,175 ha are in the Sahelian mixed formations and 3,962,862 ha in the Saharan steppe formations (Mahamane et al., 2011). In addition to these plant formations, it should be noted that there are important ecosystems consisting of agroforestry parks and urban and peri-urban forests. Agroforestry parks are situated in the southern agricultural zone (Sahelian and Sudano-Sahelian zones), with densities varying between 10 and 100 trees per ha, depending on the species (MH/E, 2012). In particular: (i) parks of *Faidherbia albida*; (ii) *doumeraies*; (iii) nurseries; (iv) parks of *Vitellaria paradoxa*, *Prosopis africana* and *Neocarya macrophylla*.

This encouraging situation can be explained by the different interventions of projects and NGOs and by a process of spontaneous adoption of the practice of natural regeneration assisted by producers. The importance of regenerated trees in fields far exceeds artificial planting done in Niger since 1960. These trees contributed to vulnerability reduction of the population during drought years through the collection of leaves and fruits and the sale of wood and fodder for livestock. For urban and peri-urban forests, since the 1984 Maradi commitment date, many plantations (including the 2,500-hectare wide green belt of Niamey) have been carried out by the state, communities, projects and private actors, often with local people.

In 2010, several achievements were made by the government (INS, 2011), including:

- Development of 917,058 ha of forests
- Production of 5,344,737 tree seedlings
- Recovery of 35,239 ha of degraded lands
- Fixation of more than 4,000 ha of dunes.

Also, since 1980, the International Fund for Agricultural Development (IFAD) has introduced the Assisted Natural Regeneration (ANR) in many areas (Adam et al., 2006). This is a participatory agroforestry method valuing the release of endogenous woody shrubs allowing a reconstitution of the woody cover of agricultural plots (Botoni et al., 2005). For 30 years, ANR has induced an opposite effect (a regreening) allowing for improvement of the environment and the woody cover (soil fertility, protection against winds, shade) but also the incomes and living conditions of households (Andres et al., 2015). For example, half-moon micro-catchments are used around acacia trees (*Senegalia senegal*) for water retention at landscape restoration sites.

4.2 Household and community responses

Faced with environmental degradation and increased cyclical and structural shocks in the region, populations have developed strategies to address the risks of vulnerability to food insecurity and to poverty. In fact, the numerous climatic and food crises have led to the development of some strategies.

4.2.1 Livelihood diversification and migration

Poverty, recurrent droughts, and structural famines combined with dynamic demographic and unemployment pressures have been the main underlying causes of the persistence of migratory movements in Niger (Di Bartolomeo, 2011). Initially, these flows developed within the framework of intra-regional mobility by following the West African roads, in which circular and temporary migrations have always played a role in adjusting dynamics of population, natural resources and work opportunities among the countries in the region. Nigeriens, mostly from the Tillabery and Dosso regions, migrate to countries with labor shortages like Côte d'Ivoire and Ghana to work on plantations

and in construction industries. Nigeria attracts many, particularly from the regions of Tahoua, Zinder and Maradi. From the mid-1980s, and as a result of the prolonged economic crisis in West Africa, this regional mobility was partially weakened. At the same time, the worsening of the population's general condition has led to an increase in emigration farther in the direction of the USA and Europe. Today, emigrants - mostly irregular - are more attracted to Maghreb countries (in particular Libya and Algeria), the Middle East (Saudi Arabia), and, to a lesser extent, to other countries of the world (Di Bartolomeo, 2011). According to the Global Migrant Origin Database (GMOD), the stock of Nigeriens residing abroad in the 2000s amounted to 497,000 individuals, or 3.5% of the total population residing in Niger (Di Bartolomeo, 2011).

Seasonal migration prevails despite the fact that the duration of residence abroad largely depends on changes in agricultural production, as migration is considered a fundamental survival strategy for many Nigerien households both in terms of remittances and reducing pressure on the local labor market (INS, 2015). Seasonal migration plays an important role in ensuring sustainable livelihoods. Nigeriens regularly undertake seasonal migration to reduce the pressure on food at home (one less mouth to feed) and to earn some income during the off-season. Social transfers from migration contribute to increasing household incomes (INS, 2015). Social safety nets can be used as short-term instruments to help the poor cope with economic shocks. They can also operate as medium/long-term poverty alleviation programs, supporting minimum consumption levels and promoting the accumulation of human and physical capital. When transfers are provided over multiple periods to poor households, for instance, they are used to pay off debts, accumulate productive assets, or buy inputs (fertilizer). This enhances productive capacity and resilience of the households.

4.2.2 Community collective action

Climate change presents a wide range of significant challenges for communities especially in developing countries where the adaptive capacity is weak. These challenges include changing weather patterns and an increase in frequency and intensity of climate hazards. Hence, collective action from many professionals as well as local partners is needed for climate risk reduction and adaptation (USAID, 2018).

Since the 1970s, the government has initiated collective activities in environmental restoration and protection. NGOs have undertaken several activities in many villages with approaches called "food for work" and "cash for work" (CRS, 2012).

Mutual aid is also a consistent response to help meeting basic household needs. Remittances that are sent home by workers in cities or other family members like migrants are shared with others in the community. Community-led initiatives contribute to psychological and social well-being through restoring dignity and a degree of control to disaster-affected populations. Access to social and financial support through community activities helps to re-establish individual and community self-respect and identity, decrease vulnerability and enhance resilience (CRS, 2012).

4.2.3 Farmer and indigenous innovations

Production level in Niger is low because of inherently poor soil fertility and highly variable inter- and intra-annual precipitation. In some parts of the country where rainfall is too low for cropping, mobile livestock activities predominate. In the past, the fallow cultivation system prevailed in southern Niger. Farmers cultivated fields for 2 to 5 years, followed by a long period of fallow of more than 15 years. When a farm was left fallow, they cultivated other village fields. Since the population has increased enormously during the last twenty years, this system underwent great changes. An increase in agricultural production during that time for the growing population has only been accomplished by doubling the land area under cultivation from 23 to 50 million ha while yield per hectare of the most important crop, millet, decreased from 488 kg/ha (average 1961–69) to 377 kg/ha (average 1991–99). Moreover, besides fallow, other approaches of land restoration and management can be found in

Niger. These include among other techniques such as zero tillage, minimum tillage, stone lines, crop rotation, agroforestry, stones and zai (Sahelian agricultural technique consisting of sowing in holes that naturally concentrate water and fertilizers through simple runoff) (Issoufou et al., 2020). However, it has been demonstrated that zai and mulch is the most effective practice with the largest positive effects on the parameters compared to the other strategies in terms of productivity and climate change (Issoufou et al., 2020).

4.3 Policy level responses

Droughts recorded in the country combined with anthropogenic actions are gradually leading to desertification and the almost irreversible degradation of agricultural land and pastoral resources. Factual and objective data analysis shows that Niger is extremely vulnerable to climate variability and change for structural and cyclical reasons. This situation will not improve if sustainable and effective efforts are not made in order to increase climate resilience in the country. It has become imperative that the issue of climate change should be taken into account in the country's socio-economic planning and development process in order to provide adequate adaptation measures and build resilience to climate change. Adaptation and resilience measures need to be built on solid understanding of climate and its evolution, as well as a clear knowledge of its consequences on the main production sectors and socio-economic life.

Many achievements have been realized on climatic risks, vulnerability and its "hot spots" (zones and most vulnerable sectors), as well as on the anticipation of future climate change effects. However, there is a lack of synergy in the profusion of actions and programs, both within the actions of the government and between the different categories of actors, such as civil society or donors. These dysfunctions concern both the intrinsic difficulty of effectively managing such a large number of initiatives and the limited means and capacities of the planned coordination structures which need to be strengthened by adequate policy level responses.

4.3.1 Facilitating carbon trading

Voluntary carbon trading is a financing mechanism by which a country or an entity (administration, firm, individual) partially or totally replaces a source reduction of its own greenhouse gas emissions with an equivalent amount of carbon credits, by buying them from a third party. Thus, a country or an entity having more emissions of carbon purchases the right to emit more and the country or entity having fewer emissions sells the right to emit carbon to other countries or entities.

