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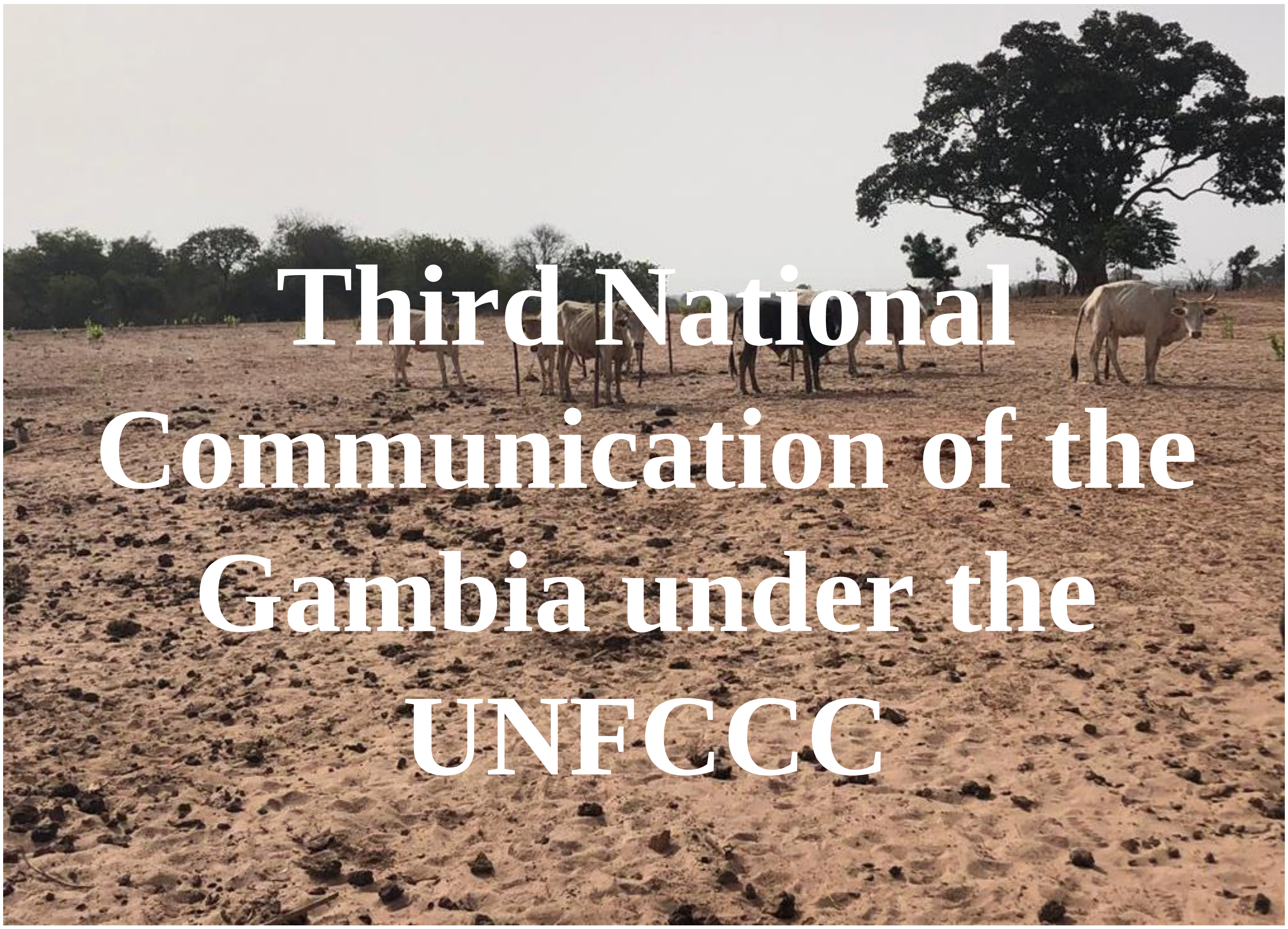

Third National Communication of the Gambia under the UNFCCC

Banjul **July 2020**

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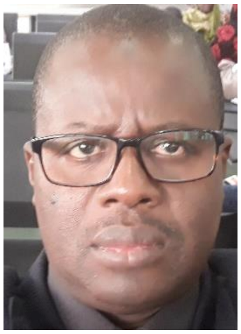

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Foreword

On behalf of the Government of the Republic of The Gambia, it is an honour and privilege to present The Gambia's Third National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change.

The Gambia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 and became obligated to submit national communications as per requirement of the UNFCCC. The Initial National Communication (INC) of The Gambia was presented to the UNFCCC in 2003 and the Second National Communication (SNC) in 2013. The Third National Communication (TNC) is a follow up to the SNC. Since the submission of the SNC, much has happened at national level. The Gambia, in particular, has developed its National Determined Contribution (NDC) to the Paris Agreement 2015, and other key policy and strategic documents such as the National Climate Change Policy (NCCP) 2016, Low Emission Climate Development Strategy (LECRDS) and Strategic Programme for Climate Resilience (SPCR), in its efforts to address challenges and seize new opportunities presented by climate change.

The Gambia's SPCR spearheaded by MECCNAR is a comprehensive transformational adaptation and mitigation investment plan, designed to reduce and manage the country's high vulnerability to climate variability and change, and in so doing, to secure catalytic financing from international and national climate financing sources, thereby making the SPCR a key building block in country's quest for a successful transition to a low-emissions climate-resilient development pathway. Specifically, the programmatic approach of The Gambia's SPCR entails a long-term, strategic arrangement of linked investment projects to maximise synergistic effects, take advantage of co-financing opportunities, and achieve long-lasting impacts in the following priority thematic areas:

- **Climate resilient food and landscapes:** Agriculture, food security, forestry and natural resources, including water, biodiversity and wildlife
- **Low emissions and resilient economy:** Energy, transport, infrastructure, and the key economic sectors of tourism and financial services
- **Climate resilient people:** Health, education, equitable social development, migration and human settlements, including climate proof urban planning and waste management, climate information and early warning system
- **Managing coastlines in a changing environment:** climate-aware Integrated Coastal Zone Management, including coastal erosion management
- **Infrastructure and waste management:** developing climate proof infrastructure, sanitation and solid waste management.

With a successful 1st Phase of the Pilot Programme for Climate Resilience (PPCR) now behind us, The Gambia is well-positioned to embark on the 2nd phase of the PCCR commencing with the mobilisation of funds through bankable project proposals drawing upon the Concept Notes contained in the SPCR.

In collaboration with the International Institute for Environment and Development (IIED), the government has embarked on the development of a long-term strategy aiming to achieve net zero carbon emission by 2050. Within that dynamics, The Gambia has started the process of reviewing its Intended Nationally Determined Contribution (NDC) within the framework of the National Climate Change Policy, with support of UNDP, and expects to submit a revised INDC to the UNFCCC by the end of 2020.

The Third National Communications of The Gambia under the UNFCCC provides a quantitative assessment of greenhouse gas emissions from the major economic sectors and activities of the country, develops plausible climate change scenarios for assessment of the potential impacts of the projected climate change on some key sectors of the national economy. The potential impacts of climate change on crop production, forestry, fisheries, and rangelands and livestock have been assessed in great detail. As was the case however with the SNC, detailed cost-benefit analyses of mitigation and adaptation measures are omitted due to inadequate capacity.

Doubtless, adaptation to a changing climate is not an option but a necessity for The Gambia in view of its economic and social vulnerability to climate change, but there is an imperative need to strengthen institutional and the human resources base of the country to bring about effective implementation of adaptation policies and measures. The Gambia has mitigation potential in some sectors like energy and waste but funding also remains the limiting factor for exploring such opportunities. Despite these limiting constraints, The Gambia committed more than ever to participating in different regional and international activities on climate change.

Hon. Lamin B. Dibba, Minister
Ministry of Environment, Climate Change and Natural Resources
Banjul, The Gambia

Acronyms

AfDB	African Development Bank
AWS(s)	Automatic Weather Station(s)
CBG	Central bank of The Gambia
CILSS	*Comité Inter-états de lutte contre la Sechresse au Sahel*
CRR	Central River Region
DHI	Danish Hydraulic Institute
DJF	December, January and February
DOF	Department of Fisheries
DOSF&NR	Department of State for Forestry & Natural Resources
DWR	Department of Water Resources
ECOWAS	Economic Community of West African States
EUMETSAT	EUropean organisation for the exploitation of METeorological SATellites
ERC	Energy Research Centre (University of Cape Town, South Africa)
FAO	Food and Agricultural Organisation
GBOS	Gambia Bureau of Statistics
GCAA	Gambia Civil Aviation Authority
GEF	The Global Environment Facility
GHG(s)	Greenhouse gas(es)
GMD	Gambian Dalasi
GOTG	Government of The Gambia
GPA	Gambia Ports Authority
GRB	Gambia River Basin
GT Board	Gambia Tourism Board
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
JAS	July, August and September
LDCF	Least Developed Countries Fund
LRR	Lower River Region
MAP	Mean Annual Precipitation
MECCNAR	Ministry of Environment. Climate Change, and Natural Resources
MOBSE	Ministry of Basic and Secondary Education
MOFEA	Ministry of Finance and Economic Affairs
MOHERST	Ministry of Higher Education, Research, Science and Technology
MSU	Michigan State University
NAMA	Nationally Appropriate Mitigation Action
NAPA	National Programme for Adaptation
NBR	North Bank Region

NCAR	(US) National Centre for Atmospheric Research
NCEP	(US) National Centers for Environmental Prediction
NDMA	National Disaster Management Agency
NDP	National Development Plan
NEA	National Environment Agency
NMHS	National Meteorological and Hydrological Service
PCA	The Portland Cement Association
QUT	Queensland University of Technology
SDGs	Sustainable Development Goals
SNC	Second National Communication
TNC	Third National Communication
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UNESCO	UNITED Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
URR	Upper River Region
USD	United States Dollar
UTG	University of The Gambia
UV	Ultraviolet
WASCAL	West African Science Service Centre on Climate change and Adapted Land Use
WCR	West Coast Region
WMO	World Meteorological Organisation
WTO	World Tourism Organisation

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Executive Summary

Mandatory on signatories to the United Nations Framework Convention on Climate Change (UNFCCC), this Third national Communication is in fulfilment of The Gambia's obligations under the said convention.

1. The Gambia's Third National Communication (TNC) under the United Nations Framework Convention on Climate Change (UNFCCC) follows in the footsteps of its Second National Communication (SNC) in 2013, in accordance with reporting requirements stipulated in Articles 4 and 12 of the said convention. Similar to its predecessor, the TNC documents the status of socio-economic and ecological conditions as they relate to greenhouse gas emissions and vulnerability to climate change as well as steps taken by The Gambia toward implementation of the UNFCCC which the country ratified in 1994.

Geographically, The Gambia is a low-lying coastal country wherein the climate, landscapes, ecosystems and real economy are to a greater or lesser degree shaped by regional atmospheric and marine circulation systems. Predominantly covered by savannah woodland, the country has a rich diversity of plant and animal life-forms, but a tendency towards over-extraction of resources leading to environmental resources depletion and degradation. With a predominantly youthful population, and majority of workers employed in the agricultural sector, the county is still short of achieving food self-sufficiency due to low labour productivity, among other factors. Agriculture, light industries, and personal consumption are principal sources of greenhouse gas emissions. The Gambian Ministry of Environment, Climate Change and NAtural Resources (MECCNAR) has overarching responsibility for implementation of climate policy, whilst other government ministries are responsible for specific aspects of climate policy as it relates to their portfolios.

2. Lying on the eastern seaboard of the Atlantic Ocean, The Gambia's exclusive economic zone (EEZ) is more than double the size of its land area of 11,300km^2, the smallest on the African continent. By virtue of its geography, the country's Sudano-Sahelian climate, landscapes and ecosystems are (strongly) influenced by regional and global atmospheric circulation systems (West African monsoon, north-easterly trade winds, El Niño/La Niña weather) and transboundary fluxes of water and nutrients from the Gambia River Basin and Canary Current both of variable intensity at different times of the year and/or during particular years.

3. On a sub-national scale, principal climate parameters (temperature and rainfall) exhibit spatial variations governed by locational and landscape factors including the presence of

and proximity to large water bodies. Regardless however, observational records indicate that the average length of the rainy season has decreased by at least 6 days over the last 30 years, whilst surface temperatures have increased by 0.4°C to 0.67°C per decade, over the same period.

4. A low-lying coastal state (i.e. 10% to 20% of the country seasonally or diurnally flooded), The Gambia is almost divided in half into northern and southern landmasses by the River Gambia, which flows in sweeping meanders from East to West and debouchs through a wide estuary into the Atlantic Ocean. The morphology of the Gambia's Atlantic coast is defined by a succesioon of bays bounded by headlands. Some bays are fronted by uninterrupted stretches of sandy beach, whilst others are dissected by coastal streams notably Kotu stream and River Tanji, flowing out to the ocean. Mangroves populate long stretches of the River Gambia and coastal streams. Protected area covering 352 km^2 (3.3% of country) provides sanctuary and life-cycle habitat for rare and endangered species of global importance, as well as for 100+ fish species, and 500+ species of birds. Through a decades-long process of land use conversion, savannah woodland is currently the dominant forest cover (52% of land area of which 84% is of savannah woodland). Both cropland area (32% of land area) and settlements (2% of land area) have steadily increased in size over the last half-a-century to meet rising social demand. Invariably, settlements with large populations are collocated with important commercial and cultural hubs served by major transportation highways. In particular, the Greater Banjul Area (GBA) incorporating Kanifing Municipal Area (estimated population: 385,000), accounts for approximately 80% of the formal economy. Concomitantly, built-up areas and local economies exert inordinate pressures on the natural environment accelerating natural resource depletion and environmental pollution.

5. The Gambia's population of 2 million is a socially cohesive composite of people belonging to 10 ethno-linguistic communities, and immigrants mostly originating from other West African countries. Similar to previous censuses, the population remains a predominantly youthful population, with children and young adults below 30 years making up approximately three quarters of the population.

6. Within the country's school system (under which 42% of establishments are privately run under charter granted by the Ministry of Basic and Secondary Education), gross enrolment ratios (GER) are on average 101.6%, 56.6% and 45.2% in primary (Grades 1-6), upper basic (Grades 7-9) and secondary schools (Grades 10-12). The national healthcare delivery system is run by 16,000 certified medical professionals representing 1.1 doctors for 10,000 people; 1.3 community health nurses for 10,000 people, and 1.5 midwives for 10,000 people. In 2015, government budgetary allocation was 10.6% of total revenues, and its expenditure equivalent to 5.7% of GDP.

7. An open economy, the Gambia mainly exports groundnuts, cashew and fish products, while its imports are dominated by food, petroleum products, machinery and other equipment, making the country vulnerable to adverse developments in the global economy. Gross Domestic Product (GDP) in 2015 was USD939 (current prices) and USD491 million (constant prices), of which slightly more than one-fifth is attributed to diaspora remittances. A thriving informal economy could be as large as 40% the size of the formal economy. Four-fifths of the working-age population are employed, with a large majority engaged in the agriculture and natural resources (ANR) sector. Joblessness is far worse among people aged between 15 and 35 years, who are four to five times more likely to be out of work, and have, in recent years, left the country in their thousands in search of their fortunes elsewhere.

8. Between 2015 and 2016, agricultural output grew by 1%, whilst the industrial sector contracted by 3%. On the other hand, service industries registered an aggregate growth of 4%. Specifically, wholesale and retail, communication, finance and insurance sectors are the most dynamic sectors of the Gambian economy and main drivers of growth. The ANR sector is dominated by extensive rain-fed agriculture organised around family production units. The agribusiness sub-sector remains under-developed, and market linkages with domestic, regional and international markets are under-exploited. Livestock production, albeit supported by improved animal welfare services and market opportunities, remains essentially unchanged from traditional pastoral systems. Almost all major industries are located in the GBA. Light industries focus *inter alia* on the manufacture of plastic products, detergents, and beverages. Medium-sized enterprises scaling down to cottage industries produce a variety of goods including garments, footwear, jewelry, furniture and fabricated metal structures. The services sector comprises business establishments of different sizes, with those employing more than 20 people concentrated in major population areas.

9. Under the country's political system of electoral democracy, sustainable development policy instruments are co-developed by persons holding elective office (head of the executive and legislators), in collaboration with public officials appointed legally empowered to do so on the basis of specific statutes, and due regard to contributions from civil society and the Gambian public. Legislators are tasked in particular with crafting/adoption of legislation, ratification of treaties, keeping local and national development issues in the public policy space, and general oversight of executive branch of government and its agents. The Ministry of Environment, Climate Change and NAtural Resources (MECCNAR) has overarching responsibility for implementation of climate policy. Other ministries are responsible for specific aspects of climate policy as it relates to their portfolios. To that effect, an Inter-Ministerial Coordinating Committee (IMCC) on climate change is co-chaired by the Permanent Secretaries from the MECCNAR and

MOFEA (Ministry of Finance and Economic Affairs), the latter being the Designated National Authority (DNA) for the Green Climate Fund (GCF).

Whereas the national greenhouse gas (GHG) inventory does not cover specific sources, overall emissions accounted for have increased by 15% since 2000, and by 70% since 1993. By contrast, sulphur hexafluoride (SF_6) and hydrofluorcarbons (HFCs) emissions reflecting the gradual phase-out of ozone-depleting substances (CFC12, HCFC22, RSO2, HCFC134a) in refrigeration, air conditioning, and electrical equipment. In the 2000 inventory, direct greenhouse gases; carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) account for 82% of all GHG emissions. The Agriculture, Forestry and Land Use (AFOLU) emissions category has the largest (62%), and Waste category the smallest (3%) carbon footprint. Fluxes from agricultural soils are found to be the principal sources of carbon dioxide; swamp rice cultivation, livestock production, and biodegradation of solid waste the key sources of methane; and burning of agricultural residues the key source of nitrous oxide. Residential applications constitute the most prolific source of indirect GHGs (CO, SO_2, NMVOCs and NO_x). Sulphur dioxide (SO_2) emissions are associated with power plants, whereas road transport is the principal source of oxides of nitrogen (NO_x) emissions.

10. The Gambia's TNC provides a summary of the country's greenhouse gas (GHG) emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorcarbons (PFCs), sulphur hexafluoride (SF_6) and hydrofluorcarbons (HFCs) for 2010, as contained in its National Inventory Report (NIR) for the same year.

11. During the inventory year 2010, GHG emissions from Gambian territory amounted to 4,043 Gg of carbon dioxide equivalent (Gg CO_2 eq). Compared with 2000 and 1993 data, this represents an increase of 15% and 70%, respectively. A little more than three-fifths (61.2%) of emissions is attributable to the agriculture, forestry and other land use (AFOLU) source category, whereas a 35% originates from industrial processes and product use (IPPU) and energy source category, in about equal measure. Handling and disposal of solid (and liquid) waste streams generates less than 3% of total emissions reported.

12. GHG emissions from the energy source category in the NIR is limited in scope to fuel combustion activities. GHG emissions from fugitive sources, or indirect GHG emissions associated with CO_2 transport and storage are not considered because economic and industrial activities associated with these two source categories did not exist in the Gambia at the time of the inventory in 2010. Thus, total GHG emissions reported is 620Gg CO_2 eq., with transport (TRN) and energy industries (ENI) releasing 89% of CO_2 emissions, whilst "Other Sectors" generate 87% and 99% of N_2O and CH_4 emissions, respectively. The residential sub-category within "Other Sectors" represents the largest source of CO (105Gg) and NMVOC (18Gg) emissions.

13. GHG emissions from the IPPU source category totaled 778Gg CO_2 eq. The largest contribution by far (705Gg CO_2 eq or 91%) to IPPU emissions comes from HFCs generated through the use of substitutes for ozone-depleting substances (ODSs) in refrigeration, air conditioning, aerosols and fire retardants. CO_2 share of IPPU sector emissions (19GgCO_2 eq) derive from the earth mineral industry and industrial processes involving the use of solvents and other chemical products. On the other hand, CH_4 emissions (44GgCO2 eq) stem from food and beverage industry operations. At the time of reporting, neither metallurgical nor electronic industries had taken root in The Gambia. Light and small-scale industries focus *inter alia* on the manufacture of foam and plastic products, detergents, and beverages.

14. GHG emissions generated from biodegradable waste accounts for the totality of GHG emissions reported (116GgCO_2 eq). This statistic does not include un-assessed emissions from wastewater, or emissions generated through incineration of solid waste.

15. Emissions of GHGs from the AFOLU source category in 2010 added up to 2,514GgCO_2 eq. About 53% of these emissions came from agricutural production activities (i.e. crop cultivation and raising livestock), and the remaining 47% from forest and land use (FOLU) changes. The inventory further reveals that emissions associated with agriculture are dominated by CH_4 from rice cultivation (34%), CH_4 from enteric fermentation (29%), and CO_2 fluxes from agricultural soils (25%). CO_2 emissions from forests were computed as 1,334 GgCO_2 eq. In combination with emissions from forest soils (967GgCO_2 eq), aggregate emissions from forestry and land use (FOLU) adds up to 2,301GgCO_2 eq. Taking into consideration CO_2 absorption (1,109GgCO_2 eq) by soils and vegetation in other wooded lands, net FOLU emissions are reported as 1,182GgCO_2 eq.

16. From the perspective of gaseous composition of GHG emissions, CO_2 emissions (1,090 GgCO_2 eq) account for 26% of national emissions, or 32% of emissions when GHGs controlled under the Montreal Protocol are excluded. CH_4 emissions (1,914GgCO_2 eq) in 2010 represent 47% of national emissions, and 57% of emissions excluding GHGs controlled under the Montreal Protocol. N_2O emissions (338GgCO_2 eq) in the NIR represent 8% of national total emissions, and increases to 10% if GHGs controlled under the Montreal Protocol are excluded from the inventory total.

17. HFC emissions (705GgCO_2 eq) in 2010 represent 17% the total national emissions. HFCs are generated almost exclusively from substitutes for ozone depleting substances (ODSs) used in refrigeration and air conditioning (311GgCO_2 eq), and in aerosols (308GgCO_2 eq). Trace emissions (8GgCO_2 eq) were associated with the use of

fire retardants. PFC emissions were not estimated (and consequently not reported in the 2010 GHG inventory report. SF_6 emissions (1.1GgCO_2 eq), generated entirely within the operational environment of high-voltage electricity transmission, amounts to 0.03% the national emissions.

18. Emissions of indirect GHGs (CO, NMVOCs, NO_x and SO_2) were solely estimated for the energy source category. With the exceptions of SO_2 and NO_x, the NIR found that residential applications generated between 45% and 97% of all indirect GHGs. Indeed, energy was the key sources of SO_2 emissions (1.2 Gg SO_2 or 70% of total), whilst road transport accounted for 34% of NO_x emissions (1.11Gg).

19. As a direct reflection of the country's tourism industry and external trade, Banjul International Airport and Banjul Seaport have both been expanded to handle higher volumes of cargo and passenger throughput. Assessed emissions attributable to international aviation was 29.9 GgCO_2 and 0.001 GgN_2O, for the year 2010. In addition, emissions attributed to international water-borne navigation were 23.5 GgCO_2, 0.002 GgCH_4, and 0.001 GgN_2O.

20. Comparative analyses of GHG inventories in 1993, 2000 and 2010 indicates dynamic changes in emissions across all classes of GHGs. CO_2 emissions from energy industries in particular, continue to rise as the sector expands to meet increasing domestic, industrial and commercial electricity demand. Transport, which is another key source of CO_2 emissions, albeit struggling to keep pace with demand, continues to grow in tandem with urban and inter-city travel and haulage of goods. HFC and SF_6 emission inventories initiated in the year 2000 indicate negative trends reflecting to some extent the gradual phase-out of CFC12, HCFC22, RSO2, HCFC134a and their in refrigeration, air conditioning, and electrical equipment.

Global circulation models - GCMs (CCC199, BMRC98 and GDFL90) used in the TNC substantially agree on expected changes in average temperature in the future. However the GCMs do not agree on the intensity of xerification, and contrast sharply with an increase in average rainfall reported in recent studies using regional climate models - RCMs. Associated uncertainties in precipitation therefore suggest the use of alternate wet and dry climate scenarios to explore the range of possible impacts. Adverse impacts in agriculture, forestry, fishing, construction and real estate sectors, and the Gambian tourism industry, are amplified and/or accelerated by losses in productivity of land resources (arable land, grassland, forests); water, nutrient and sediment fluxes, and scarcity of sand for building purposes. Natural forest cover and crops with access to dependable sources of water are least affected under a dry future. Higher annual precipitation values generally translate into higher levels of production in all

biomes. Some parts of the country are expected to experience lower rates of groundwater renewal and higher runoff reflecting differences in rainfall and surface geology. Anticipated impacts on public health are diverse, from increasing cases of heat stress dehydration among vulnerable groups, to the spread of allergens (dry climate) and resurgence of endemic diseases emanating from favourable conditions for spread of water-borne diseases (wet climate). The future of beach resort tourism faces the challenge by destination attractiveness linked to milder winters in source countries in northern Europe, and adverse changes in coastal morphology. Most other environmental changes accruing from climate change within the geostrategic coastal zone presage huge risks for the sustainability of ecosystems and viability of specific elements of human systems, and quality of life of the resident population. A re-adjustment of the local economy would be in order to further consolidate growth of service sector industries over the next three decades.

21. The trio of global circulation models (GCMs); CCC199, BMRC98 and GDFL90, were run with different radiative forcings to generate an ensemble of temperature, precipitation, evapotranspiration time series at ten year intervals, up to the year 2100. Projected changes in mean sea level were adopted from the Intergovernmental Panel on Climate Change (IPCC) fourth Assessment Report (AR4)

22. Relative to the year 2000, annual mean temperatures in the Gambia are estimated to increase by 1.7 to 2.1 ºC in 2050, and by 3.1 to 3.9ºC in 2100. Stronger warming is expected in winter (DJF) compared to summer months (JAS). Annual rainfall is projected to decrease by a minimum of 2% (CCCM199) and maximum of 54% (BMRC98) by the year 2100. However, recent studies using the US National Centers for Environmental Prediction (NCEP) and National Centre for Atmospheric Research (NCAR) datasets in HadGEM2 climate simulations indicate that a positive trend in annual rainfall cannot be discounted, inviting caution and use of sensitivity analyses in applications using rainfall projections. In all model outputs, potential evapotranspiration (PET) is projected to increase to between 1,370mm and 1,945mm by 2100, that is, an increase of 2% and 45% above historical levels. Expected sea rise in sea levels is in the order of 19cm to 43cm by 2050. Limitations of and uncertainties in all projections emanate principally from incomplete understanding of underlying physical processes, digital representation of those processes, and quality of observational data (used for model calibration).

23. Unmitigated biological and physical impacts of climate change (up to 2050) on ecosystems, landscapes, seascapes, economic activities and society were assessed. Anticipated impacts on land and water resources, agriculture, forestry, construction and real estate sectors, and tourism industry, are assessed from a short-term perspective. Climate change impacts on the Gambian coastal zone, fisheries and healthcare sectors are assessed on multi-decadal

time scales, to reflect impact receptors' differential exposure and sensitivities to synchronous climate stresses and shocks.

24. Under the scenario of decreasing rainfall which approximates a persistent pattern of successive drought years over a period of nearly three decades starting in the late 1960s, soil salinisation and acidification in lowland areas is expected to intensify, thus exerting additional pressure on marginally productive soils or soils already exposed to climate stressors. Whilst extreme rainfall events are strong triggers for gulley and sheet erosion in sloping upland areas and deposition of inert sediments in at the foot of slopes and in lowlands, increased runoff at the watershed scale could improve the restorative impact of annual floods on alluvial soils in backswamps and flood-plains of the River Gambia.

25. Excluding confounding factors such as human disease, fire, and human pressures, biomass production within forests and grasslands will largely depend on edaphic factors and projected changes in climate, particularly mean annual precipitation (MAP).

26. Phytomass production in grasslands, under an MAP between 600 and 800mm, is estimated to range between 337 and 1,443 g/m^2, with below ground biomass (BGB) accounting for over 80% of biomass within this biome. Concomitantly, grassland species composition is expected to progressively shift towards drought-resistant annual grasses exemplified by creeping, shallow-rooted grasses. By comparison, biomass production under MAP fluctuating between 1,000 and 1,200 mm, is estimated at 367 to 1,554 g/m^2, an increase of 9.0% and 7.7% respectively with respect to semi-arid conditions, a result attributed by some researchers to the resilience of grasslands under variable precipitation regimes. In large parts of the country, favourable growing conditions are expected to speed up the dominance of tall and perennial grasses over annual grass species.

27. Regarding lowland forests, riparian forests benefitting from augmented dry season flows in the River Gambia are expected to be least affected by a low precipitation regimen. Annual fluctuations of freshwater inflow into mangrove forest will be a key determinant of mangrove forest structure, growth and productivity in brackish environments. The combined onslaught of lower rainfall, intensified soil and open water evaporation, and prolonged tidal inundation sustained by sea level rise are expected to escalate saline and anoxic conditions with a strong likelihood of massive mangrove mortality in lower estuary areas. In well-drained soils, outside the River Gambia flood-plain, savannah forest is expected to shrink in overall size whilst simultaneously becoming more fragmented to the advantage of grasslands, but average stocking volume of remnant savannah is still expected to grow by 13% at least or 2.76t/ha by 2050, in response to CO_2 fertilisation. Forest densification, upward shift of tree diameter sizes, and higher growth of 6.53t/ha or 25% by 2050 is expected under a wetter climate.

28. Under a semi-arid climate future, annual recharge of the shallow sandstone aquifer is estimated at 30mm to 66mm (268Mm^3 to 591Mm^3) by 2050, reflecting the stochasticity of MAP and hydrological effects of projected land cover transformations. Under MAP of 1,000mm and 1,200mm, average recharge is projected to decrease from 85mm (750Mm^3) to 77mm (689Mm^3) respectively, as a larger proportion of effective rainfall is diverted to surface runoff. Local recharge which is projected to be higher in West Coast Region (WCR) and southern parts of Central River Region (CRR) and Upper River Region (URR) than in North Bank Region (NBR) and Lower River Region (LRR). Natural flows in the perennial freshwater stretch of the River Gambia is projected to vary between –30% and +9% relative to flows observed at Kuntaur in the 1970s and 1980s (168m^3/s) under semi-arid conditions, and to increase by 38% to 161% under wet conditions. Interactions between surface and ground water along the course of the River Gambia still remain open to investigation. Future operations of the dam pallned to be built at Sambangalou (Senegalese-Guinean border) are expected to downgrade natural peaks flows, augment low flows and generally modify mean flows to fit with multiple objectives of dam operation.

29. Mindful that crop yields are influenced by the interplay between crop genetics, environmental controls, pest control, and crop management systems (including soil fertility amendment, water control), a progressively drier climate is expected to depress yields of major crops grown in The Gambia. By 2050, yields are expected to change under rain-fed agriculture as follows: −17 to 0% (millet), −25% to −15% (sorghum), –22 to 0% (maize), −18% (groundnuts), with the possibility of losses being amplified by nitrogen stress. Climate change impacts on sesame are less clear, with yield changes of −23% to +33% exhibiting strong dependence on sowing date. Swamp rice yields are expected to remain at current levels as long as crop cycle water demands are not compromised, or growing areas degraded by soil salinisation or acidification. Likewise, horticultural crop yields remain relatively insulated from climate change insofar as crop water demands are met. Studies relating to favourable growing conditions under a wetter climate future suggest a 26% increase in millet yields, and 9% to 25% increase in groundnut yields. Combined with information on expected loss of agriculturally suitable land, millet is expected to register production gains of 18%, and groundnuts 8% to 13% by 2050.

30. Essentially pastoral in their operations, livestock production systems in The Gambia are mirror climate change impacts on net primary productivity of naturally-occurring pasture, under different pluviometric futures. Notably, provisioning services of grasslands under low rangeland productivity is expected to drastically limit resident herds to 87,000 tropical livestock units (TLUs), that is, a 75% reduction relative to current herd size) by 2030. Conversely, a wetter climate is expected to boost carrying capacity of grasslands to 637,000 TLUs (i.e. 86% increase relative to current herd size) within the same time span. Insofar

as extra feed resources are available through transhumance and supplementary feeding, afore-mentioned stocking capacities especially lower ones could increase significantly. Whereas, distance to drinking water points and water availability is unlikely to represent a production constraint under future climate, latent conflicts between farmers and herders may be transformed into overt conflicts during protracted periods of poor harvests and pasture conditions.

31. As in the past, cropland expansion and logging are expected to be the major driving force behind forest cover loss. Under specific assumptions on land use changes, particularly the percentage area of productive forest, expected volume of roundwood and fuelwood production from Gambian forests ranges between 694,850 m^3 (i.e. – 68% relative to 2013) and 3,392,293 m^3 (i.e. +53% relative to 2013) by 2030. Low and high estimates of wood production by 2050 lie within the range of 463,233m^3 (i.e. –79% relative to 2013) and 3,043,087m^3 (i.e. +37% relative to 2013). Climate change impacts on non-energy, non-timber products (NENTPs) such as honey, wild edible fruit and nuts, gum arabic, leaves, bark, from which some households derive their livelihood, has not been studied.

32. Despite strong dependence of the tourism industry on weather and climate, climate change impacts are yet to be studied in earnest. As mean winter temperatures rise in key source countries in Northern Europe, a long-term warming trend poses serious challenges to the Gambia's destination competiveness. By mid-century, beach loss to relentless sea level rise and wave action driven by high impact weather events, will diminish shoreline attractions, degrade amenities and restrict recreational activities in space and time. A smaller number of expected winter tourist arrivals and summer visitors, sustained over a period of time, exposes tour operators to greater financial risk, and is likely to jeopardise the profitability of tourism establishments (unless the industry re-invents and successfully markets itself).

33. Although locally relevant information is limited, climate change impacts on construction and real estate sectors of the economy could be significant. Engineering work in particular is likely to suffer from disruptions in the supply chains of construction material such as sand, partly driven by shoreline changes and beach erosion, and roundwood due to relatively slow increase in production from natural forests. Thus, future construction projects are very likely to be more costly due to input prices and insurance slowing down progress in urban development and regeneration, and home ownership. In 2016, home ownership was 56% (downward from 78% in 2013), reflecting a growing gap between social demand and access to land, and housing finance as well. High impact windstorms are more likely to be prejudicial to processes pursued and activities undertaken by medium- and micro-sized construction enterprises during July through October.

34. Although failure probabilities of specific fisheries arising from aggregate extraction rates of artisanal and industrial fleets are not quantified, there is a risk that environmental and human pressures, including illegal, unreported and unregulated (IUU) fishing activities, might precipitate the collapse of some fisheries. Based on the available evidence, there is no end in sight to the downward trend in demersal fisheries. Arguably, pelagic species with short population doubling times such as *Sardinella maderensis* (Madeiran Sardinella) and *Caranx crysos* (Blue Runner) are expected to be most resilient to fishing pressure and ecosystem changes. Irrespective of the climate change signal, recovery of benthic species with long population doubling times remains in doubt. Shellfish fisheries are quite likely to gain from higher mangrove productivity under higher freshwater inflows, but warmer water temperatures and higher pollutant loading of wetlands under a wetter climate future are quite likely to depress harvested tonnage of shellfish In addition to compromising food safety. There is no assessment of climate change impacts on shellfish fisheries (i.e. oysters and cockles), dominated by fisherwomen operating within the lower estuary of the River Gambia.

35. Under a warmer and wetter climate future, prospects for the resurgence of some endemic diseases emanating from favourable environmental conditions for breeding mosquitoes, the geographic spread and persistence of other health-threatening agents, abetted by inadequate environmental sanitation infrastructure, cannot be discounted. Although it stands to reason that people living in areas/households with inadequate access to safe water supplies are most exposed to enteric diseases; and persons who fail to take protective measures against mosquitoes and other biting insects are more vulnerable than the average person to diseases transmitted through insect bites, only a small minority of the population is insulated from infections contracted through contact with water-borne pathogens and toxins. Residents of low-lying areas, children, farmers, and professional launderers represent population sub-groups most exposed to diseases transmitted through water contact. As habitats for mosquitoes expand, dense forest stands close to human habitations are a serious cause for concern regarding public health threats of Zika.

36. Severity of water-based public health threats are generally attenuated and possibly suppressed under a drier climate future whereby airborne transmission of allergens and pathogens constitute the major pathway for infection of an otherwise healthy young population with meningitis and/or measles.

37. Sporadic heat waves accentuated by the urban heat island effect are likely to increase in intensity and duration leading to minor and severe cases of heat stress, dehydration among vulnerable population sub-groups, and to fatalities actuated by increased concentrations of ground-level ozone and vehicle tail-pipe.

38. Specific climate change impacts on the geostrategic coastal zone are qualified as direct or associated impacts on natural and human systems within and around the marine, estuary, littoral, and interfluvial domains.

39. Within the marine domain, warming of the water column between the Gambian shoreline and 500m isobath is expected to continue unabated well beyond 2050. At depths below 100 metres, temperatures could increase by 0.1°C per decade. Anticipated changes in the thermal structure of the water column are also expected to dampen the intensity of coastal upwelling (of colder nutrient-rich water) and translocate the active upwelling zone inshore towards the edge of the continental shelf. In conjunction with nutrient fluxes from the River Gambia estuary, the altered marine environment is expected to usher in changes in the population structures and geographic distribution of marine species including emblematic *S. maderensis*, *S. aurita* and shad (*Ethmalosa spp*.). Not much is known about seabed sediments and the prospects of benthic communities. However, adverse impacts of ocean warming is likely to be strongest among bottom-dwelling species with little or no opportunity for range expansion under changing environmental conditions.

40. Rising sea levels are expected to trigger the migration of mangrove stands into contiguous swamp-rice production areas rendered unproductive by salt accruing from rising groundwater and tidal inundation of marginal croplands in tidal floodplain within in lower estuary areas. The resultant re-wilding of the current buffer zone between settlements and mangrove stands would most likely lead to increased human-wildlife conflicts and further endangerment of threatened and rare species such as the monitor lizard, crocodile, and boa species living in close proximity to human settlements. Furthermore, wetland shrinkage in specific areas is likely to reinforce negative impacts on pollution abatement efficiencies with adverse effects on shallow coastal waters, aquatic species, resident and migratory species. Lower harvests of bony fishes, crustaceans and shellfish, threatens livelihood strategies of fisherwomen living around the Tanbi National Park and ecotourism (at Mandinaray). The United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Heritage site on Kunta Kinteh Island (formerly James Island), is projected to come under increasing pressure from wave erosion and partial submergence by rising water levels in the Gambia estuary. Subject to proper location, environmental and social impact assessments (ESIA), aquaculture is one of the few industries that could benefit from sea level rise.

41. Certain coastal infrastructure including berthing facilities, roads, culverts, bridges and dykes designed with safety margins, will remain relatively safe from sea level rise by 2050. In contrast, infrastructural assets owned and/or operated by beach resorts are increasingly imperiled by extreme shoreline erosion. Several high-voltage electricity pylons, inaccessible by foot at high tide, will need to be relocated on higher ground. Rising

temperatures are likely to compromise the operation of oxidation ponds in Kotu, which will probably need to be replaced by a conventional Waste Water Treatment Plant (WWTP). Likewise, environmental sanitation infrastructure need to be retrofitted to cope with rising sea levels and a wetter climate future. Productivity of boreholes located within 3 km of the coastline would be decreased by restrictive operating guidelines meant to minimise the risk of saline intrusion. Without adequate drainage infrastructure, runoff generated on relatively strong ground slopes has been the cause of serious damage to (unsurfaced) roads under extreme rainfall events, and will continue to do so in both northern and southern provinces of the coastal zone, under a wetter climate.

42. In combination with a potentially more energetic wave climate on the open coast, sea level rise is expected to alter coastal morphology significantly. Net accretion of sediments is projected around the Bald Cape, Barra Point and on the curved spit in Banjul, by 2050. The Bijol Islands, currently a nesting and roosting site for terns (*Sterna spp.*) and the grey-headed gull (*Larus cirrocephalus*), is expected in the future to develop into a viable nesting site for the green turtle (*Chelonia mydas*) as sand accretes over time on these offshore islands. By contrast, sediment starvation of erodible landforms located between Tanji and Bakau will lead to their progressive degradation. Local topography will be a key determinant to the size and fate of tidal lagoons, tidal marsh, mudflats, salt pans and fringe vegetation in the lower estuaries of both the Tanji and Allahein rivers. In the northern province of the coastal zone, a dynamic equilibrium of sediment accretion and erosion is expected to maintain stable beach profiles on the Atlantic seafront of the Niumi National Park. Within this protected area, which forms a single ecological entity with Parc du delta de Saloum (in Senegal), wildlife species threatened by landscape and ecosystem changes include the green turtle (*Chelonia mydas*), cape clawless otter (*Aonyx capensis*) and manatee (*Trichechus senegalensis*).

43. Explosive growth of relatively small settlements, and their subsequent fusion into the Greater Banjul Area (GBA) located on the southern province of this domain, owes a lot to rural-urban migration initiated by protracted drought starting in the 1960s, and subsequently sustained by destination attractiveness. Currently, modernisation has taken over as the major driving force for land use conversion and urbanisation in the southern province of the coastal zone.

44. Against the background of significant improvements in transport and basic services in the northern province of the coastal zone over the next few decades, a warmer and drier climate regimen coupled with diminishing space and regulatory restraints in the southern province of the coastal zone, is expected to stimulate rapid expansion of and coalescence of settlements into a new metropolis located on the spur connecting Karang/Amdalai to Fass

and Ginack-Kajata. Although, transformation of the agricultural landscape is likely to occur at slower pace under a wetter climate, long-term adverse effects of upland soil degradation, loss of agricultural productivity, and precarity of farm-based livelihoods, are quite likely to amplify the scale of land use conversion from agriculture to residential purposes.

45. In the southern province, increased atmospheric CO_2 tends to promote productivity of diverse vegetation species and augurs well for biomass stocks in remnant woodland, private orchards and gardens, commercial/private woodland (Nyambai Forest), and protected areas (Furuya National Park, Abuko Nature Reserve). However, these green spaces remain susceptible to protracted drought, pest outbreaks and encroachment. A drier climate is expected to usher in a host of challenges to urban agriculture (irrigated plots in Bakau, Banjulunding, and few other places). Increasingly, water-stressed monospecies plantations are likely to be replaced by more drought-resistant species.

46. Uncertainties surrounding the typology and scope of climate change impacts are linked to public investment scheduling (quality of infrastructure and services; health, electricity water, roads), novel housing finance options, youth employment, growth of micro and small scale medium enterprises (MSMEs), and socio-political landscape. Concomitant with land use changes (and area-wide impairment of ecosystem services), a re-adjustment of the local economy is expected to further consolidate growth of service sector industries over the next three decades. However, expansion in some service sectors is likely to be curtailed by financing constraints and natural resource scarcities. Paradoxically, sand scarcity could be a force for innovation and rapid/accelerated switch to eco-architectural building designs. A worst case scenario involves a slump in housing and infrastructure development, leading to a housing and infrastructure crisis (in terms of investment/replacement costs, impaired services, overcrowding).

Building and sustaining long-term resilience and short-term response/coping capacities to unexpected events is primarily premised on cultivating awareness about climate and related risks at all levels of society, enhancing decision-making at individuals/household and other organisational levels within society, and creating options/avenues for empowerment of actors. Translation of common meteorological terms and key climate science concepts into local languages, multiple training initiatives for different audiences at different times augurs well for awareness-building. Although, new and country-driven scientific research is beginning to take root, postgraduate research needs to be guided by a national agenda that that takes advantage of new datasets (from state-of-the-art scientific infrastructure) to narrow down specific knowledge gaps, provide deeper insights on climate risks and other environmentally-related

themes of public interest, creates/demonstrates the need for new data, and stimulate integration of new knowledge in climate-sensitive sectors. In parallel, new knowledge needs to be disseminated through informal and formal channels including school curricula, websites, public symposia, and written policy briefs. For this to successfully unfold however, there is a pressing need to set up a premier climate change research cluster to undertake high-level issues-based research, and improvements in (physical and virtual) research infrastructure; contributing to full implementation of the UNFCCC and meeting the expectations of government, development and other major stakeholder groups.

47. Confronting the vagaries of future climate change, while addressing human activities that contribute to global warming is primarily premised on agile capacity building through education and research, empowerment of actors, technological improvements, and implementation of other activities contributing to the attainment of UNFCCC objectives, and national development imperatives.

48. The Ministry of Basic and Secondary Education (MoBSE) continues to champion environmental education and awareness through curricula reforms, periodical training workshops, and its interactions with communities across the country. Since the publication of the country's SNC in 2013, the University of The Gambia (UTG) has graduated two cohorts of Gambian and international students on climate change and education, under the West African Science Service Centre on Climate change and Adapted Land Use (WASCAL) signature capacity-building programme. In addition, the UTG is offering an MSc Programme in Physics that offers renewable energy as one of several possible specialisations. Scores of other Gambians have been trained in African, Caribbean, and European countries, in diverse specialisations (meteorology, hydrology, data science, ecology, public health, agriculture, science, technology, engineering and mathematics) at different competency and academic levels (technician to PhD), to fill in systemic capacity gaps. Most graduates are employed with government agencies, and the remainder with non-governmental or business organisations.

49. Non-academic training is also provided to different target groups to boost individual and group awareness of, familiarity with, and competencies in specific climate risk and management themes. With financial support from the United Nations Development Programme (UNDP), a one-week crash course on the science of climate change and its potential impacts and appropriate response strategies, targetting middle-level managers in the public sector, was successfully carried out in 2014. With the Global Environment Facility (GEF) funding support, scores of senior policymakers from across government ministries have also received training on key technical and administrative aspects of policy review through a climate change and development lens, under the Climate Change Early Warning System (CCEWS) Project. Under the aegis of the Gambian Ministry of Higher Education, Research, Science and Technology (MOHERST), UTG has conducted a series

of seminars on climate change and adapted land use, and climate change and renewable energy, with funding support from the German Federal Ministry for Education and Research (BMBF). Through its postgraduate studies programme and commissioned research, UTG is advantageously positioned for disseminating scholarly research findings through public symposia and written policy briefs.

50. A glossary of the most common meteorological terms featuring in public weather forecasts, translated into three local languages by the National Meteorological and Hydrological Service, in collaboration with and financial support from the CCEWS Project, still considered work in progress, is available to scientists, linguists, development workers and journalists engaging with citizen groups and individuals for whom English, the official language, is not an effective medium of communication. Forty five media practitioners underwent an intensive two-day training workshop combining teacher-focused and participant learning approaches to convey key facts on causes and consequences of climate change, societal responses, and the media's role in shaping public awareness about these issues. On the back of training received by media practitioners, it is worth noting that media houses now routinely request and disseminate forecasts generated by the weather office, as well as news about events addressing climate change themes.

51. Nearly 300 farmers from communities across North Bank Region (NBR) and West Coast Region (WCR) and 30 extension workers have also benefited from basic instruction and training in agrometeorological practice, thus boosting their awareness about linkages between climate risks and productivity, generating greater enthusiasm for and curiosity about the practical uses of climate information products and services including a weather-index insurance scheme, under study. Over the past three years, MECCNAR has engaged more than 50 business leaders drawn from climate-sensitive industries to exchange information on risks posed by climate variability and trends, potential roles for Gambian private sector entities in implementing the UNFCCC, and new opportunities for business and industry players under the UNFCCC. For comprehensiveness and impactfulness, development and implementation of a long-term climate change capacity development strategy (LT-CCCDS) is expected to cater to the capacity development needs of public sector public sector employees, grassroots organisations, and implementing partners at national and sub-national levels.

52. Climate and environmentally-related information of public interest generated and/or disseminated by national agencies are accessible through several media. As an important repository of meteorological and other geophysical information in its own right, the NMHS disseminates daily public weather, seasonal climate outlooks, and special forecasts through multiple platforms including print and audiovisual media. The NMHS web portal also features publications, administrative and project management information. MECCNAR is

well positioned to disseminate its policy instruments, administrative and programmatic information, internally-generated and commissioned studies via its web portal www.meccnar.gm, The National Disaster Management Agency (NDMA) also runs a website http://www.ndma.gm/home/ linked to the risk management portal, http://gm-risk.ige.fr/, that creates opportunities for visitors to search geospatial information products; reports and data sheets, and geolocation of precipitation in real-time through the EUropean organisation for the exploitation of METeorological SATellites (EUMETSAT) facilities.

53. In accordance with the World Meteorological Organisation (WMO) Resolutions 40 Cg-XII and 25 Cg-XIII, meteorological and aviation related messages are transmitted tri-hourly to the WMO regional telecommunication hub in Dakar by satellite and aeronautical fixed telecommunications network (AFTN) line. An MOU between the NMHS and WASCAL also provides for the exchange of observational data with the WASCAL Data Centre in Ouagadougou (Burkina Faso).

54. Over the last five years, there has been significant upgrades of atmospheric and terrestrial observation networks, which now boast of telemetric systems collecting data on a broad range of parameters under challenging operational conditions. However, individual efforts and initiatives, knowledge, leadership, and coordination issues represent formidable hurdles to the emergence of a vigorous issue-oriented research environment. The National Climate Committee (NCC) is one of few groups addressing programmatic issues related to the UNFCCC, but the NCC still falls short of taking on the role of a high-level research cluster due to its limited mission and competencies. Other organisations with a genuine claim to membership of the global change research community continue to grapple with knowledge management issues. Specifically, the newly established National Climate Change Secretariat (NCCS) and antecedent lead agencies/actors are yet to unveil and garner support for priority research themes/topics guided by knowledge gaps hindering evidence-based, long-term and sector-wide approach to policymaking and development practice. Excluding the National Agricultural Research Institute (NARI) which conducts research on improved varieties of grain crops, oilseeds, tubers and fruits, only a handful of climate-related research projects are active during any particular year, and most of these fall within the ambit of WASCAL postgraduate study programmes. Above all, this demonstrates the importance of setting up a premier climate change research cluster to undertake high-level issues-based research contributing to full implementation of the UNFCCC and meeting the expectations of government, development and other major stakeholder groups. Without being overly prescriptive, it is expected that the cluster would assign a high priority to uncertainties and knowledge gaps in country-level assessments and other research carried out to date, in its research agenda.

55. Other urgent capacity building needs for the moment, are organisational and individual competencies in conducting high-fidelity research and sectoral assessments to distill clear guidance for mainstreaming climate change into sectoral policy instruments, programmes and activities at national and sub-national levels. Greater efforts are also required to strengthen the newly established NCCS to address *inter alia* inclusiveness, conflict resolution, information management, and scientific integrity issues, and to build and manage strategic working relations with international groups with shared interests.

56. Crucially, organisations entrusted with research and systematic observations (R&SO) responsibilities require strengthening of end-to-end R&SO systems (i.e. additional/enhanced physical and virtual resources) for meaningful contributions to national development planning, emergency management, and regional/global information exchange networks. In particular, deployment of data buoys at strategic locations within the Gambia's exclusive economic zone, EEZ (more than double its land surface) is certain to add value to marine and shipping forecasts, give impetus to the development of national capacity for operational oceanography and strategic management of the country's ocean economy.

57. Further to priority scientific equipment deployed in R&SO systems, The Gambia needs to move forward with progressive deployment of environmentally sustainable technologies (ESTs); identified through a rigourous identification and evaluation process supported by veteran national experts, technical assistance from the United Nations Environment Programme (UNEP), Energy Research Centre (University of Cape Town, South Africa) and financial assistance from the Global Environment Facility (GEF), in key sectors of the economy (energy, transportation, agriculture, and waste management) and in water resources and coastal zone management Suffice to say that those ESTs are quite relevant to implementation of the Gambia's Intended Nationally Determined Contributions (INDC).

A selection of mitigation measures under the energy, transport, agriculture, and waste management sectors/source categories assessed under The Gambia's Intended Nationally Determined Contributions (INDC) towards implementation of the UNFCCC are summarised and reproduced under the TNC. Between 2020 and 2030, the agriculture sector, through expansion of cropland areas cultivated with the NEw RICe for Africa (NERICA) cultivar, and also of lowlands using System of Rice Intensification (SRI) water control techniques, is expected to generate the biggest reduction in GHG emissions. Year-on-year reductions are highest in the waste sector.

58. Against the backdrop of COP decisions 1/CP.19 and 1/CP.20, The Gambia, in 2015, with financial and technical support from the German Agency for International Cooperation (GIZ) and the Climate and Development Knowledge Network (CDKN), articulated and published its Intended Nationally Determined Contributions (INDC) focusing on GHG mitigation in: 1) Energy; 2) Transport; 3) Agriculture; and 4) Waste Management sectors/source categories. Relevant analyses carried out using 100 year Global Warming Potentials (GWPs) from the IPCC 4th Assessment Report (AR4), and IPCC 2006 greenhouse gas inventory methodologies.

59. In the mitigation scenario analysed under the energy sector, four mitigation strategies and their combined impact on emissions are assessed. These strategies, which can be aptly described as 1) fuel substitution; and 2) fuel conservation strategies, are projected to cut down GHG emissions from energy industries and CO_2 from biomass combustion by 425.7 $GgCO_2e$ in 2020, 541.1 $GgCO_2e$ in 2025 and 629.6 $GgCO_2e$ in 2030.

60. Emissions reductions resulting from the introduction of fuel-efficient technologies in the transport sector were assessed. It was found that increased deployment of fuel efficient vehicles would generate greenhouse gas emission reductions of 40.8$GgCO_2$ eq by 2020, 115GgCO2 eq by 2025, and 193GgCO2e by 2030, compared to the baseline scenario under which incentives or regulations are not strong enough to influence (widespread) adoption of fuel efficient vehicles.

61. Under the Agriculture sector, potential emission reductions using the NEw RICe for Africa (NERICA) cultivar and System of Rice Intensification (SRI) irrigation technique were assessed. Under intensification of NERICA cultivation and production, emission reductions computed are in the order of 124$GgCO_2$ eq in 2020, stabilising at 398$GgCO_2$ eq between 2025 and 2030. As for SRI, which provides documented gains in water use efficiency in swamp rice production, emission reductions are 438 $GgCO_2$ eq in 2020, stabilising at 707$GgCO_2$ eq by 2025 and 2030.

62. Three mitigation strategies, namely methane capture, waste recycling and waste composting, are ported for the Waste sector in the TNC. When implemented, these strategies are expected to generate GHG emissions reductions in the order of 141 $GgCO_2e$ in 2020, 239.7 $GgCO_2e$ by 2025, and 413.7 $GgCO_2e$ by 2030.

A diagnostic analysis of process management within the TNC context has uncovered several systemic and circumstantial problems impeding timely publication of a comprehensive report. Specifically, the compounding effects of poor institutional memory, weak organisational

frameworks and task-related capacity gaps, show up in the content as missing information on the actual status of sector-wide implementation of the UNFCCC. Climate related constraints to implementing national development priorities can be construed as risk aversion towards agricultural expansion, vulnerable infrastructure, and private sector engagement and leadership.

63. An objective introspective analysis of the National Communication (NC) preparation process has revealed several systemic and circumstantial problems that remained largely unsolved up to the time of the TNC publication. Crucially, activities involving pooling, analysis and packaging of relevant information were continually challenged by poor institutional memory, task-related capacity gaps, and weak perception of country-ownership, reflected in delivery schedules, quality of intermediate outputs, and the final TNC report. In effect, failure to provide specific details along with inventory information, or a full re-analysis of 1990 and 2000 inventory data, failure to provide an overview of institutional arrangements for GHG inventories, and absence of reporting on Quality Assessment/Quality Control (QA/QC) and uncertainty analyses, are considered as important gaps in the TNC. Other gaps relevant to comprehensiveness of document are briefly listed as follows:
    - Harmonised socioeconomic scenarios to be used in sectoral assessments and mitigation analysis.
    - Information on the institutional framework for implementation of the Convention, legal frameworks for stakeholder participation and public access to information, stakeholder engagement processes, level of involvement, and outcomes.
    - Information on scope and areas of The Gambia's participation in the global research and observation systems and information networks.
    - Information on the status of activities and level of participation in South-South cooperation, including capacity building activities for building resilience.
    - Information on the status of activities related to coordination and sustainability of capacity-building activities, and level of public awareness and understanding of climate change issues.
    - Specific (sectoral) mitigation and adaptation policies and measures and where relevant, linkages to the country's Nationally Appropriate Mitigation Actions (NAMA), Intended Nationally Determined Contributions (INDC), National Adaptation Programme of Action (NAPA), and Sustainable development Goals (SDGs).
    - Measures relating to enhancing the enabling environment for the development and transfer of technologies.

64. Climate related constraints to implementing development priorities relate to 1) agricultural expansion; 2) building critical infrastructure; and 3) turning the private sector into the engine of growth (of the economy). Unfavourable weather and seasonal rainfall patterns have had and still continue to exercise a strong influence on the production of rain-fed agricultural production systems. Specifically, a shorter rainy season continues to exert a strong negative influence on groundnut, maize, and rice production. To a large extent, revitalisation of the National Agricultural Statistics Survey (NASS) would be crucial to a holistic assessment of progress, evidence-based planning and decision-making in the ANR sectors.

65. Proposed interventions contained in the Gambia's Special Programme for building Climate Resilience (SPCR) in the form policy integration, strategic assessments and audits, underpinned by requisite investments in scientific assets and human resources, designed to overcome obstacles to an evidence-based (Component 3), long-term and sector-wide approach to policymaking (Components 1, 4 and 5) and development practice (Components 2 and 5), geared towards climate resilient development in The Gambia, are estimated at USD28.5 million.

Gambian landscapes, economy and its people are exposed to changes moderately to highly sensitive to climate variability and manifestations of future climate change. Therefore, the lead ministry, Ministry of Environment, Climate Change and NAtural Resources (MECCNAR), has a big role to play inter alia in service provision, problem solving, information diffusion, capacity building, and building strategic partnerships, with respect to climate risk management and implementation of the UN Framework Convention on Climate Change (UNFCCC). To this effect, MECCNAR and other relevant government agencies need to establish stronger cooperative framework. To complement, self-improvement efforts, international partners are called upon to provide targeted capacity building support and technology transfer through relevant convention bodies/mechanisms, or bilateral arrangements.