The national GHG emission was 30,801 $GgCO_2eq$ in 2000 and 35,900 $GgCO_2eq$ in 2008, and is projected to be 66,821 $GgCO_2eq$ in 2020 and 96,468 $GgCO_2eq$ in 2030. The country has planned to reduce its CO_2 emission by 30% by 2030 (INDC, 2015). The country's emissions are relatively low compared to those of industrialized countries. It can benefit from this advantage by selling its right to emit carbon to finance more carbon sequestration initiatives through afforestation and reforestation of valuable species. Therefore, with the support of technical and financial partners, carbon trading can help the country implement some development projects. One of the most important initiatives in the area is the Niger Acacia Senegal Plantation Project which aims to restore deforested and highly degraded land in the Sudano-Sahelian zone by empowering rural communities to adopt sustainable agro-forestry practices by establishing plantations using the native species *Acacia senegalensis* (Acacia Senegal). This project is an innovative public-private partnership. It planned the development of about 8,472 ha of Acacia plantations, expected to produce around 4,600 tons of Arabic gum each year at full capacity and sequester about 135,770 tCO2e by 2012 and over 313,008 tCO2e by 2017 which would amount to an annual average GHG emission reduction of 24,957 tCO2e.

To reduce household's wood consumption and related GHG emissions, improved cooking stoves (called Kiva-Hybrid) are implemented to replace traditional cooking stoves. This project not only

reduces worldwide greenhouse gas emissions but also improves the local populations' livelihoods. Indeed, it will help fight against deforestation, improve of indoor air quality, save money and reduce time collecting wood. The wood savings are assessed at an average of 1.5 tons/stove/year, which lead to 2.79 tCO_2e emissions avoided per year.

4.3.2 Land-use zoning and integrated landscape planning

Increasing demands on limited resources due to population growth coupled with the challenges of land degradation, biodiversity loss and climate change require the rational use of resources to sustain and enhance productivity and maintain resilient ecosystems. This prompted the country to adhere to the targets definition program on land degradation neutrality (LDN) in 2016 by appealing for financial and technical support from the United Nations Convention to combat desertification. Therefore, many related policies have been put in place since the precolonial period for sustainable land management (SLM). One of the latest policies in SLM in the country is the adoption of the forest law in Niger in 2004 which aims to improve the management of natural resources by giving the responsibility to the local population. Many institutions took part in SLM in Niger. These institutions include:

- Presidency of Niger
- National assembly
- CNEDD
- Ministry of Environment and sustainable development
- Ministry of agriculture
- And some national and regional institutes such as ACMAD (African Centre of Meteorological Application for Development), INRAN (Niger national institute for agronomic Research), AGRHYMET (regional center on Agriculture and Hydro-Meteorology).

By 2030, the country is projected to reach LDN by decreasing degraded land from 9 to 5% while increasing the vegetation cover from 17 to 19% in order to improve the livelihoods of the local population (NDT, 2018). The specific targets are (NDT, 2018):

- Restore 44% of degraded land till 2010
- Decrease the cultivated land showing a negative trend of net primary productivity to 2%
- Decrease the annual conversion rate of forests/savannahs/humid areas to other land cover types from 1% to 0%
- End silting and hydrological erosion along the River Niger
- Sequester about 292,000 tons of carbon by appropriate agroforestry practices.

Land is a scarce resource increasingly affected by the competition of mutually exclusive uses (*GIZ,* 2010). Fertile land in rural areas becomes scarcer due to population growth, pollution, erosion and desertification, effects of climate change, urbanization, etc. On the remaining land, local, national and international users with different socioeconomic status and power compete to achieve food security, economic growth, energy supply, environmental conversation and other objectives. Land use planning can help find a balance among these competing and sometimes contradictory uses.

The extent of environmental degradation and the low capacity of the various ecological units accentuates social conflicts over the use of natural resources (CNCA, 2003). Land issues arise because of both the crisis in which rural operators find themselves and the coexistence of several often-conflicting legal systems. An overall reflection on rural spatial management systems has been launched since 1982 with the creation of an ad hoc committee to reflect on the development of a rural code and to adopt the principles of rural management. The orientation of the rural code stipulates that: "natural resources are part of the common heritage of the nation and that all Nigeriens have an equal vocation to access them without discrimination of sex or social origin".

Most of the agricultural land in Niger consists of "dune" soils that have good permeability but are also characterized by low fertility and very high leachability. In addition, these soils are subject to wind erosion, which largely contributes to their depletion. The theoretically cultivable area corresponds to the Sahelian zone, to the Sahelo-Sudan zone and to the Sudanian zone, i.e. to a total of about 29 million hectares. Official figures admit that the 29 million hectares of arable land can be divided into 15 million hectares of directly arable land and 14 million hectares of forests. The forest resources currently barely cover 9 million hectares, of which 4 million are suitable for conversion. Parks and reserves cover 6.1% of the national territory. Classified areas are estimated at 600,000 ha. The area cultivated each year is around 4 million hectares with an annual growth of 100,000 ha. By comparing arable land (corresponding to about 2 ha per inhabitant, including forests) and the current demographic level, it turns out that the level of agricultural land use is very close to saturation, given capacity of load equal to 1.5 ha per capita in the Nigerien context. The total irrigation potential of the country is about 270,000 ha, of which only 78,000 ha are irrigated in water control including 13,000 ha in total control and 65,000 ha in partial control.

In addition to pastoral enclaves located in agricultural areas, the grazing areas themselves occupy about 35 million hectares under Sahelo-Saharan climates (100 to 300 mm).

The vegetation is of discontinuous contracted steppe type with an annual grass *herbaceous stratum* (*Cenchrus biflorus, Eragrostis Spp, Aristida Spp*) and a low shrub layer (*Acacias* and *Combretaceae*) on sandy or loamy substrate. Overgrazing and regression of the vegetation cover (100,000 ha/year) contribute to the reduction of rangeland productivity, the reduction of biodiversity through the disappearance of quality forage species (perennial grasses) and their replacement by invasive species with little or no palatability (*Sida cordifolia, Pergularia tomentasa*, etc.). In addition, the nutritional value of pasture acceptable during wintering decreases gradually during the dry season resulting in nutritional deficiencies (vitamin A deficiency). Many herds migrate from pastoral areas to agricultural areas in the dry season.

The fishing potential of Niger contains nearly 400,000 ha of water bodies spread over the Niger River, Komadougou, Lake Chad and the ponds located in the beds of temporary streams (MHA, 2017). However, it should be noted that successive large droughts and unfavorable factors related to fishing practices have led to profound changes in the functioning of aquatic ecosystems. The exploitable areas have been considerably reduced and overall production has fallen steeply and continuously since 1973, especially with the total withdrawal of Lake Chad from Niger territory which has caused the disappearance of 310,000 ha of water from the country.

Furthermore, Niger is one of the countries in West Africa with rich and varied wildlife. The country has conserved 6.1% of its national territory in the form of wildlife reserves, however the level required worldwide is 11%.

Many strategies have been developed by the government in order to promote integrated management of natural resources. The forest management scheme is a planning tool that aims to manage and sustainably use forest resources. It aims in particular:

- To stop the mining of resources by adjusting the quantities of forest that may be harvested and by promoting concerted management
- To ensure that the exploitation of forest products becomes a factor of rural development and the fight against poverty
- To promote good governance of forest resources, decentralized to local communities (related policies).

4.3.3 Payment for ecosystem services

Payments for ecosystem services (PES) are a relatively new approach to natural resource management and ecosystem restoration in which users of ecosystem services compensate landowners who protect,

enhance, or restore ecosystem services through their land management and land use decisions (MHE, 2012). Ecosystem and biodiversity services are important for society as they provide genetic resources, food, shelter, or climate regulation. Niger put PES into practice in 2007 and has specific organizations to control the finances. In Niger, the organizations in charge of the PES are government agencies such as the ministry of water and environment, NGOs, the Global Environmental Facility (GEF) and also the Niger Basin Authority (NBA) which is a joint organization of the countries sharing the Niger basin. For instance, for the NBA, the remuneration of ecosystem services includes land markets for major natural habitats, remuneration for the exploitation or management of biodiversity, for private access to species or a natural environment, biodiversity protection management methods, or remuneration for biodiversity compensation (UICN, 2015).