66. Due to its unique geography, the country's landscapes and ecosystems are exposed to projected climate change from multiple perspectives, notably economic growth, household livelihood strategies and social progress.

67. Using administrative and scientific information from trusted sources, assessments presented in the Third national Communication (TNC) indicate moderate to high levels of sensitivity of the environment, public health, and selected economic sectors, and quality of life of population groups engaged in the real economy, to adverse impacts of projected climate change. Greenhouse gas (GHG) emissions have grown by 70% since 1993, with methane (CH_4) contributing 47% of emissions recorded in 2010. Notwithstanding, several

weaknesses including secondary data collection, data aggregation, quality control and analysis, attributable to the absence of a formalised Greenhouse Gas Inventory (GHGI) system embedded in administrative law, have come into evidence during the preparation of the TNC.

68. There is sufficient reason to believe that improvements are needed with regards to the Ministry of Environment, Climate Change and NAtural Resources' (MECCNAR's) leadership, service provision, problem solving, and information dissemination roles in matters related to climate risk management and implementation of the UN Framework Convention on Climate Change (UNFCCC). Doubtless, the allocation of resources commensurate with expected outputs would eliminate some major shortcomings in the dissemination of diverse genres of information generated within the climate change stakeholder community.

69. Capacity building outcomes (with support from development partners) continues to lag behind actual needs. Indeed, leadership training of public sector employees and competency gaps in the fields of project management; environmental, ecological and economic modelling; engineering; and datascience, remains a top priority at sectoral and at different administrative levels. In this regard, greater effort should be expended in developing the country's South-South cooperation in the field of climate risk management.

70. Public awareness, supported by multiple agencies/interventions, is increasing but inadequate due to the absence of communication guidelines and weak coordination of public awareness building efforts. However, a sustained drive to train media professionals, extension workers, and community groups, and the recent publication of a glossary of key terms and concepts into major local languages could be seen as a significant step towards greater public enlightenment and engagement on climate change issues.

71. Three key recommendations as follows are formulated for the attention of international partners:
    - Provide training support to Gambian sectoral experts (including social scientists) on various thematic areas and integrated assessments, through the relevant convention bodies/mechanisms, or bilateral arrangements, and monitor impacts and outcomes through participatory programmes.
    - Provide technical assistance in the person(s) of a GHG inventory expert(s) to establish and operationalise a formalised GHGI system, building on potential synergies with the National Statistics System (NSS) reporting biennially on core environmental statistics including GHG emissions.
    - Provide technical assistance and programming support towards the establishment of a productive National Climate Change Centre (NCCRC), built around research

clusters working on key Convention and national development issues (including transition to a low emissions economy).

72. MECCNAR and relevant government agencies need to urgently address some of the problems identified in this report, through:
    - Initial framing of issues and expectations relating to the establishment of formalised GHGI system (under the NSS coordinated by the Gambia Bureau of Statistics), climate risk management coordination mechanism (including role definition and MOUs if required) and system audit to assess deficiencies, should follow the publication of this report. UTG should lead discussions around the establishment of an NCCRC, criteria for affiliation and modalities for deciding upon research priorities.
    - Joint development of key messages for various audiences to ensure coherence between GOTG Education & Awareness Programme, and its Research Programme.
    - Take advantage of UNFCCC Biennial Update Reviews (BURs) to implement imperative structural and management reforms.
    - Measurement and reduction of their GHG footprint (additional to the INDC), as a sign of leadership by example.

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CHAPTER 1: INTRODUCTION AND CONTEXT

According to Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), all country Parties must report on the steps they are taking or envisage undertaking in order to implement the Convention, its subsidiary protocols and agreements. During the eighth meeting of the Conference of Parties (COP 8) held in New Delhi (India) in 2002, Parties adopted the revised guidelines for the preparation of National Communications (NATCOMs) from non-Annex I Parties. In accordance with the principle of "common but differentiated responsibilities" enshrined in the UNFCCC, the prescribed content NATCOMs and submission schedules are different for Annex I and non-Annex I Parties.

Accordingly, The Gambia which is one the Least Developed Countries (LDCs) is entitled to appropriate financial and technical support to prepare and submit its National Communications (NCs) at appropriate intervals. In the circumstances, the Global Environment Facility (GEF) provided requisite financial support through UNEP which served as implementing agency. National authorities responsible for reporting also leveraged technical assistance from Gambian specialists and international consultants to carry out a national inventory of greenhouse gas emissions, perform mitigation and vulnerability assessments which constitute essential elements of The Gambia's Third National Communication (TNC), based on the revised guidelines adopted during COP 8.

Specifically, this TNC contains twelve chapters as follows: 1. Introduction and Context; 2. National Circumstances; 3. National Greenhouse Gas Inventory Information; 4. Mitigation Assessment; 5. Vulnerability and Adaptation Assessment; 6. Education, Training and Public Awareness; 7. Research and Systematic Observations; 8. Technology Transfer; 9. Capacity Building 10. Networking and Information sharing; 11. Constraints and Gaps, and related Financial and Technical Capacity Needs; and 12. Conclusions and recommendations.

In chapter 2 which follows this introduction, the TNC provides an account of national circumstances relevant to implementation of the UNFCCC. This is followed by a national inventory of greenhouse gases in chapter 3, leading on to a partial assessment of mitigation measures and strategies aligned with The Gambia's Intended Nationally Determined Contribution (INDC) and Nationally Appropriate Mitigation Action (NAMA) in chapter 4. Impacts of projected climate change are addressed under chapter 5. Chapter 6 on education, training and public awareness presents formal and non-formal education in The Gambia and climate change mass media activities conducted in The Gambia. Chapter 7 on research and systematic observation discusses the national framework for research and systematic observations; describing existing systematic observations (meteorological, atmospheric, oceanographic and terrestrial) and programmes, and spotlighting data needs and priorities. Chapter 8 presents existing technologies and other promising technologies that can be applied in the implementation of mitigation and adaptation activities identified in the TNC. Chapter 9 which addresses capacity building provides information on the capacity assessment with emphasis on critical capacity needs for implementation of the UNFCCC and maximising synergies with other multilateral environmental agreements. Issues on networking and information sharing relevant to the implementation of the UNFCCC in The Gambia are presented in chapter 10 of the TNC. Chapter 10 includes both national and international knowledge and information networks. Climate change implementation constraints and gaps with particularly reference to finance, technology and capacity building are articulated and discussed in chapter 11. The final chapter of the TNC enunciates key recommendations for improving climate change management processes in the country.

CHAPTER 2: NATIONAL CIRCUMSTANCES

2.1. Geography, climate and demography

2.1.1. <u>Location</u>

The Gambia, lying between 13º and 14ºN and longitudes 13°40′ and 16°50′ W is the smallest country on the African continent. 11,300km^2 in size, the country has a total land boundary of 740km, all of which is shared with the Republic of Senegal in the North, East and South while in the West the country is open to the Atlantic Ocean. Except for a small fraction of territory on its Atlantic seaboard, The Gambia is perfectly nested within the Gambia River basin, one of several transboundary catchments in recycling water between the ocean, atmosphere, and West African sub-continent. The Gambia's pivotal position also places the country squarely within the Sudan bioclimatic zone (Le Houerou 1980). The chief cities are Banjul (the capital), Kanifing Municipality, Brikama, Soma, Bansang and Basse.

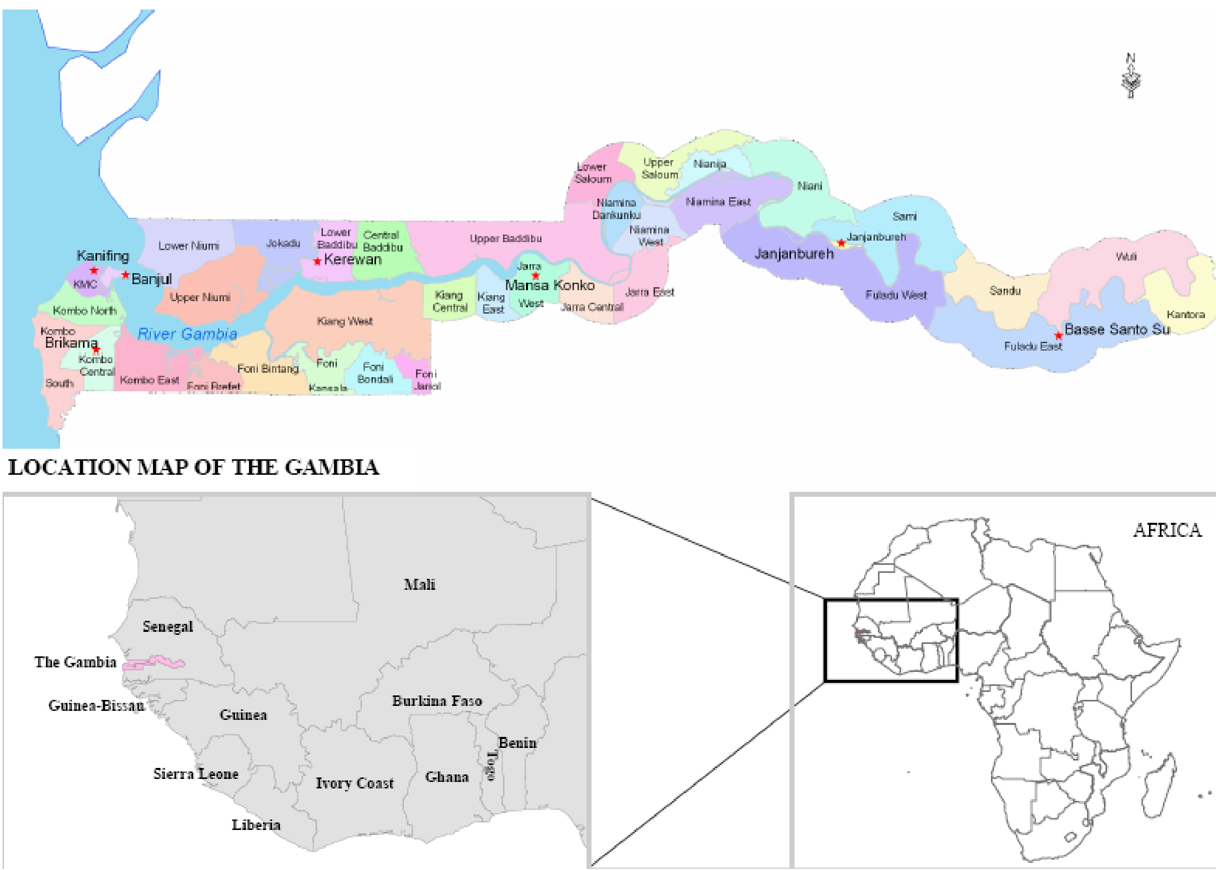

Figure 1. Location map of The Gambia (Source: Jaiteh and Saho, 2006)

2.1.2. Climate

The climatic system of the Sudan bioclimatic zone is driven by the West African monsoon, which brings rain to The Gambia between June and October (Gu and Adler, 2004; Gianini et al., 2003). Average rainfall in a year varies from 1,000 mm in the South and Southeast to 700 mm in the most northerly part of the country, with 80-85% of rainfall concentrated in the months July, August and September (JAS). Annual rainfall declines gradually from 1,000 mm in the South and Southeast to 700 mm in the most northerly part of the country. The area of the country with average cumulative JAS rainfall below 800 mm has increased from 36% in 1965 to 93% of the country consistent with regional changes in annual precipitation over West Africa (GOTG, 2007; Mahé and Olivry, 1995). Moreover, the average length of the rainy season decreased by 6 to 9 days in the western and eastern parts of country. Intra-seasonal, inter-annual and decadal variability is linked to large-scale ocean-atmosphere structures and perturbation (Lavender and Matthews, 2009; Joly and Voldoire, 2008; Sultan and Janicot, 2003; Sultan et al., 2003).

Average temperatures vary between18°C and 30°C during the dry season, and range between 23°C and 33°C during the wet season. In La Niña years (e.g. 1999-2000, 2007-2008, 2010-2011), temperatures tend to be cooler than average throughout the year. Summertime temperatures ranging from 13ºC to 43ºC are modulated among other factors by the ocean and extensive areas of swamp/wetland. These equally have a moderating influence on winter temperatures lying between 13ºC and 37ºC. The lowest daily temperature of 4°C was measured in Jenoi (13°28′ N, 15°34′ W) in 2003, and the highest daily temperature of 49.0°C was recorded in 2001 at Jenoi (Stafford, 2019). Spatial distribution of temperature, which is governed by the combined effects of cosmic, locational, landscape and pluviometric factors, exhibits a general temperature gradient increasing landwards from the coastline into the hinterland. Since the 1950s, routine observation also indicate that minimum temperatures across The Gambia have increased steadily at the rate of 0.4 to 0.67°C per decade (GOTG, 2007).

Relative humidity is about 68% along the coast and 41% inland during the dry season and generally above 70% throughout the country during the wet season. Seasonal Northeast trade winds, known as Harmattan, also have an associative relationship with atmospheric circulations, and are notable for their chill factor, and significant amounts of dust picked up from the margins of the Sahara desert. Sunshine duration from January to May hovers around 8 hours a day, dropping steeply to around 6 hours during July, August, September (Stafford, 2019; Sima, 2010). Average ultraviolet (UV) indices are lowest (UV index = 9) around December and significantly higher (UV index = 12) between February and September.

2.1.3. Population

The Gambia's population of 2 million is a socially cohesive composite of people belonging to 10 ethno-linguistic communities, and immigrants mostly originating from other West African countries. Five of the most populous ethno-linguistic communities account for 90% of the population. The current population is projected to increase to 3 million by 2030 as a result of external migration and sustained rates of natural growth since the last population census in 2013 (GBOS, 2016a, 2016b).

According to the 2013 population Census, the Gambian population is predominantly youthful, with children and young adults below 30 years making up approximately three quarters of the population (GOTG, 2016b). By contrast, people above the pension age of 60 years account for less than 5% of the population, with more females represented in this population sub-group consistent with disparities in life expectancy between men and women in the Gambia. A ratio of 963 males to 1,000 females was measured within the general population, and 933 males to 1,000 females among persons aged 15 years and above.

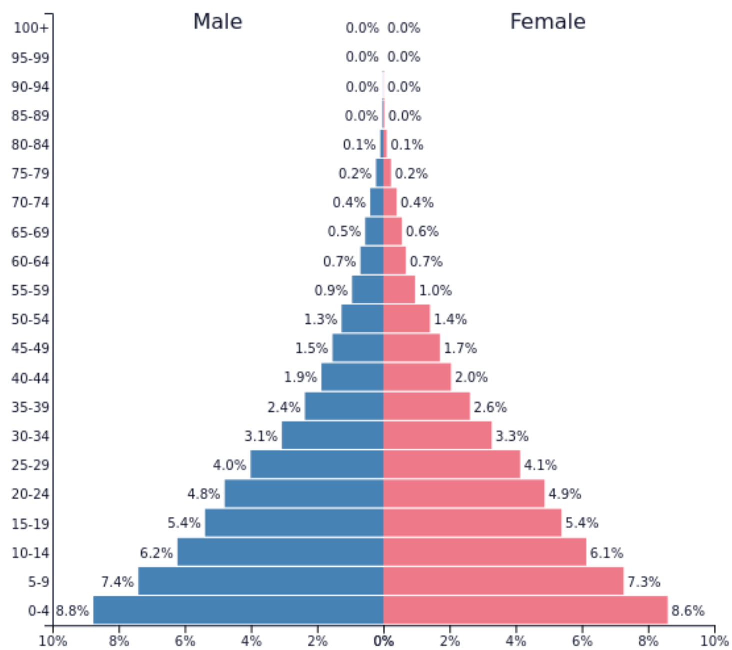

Figure 2. Population pyramid of The Gambia

The greatest concentration of population are in Kombo Peninsula, conurbations on major highways, transportation and commercial hubs. More than half the population settled on the Kombo Peninsula, bounded to the West by the Atlantic Ocean, the center of which is Kanifing Municipality, with a population of 475,000. People in rural areas characteristically live in scattered settlements with populations rarely exceed 1,000 inhabitants (GBOS, 2016c).

According to 2013 census data, 96% of people regarded themselves as Muslims, 3.8% as Christians, and 0.1% as followers of ancestral African religions. Around 2% of adults aged 20 years and above possess a bachelor's degree or higher qualification, whilst 12% have secondary school diplomas. Four-fifths of the working-age population is employed and of those 42% work in the agriculture sector (GBOS, 2016d).

2.2. Government and administration

The Gambia is a Constitutional Republic. Its current constitution, adopted in 1997 establishes executive, legislative and judicial branches of government, substantially independent in the exercise of their powers, and collectively responsible for upholding the rule of law, promotion and protection of fundamental human rights, fostering and strengthening good governance based on high moral and ethical standards. Persons holding public office are distinguished between those holding elective office and others appointed by officials legally empowered to do so on the basis of specific statutes. An independent electoral commission is responsible for organising and supervising elections for public office.

2.2.1. Executive Branch

The Executive Branch of Government consists of the President of the Republic, who is also the Head of State and Government, and a Cabinet of Ministers appointed by the President. Cabinet and subsidiary organs of the executive are primarily responsible for statecraft geared towards national prosperity, social progress and equitable development. Notably, the ministry responsible for finance and economic affairs is challenged with financial resources mobilisation and optimal allocation of public funds; the ministry responsible for environment shoulders the burden for protection of the environment, biodiversity conservation and climate change administration; the ministry responsible for health is confronted with the task of organising and managing the healthcare sector, prevention of pollution and nuisances, and promotion of food safety.

For administrative purposes the country is divided, under the subsidiarity principle, into two municipalities; Banjul City and Kanifing Municipal Area, and five administrative regions. Municipalities are further sub-divided into Wards, and Administrative Regions further sub-divided into 48 Districts locally administered by Chiefs (Seyfos). Each District covers a number of villages and settlements under administrative stewardship of a Village Head (Alkalo). Whereas elected officials head and run municipal governments, executive appointees who bear the title of Governor are administrative heads within regions. In sum, territorial administration, spatial planning and resolution of land disputes fall within the purview of the Minister for Local Government and Lands.

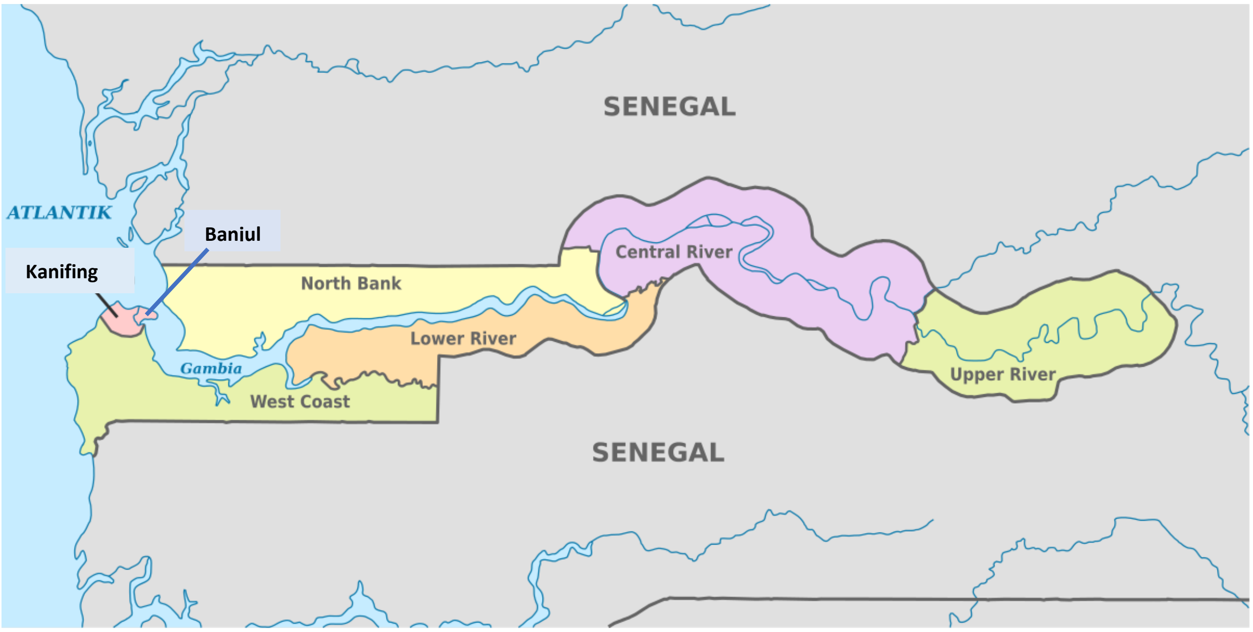

Figure 3. Administrative regions of The Gambia

2.2.2. Legislative Branch

The legislative branch, comprising a unicameral National Assembly has 58 members, 53 of whom are elected by a majority of voters ordinarily resident within each electoral district, and five members nominated for office by the President of The Republic. National Assembly Members (NAMs) are primarily responsible for the enactment of legislation (including approval of financial appropriation bills), ratification of treaties, keeping local and national development issues in the public policy space, and oversight of organs and agencies of the executive branch of government. Currently, the current National Assembly in its 5th legislative session has eight standing committees, nine select committees and seven international parliamentary delegations to ensure responsiveness and operational efficiency vis-à-vis internal and external challenges.

2.2.3. Judicial Branch

The judicial branch of the government in the interpretation and enforcement of constitutional law, administrative law, responsible for criminal and civil justice statutes. Adjudicatory and law enforcement powers are vested in officials of a hierarchical criminal and civil justice court system in which the Supreme Court of The Gambia sits at the apex. Subordinate courts consist of: magistrate courts, cadi courts, district tribunals, and other specialised courts.

The Gambian judicial system works within the parameters of a composite system of English common law, Islamic law, Customary laws, and statute law passed by the National Assembly. As a general rule, sub-ordinate courts have jurisdiction to hear civil matters such as family, property, contractual disputes and torts. Serious offences such as murder, human trafficking, illicit trafficking in narcotic drugs and psychotropic substances, robbery, racketeering, currency counterfeiting, corruption and bribery, fall within the ambit of the High Court, Court of Appeals or Supreme Court.

The Chief Justice is the head of the Judiciary and responsible for administration of all courts. Highest judicial appointments including those of Chief Justice by the President of the Republic on the advice of a Judicial Service Commission. The Attorney-General and Minister of Justice who doubles as principal legal adviser to the executive is also responsible for enforcing criminal law.

2.3. The Environment

2.3.1. Natural and semi-natural environment

The Gambia is predominantly a lowland country. The country has four major topographic landscapes, namely the floodplain, colluvial slopes, the lower plateau and upper plateau, with correspondingly different soil types. The highest point located around Basse in the south-eastern part of the country is 53 metres above sea level.

The Gambia is almost divided in half into northern and southern landmasses by the River Gambia, which flows in sweeping meanders from East to West and debouchs through a wide estuary into the Atlantic Ocean. Along its course towars the ocean, a few tributaries, locally known as 'bolong', including the Bao Bolong; the locus of a Ramsar site, with headwaters in Senegal drain into the River Gambia. Under the influence of oceanic processes, the River Gambia is noted for its daily tidal and salinity regimes, modulated by freshwater inflows during the rainy season.

According to CILSS (2016) and Tappan et al. (2016), forest formations cover 52% of the Gambia's territory. Mangroves stands which make up a tenth of this area thrive in brackish wetlands along the banks of the River Gambia, bolongs, and network of water channels that separate small islets formed by depositinal processes constantly at play within the lower estuary (Jaiteh and Sarr, 2011). In general, mangrove tree heights taper downwards away from waterfronts to places where the tree line merges with reeds and brackish water grass species. Mangroves can be found as far as Pappa Island, 215 km upriver from Banjul. In several places, mangrove stands extend up to 3km inland from the river, and up to to 10km in some lower parts of the estuary. Flat barren areas locally known as 'tannes', characterised by a patent absence of vegetation and visible translucnet sheen of salt is oten found on the margins of brackish swamps (MSU, 1985). Upstream of Kuntaur, located 254 km from the mouth of the estuary, freshwater swamps are maintained by inundation of the flood plain by tidal cycles. Trees found within freshwater riparian forest can reach reach a height of 10 metres and are associated with and undergrowth of shrubs and grasses. Freshwater swamps subsisting at the bottom of valleys and poorly-drained depressions some distance from the River Gambia, are flooded during the rainy season. Any subsisting pools of water gradually evaporating during the following dry season.

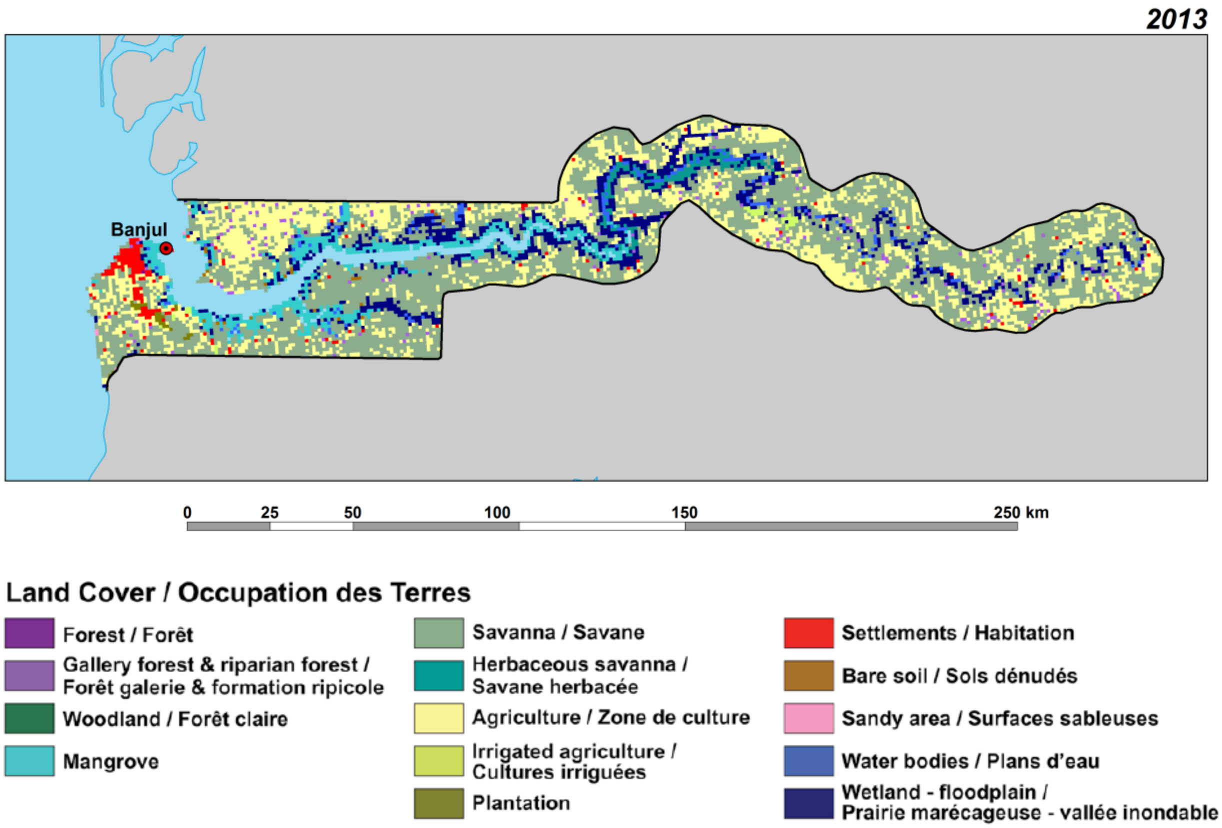

Figure 4. Land luse land cover within The Gambia in 2013 (CILSS, 2016).

The morphology of the Gambia's Atlantic coast is defined by a succesioon of bays bounded by headlands. Some of the bays are fronted by uninterrupted stretches of sandy beach, whilst others are dissected by coastal streams notably Kotu stream and River Tanji, flowing out to the ocean. Mangroves are also found along the banks of coastal streams and on the north-west coast of the country, integral to the Niumi National Park that forms a single ecological entity with Parc du delta de Saloum (in Senegal).

Off the coastline, the ocean floor is relatively shallow, with maximum depths of 15 and 20 metres inside 7 and 12 nautical miles off the coast, respectively (Bijl, 2011). The continental margin (200-metre isobath) is located between 72 and 90 km from the coastline. The Canary current which traverses the Gambia's maritime claim consists of North Atlantic Central Water (NACW) has a vertical dimension of about 500 metres. Deeper water masses include the South Atlantic Central Water (SACW) and North Atlantic Deep Water (NADW) with distinct temperature, salinity, and dissolved oxygen profiles. Upwelling of colder and nutrient-rich water which occurs seasonally in January to April is an important driver of marine ecosystem productivity (Ndoye et al., 2014; Lee et al., 2009, Hernandez-Guerra *et al.*, 2001; Wooster *et al*. 1976). Surface waves are generated by momentum transfer from winds to underlying water surface. According to field data (DHI, 1982), the wave regime is dominated by swell waves with lengths of between 350 and 600 metres. Waves breaking onshore could be as high as two metres.

Inland from water courses and the Atlantic coast, tree and shrub savannah, characterised by low density of trees and herbaceous vegetation dominated by annual and perennial grasses, is the dominant land cover, especially wthin the south-western part of the country. Elsewhere savannah lands are fragmented by cropland verdant from sorghum, millet, groundnut, maize and other crops planted in the rainy dry seasons; but mostly devoid of vegetation cover after crops have been harvested. By contrast, 84% of land in the north-west is is under rain-fed agrricultral production, with insular patches of tree and shrub savannah forest. Forest plantation are scare and of limited size. Nyambai, the largest, in the south-west has an area of 100ha, one-tenth of total plantation area (Tappan et al., 2016; FAO, 2015).

A species inventory conducted by Barnett and Emms (2005, 2000) and Barnett el al (2001) found 1,005 species of flowering plants, 126 species of mammals, 627 species of fishes, 566 of birds, 784 species of insects and 77 species of reptiles in the Gambia. Protected area covering 352 km^2 (3.3% od country) provide sanctuary and life-cycle habitat for a significant number of species including endangered ones such as the sitatunga (*Tragelaphus spekii*), West African manatee (*Trichechus senegalensis*), green turtle (*Chelonia mydas*). Notwithstanding, pressure, in various modes of biotic and abiotic resource extraction, and pollution, is continually exerted on the natural environment by human activities. Forests in particular are undergoing a steady areal decline due to cropland and human settlement expansion (Tappan et al., 2016; NEA, 2010).

2.3.2. <u>Built environment</u>

Built environments made up of buildings and facilities, publicly or privately owned, that serve as habitation, business and commercial districts, health and education facilities, devotional and recreational spaces, amongst other functional uses, are found in nearly 2,000 official settlements spread across the country (GBOS, 2016c, 2016e). Invariably, settlements with large populations are collocated with important commercial and cultural hubs found along or in close proximity to major transportation highways. Civilian infrastructure systems found in larger towns and cities include roads and electricity networks. Sewerage networks are limited to Banjul, the capital city, and parts of Kanifing Municipality. For logical and strategic reasons, some facilities associated with particular settlements lie outside their boundaries, but remain accessible by public roads. Examples of such facilities include healthcare delivery, air transport, marine/river transport, and factories. Overall, industrial and non-residential buildings represent a tiny proportion building stock, overwhelmingly used for residential purposes in both urban and rural areas (GBOS, 2016e). Only a small number of buildings exceed 50 metres in height, and multi-storied buildings are the exception in Banjul and Kanifing Municipality central districts.

Irrespective of their size, major urban centres account for approximately 80% of the formal economy. Concomitantly, they exert inordinate pressures on the natural environment, thus contributing to natural resource degradation and depletion, and environmental pollution in peripheral and other areas providing food, water and energy resources. In times of rising social demand for housing, resource constraints, and potential climate change impacts on the built environment, new building designs, favouring energy efficiency and new materials, in combination with robust planning and regulatory frameworks encapsulate the challenge for sustainability of built environments (GOTG, 2007).

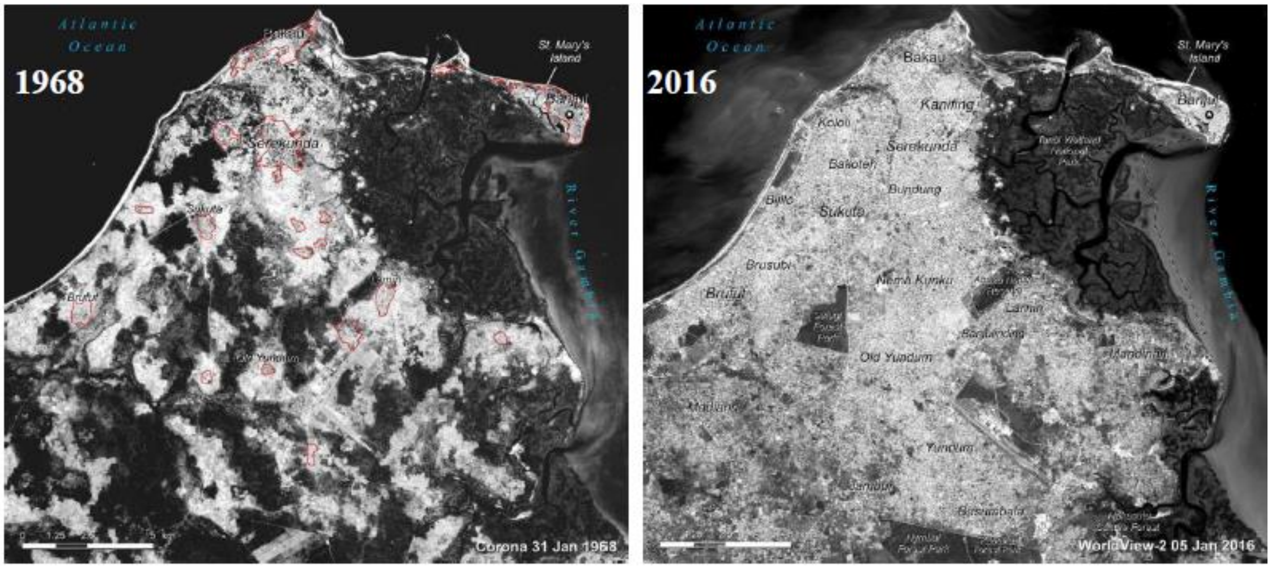

Figure 5. Built-up in Kanifing Municipality and parts of Kombo North in 1986 (left) and 2016 (right).
Land use change is characterised by expansion of built environment (seen as brighter areas in the images) at the expense of croplands and tree cover.
Panchromatic (black-and-white) images taken from Earth Observation Satellites: Corona J-1 31 Jan 1968, WorldView 2 05 Jan 2016 (CILSS, 2016)

2.4. Economic Affairs

Gross Domestic Product (GDP) in 2015 was USD939 (current prices)1 and USD491 million (constant prices), of which slightly more than one-fifth is attributed to diaspora remittances. A thriving informal economy could be as large as 40% the size of the formal economy. Headline inflation, measured by Consumer Price Index (CPI) was slightly under 8% in the third quarter of 2016. The total value of CBG assets at the end of the year was GMD16,546 (sixteen thousand five hundred and forty six million Gambian dalasi) (CBG, 2015, 2017; Medina et al., 2017; UNECA, 2017; World Bank, 2016a, World Bank, 2016b).

The most recent population census classifies 80% of the working-age population as economically active. On aggregate, manufacturing sectors account for less than 8% of the workforce, whilst agriculture and natural resources sector remains the biggest employer in the economy. Although national unemployment rate is estimated at around 6% of the workforce, joblessness is far worse among people aged between 15 and 35 years, who are four to five times

[1] 1 US Dollar (USD) = 42.5 Gambian Dalasi (GMD)

more likely to be out of work, and in recent years, have left the country in their thousands in search of their fortunes elsewhere (GBoS, 2016a).

2.4.1. Economic strategy

The Government's overarching economic policy objective is to ensure sustainable economic growth through low inflation and sound public finances. Government's macroeconomic policy is directed towards keeping inflation below double digit figures, whilst microeconomic policies seek to improve efficiency, and the general environment for business and investments.

Economic policy is set within the context of a medium-term National Development Plan (NDP) and its associated financing strategy, reviewed annually. In the NDP, fiscal and monetary policies are designed to keep inflation below 5%. Monetary policy is guided by inflation forecasts using growth forecasts for the Gambian economy. Fiscal policy seeks to reduce the share of public expenditure in national income and to curtail public sector borrowing in order to bring down the budget deficit from 10% to 3% of GDP, within 4 years, and thus move the country towards debt sustainability. While the strategic thrust of NDP is primarily driven by the need to respond to domestic challenges, it also seeks to accommodate the international development agenda and cooperation agreements the country subscribes to, notably, the UN Sustainable Development Goals (SDGs), Paris Climate Deal, and AU Agenda 2063 (GOTG, 2018a).

2.4.2. Economic management

The Ministry of Finance and Economic Affairs (MOFEA) has responsibility for the formulation and implementation of Government's economic policy, which the ministry carries out in conjunction with key sector ministries. Other government entities, notably those invested with regulatory, strategic assessment and compliance-monitoring functions, and the legislature deal with specific aspects of economic policy. The government keeps an open dialogue with key industrial, financial, and other interest groups through a High-level National Multi-stakeholder Committee that brings together Government Ministers, industry captains, development partners, and representatives of civil society and professional associations (GOTG, 2018a).

2.4.3. Economic activities

In anticipation of private investments in energy, agriculture and manufacturing sectors, most public investments are in the transportation and construction sectors of the economy. However, domestic direct investment remains constrained by lending rates. Private investments follow a skewed pattern informed by investors' assessments of opportunity and profitability. This has led to the communication sector acquiring a high preference status, and establishment of the Gambia's first public-private partnership (PPP) venture under the Africa Coast to Europe (ACE) Submarine Cable project (GOTG, 2018a; UNECA, 2017; ProPAG, 2013).

The agriculture and natural resources (ANR) sector is dominated by extensive rain-fed agriculture organised around family production units. The agribusiness sub-sector remains under-developed, and market linkages with domestic, regional and international markets are under-exploited. A few interest groups and commercial operators are engaged in horticultural production. Livestock production, supported by improved veterinary services, watering and market opportunities, remains essentially unchanged from traditional pastoral systems. According to the 2013 census, the ANR sector employs 40% of country's workforce with a majority coming from non-formal education background. Government's National agricultural Research institute (NARI) provides research and development (R&D) support to the sector (Touray et al., 2015; GBOS, 2016d).

The industry sector encompasses operational and supporting activities in mining and quarrying, manufacturing, construction, water, electricity and gas industries. By nature capital-intensive by nature, current operators within the sector and new entrants are both constrained by capacity issues and market conditions. Almost all major industries are located in the Greater Banjul Area. Light industries focus *inter alia* on the manufacture of plastic products, detergents, and beverages. Medium-sized enterprises scaling down to cottage industries produce a variety of goods including garments, footwear, jewelry, furniture and fabricated metal structures. The state-owned enterprise, NAWEC (National Water and Electricity Corporation), remains the lead actor in the water supply and electricity generation industries. Industry accounts for employment of 13% of the country's workforce, most whom are in their mid- to late-twenties (Njie, 2015a; GOTG, 2018a).

The services sector employs approximately 40% of the workforce, is composed of business establishments of different sizes, with those employing more than 20 people concentrated in major population areas State-owned enterprise (SOEs) are active and often lead actors in the transportation, communication, education and healthcare sectors. Except for regulatory matters, private entrepreneurs and business firms have exclusive control over retail, finance, real estate, and hospitality industries.

The Gambia pursues a liberal trade policy regimen consistent with regional integration goals and economic globalisation processes. Currently, the Gambia import 50% of the country's food, petroleum products machinery and other equipment, making the country vulnerable to adverse developments in the global economy. Since 2008, the official currency, the Gambian dalasi, has lost more than 50% of its value. The country's trade balance has also worsened since 2014, and its current account deficit at the end of 2016 was a just under 10% of GDP (GOTG, 2018; UNECA, 2017; CBG, 2016).

Between 2007 and 2016, the Gambian economy grew at an average rate of 3.6% annually, well below the 5% threshold targeted for the period. In part, this shortfall is attributable to structural constraints, and exogenous shocks that saw the economy shrink by 4.3% between 2010 and 2011, due to knock-on effects of drought on the agricultural sector. The Ebola pandemic in some ECOWAS countries in 2014 also had a significant impact on the Gambia's tourism industry. Between 2015 and 2016, agricultural output grew by 1%, whilst the industrial sector contracted by 3%. Service industries on the other hand, registered an aggregate growth of 4%.

Table 1. Sectoral economic outputs in 2007 and 2016

	2007			2016		
	GDP (GMD million)	GDP share	GDP growth	GDP (GMD million)	GDP share	GDP growth
Gross Domestic Product (GDP)	16,325	100.0%	2.8%	21,103	100,0%	1.0%
Agriculture	3,826	23.4%	-1.8%	4,590	21.8%	0.5%
Crops	1,691	10.4%	-17.9%	1,836	8.7%	-3.5%
Livestock	1,652	10.1%	10.9%	2,107	10.0%	3.1%
Forestry	107	0.7%	-4.2%	135	0.6%	2.9%
Fishing	375	2.3%	15.3%	513	2.4%	3.4%
Industry	2,473	15.2%	-0.9%	3,405	16.1%	-3.2%
Mining and quarrying	343	2.1%	-16.4%	541	2.6%	-11.5%
Manufacturing	1,238	7.6%	3.7%	1,264	6.0%	1.0%
Electricity, gas and water supply	222	1.4%	25.1%	305	1.4%	6.8%
Construction	670	4.1%	-10.1%	1,295	6.1%	-6.2%
Services	8,981	55.0%	5.2%	12,591	59.7%	3.9%
Wholesale and retail trade	5,004	30.7%	10.0%	5,899	28.0%	1.6%
Hotels and restaurants	694	4.3%	12.5%	552	2.6%	16.5%
Transport& storage	666	4.1%	4.9%	890	4.2%	3.2%
Communication	1,684	10.3%	9.4%	3,414	16.2%	8.5%
Finance and Insurance	1,183	7.2%	-6.2%	2,862	13.6%	4.7%
Real estate, renting and business activities	648	4.0%	2.7%	870	4.1%	3.0%
Public administration	282	1.7%	-38.4%	543	2.6%	2.7%
Education	209	1.3%	5.6%	455	2.2%	11.0%
Health and social work	204	1.3%	-0.5%	398	1.9%	11.1%
Other community, social and personal services	90	0.6%	2.7%	121	0.6%	3.0%
Adjustments for financial services	-610	-3.7%	-6.6%	-1,622	-7.7%	13.2%
Gross Value Added (GVA) at basic price	14,671	89.9%	2.8%	18,964	89.9%	1.0%
Taxes less subsidies on products	1,655	10.1%	2.8%	2,139	10.1%	1.0%

Source: National Accounts, Gambia Bureau of Statistics (GBOS)

Over the decade commencing in 2007, forestry, fishing and livestock GDP exhibited a steady annual growth of 2 to 3%. In contrast, an upswing in crop production from 2007 to 2010 was followed by a sharp downturn in 2011, with output improving briefly before taking a further downward trend in 2014. The construction sector which has enjoyed a boom since 2007 is now showing some signs of slowing down. Steady growth in output from the mining and quarrying sector suffered a reversal in 2013 persisting right through 2016. A sharp decline in manufacturing output in 2007 had lasting effects on the sector which only regained it 2007 performed in 2014, riding on a strong positive trend. Exceptionally, the service sector registered steady growth averaging 2.9% per annum. Wholesale and retail, communication, finance and insurance sectors, the fastest growing, are some of the sectors driving performance of the Gambian economy.

In 2016, agriculture, industry and services accounted for 24, 18 and 66% respectively of The Gambia's GDP (value-added at fixed prices) amounting to GMD 18,964 million (eighteen thousand nine hundred and sixty four million Gambian dalasi) (see Table 1). Labour productivity in agriculture increased marginally by 1.2% between 2007 and 2016, reflecting *inter alia* changing demographics of the agriculture workforce, natural factors, access to capital, marketing issues, and technological stasis. In sharp contrast, productivity in the manufacturing sector has suffered a precipitous decline under the combined effect of technology, investment and energy supply deficits, during the same period (GOTG, 2018a; UNECA, 2017; GBOS, 2016b; MOTIE, 2013; Jaiteh and Saho, 2006).

2.5. Social Affairs

2.5.1. Education

Formal education in the Gambia is organised around a three-tiered system comprising primary, secondary and tertiary levels.2 Around 1,564 primary and secondary-level schools are unevenly spread country-wide. West Coast Region and Kanifing Municipality with populations of 689,000 and 377,000; respectively, have the highest number of educational establishments. Secondary schools make up around 11% of all schools, and 42% of those are privately-run under charter granted by the Ministry of Basic and Secondary Education. Overall, private schools account for 47% of all educational establishments in the country. Gross enrolment rations (GER) average 101.6%, 56.6% and 45.2% in primary (Grades 1-6), upper basic (Grades 7-9) and secondary schools (Grades 10-12).[3]

To pursue studies at the tertiary level, pupils successfully completing the Grade 12 West African Senior School Certificate Examination (WASSCE) have the option of enrolling with the Gambia Technical Training Institute (GTTI),4 Gambia College,5 Management Development Institute (MDI), University of The Gambia (UTG) and a few other private universities, regulated by the National Accreditation and Quality Assurance Authority (NAQAA). However, low success rates in the core subjects of English, Math, Science, Social and Environmental Sciences (SES) remain an entry barrier for many aspiring students. Under the World-Bank sponsored Africa

[2] This does not include optional pre-primary level preparation otherwise known as early childhood development. Country-averaged GER in these establishments is 47.7%. Janjanbureh (Population =3,800) has the highest GER of 188, followed by the capital city, Banjul (88.7)

[3] https://www.gbosdata.org/topics/education

[4] GTTI is the only Technical and Vocational Education and Training (TVET) institute in the country (2,046 students enrolled during 2016/17 academic year).

[5] Gambia College provides professional training for teachers, nurses, public health officers and agricultural Supervisors

Centres of Excellence (ACE) project, implemented by MOHERST, nearly 150 students are currently enrolled in Masters and Doctoral-level programmes in the fields of public health, agriculture, science, technology, engineering and mathematics (STEM), offered in select Cameroonian, Ghanaian, Nigerian, Togolese and Senegalese universities.

2.5.2. Healthcare

Diagnostic and therapeutic services are available to families and individuals consulting on health issues at approximately 1,500 facilities within or close to major population centres in the country. Around 7% of these are under private and community management within the framework of operational licenses issued by the Ministry of Health. Under the ministry's classification system for health facilities, seven of the facilities are classified as major health centres and eight others as hospitals. The latter include Edward Francis Small teaching Hospital (EFSTH) the apex referral hospital in the country, and other strategically located regional hospitals. Between 2011 and 2015, out-patient department (OPD) visitors numbered between 1.5 and 2 million annually in public health facilities across the country (Sowe, 2016). In principle, medical cases that cannot be addressed locally are referred to a care facility of higher category.6 On aggregate, health facilities have approximately 2,500 in-patient beds of which 22% are allocated to ante-natal and post-natal care patients, providing some indication of the challenges faced by the Gambian healthcare delivery system.7 The healthcare delivery system is run by 16,000 certified medical professionals representing 1.1 doctors for 10,000 people; 1.5 midwives for 10,000 people; 1.3 community health nurses for 10,000 people in 2015, government budgetary allocation was 10.56% of total revenues, and its expenditure equivalent to 5.67% GDP. Some prescription drugs are dispensed free of charge, but others are purchased by patients from licensed drug stores. On average patients' out-of-pocket expenditures amount to 20% of treatment costs (Sowe, 2016).

2.5.3. Housing

Home ownership is a culturally-ingrained aspiration of all Gambians. According to the 2013 Population and Housing Census, 78% of households were living in owner-occupied dwellings. Two to three years later, this statistic had dropped to 56% reflecting the mismatch between social demand and access to land, and housing finance as well (GBOS, 2017, GBOS, 2016e) In general, tenure security is higher in rural areas highlighting housing deficits as an urban problem.

Housing units vary considerably in size in relation to owners' affluence, taste, need, and legal strictures, amongst a host of factors. The quality of buildings reflected by the type of materials used in the construction of exterior walls, flooring and roofing of buildings also vary geographically. On average, three-fifths of housing stock have three or more bedrooms. One- and

[6] Referral centres are generally better equipped and employ more qualified medical personnel to deal with complicated medical cases

[7] https://www.gbosdata.org/topics/health-and-nutrition

two-bedroom houses are more commonplace in urban areas. Approximately 44% of housing units have access to (on- and off-grid) electricity, 34% have access to drinking water within premises, and 47% improved sanitation facilities that are not shared (GBOS, 2019a; GBOS, 2016e).

The predominant model for financing housing development is construction based on private savings, or through mortgage arrangements with owners' bankers or employers. The sate-owned enterprise, SSHFC when established in 1981 set its sights on developing housing units for low- and middle-income families, with limited success, and has since adapted its approach first by providing loans to prospective home-owners, and is now selling serviced plots of land by public tender, or complete housing units for outright purchase. In a similar vein, private sector players operating in The Gambia in the past two decades, are providing a range of realty services and some companies are catering to the high-end of the housing market.[8] Other industry players include architects, wholesalers and retailers of building material, and building professionals organised in groups or as individual contractors.[9]

The real estate sector faces multiple challenges. Chief amongst these is a delayed recognition of housing as a major land-use sector of increasing importance (considering urbanisation trends). To this effect, housing-specific policy instruments are urgently needed to guide urbanisation patterns. In parallel, anti- land grabbing and speculation policy measures are needed to ensure equity. Furthermore, the environmental costs of new housing development supported by sand mining requires critical assessment.

2.5.4. <u>Social progress indicators</u>

According to the 2018 UN Human Development Index (HDI) Report, The Gambia, is ranked 174th out of 189 countries, reflecting its status as one of the poorest countries in the world. The country's HDI value for 2018 was 0.460. The rate of adult literacy is 42%. Average life expectancy is 61.2 years. Health insurance coverage is 0.4% and 1.7% for women and men, respectively. The proportion of Gambians living in extreme poverty' (i.e. on less than USD1.25 a day is, 20.8%, whilst the 'working poor' (earning USD3.10 a day or less) account for 62.3% of workforce (GBOS, 2019a; UNDP, 2018). From the perspectives of Gambians, socio-economic poverty is manifested in: (a) food insufficiency, (b) inadequate shelter, and (c) inadequate access to safe water, health facilities and quality education. Indeed, these are some of the key challenges reflected as priority areas in the Gambia's short-term development plan (GOTG, 2018a).

[8] http://www.accessgambia.com/houses-sale.html

[9] Individual contractors are indeed key to the fulfilment of new home owners' aspirations as they allow for flexible construction schedules to match owners financial strength.

2.6. Development priorities

The Gambia's development priorities spelt out in Government's recently crafted four-year national development plan (GOTG, 2018a) entails the following:

1) restoring good governance, respect for human rights, the rule of law, and empowering citizens through decentralisation and local governance;
2) stabilising the economy, stimulating growth, and transforming the economy;
3) modernising the agriculture and fisheries sectors to foster sustained economic growth, food and nutritional security and poverty reduction;
4) investing in people through improved education and health services, and building a caring society;
5) building infrastructure and restoring energy services to power the economy;
6) promoting an inclusive and culture-centred tourism for sustainable growth;
7) reaping the demographic dividend through youth empowerment; and
8) making the private sector the engine of growth, transformation, and job creation.

Current thinking and orientation at the highest levels of policy- and decision-making is in alignment with the Paris Agreement of 2015 which puts the economy on a 'green growth' pathway. This new paradigm is reflected in the NDP, and related SDGs are accorded the highest priority evidenced by the establishment of a dedicated coordination unit for SDGs within the Ministry of Finance and Economic Affairs (MOFEA).

The strengthening of local government structures is recognised as the most effective way of responding to economic development and public welfare priorities under their jurisdiction, particularly under emergency situations exemplified by climate-related disasters. Official policy for devolution of administrative powers and responsibility for a raft of social services from central to local government authorities (LGAs) is already rooted in the decentralisation policy and supporting legislative instruments. Seizing on seismic changes in political landscape in December 2016, the NDP and related climate risk management frameworks provides an opportunity for capacity building and investments. Incidental challenges related to awareness of governance issues fall within the remit of the National Council for Civic Education (NCCE) and non-formal education programmes. When fully development, eco-tourism and cultural tourism are expected to generate significant revenue streams for industry players and local communities, and enhance ecological assets of the country.

Energy is critical to economic growth and social progress. Thus, decades of deficits in infrastructure and service standards need to be addressed. Likewise, household energy security primarily dependent on fuelwood supply chains needed to be re-assessed. 'Greenbiz' opportunities need to be further leveraged, and private sector participation under build-operate-transfer (BOT), build-own-operate-transfer (BOOT), and public-private partnership (PPP) investment arrangements expanded.

2.7. Climate change institutional arrangements

Prior to the formulation of a national climate change policy (NCCP) in 2016, The Gambia government's climate change portfolio was handled by the Department of State for Natural Resources and the Environment (DOSFNR&E). Following a split of DOSFNR&E into two ministries and change in administrative nomenclature, the MECCNAR was trusted with climate change policy issues whilst the MOF&WR which oversee the NMHS, officially known as the Department of Water Resources (DWR), retained leadership of technical issues related to climate variability and change and residency of the UNFCCC Focal Point.[10] Under DWR leadership, The Gambia established an *ad hoc*, albeit Standing National Climate Committee (NCC) comprising a wide array of stakeholders representing public, private and voluntary sector interests. With regards to working arrangements, members of the NCC are sub-divided into thematic working groups supporting convention-related activities led by the DWR Director and/or his/her designated UNFCCC Focal Point. The National Environment Agency (NEA) serves as secretary to the NCC.

The 2016 NCCP (Urquhart, 2016) provides for the establishment of a National Climate Change Council (NCCC) comprising ministers with portfolios on climate change, foreign affairs, economic affairs, environment and natural resources, health and social welfare, basic and higher education, food security and agriculture, energy, disaster management, local governance, gender issues, youth affairs, with the possibility of further enlargement for greater inclusivity and successful execution of its functions. Among other functions, the NCCC is assigned with the responsibility of implementing the NCCP, coordinating related policy processes, fostering and strengthening international cooperation on relevant transboundary issues, and governing the Gambian Climate Change Fund (GCCF).

An institutionalised Climate Change Secretariat housed within the MECCNAR interfaces and works in close collaboration with 1) a national network of climate change focal points, 2) a national stakeholder forum, 3) sub-national administrative authorities, and 4) research clusters to catalyse knowledge integration and evidence-based decision-making; effective implementation of policies programmes, and projects; effective communication and information dissemination; and seamless coordination of policy processes and programme activities, under the supervision of a newly established Inter-Ministerial Climate Committee (IMCC). The National Climate Change Stakeholder Forum comprising representatives from farmers groups, women associations, professional associations, faith groups, children's and youth groups, workers and trade unions, media outlets, business and industry, caritative organisations, etc., will maintain vibrant bi-

[10] The pre-2005 Department of State for Natural Resources and the Environment (DoSFNR&E) was split into the: (1) Department of State for Fisheries and Water Resources, and (2) Department of State Forestry and the Environment (DoSF&E). Since 2005, the Department of Water resources (DWR), the national authority on climate science matters and seat of the UNFCCC Focal Point has been under the Department of State for Fisheries and Water Resources. As of April 2009, the previous nomenclature of 'Ministry' headed by a Minister was re-introduced by constitutional amendment, replacing 'Department of State'.

directional exchanges with the Secretariat especially on matters relating to policy and scientific research agenda setting and social auditing.

When fully functional, the IMCC, composed of the Permanent Secretaries and Directors of the line ministries represented in the NCCC. The IMCC will meet once every three months, to review reports and documents submitted to the oversight body by the Climate Change Secretariat, take a lead role in setting short- and medium-term goals in the National Climate Change Response Strategy and Action Plan prepare documentation (policy briefs, updates, etc.) and recommendations for consideration by the NCCC. The IMCC is co-chaired by the Permanent Secretaries from the MECCNAR and MOFEA, the latter being the designated national authority (DNA) for the Green Climate Fund (GCF). At the sub-national level, entities established under the Local Government Act (2002) are empowered to play lead and proactive roles in the formulation, implementation, monitoring and evaluation of Local Climate Change Action Plans (LCCAPs). Similarly, competent authorities and communities are envisaged to participate in social audits of external interventions promising to improve public welfare within their jurisdiction.

CHAPTER 3: GREENHOUSE GAS INVENTORY INFORMATION

3.1. Introduction

The chapter provides a summary of information contained in the Gambia's 2010 inventory of emissions and removals of greenhouse gases prepared by Manneh et al. (2015). The *Tier 1* level of analysis and default emission factors were used by the authors. A comprehensive description of data and methodology used can be found in the afore-mentioned document (Manneh et al., 2015).

3.2. Total emissions and removals of GHGs

During the inventory year 2010, greenhouse gas (GHG) emissions from Gambian territory amounted to 4,043 Gg of carbon dioxide equivalent (Gg CO_2 eq). Compared with 2000 and 1993, this represents an increase of 15% and 70%, respectively (GOTG, 2012; 2003).

Fig. 3.1, derived from emissions summary contained in table 2, indicates that {more than three-fifths of GHG emissions (61.2%) is attributable to the agriculture, forestry and other land use (AFOLU) source category/sector, whereas a 35% originates from industrial processes and product use (IPPU) and energy source categories in about equal measure. Handling and disposal of solid (and liquid) waste streams generates less than 3% of reported emissions.