The main environmental services involved in this mechanism are carbon sequestration and storage, biodiversity conservation, and watershed protection (AfDB, 2015). The payment systems identified are quite similar and include:

- public payment systems for private owners,
- individual private transactions where the individual beneficiaries of ecosystem services contract directly with the providers of these services,
- tax exemption, which is a form of indirect compensation by the state for owners who protect ecosystem services,
- certification or eco-certification programs.

PES schemes will be able to make a marked contribution to poverty reduction if they pay program participants significantly higher prices than what recipients normally would earn from their land or the ecosystem services provided by the lands.

4.3.4 Securing land tenure

As shown by a number of empirical studies (Fenske, 2010; Pennec and Mamalo, 2010), in Africa there is a tendency towards the individualization of rights on space and resources with the regression of the community control, and the increasing monetarization of land transactions. Recent developments tend to change the principle of collective control, they consecrate the legalization of the land chief and especially the partition of the inherited lands.

Since the gradual withdrawal of the state from agricultural policy and the ever-increasing competition for land and natural resources, it became necessary to introduce new management systems for space. As a result, it was crucial to cope with new challenges (in particular to increase the productivity of the land) or to change or simply improve different ways of accessing land under the impetus of the state. The creation of private property of the land seemed to be the only institutional form capable of stimulating investments. For farmers, the fact that land becomes "private" and can therefore be exploited individually allows a certain security.

Land tenure reform in Niger has a history of conflict (Lawali et al., 2014). While land conflicts occurred prior to independence, their number and intensity have increased since then, due to population growth. The different authorities attempted in vain to solve the problem of tenure security engendered by inegalitarian control of land. In order to respond to this demand, the Nigerien authorities, with the introduction of the new Rural Code (Pennec and Mamalo, 2010), whose orientation principles date back to 1993, offer an institutional innovation in the form of titles or deeds written and registered by the competent authorities (territorial property commission or communal). It therefore represents a passage from oral recognition to written recognition of the property.

However, the most recent campaign, to design and implement a rural code to promote peace and security in rural areas, was not a success. Indeed, land privatization does not guarantee the process of land ownership by the operators (Mamalo at al., 2007). To secure land, farmers must prove that it belongs to them and pay a financial counterpart to institutions responsible for establishing the titles;

however, due to endemic poverty, most farmers are not able to fulfill the financial counterpart. Moreover, the lack of education makes it difficult for some to understand the complexities of the rural code (Mamalo at al., 2007). Land tenure security is closely linked to economic security: for farmers and their families, it provides for the possibility of production and brings complete freedom of exploitation. Therefore, there is a need to create conditions to secure owners' property. The main challenge of securing land tenure is its marginal implementation as well as emergence of conflicts without an effective dispute mechanism. Hence, governments, NGOs and partners should provide technical advice for better implementation (USAID, 2017).

4.3.5 Empowering women

In Niger, women represent 50.1% of the population (INS, 2011). Poverty has a rural and feminine face. Indeed, 3 out of 4 of those living in poverty live in rural areas, and 3 out of 4 of those living in poverty are women (INS, 2011). The country addresses the issue of gender-based violence from four perspectives: institutional, legislative, regulatory and from the angle of development programs. These initiatives included the creation of a ministry dedicated to women's empowerment and child protection, and the adoption and implementation of sensitive acts (laws and decrees) in line with African and International conventions on the protection of women and children. Under these acts are the adoption of a law punishing the perpetrators and accomplices of the practice of female genital mutilation, the adoption of a law establishing a minimum gender quota in nomination of parliamentary, regional and municipal representatives, and the law of orientation of the national educational system.

The empowerment of women is reflected in the strategy for sustainable development and inclusive growth. Several projects and programs contribute to the achievement of the goal of "making Niger a country free from gender-based violence, where men and women, girls and boys live in peace, harmony and without discrimination. Awareness of the issue of gender-based violence is carried out through programs like Niger "ILLIMIN" (knowledge) and the MARIAN SCHOOL initiatives. Other important initiatives are Women's Empowerment and Local Development Programs, which aim to build women's capacity through training and equipment, the program "Mata Masu Dubara" (women who know how to sort issues) which empowers women through revenue generating activities, and is a community-based child protection program that allows girls to express themselves and share the knowledge they acquired, and the Gender Integration Program in Humanitarian Actions, which aims to provide holistic care for women survivors of Boko Haram terrorist attacks.

In addition to these programs, the government has made provisions to make school compulsory until the age of 16, especially for young girls (INS, 2011).

Important achievements have been made in the fight against women's poverty, mainly through:

- Production of strategic documents on Women Empowerment and Child Protection;
- Creation of a position of a gender advisor at the Prime Minister's Office and at the Presidency;
- Creation of focal points on gender issues in the ministries;
- Revision of poverty reduction strategies to take into account inequality reduction and strengthening the social protection of vulnerable groups;
- Elaboration of the different Economic and Social Development Plans (PDES 2012-2015, 2017-2021) which put emphasis on women's empowerment and their role in the country's development;
- Elaboration of the National Gender Policy and its Decade Action Plan 2009-2018;
- Endowment of women's groups in menstrual hygiene products equipment for stain relief;
- Support of women's groups for economic activities, cattle raising and market gardening.

5 Evaluation of existing major policies and investments

5.1 Inventory of major policies and investments

Several strategies and policies have been carried out by different governments of Niger since independence to improve the agriculture sector in order to create adequate conditions for food security. During the last decades, the main adopted strategies are (World Bank, 2017; 2018):

- 2000-2011: adoption of the Rural Development Strategy;
- 2012-2019: promotion of the Economic and Social Development Program (PDES) and the 3N initiative (Nigeriens Nourish Nigeriens).

To reduce the vulnerability of rural areas, most of the interventions in the period 1987 to 2010 were focused on the rural sector. The developed policies and strategies include: Ordinance No. 92-30 of 8 July 1992, which laid down the "Guiding Principles for a Rural Development Policy for Niger" and Ordinance No. 93-015 of 2 March 1993 describing the Orientation Principles of the Rural Code, followed by the elaboration of real plans and programs. These are mainly the 1994 Comprehensive Food Security Program, the Economic Recovery Program adopted in 1998, the document "Diagnosis and Food Security Strategy for Niger" and the Sustainable Agricultural Growth Strategy in 1999 (Decree No. 99-531 / PCRN of 21 December 1999) and the Operational Strategy for Food Security in Niger (SOSA) in 2000 (Decree No. 2000-281/PRN of 4 August 2000). These guidelines were based on an integrated and coherent approach, including the redefinition of the roles of various actors, notably public actors, the promotion of the private sector, and the necessity to give more priority to the management of natural resources. These policies and strategies are first and foremost underpinned by the Poverty Reduction Strategy (2002), which became the Accelerated Development and Poverty Reduction Strategy (SDRP) adopted in 2007. The purpose of the SDRP is to reduce poverty in all its dimensions and achieve all the Millennium Development Goals (MDGs) set for 2015. The SDRP resulted in the set of sectoral policies and strategies, including the Rural Development Strategy (SDR). The SDR has named the rural sector the main driver of the country's economic growth by 2015. This predominant role given to rural development results from the importance of agro-silvo-pastoral production in GDP, the existence of sources for development growth and also the extent of poverty in rural areas. The latter, adopted in 2003, had the general objective of reducing the incidence of rural poverty from 66% to 52% in 2015. From 2012, the SDR was repealed and replaced by the 3N Initiative (Nigeriens Nourish Nigeriens) for food and nutritional security and sustainable agricultural development adopted by Decree 2012-139/PRN of 18 April 2012. Its overall objective is to help protect Nigerien people from hunger and to guarantee them the conditions for full participation in national production and the improvement of their income. It constitutes a major axis of the first Economic and Social Development Program (MP, 2012) adopted by the Government in August 2012 (PDES 2012-2015). Also, it should be noted that there are many constraints for the management of natural resources (water, soil, forest, etc.) and activities (agriculture, breeding, transport, etc.), which represent vital resources for the subsistence of the population. Despite all these efforts, access to adequate food is still a major challenge for most vulnerable populations. Development efforts are threatened especially by climate variability and change characterized by an increase in temperature, a high variability in rainfall and an increase in/or resistance of germs and disease vectors. Elsewhere, the relatively short period of the different development programs implemented in the country can also explain the limitations of applied strategies and policies.