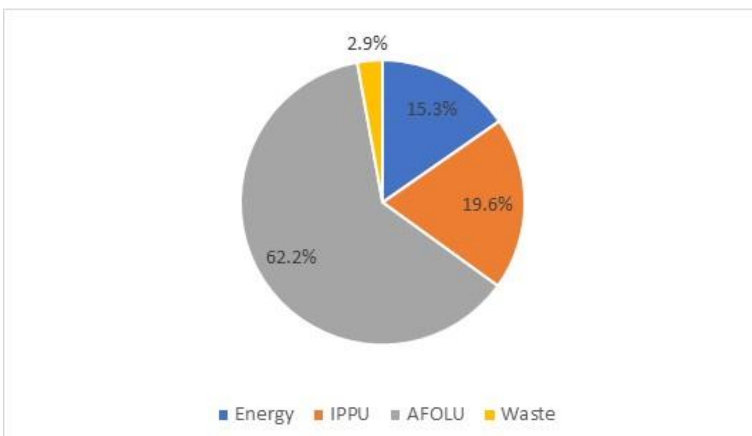

Figure 6. Sectoral contributions to The Gambia's total GHG Emissions (GgCO_2 eq) in 2010

Excluding gases controlled under the Montreal Protocol and AFOLU contributions, a breakdown of emissions by gases is shown in Fig. 3.2. CO_2 which accounts for 56% of emissions originates from fuel combustion activities in the energy sector. In conjunction with solid waste disposal, fuel combustion contributes almost a half of CH4 emissions representing 40% of emissions of direct greenhouse gases. Nitrous oxides (N_2O) from fuel combustion activities make up the remaining emissions in CO_2 eq of direct greenhouse gases.

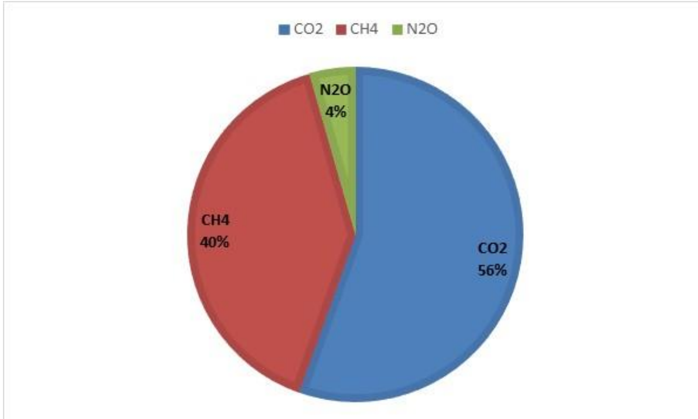

Figure 7. GHG emissions in 2010 (excl. HFCs, PFCs, SF6) by gas, in carbon dioxide equivalent terms.

Data in Table 2, synthesised from GHG inventories in 1993, 2000 and 2010 indicates precipitous drop in emissions across all classes of GHGs. In this table, data on direct greenhouse gases; CO_2, CH_4 and N_2O for which inventories reach back to 1993 (GOTG, 2003, 2012), suggest contrasting dynamics within economic sectors and key source categories. CO_2 emissions from energy industries in particular, continue to increase as the sector expands to meet rising domestic, industrial and commercial electricity demand. Transport, another key source of CO_2 emissions, albeit struggling to keep pace with demand, continues to grow in tandem with urban and inter-city travel and haulage of goods.

Table 2. National Emissions Summary for year 2010

Categories	CO2 Equivalents(Gg)								
	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO2 equivalent conversion factors (1)	Other halogenated gases without CO2 equivalent conversion factors (2)	N
Total National Emissions	**1,085**	**1,898**	**338**	**705**	**0**	**1**	0	0	3
1 ENERGY	**437.6**	**154.3**	**27.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	3.
1A Fuel Combustion Activities	437.6	154.3	27.8	0.0	0.0	0.0	0.0	0.0	3.
1B Fugitive Emissions from Fuels									
1C Carbon Dioxide Transport and Storage									
2 INDUSTRIAL PROCESSES AND PRODUCT USE	**19.1**	**44.3**	**8.4**	**705.0**	**0.0**	**1.1**	**0.0**	**0.0**	**0**
2A Mineral Industry	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
2B Chemical Industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
2C Metal Industry	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
2D Non-Energy Products from Fuels and Solvent Use	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
2E Electronic Industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
2F Product Uses as Substitutes for Ozone Depleting Substances	0.0	0.0	0.0	705.0	0.0	0.0	0.0	0.0	0
2G Other Product Manufacture and Use	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0
2H Other	1.7	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0
3 AGRICULTURE, FORESTRY AND LAND USE	**628.5**	**1,583.8**	**301.7**						
3A Livestock									
3B Land									
3C Aggregate Sources and Non-CO2 Emissions Sources on Land									
3D Other									
4 WASTE		**115.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0**
4A Solid Waste Disposal		115.6							
4B Biological Treatment of Solid Waste									
4C Incineration and Open Burning of Waste									
4D Wastewater Treatment and Discharge									
4E Other (please specify)									
5 OTHER									
5A Indirect N2O emissions from the									

Categories	CO2 Equivalents(Gg)								
	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO2 equivalent conversion factors (1)	Other halogenated gases without CO2 equivalent conversion factors (2)	N
Atmospheric Deposition of Nitrogen in NOx and NH3									
5B Other (please specify)									
Memo Items									
International bunkers	73.4	0.05	0.6						
International Aviation (International Bunkers)	56.6	0.00	0.6						
International Water-borne Transport (International Bunkers)	16.8	0.05	0.0						
Multilateral Operations									
Information items									
CO_2 from Biomass Combustion for Energy Production	2,287								

Source: Manneh et al., 2015

Notes: Data generally reported to one decimal place. In cases where emissions are less than 1/100th the unit of measure, the accuracy of reporting is to two decimal places. Totals may not add up exactly due to rounding up effects.

Table 3. Inter-comparison and trend of GHG emissions for the years, 1993, 2000 and 2010

Greenhouse gas	GWP	Emissions ($GgCO_2$) [1] [2]			1993-2010 change[3]
		1993	**2000**	**2010**	
CO_2	1	936	329	1,085	70%
CH_4	25	1,370	1,096	1,914	43%
N_2O	298	66	1,110	338	-228%
HFCs	14,800		21	705	97%
PFCs	7,390		0	0	ind.
SF_6	22,800		935	1	-88018%
Total $GgCO_2$ equivalent		2,372	3,490	4,043	

Sources: Manneh et al., 2015; GOTG (2003, 2012)

Notes:

Emissions data rounded up to nearest whole number. Totals may not add up exactly due to rounding up effects.

[1] 1993 total excludes emissions (138GgCH4) from industrial wastewater handling (GOTG, 2003); [2] 2010 emissions and computations related thereto are likely to change in definitive version of inventory. Note also that The Gambia had a total net removal of 50,000 Gg CO2 eq in 1993 attributed to forest regeneration. This is not shown in the current table for comparability with subsequent years which registered positive values of et CO2 removals from the AFOLU source category; and [3] the year 2000 is taken as baseline for change in HFC, PFC and SF6 emissions.

HFC and SF_6 emission inventories initiated in the year 2000 indicate negative trends reflecting to some extent the gradual phase-out of CFC12, HCFC22, RSO2, HCFC134a and their in refrigeration, air conditioning, and electrical equipment. Indeed, the 2008 version of the Gambia's State of the Environment Report (NEA, 2010) highlights a 90% reduction of CFC consumption between 1998 and 2006, quite similar to reductions between 2000 and 2010 as reported by Manneh et al., (2015). From the foregoing, emissions per capita between 1993 and 2010 have remained relatively stable between 2.23 and 2.63 tCO2 eq.

3.3. Emissions and removals of GHGs by sector

This section covers GHG missions from the Gambian territory, excluding bunker fuels from international aviation and shipping which are reported separately.

3.3.1. Energy sector emissions

GHG emissions from the energy sector as reported in Manneh et al. (2015) is limited in scope to fuel combustion activities. Indeed, no attempt was made to estimate GHG emissions from fugitive sources, or indirect GHG emissions associated with CO_2 transport and storage, because economic and industrial activities associated with the last two source categories did not exist in the Gambia at the time of the inventory in 2010.

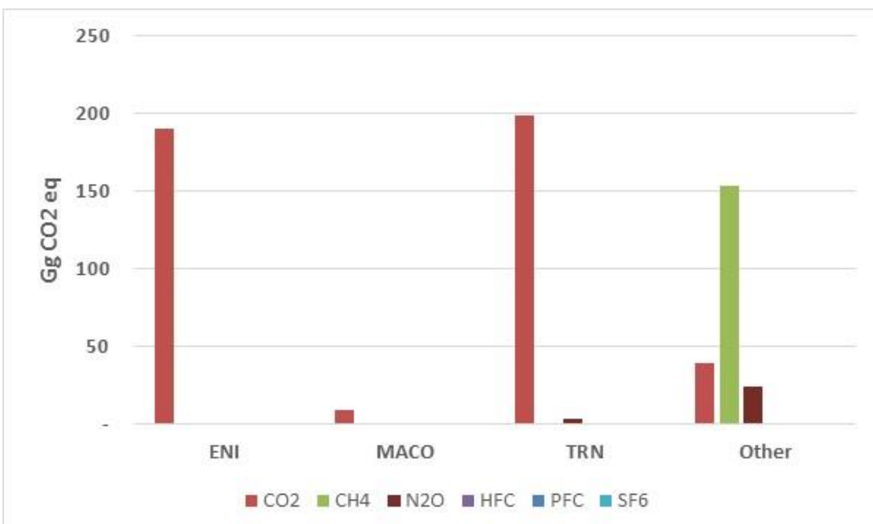

Figure 8. Emissions from energy subcategory sources

This inventory shows that the energy sector is responsible for GHG emissions totaling 620Gg CO_2 eq. Excluding emissions from manufacturing and construction (MACO) activities, the remainder of sectoral emissions (93%) is almost evenly divided between energy industries (ENI), transport (TRN) and miscellaneous sources aggregated under "Other Sectors" (i.e. source category

1A4). TRN and ENI are the main sources of CO_2 emissions, whilst "Other Sectors" generate 87% and 99% of N_2O and CH_4 emissions, respectively. The residential sub-category within "Other Sectors" represents the largest source of CO (105Gg) and NMVOCs (18Gg).

Electricity generation in The Gambia is the based on conversion of chemical energy contained within fossil fuels with electromechanical generators strategically located around the country. Between 2004 and 2016, production has ramped from 128 to 313 GWh/annum, paralleling heavy fuel imports (AF-MERCADOS EMI, 2013). Fuel imports continue to rise to feed growing demand from the national road vehicle fleet.[11] Renewable energy production remains marginal (Njie, 2016).

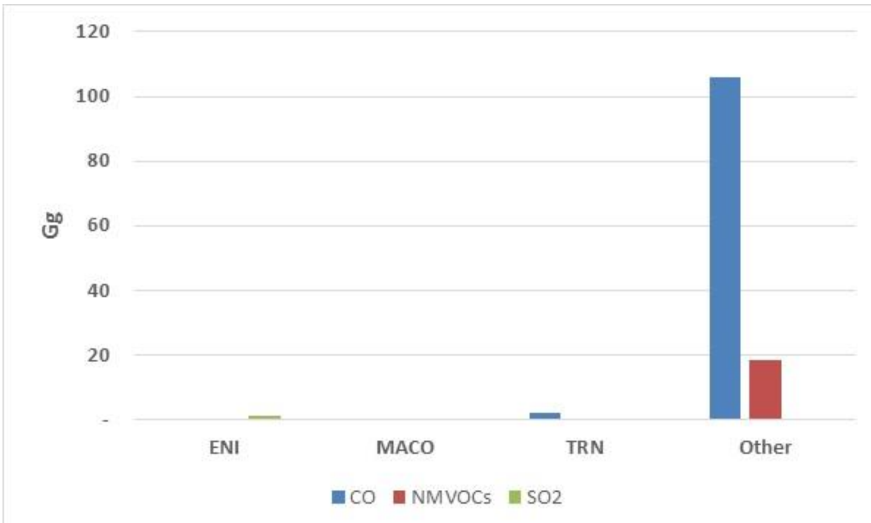

Figure 9. Indirect GHG emissions from energy subcategory sources

3.3.2. Industrial Processes and Product Use (IPPU) sector emissions

GHG emissions from the IPPU sector in 2010 totaled 778Gg CO_2 eq, 91% of which was made up of gases controlled under the Montreal Protocol. Emissions from the earth minerals industry amount to 9.2Gg, or 1% of emissions from the IPPU sector.

Emissions from solvents and other products added up to 16.4Gg CO_2 eq. Almost all emissions (91%) in this sector, made up of HFCs, originate from the use of substitutes for ozone-depleting substances (ODSs) in refrigeration, air conditioning, aerosols and fire retardants. CO_2 contributions (19GgCO_2 eq), equivalent to 2.4% of aggregate emissions from the IPPU sector, derive from solvents and other products and the earth mineral industry. On the other hand, CH_4 emissions (44GgCO2 eq) stem from food and beverage industry operations.

At the time of reporting, neither metallurgical nor electronic industries had taken root in The Gambia. Light and small-scale industries focus *inter alia* on the manufacture of foam and plastic products, detergents, and beverages. Between 2007 and 2010, the contribution of the

[11] https://www.gbosdata.org/topics/economy/registered-vehicles

industrial sector to GDP fell by 8.3% mirroring the suppression of CO_2 and CH_4 contributions to national emissions.

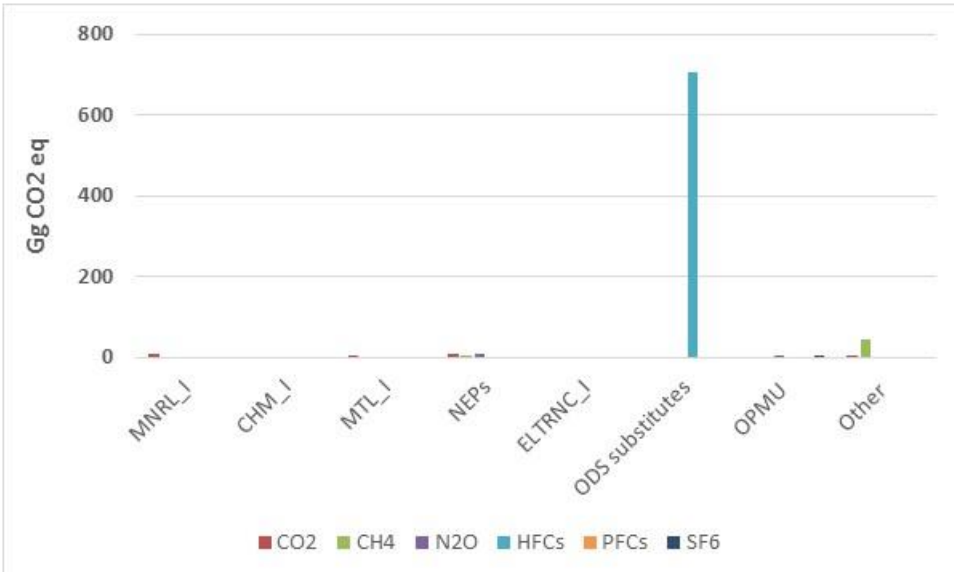

Figure 10. Emissions from IPPU subcategory sources

3.3.3. <u>Agriculture, Forestry and Other Land Uses (AFOLU) sector emissions</u>

Emissions of GHGs from the AFOLU sector in 2010 added up to 2,514GgCO_2 eq. About 53% of these emissions came from agricuture (cropland and livestock) sector while 47% were attributed to forest and land use (FOLU) changes. The inventory further revealed that emissions associated with agriculture were dominated by CH_4 from rice cultivation (34%), enteric fermentation (29%), and CO_2 fluxes from agricultural soils (25%).

Further emissions of CO_2 from forests were computed as 1,334 GgCO_2 eq. Added to 967GgCO_2 eq from forest soils, aggregate emissions from forestry and land use (FOLU) were pegged at 2,301GgCO_2 eq. Consequent to CO_2 absorption (1,109GgCO_2 eq) by soils and vegetation in other wooded lands however, net FOLU emissions reported were 1,182GgCO_2 eq.

3.3.4. <u>Waste sector emissions</u>

Waste sector emissions reported in the 2010 national inventory do not include emissions from wastewater. The assessment does not include either emissions generated by the burning of solid waste (Manneh et al., 2015). GHGs generated from biodegradable waste accounts for the totality of GHG emissions reported (116GgCO_2 eq).

3.4. Gaseous composition of GHG emissions

Emissions of direct GHG, that is, CO_2, CH_4 and N_2O, add up to 3,332GgCO_2, or 83% of the 2010 inventory total. An overview of these gases and others is provided in sub-sections below.

3.4.1. Carbon dioxide (CO_2)

CO_2 emissions (1,090 GgCO_2 eq) account for 26% of national emissions, and 32% of emissions excluding GHGs controlled under the Montreal Protocol. Energy and AFOLU source categories, including the transport and electricity sectors of the Gambian economy, as well as CO_2 fluxes from agricultural soils in particular, are the main sources of CO_2 emissions. Minor sources of CO_2 emanating from the IPPU sector include energy products and solvent use (8.0GgCO_2 eq), ceramic production and use of soda ash (7.3GgCO_2 eq), whilst food and beverages generate trace amounts (1.7GgCO_2 eq), of CO_2.

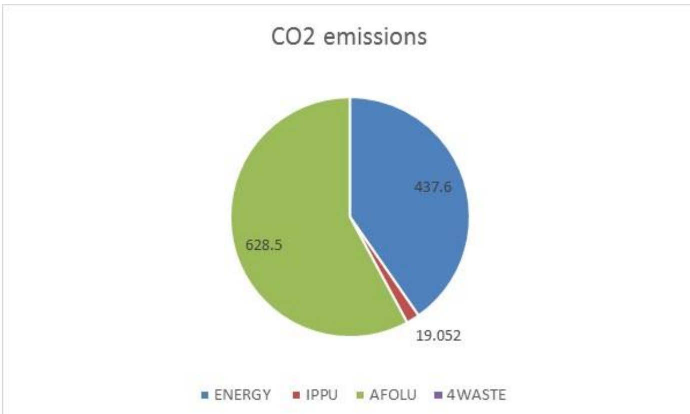

Figure 11. Sectoral contributions to total CO_2 emissions

3.4.2. Methane (CH_4)

CH_4 emissions (1,914GgCO_2 eq) in 2010 represent 47% of national emissions, and 57% of emissions excluding GHGs controlled under the Montreal Protocol. The AFOLU sector, accounting for (1,584GgCO_2 eq), or 83% of national emissions, is by far the single largest source of CH_4. Noticeably, emissions from rice cultivation (539GgCO_2 eq) and livestock farming (459GgCO_2 eq), account for nearly two-thirds of CH_4 emissions from the AFOLU sector.

Other sources of CH_4 worthy of mention include residential activities (154GgCO_2 eq) and natural breakdown of solid waste (116GgCO_2 eq). Combined with emission from solvent use within the IPPU sector (0.7GgCO_2 eq), emissions from food and beverages (43.7GgCO_2 eq), account for 2% of total CH_4 emissions.

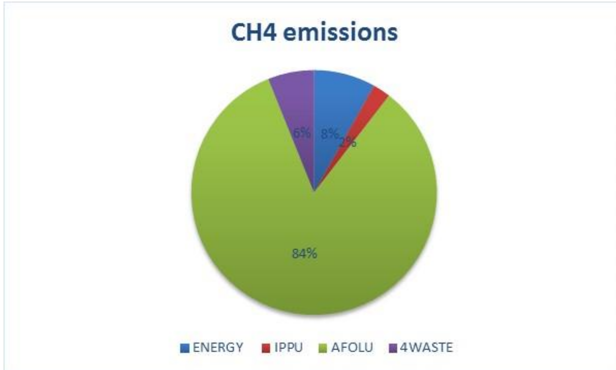

Figure 12. Sectoral contribution to total CH_4 emissions

3.4.3. Nitrous Oxides (N_2O)

The 2010 GHGI of the Gambia puts N_2O emissions (338GgCO_2 eq) represents 8% of national total emissions, which increases to 10% if GHGs controlled under the Montreal Protocol are excluded from the inventory total. Activities linked to economic production within the AFOLU sector, particularly biomass burning, account for almost nine-tenths (302GgCO_2 eq) of N_2O emissions during the inventory year. Minor and trace source sources include fuel combustion in residential (2GgCO_2 eq) and commercial (0.2gCO_2 eq) applications.

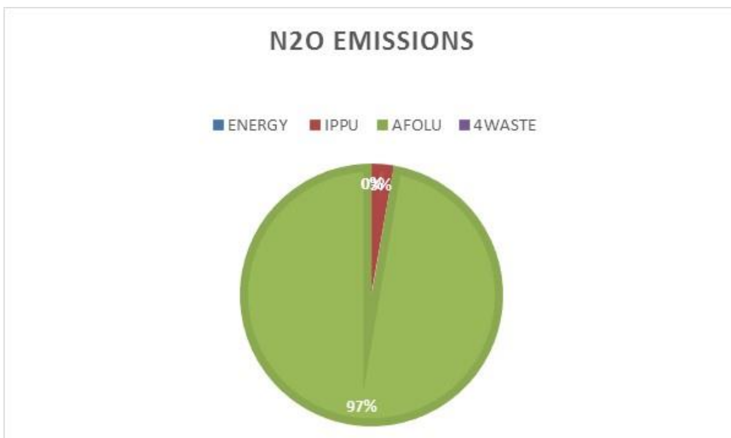

Figure 13. Sectoral contributions to total N_2O emissions

3.4.4. Hexafluorocarbons (HFCs)

HFC emissions (705GgCO_2 eq) in 2010 represent 17% the national total. HFCs are generated almost exclusively from substitutes for ozone depleting substances (ODSs) used in refrigeration, air conditioning (311GgCO_2 eq), and in aerosols (308GgCO_2 eq). Trace emissions (8GgCO_2 eq) were associated with the use of fire retardants.

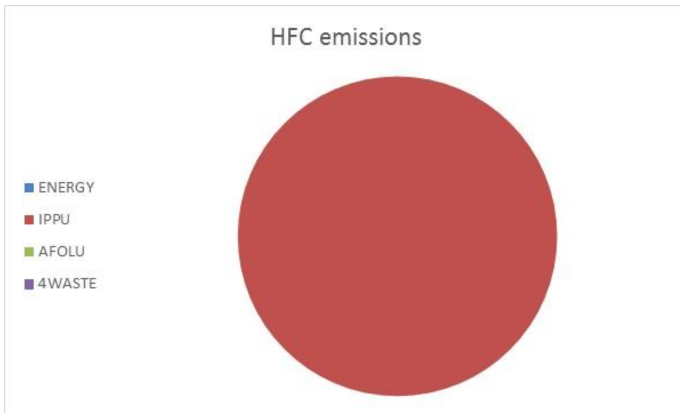

Figure 14. Sectoral contributions to total HFC emissions

3.4.5. Perfluorocarbons (PFCs)

PFC emissions were not estimated and consequently not reported o in the 2010 GHG inventory report.

3.4.6. Sulphur hexafluoride (SF_6)

SF_6 emissions (1.1GgCO_2 eq) in 2010 represent 0.03% the national total. SF_6 in this inventory was generated entirely from usage and disposal within the operational environment of high-voltage electricity transmission. Other potential SF_6 sources not covered in the inventory include ODS substitutes and gaseous by-products of fluorochemical products.

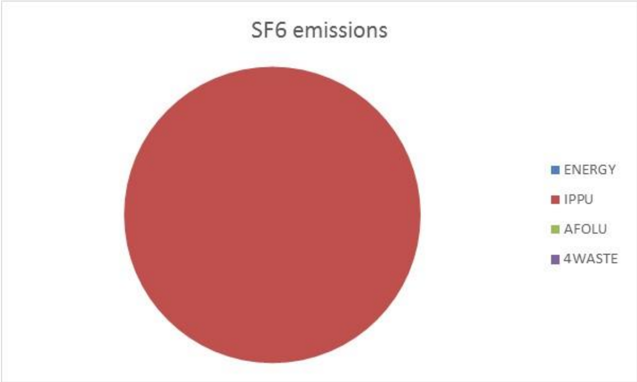

Figure 15. Sectoral contributions to SF_6 emissions

3.4.7. <u>Other gases</u> (CO, NMVOCs, NO_X, SO_2)

From the 2010 inventory, indirect GHG emissions outside the energy sector were not estimated. According to Manneh et al. (2015), residential applications, generated between 45 and 97% of all indirect GHGs, excluding exception of SO_2 emissions. Energy industries were responsible for 70% (1.2 Gg) of SO_2) emissions, whilst road transport accounted for 34% of NO_x emissions (1.11Gg).

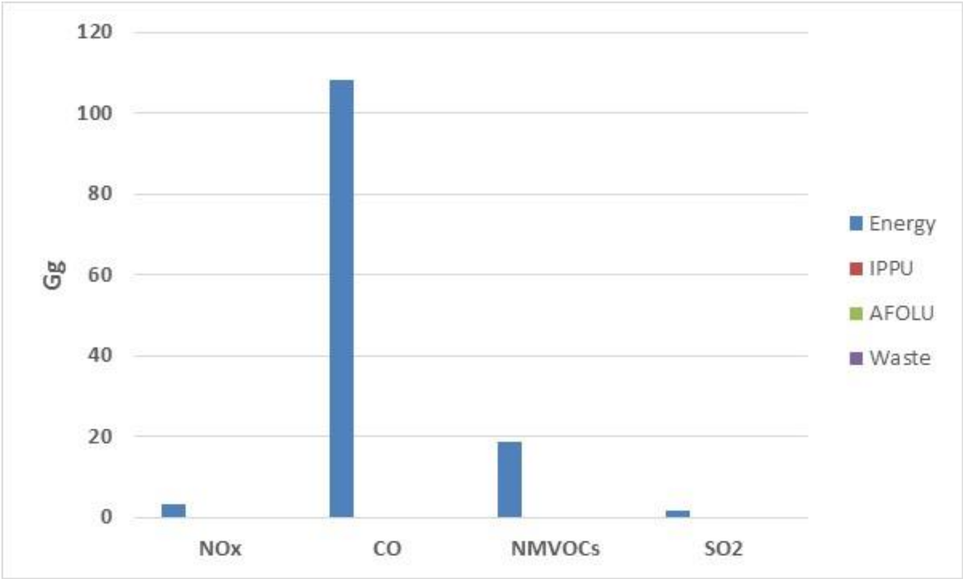

Figure 16. Indirect GHG emissions

3.5. International aviation and marine bunker fuels

As a direct reflection of the country's tourism industry and external trade, Banjul International Airport and Banjul Seaport have both been expanded to handle higher volumes of cargo and passenger throughput (GCAA, 2015; GPA, 2014; GT Board, 2015). The number of vessels berthing at Banjul sea port in 2011, the closest date to the inventory year of 2010, was 358 ships with gross registered tonnage (GRT) of 3 million metric tonnes (GPA, 2017)[12]. The number of aircraft landing at and taking off from Banjul International Airport are on average 2,200 a year (GBOS, 2019b).[13] Assessed emissions of CO_2, CH_4 and N_2O under the two modes of transport are shown in Table 4.

Table 4. Emission's from bunker fuels for the year 2010

Categories	**Emissions (Gg)**		
	CO_2	CH_4	N_2O
International Bunkers	52.9	0.002	0.002
1A3.a.i - International Aviation	29.4		0.001
1A3.d.i - International water-borne navigation	23.5	0.002	0.001

[12] GPA, 2017. Financial statements and Annual Reports for the year ended 31t December 2015. Banjul.

[13] Data for 2010 not accessible. Number of landings approximated by yearly average computed over the period 2013 to 2018

CHAPTER 4: MITIGATION ASSESSMENT

4.1. Introduction

In 2015, The Gambia articulated and published its Intended Nationally Determined Contributions (INDC) against the backdrop of COP decisions 1/CP.19 and 1/CP.20, with financial and technical support from the German Agency for International Cooperation (GIZ) and the Climate and Development Knowledge Network (CDKN). The chapter of the TNC summarises the results of sectoral assessment reported in the INDC (GOTG, 2015).

The INDC, focusing on GHG mitigation in: 1) Energy; 2) Transport; 3) Agriculture; and 4) Waste Management sectors/categories was prepared using 100 year Global Warming Potentials (GWPs) from the IPCC 4th Assessment Report (AR4) and its 2006 greenhouse gas inventory methodologies (IPCC, 2016)

4.2. Sectoral assessment

4.2.1. Energy sector

In the mitigation scenario analysed, four mitigation strategies and their combined impact on emissions are assessed. These strategies, which can be aptly described as 1) fuel substitution; and 2) fuel conservation strategies, are projected to cut down GHG emissions from energy industries and CO_2 from biomass combustion by 425.7 $GgCO_2e$ in 2020, 541.1 $GgCO_2e$ in 2025 and 629.6 $GgCO_2e$ in 2030. Figure 17 illustrates the emission reductions in relation to specific mitigation options.

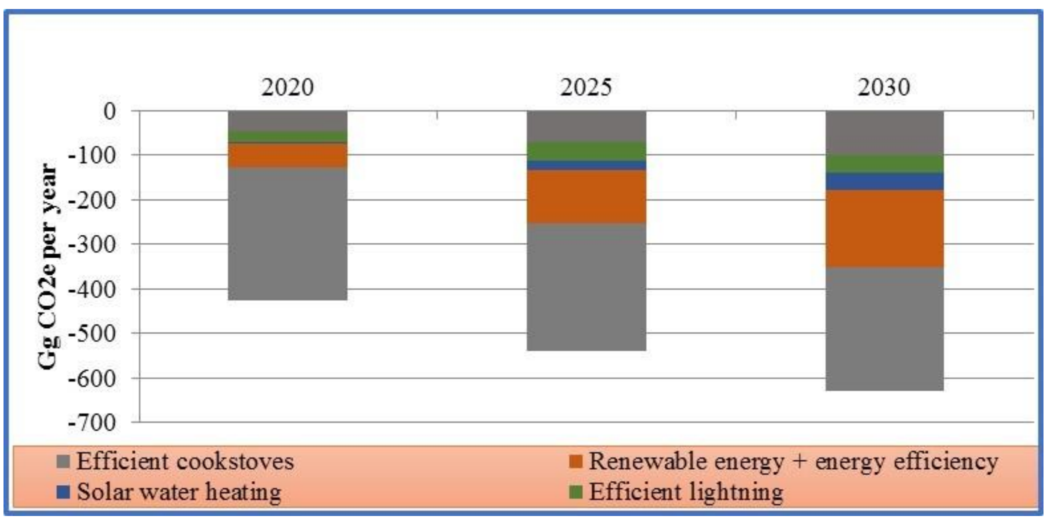

Figure 17. Emission reductions in energy industries and from combustion of biomass

4.2.2. Transport sector

Emissions reductions resulting from the introduction of fuel-efficient technologies in the transport sector were assessed. It was found that increased deployment of fuel efficient vehicles would generate greenhouse gas emission reductions of 40.8GgCO_2 eq by 2020, 115GgCO_2 eq by 2025, and 193GgCO_2e by 2030, when compared to a baseline scenario under which incentives or regulations are not strong enough to influence (widespread) adoption of fuel efficient vehicles (Figure 18).

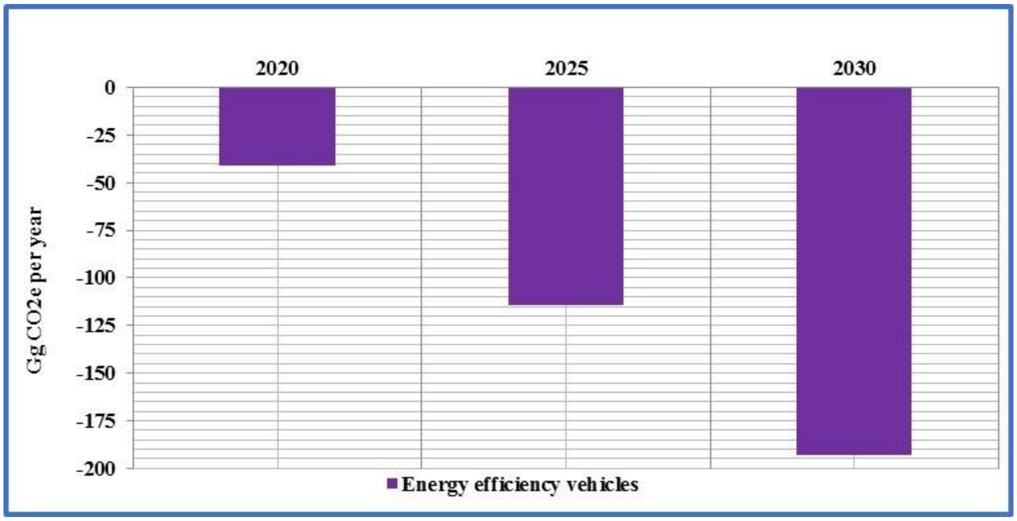

Figure 18. Emission reductions from transport source category

4.2.3. Agriculture sector

Under the Agriculture sector, potential emission reductions using the NEw RICe for Africa (NERICA) cultivar and System of Rice Intensification (SRI) irrigation technique were assessed. Under intensification of NERICA cultivation and production, emission reductions computed are in the order of 124GgCO_2 eq in 2020, stabilising at 398GgCO_2 eq between 2025 and 2030. As for SRI, which provides documented gains in water use efficiency in swamp rice production, emission reductions are 438 GgCO_2 eq in 2020, stabilising at 707GgCO_2 eq between 2025 and in 2030 (see Figure 19).

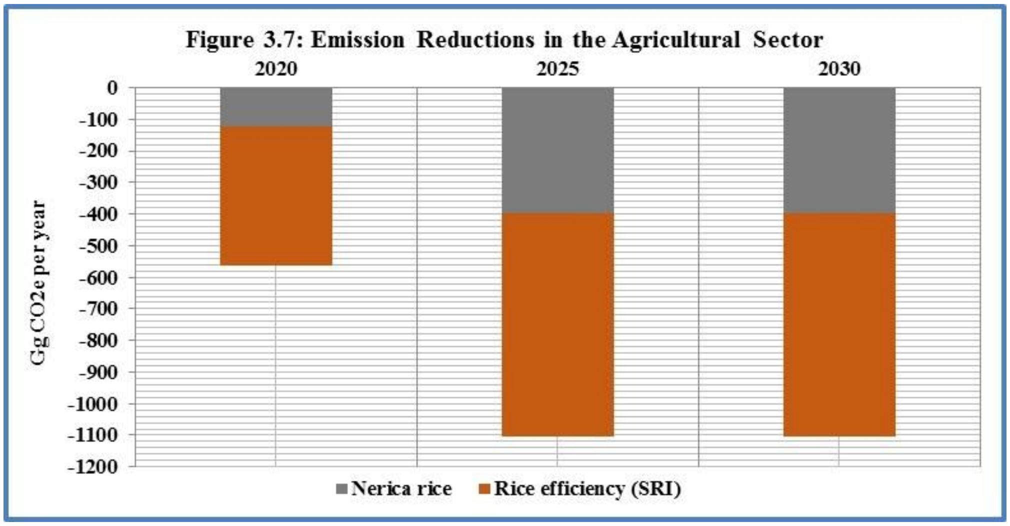

Figure 19. Emission reductions from rice cultivation (agricultyre sector/source category)

4.2.4. <u>Waste sector</u>

Three mitigation strategies, namely methane capture, waste recycling and waste composting are reported for the Waste sector in the TNC. When implemented, these strategies are expected to generate GHG emissions reductions in the order of 141 GgCO_2e in 2020, 239.7 GgCO_2e by 2025, and 413.7 GgCO_2e by 2030 (Figure 20).

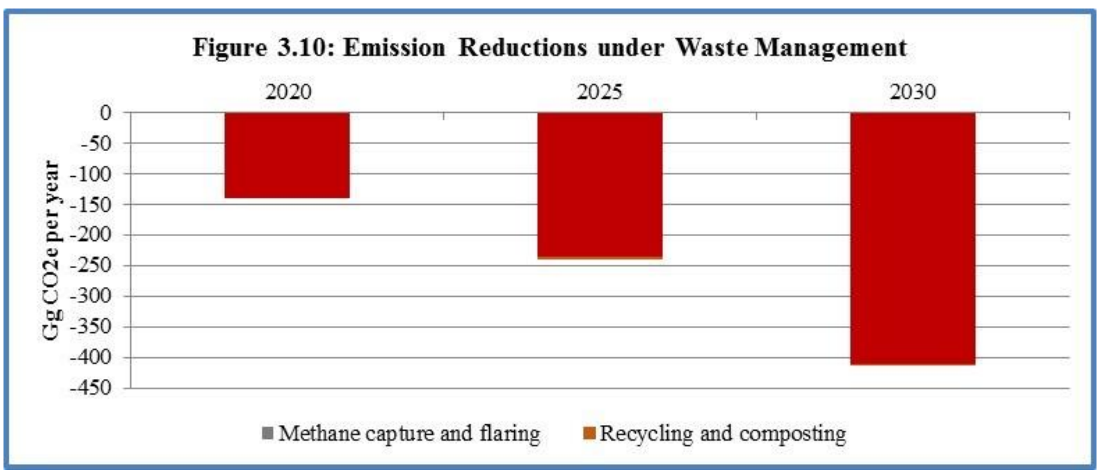

Figure 20. Aggregate emission reductions from methane capture, waste cycling and waste composting, under the waste sector

CHAPTER 5: VULNERABILITY ASSESSMENT

5.1. Climate change projections

In work previously reported in the Gambia's SNC (GOTG, 2012), spatially detailed information on future changes in climate parameters (temperature, precipitation, evapotranspiration) were produced using MAGICC/SCENGEN. The trio of global circulation models (GCMs); CCC199, BMRC98 and GDFL90, were run with different radiative forcings to generate an ensemble of time series up to year 2100 at ten year intervals. Estimates of mean sea level changes found in section 5.1.4 are derived from process-based models run under different greenhouse gas concentration trajectories that are documented in Church et al. (2013).

5.1.1. <u>Temperature</u>

For the remainder of the 21st century, GCMs used for climate change projections point to warming in all parts of the country. Annual mean temperatures are estimated to increase relative to the year 2000 by 1.7 to 2.1 ºC in 2050, and by 3.1 to 3.9ºC in 2100. According to CCCM199 and GFDL90 temperature estimates, stronger warming is expected in winter (DJF)[14] compared to summer months (JAS)[15], over the coming decades. BMRC98 which produces the fastest and largest increases in temperature point to stronger warming in summer months.

5.1.2. <u>Rainfall</u>

Annual rainfall is projected to decrease by less than 1% in 2020 to about 54% in 2100. The largest decrease is associated with the warmest climate change scenario under BMRC98, while CCCM199 suggests a 2% drop by 2100, not statistically different from inter-annual variability of current rainfall. Notwithstanding, a reverse climatological trend cannot be discounted. For instance, Sylla et al. (2012) have shown that regional climate models (RCMs) incorporating complex orographic features tend to alter the direction of rainfall change. Sanogo (2015), using the US National Centers for Environmental Prediction (NCEP) and National Centre for Atmospheric Research (NCAR) datasets in HadGEM2 climate simulations, also found evidence of positive trends in annual rainfall totals in a majority of stations in the Sahel where variability of annual precipitation is strongly influenced by sea and land-surface feedbacks with the atmospheric boundary layer (Wei et al., 2014, van der Ent et al., 2014; Sanogo, 2015). In response to increased radiative forcing, Gibba (2016), using percentile and threshold rainfall statistics, reports a shift towards more intense precipitation in West Africa, but found discordant cues for the increased frequency of extreme rainfall events. In sum, unlike temperature changes, the current state of knowledge calls for caution and sensitivity analyses in applications using rainfall projections.

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[14] December-January-February (DJF)

[15] July-August-September (JAS)

5.1.3. Evapotranspiration

Potential evapotranspiration (PET) over an annual timescale is projected to increase to between 1,370mm and 1,945mm by 2100, that is, an increase of 2% and 45% above historical levels, as per GFDL90 and BMRC98 simulations (GOTG, 2012). Estimates based on Thornthwaite's formula, pre-calibrated with 24 years of observational data with an error estimate of 4%, stand at 2,400mm (Verkerk and van Rens, 2005). In all scenarios PET is projected to lie between 1,460mm and 2,260mm/year, by 2050.

5.1.4. Sea level rise

The current report adopts sea level rise projections reported in the IPCC Fifth Assessment Report (Church et al. 2013). Accordingly, mean sea level in Gambian coastal areas is projected to lie within 20% of the global mean sea level rise of 26cm to 98cm by 2100, the latter estimate corresponding to RCP8.5 (van vuren et al., 2011). On a pro rata basis that puts expected sea level rise in The Gambia between 19cm and 43cm by 2050. Limitations of and uncertainties in these estimates emanate principally from incomplete understanding of underlying physical processes, digital representation of those processes, observational data (calibration), and fate of the marine-based sectors of the Antarctic ice sheet (Church et al., 2013.

5.2. Expected impacts on natural resources

In agreement with previous reports (GOTG, 2007; 2012), climate change is expected to put severe pressure on natural and societal systems. In this chapter, unmitigated impacts (up to 2050) of climate stressors on biotic and abiotic terrestrial and marine resources, habitat suitability and other impact receptors of relevance are assessed. In most instances, these impacts have strong connections to economic and societal impacts discussed under section 5.3.

5.2.1. Arable land

Physical and chemical properties that underpin soil productivity are moderately to highly vulnerable to direct and indirect effects of emerging climate trends and extremes. Indeed, climate change effects on arable land have already been observed across Africa (TerrAfrica, 2009). Under the scenario of decreasing rainfall which approximates a persistent pattern of successive drought years over a period of nearly three decades starting in the late 1960s (Mahé and Olivry, 1995), salinisation and acidification of lowland soils in the Gambia is expected to intensify putting a squeeze on marginally productive soils or soils most exposed to climate stressors (NEA, 2010). Increased aridity predisposes soils in uplands to higher rates of topsoil erosion, whilst extreme rainfall events are strong triggers for gulley and sheet erosion in sloping upland areas and deposition of inert sediments in lowlands (AfDB, 2007). Without adequate source controls for unconsolidated sediments, emergent trends and frequent occurrence of extreme rainfall is expected to exacerbate soil erosion within croplands. Drawing upon research findings reported by Mingguo et al. (2007) and the experience of Gambian agricultural extension workers, it is reasonable to assume that the potential for soil losses is lowest when field crops are fully established and highest at the start of the rainy season. On the other hand, increased runoff at the watershed scale could improve the restorative impact of annual floods on alluvial soils in the flood-plain and backswamps.

5.2.2. **Forests**

Based on scientific assessments, Gambian forests including coastal mangroves are expected to undergo noticeable changes in response to increasing temperature and atmospheric CO_2 concentration, modified rainfall patterns, and sea level rise by 2050. Notwithstanding, the future state of forests is expected in all likelihood to reflect mitigating or amplifying effects of climate change on land use transformations including the use of fire in farming and traditional forestry (Sillah, 1999; GOTG, 2003, 2007; NEA, 2010; Baudena et al., 2015, Bouvet et al., 2018).

Reinforced by edaphic factors, pronounced variability of rainfall, associated with BMRC98 projections, savannah forest in The Gambia is expected to undergo further shrinkage and fragmentation, to the advantage of grasslands. While the mortality rate of large trees is expected to be high, but average stocking volume of remnant savannah is still expected to grow by 2.76t/ha, or 13% by 2050, in response to CO_2 fertilisation (GOTG, 2003; NEA, 2010; Philips et al., 2010; Qasim et al., 2016). Gallery forests found along tributaries benefitting from augmented dry season flows in the River Gambia are expected to be least affected by a low precipitation regime. Indeed, higher water levels in these environments (Sogreah et al. (1999) are expected to favour expansion of gallery forests and stocking volume thereby. Increasing aridity is expected to slow down mangrove (*Rhizophora spp*.) forest die-off and short-term succession by floating aquatic vegetation in the central stretch of the River Gambia estuary (MSU, 1985). However, combined effects of lower rainfall, intensified soil and open water evaporation, and prolonged tidal inundation sustained by sea level rise are expected to escalate saline and anoxic conditions with a strong likelihood of massive mangrove mortality in lower estuary areas (Jimenez, 1985; Lugo et al., 1988; Krauss et al., 2008; Ceesay, 2015). A concomitant breach of the ecological envelopes of gmelina (*Gmelina arborea)*, cashew (*Anacardium occidentale)* and mango (*Mangifera indica)*, currently populating monospecies plantations, points to increasing mortality of these species and their replacement by more drought-resistant species within the forest landscape.

Figure 21. Mangrove in Tanbi Wetland Complex/National Park. Courtesy: Adam Ceesay

Figure 22. Savannah woodland. Courtesy: Malanding S Jaiteh

Conversely, the scenario for rainfall recovery is expected to culminate in a significant gain in forest biomass by 2050, due to increased productivity of savannah forest in The Gambia; forest densification and upward shift of tree diameter sizes, resulting in an estimated growth of 6.53t/ha, or 25% by 2050. To the same extent or greater, gallery forests found along tributaries are also expected to increase in size and stocking volume. Effects of increasing CO_2 concentration on mangroves is poorly understood. Above ground biomass (AGB) for mixed mangrove stands with similar crown heights found across tropical areas is reported as 56 to 189t/ha, whereas yields range from 1 to 12t/ha/yr (Komiyama et al., 2008; Gillman et al., 2008). All-round wetter conditions are likely to prompt expansion of cashew plantations, and support re-growth of Guinea forest tree species in areas of highest rainfall. Increasing wetness is expected to accelerate mangrove (*Rhizophora spp*.) die-off and short-term succession by floating aquatic vegetation with lower net primary productivity in the middle part of the estuary. In lower estuary of the River Gambia, annual fluctuations of freshwater inflow into mangrove forest will be a key determinant of mangrove forest structure, growth and productivity.

5.2.3. Grasslands

Similar to forests, biomass dynamics in grasslands is strongly correlated with mean annual precipitation (MAP) over a wide range of latitudes in the topics (O'Connor et al., 2001; Gill et al., 2002; Wen Hong et al, 2008). Under a semi-arid scenario in which MAP lies between 600 and 800mm, phytomass production, reflecting global warming impacts and variable conditions of grasslands, is estimated to fall between 337 and 1,443 g/m2, with below ground biomass (BGB) accounting for over 80% of biomass within this biome. Total phytomass of 615 g/m2 reconstructed from previous reports (Jallow, 1997a, 1997b; GOTG, 2003) for comparable MAP lies within the lower half of this range. By comparison, biomass production under MAP fluctuating between 1,000 and 1,200 mm, is estimated at 367 to 1,554 g/m2, an increase of 9.0% and 7.7% respectively with respect to semi-arid conditions, a result that could be attributed to the resilience of grasslands under variable precipitation regimes (Xu et al., 2015).}

In general, the spatial distribution of grass cover tracks precipitation gradients, but is locally influenced by soils, herbivory, soil moisture and fire history. Excluding non-climate effects, species composition in existing herbaceous savannah in the Kombos, West Coast Region (WCR), coastal areas of North Bank Region (NBR) and drier parts of Lower River Region (LRR) and Central River Region (CRR), is expected, under a semi-arid climate future, to shift towards drought-resistant annual grasses exemplified by creeping, shallow-rooted grasses. To a lesser degree, analogous changes in species composition is also expected in western parts of CRR. Basal area and species composition are expected to be least affected in southern CRR, even as grass species compete for water under variable soil moisture regimes. In the southwestern part of country, there is a strong possibility for the resurgence of Guinea forest (in protected areas), paralleled by a decrease in annual grass cover under a wetter scenario. The cumulative impact of recruitment success of trees and shrubs in other parts of WCR is also expected to gradually diminish grass cover in these areas. Elsewhere in the country, favourable growing conditions are expected to speed up the dominance of tall and perennial grasses over annual grass species. In all circumstances, the confounding effects of fire, herbivory, and land use conversion, will determine boundaries and areal extent of grasslands.

5.2.4. Freshwater resources

5.2.4.1. Groundwater

In addition to the River Gambia and its tributaries mentioned in Chapter 2 of this report, freshwater resources are found in a multi-layered system of aquifers that underlies the country (DWR, 1983; NIRAS, 2015a). Surface storage is virtually limited to seasonal ponds whose capacity is not known, but thought to be insignificant judging from their depths, area and life cycles (Njie, 2009). Annual recharge of aquifers, that is renewal of groundwater resources, is related to landscape factors and multiple climate controls, particularly rainfall.

Under a semi-arid climate future, annual recharge of the shallow sandstone aquifer is estimated at 30mm to 66mm (268Mm^3 to 591Mm^3) by 2050, reflecting the stochasticity of MAP and hydrological effects of projected land cover transformations. Surface conditions are also responsible for spatial variations in local recharge which is projected to be highest in WCR and southern parts of CRR and URR, and lowest in NBR and LRR. Average recharge is projected to decrease from 85mm (750Mm^3) to 77mm (689Mm^3) as a larger proportion of effective rainfall is diverted to surface runoff under MAP of 1,000mm and 1,200mm, respectively. Under both semi-arid and wet scenarios, occult recharge from on-site sanitation systems could potentially increase groundwater renewal rates by 20 to 30% locally, and NO_3 loading of the phreatic aquifer as well (Njie, 2002; NIRAS, 2014b). No information is available on recharge of the DSA, replenished through outcrops in Senegal (Senegal, 2016).

5.2.4.2. Surface water

Mean unregulated flow in the perennial freshwater stretch of the River Gambia is projected, under semi-arid conditions, to vary between –30% and 9% relative to flows observed at Kuntaur in the 1970s and 1980s (168m^3/s), and to increase by 38% to 161% under wet conditions (Howard Humphreys & Sons, 1974; Berry et al., 1985; Sogreah et al., 1999). Interactions between surface and ground water along the course of the River Gambia still remain open to investigation (Gao, 2011; NIRAS, 2014a). Future regulation of flow at Sambangalou will downgrade peaks flows, augment low flows and generally modify mean flows to fit with operational objectives of the multi-purpose dam at Sambangalou. Simultaneously, the Sambangalou dam will act as a sediment trap for particulate matter eroded from the upper GRB, but possibly aggravate river bank erosion and augment sediment transport on the downstream side of the dam (Linsely et al., 1958; Lesack *et al.*, 1984; Ouillon and Caussade, 1991, Njie, 2002).

5.3. Expected impacts on vulnerable sectors, industries and geographic areas of special interest

Anticipated impacts are assessed at the decadal to multi-decadal time scale up to 2050, to reflect sensitivity to synchronous climate stressors discussed under section 5.1. Thus, risk, resilience and sustainability issues in the agriculture, forestry, tourism, and construction and real estate sectors of the economy are assessed from a short-term perspective. Multi-decadal impacts up to 2050 are assessed for fisheries and healthcare sectors. Climate change impacts on the Gambian coastal zone is also assessed within the latter timescale.

5.3.1. Agriculture

5.3.1.1. Crops

Crop yields are influenced by the interplay between genetic and environmental factors, moderated by crop management systems including soil fertility amendment, water control, and pest management, to ensure maximum possible yields under prevailing conditions (Njie et al., 2008; Trawalley, 2016). Under a progressively drier climate, the combined effects of heat and soil moisture stress is expected to become a major constraint to crop development and yield under rain-fed cropping systems. Several studies and assessments suggest that climate change negatively influences yields of major crops grown in The Gambia (Njie et al., 2008; Schlenker and Lobell, 2010; Knox et al., 2012; Blanc, 2012; Yaffa, 2013; Trawalley, 2016). By 2050, yields are expected to change as follows: −17 to 0% (millet), −25% to −15% (sorghum), –22 to 0% (maize), −18% (groundnuts), with the possibility of losses being amplified by nitrogen stress. Swamp rice yields are expected to remain at current levels as long as crop cycle water demands are not compromised, or growing areas degraded by soil salinisation or acidification (Bagbohouna et al., 2018). Similarly, horticultural crop yields remain relatively insulated from climate change insofar as conflicting and overriding water supply objectives do not come into play. Due to limited research, climate change impacts on sesame are less clear, with yield changes of −23% to 33% exhibiting dependence on sowing date (Niguse, 2015). Atmospheric CO_2 concentration fertilisation effects on yields are less clear (Long et al., 2006; Abebe et al., 2016).

A couple of assessments on the performance of millet and groundnut under a wetter climate future report 26% yield increases for millet and 9 to 25% yield increases for groundnuts (GOTG, 2003; Njie et al., 2008). Combined with information on expected loss of agriculturally suitable land, millet is expected to register production gains of 18%, and groundnuts 8% to 13% by 2050 (AGRA, 2014). Conversely, under a drier climate future, millet and groundnut are expected to suffer production losses ranging from 1 to 24%, whereas sorghum production is likely to slump even further by 16 to 30%. Needless to say, a significant drop in smallholder crop production is likely to jeopardise farmers' food security, increase rural poverty and slow down economic growth (Sillah, 2013; GOTG, 2018a).

Figure 23. Mature rice crop in Central River Region (CRR). Courtesy Baba Galleh Jallow

5.3.1.2. Livestock

Amplifying the effects of land use changes especially those related to the boundaries and aggregate area of cropland and savannah, climate change is expected to exert strong pressures on traditional livestock production systems through net primary productivity of naturally-occurring pasture, irrespective of warming and pluviometric futures (GOTG, 2003; Xu et al., 2015). Thus, computations relying on expected pasture productivity and 2017 livestock population statistics, indicate a stocking capacity of 87,000 tropical livestock units (TLUs) (i.e. 75% reduction relative to current herd size) by 2030 under low rangeland productivity, and a carrying capacity of 637,000 TLUs (i.e. 86% increase relative to current herd size) within the same time span under high rangeland productivity. This higher livestock herd size estimate drops to 572,000 TLUs by 2050 on account of shrinking pasture, and barely reaches 60,000 by the middle of the 21st century under a xeric climate. Insofar as extra feed resources are available through transhumance and supplementary feeding, afore-mentioned stocking capacities especially lower ones could increase significantly.

All factors considered, transhumance, supplementary feeding and disease prevention and control, are expected to prop potential herd sizes and increase productivity (Perry et al, 2001; Savage, 2017). Increased warming over the next three decades, accentuated by heat extremes is likely to depress animal production, reproduction and growth. Under specific temperature conditions, extreme rainfall and out-of-season rainfall are linked to large-scale livestock mortalities. A warmer and wetter climate enhances resurgence risks of livestock diseases and pests (GOTG, 2007). Distance to drinking water points and water availability is not perceived as a production constraint under future climate (Njie, 2003; NIRAS, 2015a), but latent conflicts between farmers and herders need to be defused to avoid overt conflicts during protracted periods of poor harvests and pasture conditions.

Figure 24. Cattle grazing on fallow land. Courtesy of Malanding S Jaiteh

5.3.2. Forestry

Climate change has progressive impacts on the productivity of floristic biodiversity, but its net effects are amplified and accelerated by land use change. As in the past, cropland expansion and logging are expected to be the major driving force behind forest cover loss (Bojang, 2005; GOTG, 2007, 2010; Ferreira, 2015; Groover, 2017). Under these pressures, productive forest is projected to significantly shrink in size, down from the current estimate of 51.8% (CILSS, 2016) to between 30% and 46.7% of land area by 2030, and waning still further to between 20% and 42.7% by 2050. Under these scenarios, the expected volume of roundwood and fuelwood production from Gambian forests ranges between 694,850 m^3 (i.e. – 68% relative to 2013) and 3,392,293 m^3 (i.e. +53% relative to 2013) by 2030. Low and high estimates of wood production by 2050 lie within the range of 463,233m^3 (i.e. –79% relative to 2013) and 3,043,087m^3 (i.e. +37% relative to 2013). Although this assessment suffers from lack of forest management information including actual productive forest targeted for conversion, biological composition of remnant stands and corresponding allometric variables (Bond, 2010; Henry et al., 2011; Qasim et al., 2016), the preliminary results can be quite instructive. Principally, 1) the wood processing industry is headed for uncertain times, 2) domestic demand for roundwood and fuelwood products can only be met in future under a wetter climate and provided that aggregate demand remains at or below current demand, and 3) wood exports, currently accounting for around 7% of production are expected to fall, or if prioritised, increase domestic supply deficit of roundwood and fuelwood to 61% and 74% respectively, within the next three decades (Sillah, 1999; FAO, 2018).

As yet, there has been no studies on impact of climate change and forest degradation on non-energy, non-timber products (NENTPs) such as honey, wild fruits, gum arabic, nuts, leaves, bark, from which some households derive a living. Anecdotal evidence suggests somehow increased scarcity of these products as productive forest area shrinks and forests become more fragmented. A drier climate might is equally likely to adversely affect production of wild honey in a fragmented forest landscape.

5.3.3. <u>Tourism</u>

Despite strong dependence of the tourism industry on weather and climate, climate change impacts are yet to be studied in earnest (WTO, 2003). As mean winter temperatures rise in key source countries in Northern Europe, global warming ostensibly represents a formidable barrier for Gambian tourism authorities' plans to boost winter tourist arrivals and summer visitor numbers (Prek, 2006; GT Board, 2015; Njie, 2015a). In consequence, climate change poses serious challenges to the Gambia's destination competiveness, exposes tour operators to greater financial risk, and is likely to increases running costs of tourism establishments and (trigger fundamental changes within the industry).

Figure 25. Kololi Hotel beachfront with uprooted coconut trees at foot of receding sand cliff. Courtesy: Momodou A. Cham

By mid-century, beach loss to relentless sea level rise and wave action driven by high impact weather events will diminish shoreline attractions, degrade amenities and restrict recreational activities in space and time. Similarly, Kunta Kinteh Island (a UNESCO World Heritage site) with special significance for African American tourists is also threatened by sea level rise (NEA, 2010; Njie, 2015a; Bojang, 2016). Outside the wet corridor of the River Gambia, uncertainties surrounding qualitative changes in forest cover and wetlands abound. It remains to be seen whether development and marketing of new tourism products will open up new market segments (Mylène, 2002; GT Board, 2015) and the potential demographic shift from middle-aged to younger tourists can offset potential losses from resort tourism (Mitchell and Faal, 2007; Njie, 2015a).

5.3.4. <u>Construction and Real Estate</u>

Climate change impacts on construction and real estate sectors could be significant, but locally relevant information is limited. Key questions in urgent need of answers include risks and costs of climate-induced damage to infrastructure stock, size of new orders received by construction companies, survival rates and sectoral employment trends.