To mitigate these situations, the country is engaged in a process of contextualization of regional and international policies and strategies. These include those of sub-regional and regional organizations: CILSS (Permanent Inter-State Committee for Drought Control in the Sahel), UEMOA (West African Economic and Monetary Union), ECOWAS (Economic Community of West African States), AU (African Union) and of the international conventions. Indeed, Niger has ratified several conventions and declarations, including the Maputo declaration for investments in agricultural development, the

Malabo declaration on agricultural transformation and the Abuja declaration on fertilizers. In addition, it is making strong efforts to implement the Sustainable Development Goals (SDGs), which the entire international community is committed to achieve by 2030, and the related AU Agenda by 2063. Furthermore, commendable efforts were made to provide the rural sector with policies and strategies to attain the expected results for sustainable development. In this perspective, it has adopted the Strategy for Sustainable Development and Inclusive Growth (SDDCI-Niger 2035), whose third axis (03) was "the modernization of the rural world". To operationalize this strategy, it has been translated into a new five-years Socio-economic Development plan (MP, 2017a), which includes the following strategic axes of development: (i) cultural renaissance; (ii) social development and demographic transition; (iii) the acceleration of economic growth; (iv) improvement of governance, peace and security and (v) sustainable management of the environment.

The acceleration of economic growth mentioned above is operationalized through the I3N strategy which focuses on the use of modern farming techniques, access to water, the value chains of agro-silvo-pastoral and fisheries productions, loans, handicrafts. Implementation of the National Food and Nutrition Security/Sustainable Agricultural Development Strategy of the "3N Initiative", aimed at ensuring sustainable agricultural development, food and nutrition security and resilience and thus achieving the ultimate goal "Zero Hunger ", is a decisive vector in improving economic growth. In addition, the Ministry in charge of agriculture has a policy document with the following specific objectives:

- improve the efficiency of administration and management of the agricultural sector;
- improve food and nutritional security through the control of water;
- increase and diversify production by modernizing rainfed agriculture;
- improve the environment and the quality of crop production;
- increase irrigated area;
- increase farmer revenues;
- improve the living standard of rural populations;
- increase the contribution of the rural sector to the economic growth;
- protect the environment and ensure a sustainable management of natural resources;
- use rural space for agricultural purposes in harmony with other uses;
- modernize agriculture;
- make agricultural products more competitive and ensure the development of the internal and external markets;
- provide social protection for farmers and agricultural sector workers;
- train agricultural actors;
- create jobs and reduce rural exodus;
- structuring and recognizing agricultural professions;
- put in place a system of incentives for private investment in agriculture;
- reduce the impact of climate, environmental and phytosanitary risks.

During the last decades, in addition to the socio-economic impacts that people already faced, climate change is amplifying environment degradation. To cope with the level of environmental issues, the Government of Niger adopted a National Environment and Sustainable Development Policy on the 28th of September 2016, defining a more coherent framework for intervention and investment. This document takes into account the Sustainable Development Goals (SDGs), the ECOWAS Environmental Policy and the WAEMU (West African Economic and Monetary Union) Common Environmental Improvement Policy, the Nationally Determined Contribution (CDN) of Niger (horizon 2030) prepared in the context of COP 21 (Paris Climate Agreement 2015) and the Strategic Framework for Sustainable Land Management (CS-GDT) and its 2015-2029 investment plan. The objective of this policy is to

provide favorable general conditions for economic, social and cultural development through the preservation and sustainable management of environment and natural resources and the strengthening of adaptation measures to the negative effects of climate change in order to ensure long-term food security and to improve living environments. The specific effects expected from this axis are: (i) the sustainable management of natural resources (land, water, biodiversity) and (ii) the adaption of the living environment of the population to climate change. Consequently, they contribute to the improvement of sustainable management of the environment (axis 5 of PDES 2017-2021). This environmental policy is supported by several other strategies in the field, including: the Nigerien Strategy and Action Plan for the Promotion of Non-Timber Forest Products (NWFP), the Climate Change and Variability Strategy and its action plan; the Biological Diversity Strategy and its action plan; the CS-GDT, etc.

To reduce environmental vulnerability to climate variability and change and to create the conditions of food security in the country, many development projects were implemented. The main projects, their amounts and objectives are presented in Table 2. In addition, major adaptation activities include the development of concerted management of water through management committees for national water basins and through the joint-commission and multilateral bodies for trans-border waters, along with the improvement of knowledge about the great fossil aquifers prior to exploitation (World Bank, 2018).

Table 2: Main projects implemented with their amounts and objectives

Project Title	Project Code Amounts	Description
Poverty Reduction	P-NE-IE0-002 – USD 12 M	The project objectives were to make available to disadvantaged groups a form of credit adapted to local realities as well as the beneficiaries' needs and repayment capacities; to facilitate access for poor people to basic community infrastructure; and to promote the development of civil society and the strengthening of institutional capacities of decentralized administrative services in the context of poverty analysis and monitoring. The project area was made up of the regions of Tillabéri, Dosso and Maradi.
PASEC	P153420 – USD 111 M	The proposed project's development objectives are to increase the adaptation to climate risks and to improve agricultural productivity at the target community level. The project will also help to improve the capacity of the government of Niger to respond promptly and effectively to any eligible crisis or emergency.
Disaster and risks management and Urban development	P145268 - USD 100 M	Prevent and manage disasters and risks in the country and to promote urban development.
Exports and agro-sylvo-pastoral markets Development Project	P148681 - USD 40 % (initial project); USD 13.6M	PRODEX supports the increase in the value of certain products, inter-professional organizations and the development of financing instruments. The PASEC Project will expand PRODEX's intervention in MSMEs and will continue PRODEX's actions in rural financing.
Community Action Program	P132306 - USD 40 M	CAP3's interventions focus on strengthening planning and implementation capabilities for local development.
Community Action project For Climate resilience	P125669 - USD 63 M	This project focuses on building the resilience of populations and production systems to climate variability and change in the targeted municipalities.

Project Title	Project Code Amounts	Description
Social net project	P123399 - USD 70 M	This project aims to establish and support a social safety net system that will improve access to cash transfer and community work programs for poor and food insecure populations.

(authors' elaboration)

To achieve food security, to preserve the environment and to improve population livelihood, energy is of key importance. According to the USAID Power Africa initiative for Niger, despite the relatively low electricity rate, Niger envisions reaching universal electricity access by 2035. However, Niger's ability to achieve this ambitious goal is constrained by significant challenges. Niger's government is working to expand its electricity supply and encourage investment in the energy sector to stimulate the economy. In 2015, Niger has already taken critical steps to improve energy markets by creating the regulatory body ARSE (Autorité de Regulation du Secteur de l'Energie) to increase transparency and fair competition among numerous energy actors. The government also created ANPER (Agence Nigérienne de Promotion de l'Electrification en milieu Rural), which is mandated to design, implement, and monitor rural electrification programs throughout the country. Other reforms include a joint ministerial order that eliminates taxes on domestic solar energy production kits and wind generation equipment to enable a larger number of households to access electricity, a new electricity act that will authorize the establishment of independent power producers (IPPs), and ongoing work with consultants and the African Legal Support Facility to bolster the legal and regulatory framework for mini-grids (Table 3).