Notwithstanding, long-term sand scarcity partly driven by shoreline changes and beach erosion (section 5.3.7.3) is expected to (create) significant challenges including higher costs for urban development and regeneration. Housing development (GBOS, 2016e) in particular will be subject to further constraints from a sharp decline in roundwood production (section 5.3.2). In addition to materials flow and quality constraints, potential climate change impacts on construction processes are mediated by health and safety of workers, worker productivity and externalities including variable and extreme weather occurring during construction project life cycles.

Under warmer and wetter conditions, contractors might be unable to avoid circumstantial tradeoff between worker safety and productivity with possible consequences on cost and time-overruns. There is also a risk of quality standards not being met if construction practices are not aligned to prevailing weather and short-term weather outlook (Prek, 2006; Oakland and Marosszeky, 2006; Njie, 2015). High impact windstorms are more likely to be prejudicial to processes pursued and activities undertaken by medium- and micro-sized construction enterprises during July through October. Robust by design, construction equipment used in house building and major civil engineering works are expected to be minimally affected by weather conditions, provided their deployment is properly scheduled. Regardless, services extracted from such equipment is subordinate to operators' health and safety.

By 2030, climate change modulated by non-climatic factors such as approved design of specific infrastructural elements, construction practices followed, quality of materials used and maintenance history is expected to cause slight to advanced deterioration in concrete structures built before the year 2000, with strong ramifications for safety, serviceability and aesthetic aspects of infrastructure concerned (PCA, 2002; Wang et al., 2010; Zhou et al., 2014). Increasing temperatures and recurrent heatwaves in particular are expected to catalyse premature ageing of and damage to asphalt roads (QUT, 2009; Njie, 2015a). Without proper pre-treatment, timber used in door frames, doors, ceilings of buildings is at enhanced risk of dry rot as well as termite damage. Degradation of polymers, amplified by thermal stress on elements used in electrical, plumbing and other installations, is also expected to increase over time. In the long-run, infrastructure built after 2020 are not immune from damages to older buildings as briefly described, insofar as principals do not factor in climate risks in commissioned works. Except polymers perhaps, most damages on building materials are attenuated under a drier climate future. *Pari passus*, future construction projects are very likely to be more costly due to input prices and insurance (Njie, 2015a).

5.3.5. Fisheries

Superposition of decades-long fishing pressures (Gasceul et al., 2007; Braham et al. 2015; Daniels et al., 2016; DOF, 2017) on climate impacts (sections 5.3.7.1 and 5.3.7.2) is highly likely to accentuate changes in marine species diversity, geographical distribution and inter-species relationships. Except for all-weather water-craft, the number of days actors engage in fishing activities is restricted by inclement weather exemplified by stronger storm frequency (Harley et al., 2006).

Without credible evidence or projections of a sustained downward trend of pelagic fish stocks (Mendy, 2002; DOF, 2017), fish landings are expected to increase above the current 60,000 tonnes/annum despite a significant contraction in the size of the artisanal fisheries fleet (DOF, 2017). Although failure probabilities of specific fisheries arising from aggregate extraction rates of artisanal and industrial fleets are not quantified, there is a risk that illegal, unreported and unregulated (IUU) fishing (GOTG, 2007) and gradual modifications of marine and estuarine ecosystems by climate change might precipitate the collapse of some fisheries. Based on the available evidence (Mendy, 2002; Gasceul et al., 2007; Braham et al., 2015), there is no end in sight to the downward trend in demersal fisheries, but the greater part of such failure is attributable to fishing pressure, especially IUU (GOTG, 2007). Irrespective of climate change, recovery of benthic species with long population doubling times (DOF, undated)16 remains in doubt. Arguably, pelagic species with short population doubling times such as Sardinella maderensis (Madeiran Sardinella) and Caranx crysos (Blue Runner) are expected to be most resilient to fishing pressure and ecosystem changes.

Shellfish fisheries are quite likely to gain from higher mangrove productivity under higher freshwater inflows (section 5.2.2). In contrast, higher pollutant loading of wetlands (section 5.3.7.2), and higher water temperatures in a wetter climate future are quite likely to depress harvested tonnage of shellfish and compromise food safety (Jallow, 1989).17 There is no assessment on climate change impacts on cockle fisheries, dominated by fisherwomen operating

[16] (Monograph on the) Common marine and inland species The Gambia. 58p

[17] It is worth noting that the setting up exclusion zones and restricted harvesting seasons for shellfish can cut down contamination risks but cannot offset production/harvest losses.

within the lower estuary of the River Gambia. Climate change implications for emergence of pests and spread of diseases (Queiroga et al.; 2014; Scardua et al., 2017) is another area of uncertainty.

5.3.6. <u>Public health</u>

Changes in climate parameters (section 5.2) pose direct public health risks when individuals' and communities' are exposed to pathogens, natural and synthetic toxins via multiple pathways including ingestion of contaminated water, aerosol inhalation, and bites of insect vectors (GOTG, 2007; IPCC, 2014; Githeko et al. 2014). In the longer-term, sporadic heat waves accentuated by the urban heat island effect (Oke, 1973, 1982) are likely to increase in intensity and duration leading to minor and severe cases of heat stress, dehydration among vulnerable population sub-groups, and fatalities actuated by increased concentrations of ground-level ozone and vehicle tail-pipe emissions (GOTG, 2007, 2010; Simöes et al., 2011; Hales et al., 2014).

Under a warmer and wetter climate future, the prospects for the resurgence of some endemic diseases (NDMA, 2014) emanating from favourable environmental conditions for breeding mosquitoes, the geographic spread and persistence of other health-threatening agents, abetted by inadequate sanitary infrastructure, cannot be discounted. In particular, flood contamination of contact surfaces and water supply points increase the risk of water-related disease outbreaks (Jarra, 2002; Cotruvo et al., 2004). In addition to concentrating pollutants from non-point sources, an increased number of seasonal ponds with extended life spans promotes the survival and proliferation of several water-based disease vectors/hosts and parasites, and increases the risk of diseases associated with wildlife being propagated into the human environment, via pastoral farming systems (Bradley, 1977; Tourre et al., 2017). As habitats for mosquitoes expand, dense forest stands close to human habitations become more of a concern regarding the appearance and spread of Zika cases (Baraka and Kweka, 2016; Nutt and Adams, 2017). Severity of water-based public health threats are generally attenuated and possibly suppressed under a drier climate future whereby airborne transmission of allergens and pathogens constitute the major pathway for infection of an otherwise healthy young population with meningitis and/or measles (Molesworth, 2003; Penn State, 2008; Yade, 2015). As habitats for mosquitoes expand, dense forest stands close to human habitations are a serious cause for concern regarding public health threats of Zika (Baraka and Kweka, 2016; Nutt and Adams, 2017). Climate impacts on transport, communication and infrastructure (Njie 2015), reflecting negatively on the standard of service and efficacy of healthcare delivery systems, is likely to persist under prevailing conditions (Cramer et al., 2014).

In general, multiple factors determine the level of risk faced by individuals, communities, and specific population sub-groups. Logic suggests however that people living in areas/households with inadequate access to safe water supplies are most exposed to enteric diseases, persons who do not take protective measures against mosquitoes and other biting insects are more vulnerable than the average person to diseases transmitted through insect bites, and only a small minority of the population, insulated from contact with surface water runoff, aquatic environments and open spaces (including public spaces and playgrounds) containing biomarkers of contamination, is safe from infections contracted through contact with water-borne pathogens and toxins. Corollary to the preceding statement, residents of low-lying areas, children, farmers, and professional launderers represent population sub-groups most exposed to diseases transmitted through water contact.

5.3.7. <u>Coastal Zone</u>

By virtue of its geography, The Gambia encompasses a terrestrial and contiguous maritime environment that constantly interact with one another. For this reason, definitions of the Gambian coastal zone have often been tailored to fit specific management challenges. In the current report, emphasis is placed on the geostrategic area (figure 26,) which represents the zone of convergence of key industries and huge investments in infrastructure, houses more than half the country's population within its northern and southern provinces, and accounts for 80% of national GDP. Additionally, this area contains ecological areas of significant importance including Tanbi National Park (a Ramsar site) and Niumi National Park (a transboundary park merging with the *Parc du Delta de Saloum* in Senegal)(Jallow and Barrow, 1997; Cham et al., 2001; GOTG, 2003; NEA, 2010; Njie, 2014; Ceesay, 2015).

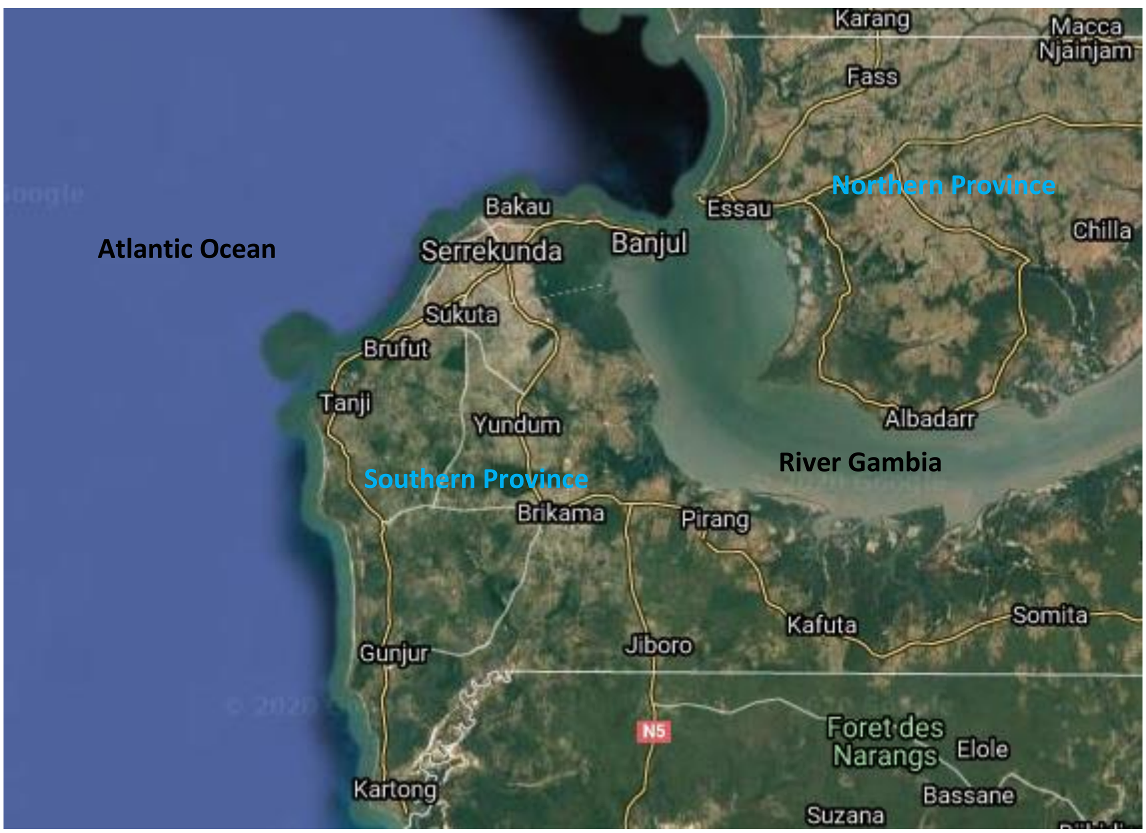

Figure 26. Location map of coastal zone. Adapted Google Earth Image.

When landward boundaries of the coastal zone are not specified or impractical, flexibility is often exercised and problem space is allowed to dictate boundaries. One might even justifiably argue, that the entire country including its exclusive economic zone (EEZ) lies within the coastal zone. A *bi-directional flow regime between River Gambia estuary and Atlantic Ocean is a permanent feature of the hydrology of this area.*

As a departure from previous assessments focusing on the littoral domain (Cham et al., 2001; GOTG, 2003, 2013; NEA, 2010), this report additionally explores potential impacts of projected climate change on natural and built environments in the estuarine, marine, and interfluvial domains of the coastal zone. An assessment of climate change impacts on the environment and people living in this geostrategic area is challenged by uncertainties surrounding the magnitude of climate stressors, and effectiveness of organisational and individual decision-making. Based on their spatial characteristics and socioeconomic profiles, climate variability and change is expected to trigger distinctive physical and social transformations in different coastal zone domains (Rotmans et al., 2001; Head and Afford, 2013).

Ignoring some overlaps between estuary and littoral domains around Bakau and Kartong (close to the mouth of Allahein River), the estuarine domain is demarcated as a 3km strip of land bordering the River Gambia estuary from its mouth to a distance of 20km upriver. The interfluvial domain represents higher elevation areas located between littoral and estuary areas, and is the current location of major urban settlements in northern and southern coastal provinces, linked by ferry boat. The marine domain covers the exclusive economic zone (EEZ) of The Gambia.

5.3.7.1. Marine domain

As a direct consequence of sea level rise, both landward and seaward boundaries of the marine domain are expected to shift with time at a rate determined by the time course of mean sea water levels and shoreline topography. In the process, the Gambia's outer EEZ boundary is expected to slightly retract landward by 2050.

Global assessments by IPCC (2001, 2014) indicate that a general warming of oceans is likely to modify physico-chemical properties of the milieu, perturb in-situ processes regulating mass and energy flows intricately linked with biodiversity within the milieu (Tait and Dipper, 1998). Warming of the water column between the Gambian shoreline and 500m isobath is expected to continue unabated well beyond 2050. At depths below 100m, temperatures could increase by 0.1°C per decade. Inversely, dissolved oxygen concentration is expected to slightly decrease, but a more energetic wind regime and wave climate is expected to partly offset the drop in oxygen levels in the active mixing layers of the water column. Driven by changes in the thermal structure of the water column, the intensity of coastal upwelling (of colder nutrient-rich water) is likely to diminish, while the active upwelling zone to expected to shrink and move inshore towards the edge of the continental shelf. Although the fertilising impacts of biogenic silica from Saharan dust and dissolved organic carbon (DOC) from estuary mangroves (Lee et al., 2009; Ndoye et al., 2014; Korte et al., 2017; Sarre et al., 2018) are yet to be evaluated, they potentially represent critical inputs to marine ecosystem productivity, which drives the abundance of marine species, their geographic distribution and population structures (Toressen et al., 2003; Komoroske et al., 2014; Harley et al., 2006). Similarly, short- and long-term changes in freshwater inputs and salinity gradients, also influence the geographic distribution of emblematic fish species such as *S.*

maderensis, *S. aurita* and shad (*Ethmalosa spp*.) (Cham et al., 2001; Sarre et al., 2018). Over short timescales, extreme rainfall could produce transient changes in sea surface salinity (SSS) and also induce range preferences among these species. Washout efficiency of aerosols or that of atmospheric contaminants (including SO_2 from electricity power plants) is expected to be higher under a wetter climate with mixed effects on acidification and fertilisation of marine environment (Korte et al., 2017, van der Does et al., 2016).

Not much is known about seabed sediments and benthic communities (DHI, 1982; Lee et al., 2009). However, adverse impacts of ocean warming is likely to be strongest among bottom-dwelling species with little or no opportunity for range expansion in response under changing environmental conditions (GOTG, 2007).

5.3.7.2. Estuary domain

Average monthly freshwater flows into the estuary domain during the flood season in the order of 115 to 720 m^3/s result in 0.2 to 1.3% dilution of resident water under dry and wet pluviometric scenarios, respectively. Suspended sediment transported by the River Gambia is not expected to make a significant contribution to bathymetric changes in the estuary zone (DHI, 1982; Ouillon and Caussade, 1991; Drammeh, 2013). Thus, rising sea levels are expected to trigger the migration of mangrove stands into contiguous swamp rice production areas rendered unproductive by salt accruing from rising groundwater and tidal inundation (Njie, 1991). However, the shrinkage of mangrove basal area observed between 1973 and 2012 on the landward fringes of Tanbi Wetland National Park (Ceesay, 2015), is quite likely to reverse under favourable pluviometric conditions, except in Old Jeshwang, Bakau, Eboe Town and a few other peripheral neighbourhoods within the Kanifing Municipality, where incompatible soil substrate or hard structures impede landward migration of mangrove stands. Re-wilding of the current buffer zone between settlements and mangrove stands can only mean one thing: increased human-wildlife conflicts and further endangerment of threatened and rare species such as the monitor lizard, crocodile, and boa species living in close proximity to human settlements.

Contraction of wetland in specific areas is likely to have a negative cascading effect on pollution abatement efficiencies with adverse effects on resident aquatic species, migratory and non-migratory bird species, and shallow coastal waters (NEA, 2010; Conkle *et al.,* 2008; Cham et al., 2001; Verhoeven and Meuleman, 1999; Jallow, 1989). Anticipated impacts of lower wetland productivity include lower harvests of bony fishes, crustaceans and shellfish, and threatens sustainability of oyster processing (at Abuko) and ecotourism (at Mandinaray) (Cham et al., 2001; Hirani, 2005; Lee et al., 2009; Ceesay, 2015). UNESCO World Heritage sites on Kunta Kinteh Island (formerly James Island), steeped in African and European colonial history, including the slave trade will come under increasing pressure from wave erosion and partial submergence by rising water levels in the Gambia estuary (GOTG, 2007).

Some types of infrastructure located within the estuary domain will remain relatively safe from sea level rise by 2050. These include berthing facilities, roads, culverts, bridges and dykes designed with safety margins allowing for normal operation if projected sea level rise remain below 50cm by 2050. Productivity of boreholes located within 3 km of the coastline would be impaired by restrictive operating guidelines meant to minimise the risk of saline intrusion (Scott Wilson and Kirkpatrick, 1993; Njie and Jarjusey, 2011; NIRAS, 2015a). For reasons of safety and accessibility, some electricity pylons in low-lying areas will need to be relocated on higher ground. Environmental sanitation infrastructure designed for current climate may also need retrofits and appropriate behavioural responses from society to cope with rising sea levels and a wetter climate future. Subject to proper environmental and social impact assessments (ESIA), sea level rise exceptionally offers investors with new opportunities in aquacultural production.

5.3.7.3. <u>Littoral domain</u>

Projected sea level rise poses a real inundation risk in low-lying areas currently found within the intertidal zone. In combination with a potentially more energetic wave climate on the open coast, sea level rise is further expected to alter patterns of erosion and sedimentation. Cross-shore and longshore transport of fine sand could be a valuable source of nourishment for Bijol Islands, possibly stimulate long-term development of a shoal at the Bald Cape where tidal circulation impedes longshore sediment transport. Measured velocity fields (DHI, 1982) also suggest net accretion of sediments around Barra Point and on the curved spit in Banjul by 2050. By contrast, open coastline and landforms between Tanji and Bakau are subject to further erosion due to sediment starvation. Morphological changes to embayed lagoons fronted by barrier spits at the mouths of Tanji River and Kotu Stream; tidal lagoons proximate to Sanyang and Kartong; and other dynamic landforms, will depend on sediment dynamics at regional scales and multi-decadal timescales. Sea level rise is expected to stimulate a progressive shift in mangrove zones and reconfiguration of coastal lagoons (Jimenez, 1985; Lugo et al., 1988). Local topography will be a key determinant to the size and fate of tidal lagoons, tidal marsh, mudflats, salt pans and fringe vegetation in the lower estuaries of both the Tanji and Allahein rivers (DHI, 1982; Sogreah *et al*., 1999; GOTG, 2010). Bijl (2011) report a net annual loss of approximately 30,000 m^3 of sediment between Bald Cape and Kotu. Suspended sediment transported by coastal streams or the River Gambia are not expected to make a significant contribution to shoreline or bathymetric changes. In the northern province of the coastal zone, dynamic equilibrium of sediment accretion and erosion is expected to maintain beach stability on the Atlantic coast fronting the Niumi National Park. Landscape transformations driven by pluviometric regimes include variable size of freshwater swamps within Niumi National Park. Wildlife species threatened by landscape and ecosystem changes include the green turtle (*Chelonia mydas*), cape clawless otter (*Aonyx capensis*), manatee (*Trichechus senegalensis*), and clupids. The status of Bijol Islands as an important nesting and roosting ground for terns (*Sterna spp.*) and the grey-headed gull (*Larus cirrocephalus*), is very likely to be enhanced and transformed into an alternative nesting site by sediment accretion on these offshore islands (Cham et al., 2001; Gilman et al., 2008; GOTG, 2007; Lee et al., 2009; Ceesay, 2015).

Figure 27. Grey headed Gull, Caspian Tern and Royal Tern congregating on Bijol Island. Courtesy: Department of Parks and Wildlife Management

Figure 28. Sand mining along vulnerable coastline. Source: The Standard Newspaper

Exclusive of erosion hotspots, some coastal infrastructure including berthing facilities; roads, culverts and bridges; and dykes (section 5.3.7.2) will remain relatively safe from sea level rise by 2050. These. In contrast, infrastructural assets owned and/or operated by beach resorts are increasingly imperiled by extreme shoreline erosion (NEA, 2010; Pinder and Callaghan, 2016; Amuzu, 2018). Sewerage systems discharging into coastal waters will also need design and technical upgrades to cope with positive water level trends. Rising temperatures are also likely to compromise the handling capacity of wastewater treatment works in Kotu, increasing the likelihood of episodic pollution of seascapes and landscapes with adverse impacts on associated ecosystems within the tidal excursion distance of sewage discharge or overflow points (Njie, 2015a).

Figure 29. Compromised seawall fronting Kairaba Beach Hotel. Courtesy Momodou A Cham

5.3.7.4. Interfluvial domain

Explosive growth of relatively small settlements, and their subsequent fusion into the Greater Banjul Area (GBA) located on the southern province of this domain, owes a lot to rural-urban migration initiated by protracted drought starting in the 1960s, and sustained by destination attractiveness over time (CILSS, 2016; GBOS, 2016a; GOTG, 2007). Currently, modernisation has taken over as the major driving force for land use conversion and urbanisation in the southern province of the coastal zone. Under a warmer and drier climate, diminishing space and regulatory restraints in the southern province of the coastal zone, in conjunction significant improvements in transport and basic services in the northern province over the next three decades, would be instrumental to the growth of new urban agglomerations absorbing the flow of in-migrants attracted by prospects of affordable housing, and (non-farm based) employment opportunities, and catalytic to the merger of settlements along and around main transportation routes into a new metropolis located on the spur connecting Karang/Amdalai to Fass and Ginack-Kajata. Although transformation of the agricultural landscape is likely to occur at a slower pace under a wetter climate, long-term adverse effects of upland soil degradation on agricultural productivity and farm-based livelihoods, are quite likely to reinforce extant agricultural to residential use land conversion trends (Barrios et al., 2006; NEA, 2010; Jiang and Yao, 2010; Hope, 2011; Mosha, 2011; GBOS, 2016c, 2016e; CILSS, 2016).

In the southern province, increased atmospheric CO_2 tends to promote productivity of diverse vegetation species and augurs well for biomass stocks in remnant woodland, private orchards and gardens, commercial/private woodland (Nyambai Forest), and protected areas (Furuya National Park, Abuko Nature Reserve) (Camara, 2012). However, these green spaces remain susceptible to protracted drought, pest outbreaks and encroachment. A drier climate is expected to usher in a host of challenges to urban agriculture (irrigated plots in Bakau, Banjulunding, and few other places). Increasingly, water-stressed monospecies plantations are likely to be replaced by more drought-resistant species (section 5.2.2). Mortality of isolated trees providing edible fruits and shade will depend on their adaptability to future climate and husbandry treatments.

Figure 30. Application of agro-chemicals to vegetable garden plots, Kombo North. Courtesy: Mbye J. Faal

Concomitant with land use changes (and area-wide impairment of ecosystem services), a re-adjustment of the local economy is expected to further consolidate growth of service sector industries over the next three decades. However, expansion in some service sectors is likely to be curtailed by financing constraints and natural resource scarcities. Paradoxically, sand scarcity could be a force for innovation and rapid/accelerated switch to eco-architectural building designs. A worst case scenario involves a slump in housing and infrastructure development, leading to a housing and infrastructure crisis (in terms of investment/replacement costs, impaired services, overcrowding) (Njie, 2015a, Ferreira, 2015). A number of assessment conducted over the past decade and a half indicate that risks of accelerated ageing, damage and dysfunction of socioeconomic infrastructure are greatest when extreme weather and cumulative effect of climate stressors are underestimated and infrastructure emplaced in precarious locations in northern and southern provinces. Runoff generated on relatively strong ground slopes in particular has been the cause of serious damage to (unsurfaced) roads under extreme rainfall events, and will continue to do so, without adequate drainage infrastructure, in northern and southern provinces under a wetter climate (GOTG, 2007; Njie, 2015a).

Figure 31. Heavily-silted streambed, compromising conveyance capacity and increase flood risk in contiguous properties: Courtesy Ousman D. Jarjusey

Figure 32. Deep gulley generated by runoff from settlements upstream of the coastal road, near Galaxy Entertainment Park. Courtesy: Momodou A. Cham

Figure 33. Poor state of unpaved roads in urban areas during the rainy season. Courtesy: Momodou Njie

Uncertainties surrounding the typology and scope of climate change impacts are linked public investment scheduling (quality of infrastructure and services; health, electricity water, roads), novel housing finance options, youth employment, growth of micro and small scale medium enterprises (MSMEs), socio-political landscape (Rieger and Wong-Rieger, 1990; Iheanacho, 2016; Sylla 1994; Njie, 2015a; Bannon et al. 2004). An ambitious agenda for social transformation by national and local government authorities, riding on the synergetic effects of UNFCCC Article 6, global partnerships, and implementation success of risk reduction policies and measures consistent with the UN sustainable development goals (SDGs) holds some promise for informed public responsiveness and community resilience to climate change risks (Beer, 2010; Cutter, 2010; Lewandowsky, 2015; GOTG, 2018a).

Figure 34. Flooding in Kanifing Municipality in August 2019. Source: Foroyaa Newspaper

CHAPTER 6: EDUCATION, TRAINING AND PUBLIC AWARENESS

6.1. Implemented or planned initiatives and programmes for education, training and public awareness

Since the publication of the country's Second National Communication (SNC), a suite of activities contributing to the fulfilment of Article 6 objectives has been successfully completed. Whilst teaching of environmental and social studies at pre-tertiary level incorporates elements of climate change, a recent curriculum audit by Oluwatobi (2018) identified significant presentation and relevance issues including gaps in the current curriculum. It is hoped that the Ministry of Basic and Secondary Education (MoBSE), which has a wealth of experience in curriculum development will look into these findings and other feedback/solicited opinions it occasionally receives from authoritative sources, in its drive to improve the quality of education dispensed in public schools. Indeed, MoBSE has championed environmental education and awareness through curricula reforms, periodical training workshops, and interactions with communities since the 1990s (MoBSE, 2016).

Since 2013, University of The Gambia (UTG) has graduated two cohorts of Gambian and international students on climate change and education, under the West African Science Service Centre on Climate change and Adapted Land Use (WASCAL)[18] signature capacity-building programme. In addition, UTG is offering an MSc Programme in Physics that offers renewable energy as one of several possible specialisations. Scores of other Gambians have been trained in West and Central African countries[19], Barbados, Kenya, South Africa, Tanzania, and United Kingdom in diverse specialisations (meteorology, hydrology, data science, ecology, public health, agriculture, science, technology, engineering and mathematics) at different competency and academic levels (technician to PhD), to partly offset the loss of talent related to historic deficiencies in recruitment polices, capacity development strategies and succession planning. In general, training abroad is facilitated by government/host country bursaries administered through MoHERST or government agencies.

Under the GOTG/GEF/UNEP LDCF Climate Change Early Warning System (CCEWS) Project[20], senior policymakers from across government ministries have received training on key technical and administrative aspects of policy review through a climate change and development lens. A one-week crash course on the science of climate change and its potential impacts and appropriate response strategies, targetting middle-level managers in the public sector, was successfully carried out in 2014, with financial support from the United Nations Development Programme (UNDP). More recently, 45 media practitioners underwent an intensive two-day training workshop combining teacher-focused and participant learning approaches to convey key

[18] www.wascal.org

[19] Cameroon, Ghana, Nigeria, Togo and Senegal

[20] https://ccews.gm

facts on causes and consequences of climate change, societal responses, and the media's role in shaping public awareness about these issues. Nearly 300 farmers from communities across North Bank region (NBR) and West Coast Region (WCR) and 30 extension workers have also benefited from basic instruction and training in agrometeorological practice, thereby boosting awareness about linkages between climate risks and productivity, and generating greater enthusiasm for and curiosity about the practical uses of climate information products.

A glossary of the most common meteorological terms featuring in public weather forecasts, translated into three local languages by the National Meteorological and Hydrological Service, in collaboration with and financial support from the CCEWS Project, still considered work in progress, is available to scientists, linguists, development workers and journalists engaging with citizen groups and individuals for whom the official language, English, is not an effective medium of communication. On the back of training received by media practitioners, it is worth noting that media houses now routinely request and disseminate forecasts generated by the weather office, as well as news about events addressing climate change themes.