Table 3: Solar energy projects along with their respective funders as well as the type of funders

Projects	Funders	Type
Solar Power system of Malbaza	EXIMBANK INDIA	solar power plantof 7MW
Rural Solar Electrification of 50 villages of Maradi, Zinder, Diffa and Agadez regions	EXIMBANK INDIA	small solar power plant and solar kits
Solar electrification of 50 villages in Niger	BIDC/CEDEAO	50 villages
Solar electricity (NESAP)	BM	Solar Kits Hybridization Mini-solar plant
Centrale Hybride d'Agadez	UE/AFD	13 MW solar 6 MW thermal
Off-grid systems (ROGEP)	BM	Solar kits and mini-grid
Hybridization of Goroubanda thermal center	UE/AFD	20 MW (hybridization)

(authors' elaboration)

From above, the country has learnt hard lessons from the past regarding the prolonged drought of the 1970s and 1980s as well as the drought and locust infestation of 2005, which caused food crisis and GDP drops. Hence, to meet the Sustainable Development Goals, a number of strategies can be envisaged:

- Taking action against land degradation;

- Strengthening communities' actions for sustainable land management;
- Incentivizing the use of renewable energy and modern energy for cooking to combat deforestation;
- Enhancing government effectiveness and rural laws;
- Improving access to markets and services.

5.2 Evaluation of key development policies and projects

The different governments of Niger have implemented several policies and strategies in order to ensure socio-economic development of the country. Some of these policies have been evaluated after implementation to identify the main strengths, weaknesses and constraints that prevented them from reaching their fixed objectives. Recently, in September 2019, the National Evaluation Policy (Politique Nationale d'Evaluation, PNE) was adopted. The overall objective of the PNE is to contribute to the promotion of good governance. The specific objectives are: to develop a culture of evaluation, to assess the progress made in terms of improving the living conditions of the population, and to propose corrective measures.

5.2.1 Evaluation of the poverty reduction project 1999-2007

The main objectives of this project were to make available to disadvantaged groups a form of credit adapted to local realities as well as the beneficiaries' needs and repayment capacities; to facilitate poor people's access to basic community infrastructure; to promote the development of civil society and to strengthen the institutional capacities of decentralized administrative services. The project covered the regions of Tillabéri, Dosso and Maradi. The project was planned for five years, from June 1999. The implementation of the project was based on a participative approach which involved representatives of administrative services, civil society organizations and the private sector, as well as representatives of beneficiaries.

The operational performance of the project was overall satisfactory as noted by the funder (FAD, 2009). The planned activities at appraisal of the project were completed at 96%. The project has contributed to improving the beneficiaries' living conditions.

However, at the beginning of the project, the Project Management Unit (PMU) had some difficulties in applying the Bank's rules on bidding procedures and administrative issues. Delay in the project implementation by 2 years and delays in disbursement and administrative processes meant that about 6% of the budget was returned to the funder (*FAD, 2009*).

5.2.2 Evaluation of the socio-economic development policy 2012-2015 (PDES 2012-2015)

The PDES 2012-2015 was designed as a "unifying framework ensuring the coherence and coordination of all short and medium terms of the development orientation frameworks at global, sectoral, thematic and local scale". It specifies Niger's strategic directions for "building an emerging country, built on a dynamic, diversified, sustainable economy that is harmoniously distributed over the national territory and, committed to promote African integration."

The PDES 2012-2015 was built around 5 development axes, 11 strategic results and an action plan priority made up with 86 programs, the implementation of which should be monitored by seven (7) sectoral committees: 1) Management of the Economy; 2) Economic Infrastructure; 3) Economic Promotion; 4) Health, Social Development; 5) Food Security; 6) Job and Training and: 7) Governance and Security.

The results of the PDES implementation were fairly average (MP, 2017b) in achieving the expected results. Certainly, compared to the baseline year of 2011, real progress is noted in various action programs. But they are below the ambitions displayed at the beginning of implementation. The PDES was developed in a participatory manner with the administration and national actors. However, a perception survey found some complaints from the actors at the base regarding their effective involvement in the implementation of the program. Also, the monitoring-evaluation system was not satisfactory because of a lack of some indicators and many identified indicators have no reference or target values. The monitoring and evaluation systems merge in certain aspects with the institutional implementation system. Indeed, the institutional implementation system included from its conception a number of shortcomings that likely impacted the coordination process of the implementation and also the production of regular technical and financial data on the achievements (*MP, 2017b*).

5.2.3 Evaluation of the Social Development Fund 2011-2015

The Social Development Fund (FSD) is a financing tool (CD / FSP) made available to the French Embassy in Niger to support the implementation of proximity projects carried out by local associations and more generally to support actors in Nigerien civil society (Roquigny, 2014). A total of 15 projects of the FSD 2011-015 were implemented. They cover a wide spectrum of themes, from basic education (primary cycle) and the literacy of young adults who have dropped out of school, to training and professional integration, to different aspects of rural development (support for family farming, the structuring of producer-breeders and the development of local value chains) and food security strengthening mechanisms (cereal banks, socio-economic reconstruction of livestock, etc.). The evaluation results show that the micro-projects supported by the FSD system have an important role to play in the targeted intervention sectors for education and vocational training, agricultural and food security and community development (Roquigny, 2014).

However, the FSD implementation has presented certain limitations. First, it depends on the capacities of the micro-project managers, which can sometimes be too weak to meet administrative and financial requirements. The lack of mastery of monitoring tools and the weakness in evaluation procedures considerably limit the promoters' appreciation of the real benefits of the projects and their possibilities of valuing and capitalizing on experiences. Finally, security and political context is a major handicap both for monitoring projects in the field and for the sustainability of the program (Roquigny, 2014).

6 Conclusions and policy implications

Niger is a landlocked Sahelian country affected by a great inter-variability of annual rainfall since the end of the 1960s. This variability is expressed by multi-year severe droughts and episodic floods during the last decades. Climate hazards have significantly impacted agriculture and other socio-economic sectors of the country. Unfortunately, despite the lack of consensus on climate projections by climate models for the future (up until 2100), three climate hazards (heatwaves, droughts and floods) present an increased trend in the country.

With the highest population growth rate in the world (3.8% per year), the country also had one of the lowest GDPs (414 USD/inhabitant) in the Sahel in 2018. Its economy is mainly based on agriculture and livestock, which are heavily impacted by climate variability and change. The recent droughts in the region coupled with high population pressure on natural resources has deteriorated land, vegetation and water resources, worsening the vulnerable population's livelihood.

Despite the improvement in the country's electricity access rate these last years, which has increased from 12% (1% in rural areas) nationwide in 2012 to an average of 18% (with around 6% in rural areas) in 2018, the energy sector continues to face serious challenges. There is a high need for investments, capacity building and source diversification in order to create the appropriate conditions for energy security in the country.

With regard to the consequences of the negative impacts of climate variability and change, recurrent droughts and related famines and the strong vulnerability of the population, the authorities have enacted many development programs which have already helped to restore some lands, vegetation and other resources. However, energy and water access are still at an undesirable state and many efforts should be advanced in these two sectors for a reliable supply. The food security and poverty levels are still also at a critical stage though many actions are being taking to solve these issues.

Nevertheless, Niger has many opportunities to improve livelihoods and thereby improve the national economy by addressing various sectors. Furthermore, the country is endowed with a tremendous amount of renewable energy resources, mainly solar energy and hydropower, on which policymakers could rely to boost the national economy through sustainable agriculture development and efficient environmental preservation strategy implementation. Hence, there is a need to formulate more robust strategic policies which will take into account the country's main challenges like food security, energy and water access, desertification and land management and will involve the main actors in the solutions search process.

7 References

Adam, T., Reij, C., Abdoulaye, T., Larwanou, M., Tappan, G., and Yamba B. 2006. Impacts des investissements dans la gestion des ressources naturelles (GRN) au Niger: Rapport de synthèse. Centre Régional D'enseignement Spécialisé en Agriculture (CRESA), Niamey, Niger et l'Université Libre D'Amsterdam, Pays-Bas., p.70.

Adams, C., and Eswaran H. 2000. Global land resources in the context of food and environmental security. Advances in land resources management for the 20th century. Soil Conservation Society of India, New Delhi, pp. 35-50.

AFTAR, 2009. Développement de l'irrigation au Niger: Diagnostic et options stratégiques. Revue Sectorielle de l'Irrigation, Rapport 493379 NE.

Alhassane, A., Soumana, I., Karim, S., Chaibou, I., Mahamane, A., and Saadou, M. 2017. Flore et végétation des parcours naturels de la région de Maradi, Niger. Journal of Animal & Plant Sciences, 34(1), 5354-5375. Available at: http://m.elewa.org/Journals/wp-content/uploads/2017/09/1.Alhassane.pdf. (Accessed December 02, 2020).

Amani, A., and Barmo, S. 2010. Contribution à l'état des connaissances de quelques plantes envahissantes au Niger. Cabinet du Premier Ministre, Conseil National de l'Environnement pour un Développement Durable.

Andres, L., Sambo, B., Dambo, L., Populin, M., Guero Chaibou, M., Moustapha, M., Seidou, L., Yamba, B., and Lebailly, P. 2015. La résilience des ménages face aux changements climatiques dans la région de Maradi au Niger: le cas de la Régénération Naturelle Assistée. Rapport technique. Available at: https://orbi.uliege.be/handle/2268/200577. (Accessed December 02, 2020).

Bello, O.M.M. 2012. Consommation des ménages en énergies domestiques dans la ville de Niamey au Niger. Mémoire. Université Abdou Moumouni de Niamey Niger - Master es sciences agronomiques 2012. Available at: https://www.memoireonline.com/01/14/8544/m_Consommation-des-menages-en-energies-domestiques-dans-la-ville-de-Niamey-au-Niger.html. (Accessed December 02, 2020).

Birungi, P.B. 2008. The linkages between land degradation, poverty and social capital in Uganda. PhD (Environmental Economics), University of Pretoria, South Africa. Available at: http://hdl.handle.net/2263/25109. (Accessed December 02, 2020).

Biasutti, M., and Giannini A. 2006. Robust Sahel drying in response to late 20th century forcings. Geophys. Res. Lett, 33(11). https://doi.org/10.1029/2006GL026067.

BM (Banque Mondiale) 2013. Evaluation des risques du secteur agricole au Niger: De la Réaction Aux Crises à la Gestion des Risques à Long Terme. Rapport numéro: 74322-NE. Available at: http://www.elevage.gouv.ne/IMG/pdf/niger-risk-assessment-french.pdf. (Accessed December 02, 2020).

Bonkaney, A.L. 2019. Modelling the potential impact of climate change and variability on electricity demand in republic of Niger. PhD Thesis, WACS, Futa, Nigeria.

Bonkaney, A.L., Madougou, S., and Adamou, R. 2017. Impacts of cloud cover and dust on the performance of photovoltaic module in Niamey. Journal of Renewable Energy. https://doi.org/10.1155/2017/9107502.

Bonkaney, A.L. 2015. Performance study of solar photovoltaic module in Niger. Master Thesis, Université Abdou Moumouni, Niamey, Niger.

Bonnassieux, A. 2015. Introduction: stratégies et dynamiques au Niger face aux contraintes environnementales. Les Cahiers d'Outre-Mer, 270, 101-113. https://doi.org/10.4000/com.7380.

Botoni, E., Larwanou, M., and Reij, C. 2010. La Régénération Naturelle Assistée (RNA) une opportunité pour reverdir le Sahel et réduire la vulnérabilité des populations rurales. In: Dia, A., and Duponnois,

R. (eds.), Le projet majeur africain de la grande muraille verte, pp. 152-162. Available at: https://books.openedition.org/irdeditions/2122?lang=de. (Accessed December 02, 2020).

Botoni, E. 2013. Réunion Partage de Connaissances du Réseau SAN, Ouagadougou 18-20 novembre 2013. Available at: https://www.fsnnetwork.org/sites/default/files/productivity_and_climate_change_-_part_1_2.pdf. (Accessed December 02, 2020).

Bull, W.B. 2013. Floods; degradation and aggradation. In Baker, V.R., Kochel, R.C., and Patton, P.C. (eds.), Flood geomorphology. New York, Wiley, pp. 157-165.

Burke, M.B., Miguel, E., Satyanath, S., Dykema, J.A., and Lobell, D.B. 2009. Warming increases the risk of civil war in Africa. Proceedings of the National Academy of Sciences (PNAS), 106, 20670-20674. https://doi.org/10.1073/pnas.0907998106.

Campbell, K.M., Gulledg, J., McNeill, J.R. et al. 2007. The age of consequences: The foreign policy and national security implications of global climate change. Washington DC, Center for Strategic & International Studies (CSIS) and Center for a New American Security (CNAS). Available at: https://www.csis.org/analysis/age-consequences. (Accessed December 02, 2020).

CEIPI (Centre d'Etudes et d'Information sur la Petite Irrigation) 2011. Projets et programmes de développement de l'irrigation au Niger (1960-2010): Eléments pour un bilan. Université de Lausanne, Belgique. Available at: https://reca-niger.org/IMG/pdf/Rapport_CEIPI_Niger_1960-2010.pdf. (Accessed December 02, 2020).

CILSS 2016. Landscapes of West Africa: A window on a changing world. U.S. Geological Survey. Available at: https://eros.usgs.gov/westafrica/land-use-land-cover-map. (Accessed December 02, 2020).

CNCA (Comité National du Code Rural) 2003. Revue nationale sur le foncier rural. Ministère du Développement Agricole, République du Niger. Available at: https://books.google.de/books/about/Revue_nationale_sur_le_foncier_rural.html?id=TUqFAAAAIAAJ&redir_esc=y. (Accessed December 02, 2020).

CNEDD 2014. Stratégie nationale et plan d'actions sur la diversité biologique, 2ème édition. Cabinet du Premier Ministre, Niamey, République du Niger. Available at: http://extwprlegs1.fao.org/docs/pdf/ner149318.pdf. (Accessed December 02, 2020).

CNEDD 2012. Africa Adaptation Program (AAP) Avant-Projet Document de Politique nationale en matière de changement climatiques. Cabinet du Premier Ministre, Niamey, République du Niger. Available at: https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/laws/8122.pdf. (Accessed December 02, 2020).

CNEDD/UNC/AAP 2011. Impact des Changements Climatiques sur le sous-secteur de l'élevage. Rapport provisoire. Conseil National de l'Environnement pour un Développement Durable, Niamey, Niger.

CNEDD 2009. Seconde communication nationale du Niger sur les changements climatiques. Conseil National de l'Environnement pour un Développement Durable, Niamey, Niger.

CNEDD/UNDP 2006. Programme d'Action National pour l'Adaptation aux changements climatiques. Rapport final. Conseil National de l'Environnement pour un Développement Durable and United Nations Development Programme, Niamey, Niger.

CRS 2012. Maximizing the Value of "Cash for Work". Lessons from a Niger land recuperation project: CRS EARLI. Available at: https://alliancecpha.org/fr/child-protection-online-library/maximizing-value-cash-work-lessons-niger-land-recuperation-project. (Accessed December 02, 2020).

Di Bartolomeo, A., Jaulin, T., and Perrin, D. 2011. Niger: Le cadre démographique-économique de la migration, Le cadre juridique de la migration, Le cadre socio-politique de la migration. CARIM – Consortium pour la Recherche Appliquée sur les Migrations Internationales, European University Institute. 12p. Available at: https://cadmus.eui.eu/bitstream/handle/1814/22442/migration%20profile%20FR%20Niger%20-%20links.pdf?sequence=2&isAllowed=y. (Accessed December 02, 2020).

DMN 2009. Actualisation des caractéristiques climatiques générales du Niger. Ministère des transports, Niamey, République du Niger.

Dodman, D., and Satterthwaite, D. 2008. Institutional capacity, climate change adaptation and the urban poor. Institute of Development Studies Bulletin, 39(4), 67-74.

Doocy, S., Daniels, A., Murray, S., and Kirsch, T.D. 2013. The human impact of floods: A historical review of events 1980-2009 and systematic literature review. PLOS Currents Disasters. https://doi.org/10.1371/currents.dis.f4deb457904936b07c09daa98ee8171a.

Duponnois, R. 2010. Le projet majeur de Grande Muraille Verte de l'Afrique. IRD ed., 151-162.

Duteurtre, G., and Faye, B. 2009. L'élevage, richesse des pauvres: Stratégies d'éleveurs et organisations sociales face aux risques dans les pays du Sud. Versailles, France, Ed. Quae. pp. 117–132

FAD (Fonds Africain de Développement) 2009. Projet De Réduction de la Pauvreté (PROJET N° P-NE-IE0-002). Rapport d'achèvement. 37p.

FAO 2018. Responses to the impacts of land and environmental degradation and desertification, Niger, 23-42.

FAO 2017. Land resource planning for sustainable land management Current and emerging needs in land resource planning for food security, sustainable livelihoods, integrated landscape management and restoration; Land and water division working paper; Rome, 2017.

FAO 2011. Gender and Sustainable Development in Drylands; Gender roles in drylands The advancement of women and gender equality are likely to help reduce; 17-24.

FAO/OECD 2011. Price volatility in food and agricultural markets: policy responses. Rome, FAO, coordinators, IFAD, IMF, OECD, UNCTAD, WFP, World Bank, WTO, IFPRI and UN HLTF, 48-54.

Fiorillo, E., Crisci, A., Issa, H., Maracchi, G., Morabito, M., and Tarchiani, V. 2018. Recent changes of floods and related impacts in Niger based on the ANADIA Niger Flood Database. Climate, 6(3), p.59. https://doi.org/10.3390/cli6030059.

Fowe, T., Karambiri, H., Paturel, J-E., Poussin, J.C., and Cecchi, P. 2015. Water balance of small reservoirs in the Volta basin: A case study of Boura reservoir in Burkina Faso. Agricultural Water Management, 152, 99–109. https://doi.org/10.1016/j.agwat.2015.01.006.

Gado, S. 2015. The energy sector of Niger: Perspectives and opportunities. Occasional Paper. Energy Charter Secretariat, Brussels, Belgium. Available at: https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/Niger_Energy_Sector.pdf. (Accessed December 02, 2020).

GIZ 2010. Land use planning: Concept, tools and applications. Gesellschaft für Internationale Zusammenarbeit (GIZ), Eschborn, Germany. Available at: https://europa.eu/capacity4dev/eu-working-group-land-issues/documents/land-use-planning-concept-tools-and-applications. (Accessed December 02, 2020).

GIZ 2012. Bonnes pratiques de CES/DRS. Contribution à l'adaptation au changement climatique et à la résilience des producteurs: Les expériences de quelques projets au Sahel. Ministère fédéral allemand de la Coopération économique et du Développement (BMZ); Division Développement rural, Alimentation mondiale. Available at: https://reca-niger.org/IMG/pdf/Bonnes__pratiques-CES-DRS-GIZ.pdf. (Accessed December 02, 2020).

Heitschmidt, K.R., and Stuth, J.W. 1991. Grazing management, an ecological perspective. Portland, OR, Timber Press.

IEA 2016. World Energy Outlook. Available at: https://www.iea.org/topics/world-energy-outlook. (Accessed December 02, 2020).

INS (Institut National de la Statistique) 2015. Rapport sur les migrations. Ministère de l'économie et des finances, Conseil National de la Statistique, Niamey, Niger. 74p

INS (Institut Nationale de la Statistique) 2011. Le Niger en Chiffres, Ministère de l'économie et des finances, Conseil National de la Statistique, Niamey, Niger. 80p.

INS (Institut Nationale de la Statistique) 2011. Rapport sur rapport sur la situation socioéconomique des femmes. Ministère de l'économie et des finances, Conseil National de la Statistique, Niamey, Niger. 80p.

IRENA (International Renewable Energy Agency) 2019. Renewable Energy Statistics 2019 . Available at: https://www.irena.org/publications/2019/Jul/Renewable-energy-statistics-2019. (Accessed December 02, 2020).

IRENA (International Renewable Energy Agency) 2013. Renewables Readiness Assessment: Niger. International Renewable Energy Agency, 1-72. https://www.irena.org/publications/2013/Dec/Renewables-Readiness-Assessment-Niger (Accessed December 04, 2020)

Issoufou, A.A., Soumana, I., Maman, G., Konate, S., and Mahamane, A. (2020). Dynamic relationship of traditional soil restoration practices and climate change adaptation in semi-arid Niger. Heliyon, 6(1), e03265. https://doi.org/10.1016/j.heliyon.2020.e03265.

JGRC (Japan Green Resources Corporation) 2001. Guide technique de l'élevage. Documentation technique de la JGRC Générer l'abondance dans le Sahel par la lutte contre la désertification Vol. 7. Available at: https://www.pseau.org/outils/ouvrages/jgrc_guide_technique_de_l_elevage_2001.pdf. (Accessed December 02, 2020).

Kirui, O., and Mirzabaev, A. 2015. Costs of land degradation in Eastern Africa. ZEF Working Paper Series No. 128. Available at: https://www.zef.de/uploads/tx_zefportal/Publications/ZEF_Working_Paper_128_complete_01.pdf. (Accessed December 02, 2020).

Lawali, S., Mormont, M., and Yamba, B. 2014. Gouvernance et stratégies locales de sécurisation foncière : étude de cas de la commune rurale de Tchadoua au Niger. VertigO - la revue électronique en sciences de l'environnement, 14(1). https://doi.org/10.4000/vertigo.14723.

Luxereau, A. 2014. Les agricultures nigériennes face à la désertification. In: Amadou, B. et Dambo L., dir. - Sahel entre crises et espoirs. Paris, L'Harmattan, pp. 151-158.

Mabey, N. 2008. Delivering climate security: International security responses to a climate changed world. Whitehall Paper 69, Royal United Services Institute. London: Routledge.

Mahamadou, Y., Mounkaila Saley, M., and Fode, M. 2018. Analyse multimodèle régional de climat des régimes de précipitations et de températures au Niger. La Météorologie - n° 101, pp. 50-61. https://doi.org/10.4267/2042/67430.

Mahamane, A., Saadou, M., Amadou, O., Abdoulaye, Boubé M., and Zaman Allah, M. 2011. Guide de planification d'inventaire forestier au Niger, DAF, R, RT, FAO, 32p.

Mahé, G., Paturel, J., Servat, E., Conway, D., and Dezetter, A. 2005. The impact of land use change on soil water holding capacity and river flow modelling in the Nakambe River, Burkina-Faso. Journal of Hydrology, 300(1-4), 33-43. https://doi.org/10.1016/j.jhydrol.2004.04.028.

Mamalo, A.K., Bretel, J.M., and Chabbert, J. 2007. Processus d'élaboration et de mise en œuvre du Code Rural au Niger – Bilan et perspectives. Secrétariat Permanent du Code Rural du Niger. Available at: https://dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/883/Code_Rurale_Niger.pdf?sequence=1. (Accessed December 02, 2020).

MCE (Ministère en Charge de l'Environnement) 2010. Projet de Promotion de la Foresterie Urbaine et Péri-urbaine dans la Lutte contre les Changements Climatiques au Niger. Niamey, Niger. pp. 1-11. Unpublished.

MEL (Ministère de l'élevage) 2012. Stratégie de Développement Durable de l'Elevage, République du Niger. Available at: http://www.elevage.gouv.ne/IMG/pdf/sddel-2.pdf. (Accessed December 02, 2020).

MHA (Ministère de l'Hydraulique et de l'Assainissement) 2017. Plan d'Action National de Gestion Intégrée des Ressources en Eau, PANGIRE Niger. République du Niger. Niamey, Niger. Available at: https://www.pseau.org/outils/ouvrages/mha_plan_d_actions_national_de_gestion_integree_des_ressources_en_eau_pangire_2017.pdf. (Accessed November 02, 2020).

Moussa, S., Kyereh, B., Tougiani, A., Kuyah, S., and Mahamane, S. 2019. West African Sahelian cities as source of carbon stocks: Evidence from Niger. Sustainable Cities and Society, 101653. https://doi.org/10.1016/j.scs.2019.101653.

Moussa, S., Matalabi, A.A., Bassirou, I.D., and Saadou, M. 2016. Systematic composition, life forms and chorology of agroforestry systems of Aguié Department, Niger, West Africa. JALSI, 8(4), 1-12. https://doi.org/10.9734/JALSI/2016/29138.

Moussa, B., Nkonya, E., Meyer, S., Kato, E., Johnson, J., and Hawking J. 2015. Economics of Land Degradation and Improvement in Niger. In: Nkonya, E., Mirzabaev, A., and von Braun, J. 2016. Economics of land degradation and improvement: A Global Assessment for Sustainable Development. Springer Cham, Heidelberg, New York, Dordrecht, London, pp. 499-539.

Moussa, S. 2013. Socioéconomique, Mémoire de Masters 2. Département de Biologie, Université de Maradi, Niger, 1-80p.

Mossi Maïga, I., Malam Harouna, S., and Maï Moussa, C. 1999. Gestion technique et organisation sociale et foncière de l'irrigation: diagnostic agronomique, foncier et hydraulique du périmètre de Karaigorou. INRAN, 29p.

MP 2017a. Plan de Développement Economique et Social (PDES 2017-2021), République du Niger, 199p.

MP 2017b. Evaluation du PDES 2012-2015. Rapport final – 30 Mars 2017. 126p.

MP (Ministère du plan) 2012. Plan de Développement Economique et Social du Niger (PDES 2012-2017), République du Niger, Ministère du plan, Niamey.

Ndiaye, A., Adamou, R., Gueye, M., and Diedhou, A. 2017. Global warming and heat waves in West-Africa: Impacts on electricity consumption in Dakar (Senegal) and Niamey (Niger). International Journal of Energy and Environmental Science, 2(1), 16-26. https://doi.org/10.11648/j.ijees.20170201.13.

NDT 2018. Processus de definition des cibles de neutralite en matiere de degradation des terres. Rapport Final du Programme de Définition des Cibles de NDT, République du Niger.

Nellemann, C., Verma, R., and Hislop, L. (eds). 2011. Women at the frontline of climate change: Gender risks and hopes. A Rapid Response Assessment. United Nations Environment Programme, Nairobi, Kenya.

Nigériens nourrissent Nigériens (3N). 2012. Cadre stratégique et coût estimatif des programmes de l'initiative pour la période 2012-2015. 1-62p. Available at: https://reca-niger.org/IMG/pdf/STRATEGIE_ADOPTE-18_AVRIL2012_VF.pdf. (Accessed December 02, 2020).

Nkonya, E., Mirzabaev, A., and von Braun, J. 2016. Economics of land degradation and improvement: A Global Assessment for Sustainable Development. Springer Cham, Heidelberg, New York, Dordrecht, London, pp. 695.

OEC 2018. Niger (NER) Imports, Exports Trade Partner. Available at: https://oec.world/en/profile/country/ner. (Accessed December 02, 2020).

Oguntunde, P.G., Lischeid, G., and Abiodun, B.J. 2018. Impacts of climate variability and change on drought characteristics in the Niger River Basin, West Africa. Stochastic Environmental Research and Risk Assessment, 32, 1017-1034. https://doi.org/10.1007/s00477-017-1484-y.

Okpara, N.J., Tarhule, A.A., and Perumal, M. 2013. Study of climate change in Niger River Basin, West Africa: Reality not a myth. pp. 5-13. https://doi.org/10.5772/55186.

Ouendeba, B., and Siaka, S.B. 2014. Le mil [Pennisetum glaucum (L.) R. Br.] au Niger: généralités et résultats de la sélection. IRD Éditions, 2004, p. 33-43. Available at :

https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers18-12/010033997.pdf. (Accessed December , 2020).

Pennec, J., and Mamalo, A.K. 2010. Code rural du Niger: une gestion décentralisée et concertée du foncier. Grain de sel, nº 49 — janvier – mars 2010. Available at: http://www.coderural-niger.net/IMG/pdf/GDS_mars_2010_Code_Rural_Niger.pdf. (Accessed December 02, 2020).

Roquigny, S. 2014. Evaluation externe continue du Fonds Social de Développement 2011-15. Rapport mi-parcours de l'évaluation externe du dispositif FSD 2011-015. Service de Coopération et d'Action Culturelle, Ambassade de France, Niamey, Niger. 85p.

Rossi, B. 2015. The development of 'development', 1946–1983. In: From Slavery to Aid: Politics, Labour, and Ecology in the Nigerien Sahel, 1800–2000. African Studies, pp. 202-255. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781316340578.008.

Saadou, M. 1998. Evaluation de la biodiversité biologique au Niger: éléments constitutifs de la biodiversité végétale. Conseil National de l'Environnement pour un Développement Durable.

Save the Children 2009. Comprendre l'économie des ménages ruraux au Niger. Save the Children, London, UK. Available at: https://resourcecentre.savethechildren.net/node/1563/pdf/3838_0.pdf. (Accessed December 02, 2020).

Studer C. nd. Pastoralisme et gestion des parcours. Technologie GDT : Pâturage tournant – Afrique du Sud. P162-175. Available at: http://www.fao.org/3/i1861f/i1861f10.pdf. (Accessed December 02, 2020).

Tanimoune, I.L. 2018. Study for the potential sites for solar PV implementation in the city of Niamey using GIS based approach. Smart Grid and Renewable Energy, 8, 394-411.

Tanser, F.C., Sharp, B., and Le Sueur, D. 2003. Potential effect of climate change on malaria transmission in Africa. Lancet, 362(9398), 1792–1798. https://doi.org/10.1016/S0140-6736 (03)14898-2.

Thébaud, B., and Batterbury, S. 2014. Sahel pastoralists: Opportunism, struggle, conflict and negotiation: A case study from Eastern Niger. Global Environmental Change, 11(1), 169–178. https://doi.org/10.1016/S0959-3780(00)00046-7.

Thiombiano, L., and Tourino-Soto, I. 2007. Status and trends in land degradation in Africa. In: Sivakumar, M.V.K., Ndiang'ui, N. (eds), Climate and land degradation: Environmental Science and Enginieering, pp. 39-53. https://doi.org/10.1007/978-3-540-72438-4_2.

Turner, M.D., Ayantunde, A.A., Patterson, K.P., and Patterson III, E.D. 2011. Livelihood transitions and the changing nature of farmer-herder conflict in Sahelian West Africa. Journal of Development Studies, 47(2), 183-206. https://doi.org/10.1080/00220381003599352.

Warren, A., Batterbury, S., and Osbahr, H. 2011. Soil erosion in the West African Sahel: A review and an application of a "local political ecology" approach in South West Niger. Global Environmental Change, 11(1), 97-95. https://doi.org/10.1016/S0959-3780(00)00047-9.

World Bank 2018. Tackling climate change in Niger; The 3N initiative "Nigeriens feed Nigeriens" is aimed at improving food security; In Niger, drought is by far the greatest risk facing the country; 42-47.

World Bank 2017. Republic of Niger, Priorities for ending poverty and boosting shared prosperity: systematic country diagnostic. Report No. 115661-NE, pp126. Available at: https://openknowledge.worldbank.org/handle/10986/28994?show=full&locale-attribute=fr. (Accessed December 02, 2020).

World Bank 2009. Impacts of sustainable land management programs on land management and poverty in Niger. Revue scientifique 2. Available at: https://openknowledge.worldbank.org/handle/10986/3050?show=full. (Accessed December 02, 2020).

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Photo: Bernhard Tischbein

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Germany

Phone: +49-228-73-1861
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