In the context of greening the Gambian economy and building resilience to external shocks, MECCWNAR has engaged more than 50 business leaders drawn from climate-sensitive industries to exchange information on risks posed by climate variability and trends, and potential roles for Gambian private sector entities in implementing the UNFCCC, and new opportunities for business and industry players under the said convention. Under the aegis of the Gambian Ministry of Higher Education, Research, Science and Technology (MOHERST), UTG has conducted a series of seminars on climate change and adapted land use, and climate change and renewable energy, with funding support from the German Federal Ministry for Education and Research (BMBF). Through its postgraduate studies programme and commissioned research, UTG is advantageously positioned for disseminating scholarly research findings through public symposia and written policy briefs.

CHAPTER 7: RESEARCH AND SYSTEMATIC OBSERVATIONS

7.1. Status of national research and systematic observation programmes

Since the publication of the Gambia's second National Communication (GOTG, 2012), there has been significant upgrades of atmospheric and terrestrial observation networks, which now boast of telemetric systems collecting data on a broad range of parameters under challenging operational conditions. However, individual efforts and initiatives, knowledge, leadership, and coordination issues represent formidable hurdles to the emergence of a vigorous issue-centred research environment. The National Climate Committee (NCC) is one of few groups addressing programmatic issues related to the UNFCCC, but it still falls short of taking on the role of a high-level research cluster due to its limited mission and competencies. Other organisations with a genuine claim to membership of the global change research community continue to grapple with knowledge management issues (Badiru, 2008; GOTG, 2012). Specifically, the newly established National Climate Change Secretariat and antecedent lead agencies are yet to unveil and garner support for priority research themes/topics guided by knowledge gaps hindering evidence-based, long-term and sector-wide approach to policymaking and development practice.

Excluding the National Agricultural Research Institute (NARI) which conducts research on improved varieties of grain crops, oilseeds, tubers and fruits, only a handful of climate-related research projects are active during any particular year, and most of these fall within the ambit of WASCAL postgraduate study programmes (Ceesay, 2016; Amuzu et al., 2018; Amuzu, 2018, Bagbohouna et al., 2018; Baldeh, 2018, Oluwatobi, 2018).

7.2. Atmospheric, terrestrial and oceanographic observations, and research

The National Meteorological and Hydrological Service (NMHS), officially known as Department of Water Resources (DWR) is the principal undertaker of systematic observations that hold a potential to improving interested parties' understanding of the climate system and its interactions with the physical environment. A systemic weakness at the moment, is the absence of active research projects making use of the datasets generated under the NMHS operational programmes. Nonetheless, subsets of data streams are continually integrated into information/knowledge products and services targeting the general public, planners and decision-makers.

7.2.1. <u>Atmospheric observations and research</u>

The NMHS operates a network of 15 surface meteorological stations which include 11 automatic weather stations (ADCON telemetry units). All automatic weather stations (AWSs) are equipped with sensors that measure barometric pressure, air temperature, wind speed, wind direction, radiation, and precipitation at sub-hourly intervals, and equipped with digital storage and a communication systems enabling remote access to in-situ data. Non-automated observation platforms are serviced by personnel who carry out and record measurements of similar variables at sub-hourly to daily time intervals, in accordance with World Meteorological Organisation (WMO) guidelines. NMHS observational datasets are supplemented in real-time by international flights providing a selected number of meteorological variables to partially offset the absence of an upper air network, and by daily rainfall measured at the Department of Agricultural Services (DAS) field stations.

7.2.2. Terrestrial observations and research

Land Use and Land Cover (LULC) imagery taken periodically by earth observation satellites Copernicus Sentinel-2 and WorldView 2 are received by conservation and land resources management institutions' through the auspices of the African Union (AU) and CILSS (CILSS, 2016).

The NMHS also operates several terrestrial observation networks. Among these are 10 evaporation measurement pans (Class A), 42 OTT Orpheus Mini borehole data loggers and five non-tidal surface water level gauges. Its other networks comprise of four soil moisture and 12 soil temperature measuring stations, co-located with meteorological stations, of which two are VAISALA-manufactured automatic weather stations (AWSs) equipped with transducers and thermistors, digital storage and remote access communication systems.

Water levels in the River Gambia that are influenced by tides are tracked and recorded in three places using OTT *ecolog 800* data loggers capable of capturing high frequency tidal components of water levels and storing measurements on digital media, for later retrieval. Surface flows are measured at {at Sami-Tenda (13°30′ and 14°28′ W) and Fatoto (13°24′ and 13°53′ W) at sub-hourly intervals using OTT side-looking dopppler (SLD) sensors, and at a third location using OTT propeller-system instruments at variable intervals depending on the need to validate or extrapolate station rating curves (NIRAS, 2013, 2015b).

7.2.3. Oceanographic observations and research

There are currently no measurements of key oceanographic variables offshore. Tidal water levels are measured at three locations between Banjul (river km 0) and Janjanbureh (river km 304) where the tidal amplitude is virtually nil during peak floods in the River Gambia. Water salinity and temperature are measured by spot sampling procedure in 10 locations and automatically logged at two others within the same stretch of estuary.

7.3. Needs and priorities for climate change research and systematic observations

More than ever, the importance of establishing a premier climate change research cluster to undertake high-level issues-based research contributing to full implementation of the UNFCCC and meeting the expectations of government, development and other major stakeholder groups[21], is in evidence. In an ideal situation, such a cluster hosted by the UTG Climate Change graduate school should be open to all Gambian scientists with relevant competencies. In developing its research agenda, the cluster would be expected to prioritise uncertainties and knowledge gaps in country-level assessments and other research carried out to date. Concomitantly, MECCNAR should compile a research database with inputs from the NCC membership and WASCAL Alumni Network.[22] In the immediate future, gaps in oceanographic and upper air atmospheric measurements need to be addressed as a matter of urgency. Complementary geo-information and environmental statistics compilation programmes (UNDESA, 2017) require further integration to better support a long-term national research agenda.

[21] farmers (including small-scale farmers, fisherfolk, pastoralists, and foresters); women; scientific and technological community (including research and academia); children and youth; indigenous peoples and their communities; workers and trade unions; business and industry; non-governmental organisations; and local authorities
(Source: http://www.unep.org/civil-society/)

[22] See http://www.wascal.org/research/core-research-programme-phase-1/ and http://www.wascal.org/graduate-programmes/doctoral-and-master-theses/).

CHAPTER 8: TECHNOLOGY TRANSFER

8.1. Activities relating to the transfer of, and access to, environmentally sound technologies and know-how

Structured technology needs assessment (TNA) focusing exclusively on GHG emissions reduction and building societal resilience to climate change (GOTG, 2007; GOTG, 2012; Ferreira, 2015; Njie, 2015a), conducted by a diverse group of technology assessors and decision-makers was, and is still being supported by UNEP, GEF, ERC (University of Cape Town, South Africa) and National Resource Persons. Assessments completed to date are published in two tomes (Jallow, 2016; Njie, 2017). Investigative research on barriers to diffusion of prioritised technologies is still in progress.

Acquisition and deployment of piezoelectric data loggers, acoustic flow meters and automatic weather stations over the past four years has followed a rigourous procurement process. Guided by procurement rules and procedures of funding agencies and the Gambia Public Procurement Authority (GPPA), supplier screening and selection has been based on the best combination of technical and financial indicators and commitment to client support. In particular, on-the job training on state-of-the-art digital technologies equipment deployed in atmospheric and terrestrial observation networks, was provided to NMHS technicians and scientists as part of supply contracts signed by Suppliers with the NMHS.

8.2. Prioritised technology needs

In addition to priority scientific equipment alluded to in section 7.3, priority mitigation and adaptation technologies in focal areas of enquiry executed by Jallow (2016) and Njie (2016), are reproduced in table 5.

Table 5. Prioritised mitigation and adaptation technologies

Policy space	Theme/Sector/Geographic area	Technology
Mitigation	Electricity generation	Diesel co-generation Wind turbine
	Road transportation	Direct fuel injection Turbocharger systems
	Waste management	Bioreactor landfill Sanitary landfill
Adaptation	Agriculture	Conservation agriculture Tidal irrigation
	Water	Water conservation Aquifer recharge
	Coastal zone	Sustainable sand management Breakwater systems

Source: Jallow (2016), Njie (2017)

It is worth noting that these results are the outcome of a series of participatory multi-criteria assessment procedures involving nearly two dozen professionals from academia, parastatal organisations and government agencies. At the time of reporting, investigative research on barriers to diffusion of these technologies is still in progress.

CHAPTER 9: CAPACITY BUILDING

9.1. Specific needs, options and priorities for capacity-building

Capacity building needs are a reflection of gaps between required and current national capacity to implement the UNFCCC. Chief amongst these, at the moment, are organisational and individual competencies in conducting high-fidelity research and sectoral assessments thereby undercutting the basis and impactfulness of mainstreaming climate change into sectoral policy instruments, programmes and activities at national and sub-national levels.

Qualified success of the National Climate Committee (NCC) predating the National Climate Change Policy (Urquhart, 2016 represents a very strong argument for group training and participatory learning on stakeholder engagement, conflict resolution, information management, and quality management, in order to galvanise inter-agency cooperation, enhance inclusiveness, and strengthen mutual accountability; (Njie, 2013; 2015b). To this effect, greater efforts are required to strengthen the newly established Climate Change Secretariat and to build/strengthen strategic working relations with other international groups/ with shared interests.

As previously mentioned in section 7.3, organisations entrusted with research and systematic observations (R&SO) responsibilities require strengthening of end-to-end R&SO systems (i.e. additional/enhanced physical and virtual resources) for meaningful outcomes and contributions to regional/global exchange of information. Ideally, data collection platforms should be automated as far as possible to enable real time data transmission to central databases. Moreover, there is considerable merit setting up (near-) real time hydrological data exchange with other Gambia River Basin (GRB) countries and launching a national flood forecasting system. Deployment of data buoys at strategic locations in the Gambia's coastal waters would indeed add value to marine and shipping forecasts23 and add impetus to the development of national capacity for operational oceanography.

Scripted roles for implementation of policies and measures by stakeholder groups vis-à-vis their corresponding capacities requires a full system audit and regular updates reflecting dynamic internal and external environmental changes. From all indications however, the general community of stakeholders stands to benefit from coaching on policy cycle management. It is equally imperative for lead public sector institutions to create opportunities for employees to enroll in professional development programmes as a way of gradually eliminating current task-related capacity gaps. To this end, the University of The Gambia (UTG) human development and public sector recruitment plans in the next 10 to 15 years would be extremely important.

Time and quality management issues emerging from technical assignments, reporting tasks and research management, point to the need for training and mentoring solutions on a wide range of tasks for analysts and administrators. To build a pool of professionals of the highest caliber, training of public sector employees for competence and prowess in the fields of project management; environmental, ecological and economic modelling; engineering; and datascience, as part of a long term climate change capacity development strategy (LT-CCCS), is particularly

[23] https://ccews.gm/index.php/fishing-and-shipping-forecast

important (Njie, 2013; Urquhart, 2016; Agrer, 2017a, 2017b). Options for building professional capacity of prospective trainees include fee-paying workshops, apprenticeship/on-the job training, on-line and conventional academic courses. For comprehensiveness, an LT-CCCDS is also expected to cater to the capacity development needs of the leadership of the administrative cadre, grassroots organisations, and implementing partners, at sub-national levels.

CHAPTER 10: NETWORKING AND INFORMATION SHARING

10.1. Efforts to promote information sharing among and within countries and regions

Until recently, the National Climate Committee (NCC), an *ad hoc* body established under the NMHS, played a lead role in supporting work processes relating to implementation of the UNFCCC. Already an important repository of climate change and other geophysical information in its own right, the NMHS, independently of the NCC, disseminates daily public weather, seasonal climate, and special forecasts through multiple platforms including print media, national radio and television, community radio stations, and its affiliated website https://ccews.gm, currently posting periodic publications, internal reports, technical reports, and notices on upcoming events and opportunities). Administrative and programmatic information is shared by the NMHS with NCC members and other stakeholders through electronic mail, and oral presentations supplemented by briefing notes during scheduled meetings and workshops.

However, the effectiveness of NCC networking and information sharing with other entities and interest groups has not been rigourously assessed, since its inception. With both leadership and coordinating roles in UNFCCC implementation shifting to the ministry responsible for climate change administration, MECCNAR (Ministry of Environment, Climate Change and Natural Resources) is well positioned to use its web portal www.meccnar.gm to disseminate its policy instruments, administrative and programmatic information, internally-generated and commissioned studies. The National Disaster Management Agency (NDMA) also runs a website http://www.ndma.gm/home/ linked to the risk management portal, http://gm-risk.ige.fr/ that creates opportunities for visitors to search geospatial information products; reports and data sheets. The underlying information management system (IMS) for this portal is directly linked to the EUropean organisation for the exploitation of METeorological SATellites (EUMETSAT) facilities, giving the location of precipitation in real-time. To some degree, all websites mentioned above have links to others run by key national and international partners.

As part of the TNC preparation, an informal audit of these information platforms points to a need for improvements in content including a catalogue of holdings (with active hyperlink to resources)[24], better housekeeping (i.e. repair of broken links, regular updates of content), and monitoring of web traffic. The fledgling Climate Change Secretariat established within MECCNAR needs to expend greater energy in reaching out to public information access centres (PIACs), comprising public libraries, and other libraries hosted by tertiary and higher education institutions, municipal/local government authority offices, and some NGO resource centres, in order to improve dissemination of in-house reports, and other publications under its authority. A consultative forum regrouping major private sector partners is also expected to add value to

[24] Scientific studies/reports(in public domain), WASCAL masters and doctoral theses, administrative and financial information products (Annual Reports, Special/Occasional Publications, Liaison Reports, contracts, MOUs/PAs..), videos, picture galleries, compiled registers of license holders

government-to-business (G2B) engagement and add further impetus to the Gambian private sector's participation in implementing the UNFCCC.

10.2. Access to and use of information technologies for information exchange

Employees and authorised users of digital infrastructure housed at the NMHS headquarters in Banjul have access to ADSL LAN internet connection with a nominal speed of 155Mbps. With this facility, users are able to exchange correspondence with their contacts, navigate internet sites of interest and download resources (tutorials, images, data, and publications) from websites without paywall restrictions.

The Yundum hub of the NMHS which houses the National Weather Forecast Office (NWFO), has access to 512Mbps fibre-optic connection, a dedicated server and integrated communication system that make it possible personnel with appropriate authorisation to remotely access AWS data. In accordance with WMO Resolutions 40 Cg-XII and 25 Cg-XIII, meteorological and aviation related messages are transmitted tri-hourly to the WMO regional telecommunication hub in Dakar by satellite and aeronautical fixed telecommunications network (AFTN) line. An MOU with WASCAL also provides for the exchange of observational data with the WASCAL Data Centre in Ouagadougou (Burkina Faso).

CHAPTER 11: CONSTRAINTS AND GAPS, AND RELATED FINANCIAL, TECHNICAL AND CAPACITY NEEDS

11.1. NC Financing

Under the aegis of the Global Environment Facility (GEF) 'Climate Change – Enabling Activities' portfolio, The Gambia, in late 2012, received USD480,000 to prepare its third national communication (TNC).

11.2. Constraints and gaps for preparing NC

Moderated by an independent expert, an objective introspective analysis of the NC preparation process has revealed several systemic and circumstantial problems that remained largely unresolved up to the time of the TNC publication. First and foremost, the structure of public sector organisations, their staffing and incentives are identified as major constraints promoting silo perspectives that frustrate group objectives such as the preparation of a national communication (NC), when country-ownership of the process and outcome is not self-evident. Crucially, delivery of intermediate and final outputs is challenged by poor institutional memory (in some cases) and impeded by disrupted networks associated with a decades-old legacy of political patronage, and the absence of insights a robust monitoring and evaluation (M&E) system guiding policy implementation. A weak integration of science and public policy, and isolated coordination leadership, engendering adverse repercussions on data acquisition, data management, research, and stakeholder commitment to providing data, feedback and other inputs, are equally reflected in delivery schedules, quality of intermediate outputs, and the final TNC report.

In effect, failure to provide specific details along with inventory information, or a full re-analysis of 1990 and 2000 inventory data, failure to provide an overview of institutional arrangements for GHG inventories, and absence of reporting on Quality Assurance/Quality Control (QA/QC), uncertainty analyses, are considered as important gaps in Chapter 3 (Greenhouse Gas Inventory Information). Missing narrative relevant to comprehensiveness of chapters 4 through 10 are indicated as follows:

Chapter 4 (Mitigation Assessment)

Overview, methodology/methods, linkage to reported GHG emissions, review/updates of data, assumptions, methodology), analysis of IPPU emission category, LU component of AFOLU liquid waste component of and Waste category, tabulated data, cost or cos0benefit analyses.

Chapter 5 (Vulnerability and Adaptation Assessment)

Socioeconomic scenarios harmonised across all sectors analyses, and with mitigation analysis in Chapter 4

Chapter 6 (Education, Training and Public Awareness)

Institutional framework for the implementation of Article 6 of the Convention

Legal frameworks for public participation and access to information

Level of awareness and understanding of climate change issues

Chapter 7 (Research and Systematic Observations)

Level of participation in the global research and observation systems

Chapter 8 (Technology Transfer)

Measures relating to enhancing the enabling environment for the development and transfer of technologies

Chapter 9 (Capacity Building)

Status of activities and level of participation in South-South cooperation

Promotion and level of involvement of a wide range of stakeholders

Status of activities related to coordination and sustainability of capacity-building activities

Dissemination and sharing of information on capacity-building activities

Capacity-building activities aimed at integrating adaptation to climate change into medium- and long-term planning

Chapter 10 (Networking and Information-Sharing)

(National) participation in and contribution to information networks

New Chapter on "Policies and Measures" (to be inserted before chapter 7)

Mitigation measures by sector, industry (mentioned in TNC), and linkages to NAMA, INDC, NDP, and SDGs)

- Energy
- AFOLU
- IPPU
- Waste

Adaptation measures (with links/ of relevance to NAPA, NDP and SDGs) in the public, private and voluntary sectors.

- Landscape and ecosystem services
- Food security and poverty reduction
- Energy and housing
- Public health
- Social and economic transformation (mainstreaming climate change in public policy)

11.3. Constraints to implementing Development Priorities

Climate and non-climate related constraints to NDP implementation relate to 1) agricultural expansion; 2) building infrastructure; and 3) making private sector the engine of growth (GOTG, 2018a; MOFEA, 2019).

Unfavourable weather and seasonal rainfall patterns have had and still continue to exercise a strong influence on the production of field crops grown under rain-fed conditions. Specifically, a rainy season shorter by 6 to 9 days in the western and eastern parts of country, and by 22 to 32 days relative to the 1981-2010 climatological normal in other parts of the country in 2018 (Sima, 2010; Stafford, 2019), had a ruinous impact on groundnut, maize, and rice production. The latter, apparently the worst hit, dropped to 40% of the 2016 NDP baseline of 69,000 tonnes/annum (MOFEA, 2019). Prices for fuelwood, a key input to light-scale fish processing is likely to destabilise the mix, quality and aggregate value of semi-processed fisheries products traded on the market. Impacts of entrepreneurship development through several capacity development avenues, and provision of start-up funds for youth entrepreneurs in food processing, handicrafts and the cosmetic industries, are moderately to strongly sensitive to changes in ecosystem service streams, on which these businesses rely upon to thrive. Non-climate moderating factors in the agriculture and natural resources (ANR) include the inadequate public sector investments in aquaculture and agriculture, and risk aversion financial institutions. Doubtless, revitalisation of the National Agricultural Statistics Survey (NASS), would be crucial to a holistic assessment of progress and impediments in the ANR sectors (Njie, 2015a MOFEA, 2019). With the benefit of experience, project cashflow challenges also need to be reckoned with to ensure timely delivery on urban road construction projects.

11.4. Capacity building and financial needs for implementation of the Convention

Proposed interventions contained in the Gambia's Special Programme for building Climate Resilience (SPCR) in the form policy integration, strategic assessments and audits, underpinned by requisite investments in scientific assets and human resources, designed to overcome obstacles to an evidence-based (Component 3), long-term and sector-wide approach to policymaking (Components 1, 4 and 5) and development practice (Components 2 and 5), geared towards climate resilient development in The Gambia, are estimated at USD28.5 million (Agrer, 2017a, 2017b).

CHAPTER 12: CONCLUSIONS AND RECOMMENDATIONS

12.1. Conclusions

Since the National Climate Committee (under DOSF&NR oversight) and Climate Change Secretariat (under MECCNAR oversight), both representing key nodes in Gambian climate change networks were established, their effectiveness in coordinating activities related to the UNFCCC has not been rigourously assessed. But there is reason to believe that improvements are needed with regards to their leadership, service provision, problem solving, and information diffusion roles in matters related climate risk management and implementation of the UNFCCC. Doubtless, the allocation of resources commensurate with expected outputs of network nodes and hubs would eliminate some major shortcomings in the diffusion of diverse genres of information generated within the climate change stakeholder community, and spur greater participation in and contribution of individual stakeholders in networking activities.

High-level research relevant to climate risk management is predominantly carried under the WASCAL post-graduate studies programme run by a consortium of universities across West Africa, represented in the Gambia by UTG. With the exception of upper air networks and marine-based data collection platforms, meteorological and hydrological networks operating on WMO Global Climate Observation System (GCOS) standards are quite well developed, and often equipped with state-of-the-art equipment.

The assessments in the report, using data generated from networks and other trusted sources, indicate moderate to high levels of sensitivity of the environment, public health, and selected economic sectors and the quality of life of population groups engaged in the real economy, to adverse impacts of projected climate change. In general, uncertainties surrounding rainfall projections lead to more nuanced impact assessments.

Public awareness, supported by multiple agencies/interventions, is increasing but inadequate due to the absence of communication guidelines and weak coordination of public awareness building efforts. Indeed, one major shortcoming is limited diffusion of national reports and/or transmission of key messages drawn from these reports to audiences/target groups which do not have direct access to the reports. However, a sustained drive to train media professionals, extension workers, and community groups, and translation of key messages into local languages could be seen as a significant step towards greater public enlightenment and engagement on climate change issues. Crucially, the number of scientists trained in fields relevant to climate risk management is steadily increasing.

Greenhouse gas (GHG) emissions have grown by 70% since 1993, with methane (CH_4) contributing 47% of emissions recorded in 2010. Notwithstanding, several weaknesses including secondary data collection, data aggregation, quality control and analysis, attributable to the absence of a formalised GHGI system embedded in administrative law, have come into evidence during the preparation of the TNC. Additionally, the level of detail provided in the mitigation assessment points to a serious challenge of capacity building and retention, but also to a risky strategy of concentrating capacity building within small groups.

Capacity building outcomes (with support of development partner) continues to lag behind needs. Indeed, leadership training of public sector employees and competence and in the fields of project management; environmental, ecological and economic modelling; engineering; and datascience, remains a top priority at sectoral and at different administrative levels. In this regard, greater effort should be expended in developing the country's South-South cooperation in the field of climate risk management.

Due to its unique geography, the country's landscapes and ecosystems are exposed to projected climate change from multiple perspectives, notably economic growth, household livelihood strategies and social progress. Although positive steps have been taken to upgrade research infrastructure, research findings on priority adaptation and mitigation technologies have had little impact on sectoral practices. It is therefore a matter of urgent priority to address inadequate sectoral capacities and weak institutional arrangements in order to build and iteratively increase resilience in all climate-sensitive activities.

12.2. Recommendations

Based on the foregoing, a number of recommendations are formulated for the attention of international partners and government agencies

12.2.1. <u>International Community</u>

- Provide training support to Gambian sectoral experts (including social scientists) on various thematic areas and integrated assessments, through the relevant convention bodies/mechanisms, or bilateral arrangements, and monitor impacts and outcomes through participatory programmes.
- Provide technical assistance in the person(s) of a GHG inventory expert(s) to establish and operationalise a formalised GHGI system, building on potential synergies with the National Statistics System (NSS) reporting biennially on core environmental statistics including GHG emissions.
- Provide technical assistance and programming support towards the establishment of a productive National Climate Change Centre (NCCRC), built around research clusters working on key Convention and national development issues (including transition to a low emissions economy)

12.2.2. <u>Gambian government agencies</u>

Guided by conventional wisdom which exhorts effort and commitment before seeking out assistance,[25] the Gambia government cannot be a passive recipient of technical and financial assistance, but commence work on engineering solutions to some of the problems identified in this report, through its agencies.

- Initial framing of issues and expectations relating to the establishment of formalised GHGI system (under the NSS coordinated by the Gambia Bureau of Statistics), climate risk management coordination mechanism (including role definition and MOUs if required) and system audit to assess deficiencies, should follow the publication of this report. UTG should lead discussions around the establishment of an NCCRC, criteria for affiliation and modalities for deciding upon research priorities.
- Take advantage of UNFCCC Biennial Update Reviews (BURs) to implement imperative structural and management reforms
- Additionally, MECCNAR, DWR and media practitioners should also work jointly on developing key messages for various audiences to ensure coherence between GOTG Education & Awareness Programme, and its Research Programme.
- As a sign of leadership by example, government agencies are also urged to initiate measurement and reduction of their GHG footprint (additional to the INDC).

[25] *Ndimbal na sa fekka lohol borom* (in Wollof) roughly translated as "The person who wishes for support/assistance should show evidence of his/her commitment through his/her own unaided efforts".

References

Abebe A. et al. 2016: Growth, yield and quality of maize with elevated atmospheric carbon dioxide and temperature in north-west India. *Agriculture, Ecosystems & Environment*, **218**, 66-72, doi:10.1016/j.agee.2015.11.014.

AfDB, 2007. Lowland agricultural development programme (LADEP) programme completion report. Agriculture and agro-industry development Department (OSAN). Tunis, Tunisia. 21 pages + Annexes

AF-MERCADOS EMI, 2013, Electricity Strategy and Action Plan. Consultancy report prepared for the Ministry of Energy, Banjul, 66p+Annexes.

Agrer s.a., 2017a. Strategic Programme for Climate Resilience (SPCR) - Volume I: Main Report. *Consultancy Report prepared for MECCNAR*. Banjul, 97 pages + Annexes

Agrer s.a., 2017b. Strategic Programme for Climate Resilience (SPCR) - Volume II: Concept Notes and Regional Consultations. *Consultancy Report prepared for MECCNAR*. Banjul, 79p.

Alliance for a Green Revolution in Africa (AGRA), 2014. Africa agriculture status report: Climate change and smallholder agriculture in sub-Saharan Africa. Nairobi, Kenya

Amuzu, J, 2018. The socio-economic impact of climate change on the coastal zone of the Gambia. Unpublished MSc thesis. University of The Gambia. Banjul, 121p.

Amuzu, J., Kabo-Bah, A. T., Jallow, B.P., and Yaffa, S., 2018a. Households' livelihood vulnerability to climate change and climate variability: A case study of the coastal zone, The Gambia. *Journal of Environment and Earth Science*, *8*(1), 1–12.

Amuzu, J., Jallow, B.P., Kabo-Bah, A.T., and Yaffa, S., 2018b. The Climate change vulnerability and risk management matrix for the coastal zone of The Gambia. *Hydrology*, *5*(1), 1–22.

Amuzu, J., 2018. The Socio-economic impact of climate change on marine and freshwater fisheries resources in the coastal zone of the Gambia, *6*(1), 1–12.

Badiru, A.B., 2008. Triple C for project management: Communication, cooperation, coordination. CRC Press. Boca Raton. 204p.

Bagbohouna M'koumfida, Yaffa S., and Bah A., 2018. The Impacts of Saline-Water Intrusion on the Lives and Livelihoods of Gambian Rice-Growing Farmers. Res. Rev. J Ecol. Environ. Sci. Volume 6, Issue 1, January- March, 2018, pp1-7

Baldeh, D., 2018. Flood impacts on the lives of school children in Basse, (Upper River Region of The Gambia). Unpublished MSc thesis. University of The Gambia. Banjul, 131p.

Baraka V. and Kweka E.J. 2016. The Threat of Zika Virus in Sub-Saharan Africa – The need to Remain Vigilant. Frontiers in Public health. May 2016, Volume 4, Article 110

Barnett L. and Emms C., 2000. Checklist of Gambian animals. Research & Development Unit, Department of Parks and Wildlife Management. The Gambia.

Barnett, L. K., Emms, C. and Camara, A., 2001. The Birds of Bijol Island, Tanji River (Kariniti) Bird Reserve, The Gambia. Bulletin of the African Bird Club 8; p39-43.

Barnett, L. and Emms, C. 2005. Common reptiles of the Gambia. Darwin Initiative Project. Rare Repro, Hailsham, East Sussex. 24p

Bannon A., Miguel E. and Posner D.N. 2004. Afrobarometer Working Papers, Working Paper No. 44 Sources of ethnic

Barrios S., Bertinelli L. and Strobl E. (2006) "Climate Change and Rural-Urban Migration: The Case of sub-Saharan Africa", *Journal of Urban Economics,* Vol. 60(3), 357-371.

Beer T. 2010, The Hazards Theme of the International Year of Planet Earth in Tom Beer (Ed). Geophysical Hazards: Minimizing Risk, Maximizing Awareness. pp 3 -16. DOI 10.1007/978-90-481-3236-2. Springer Dordrecht Heidelberg London New York

Bijl, E., 2011. The cause of coastal erosion on a nourished beach in Kololi. Unpublished MSc thesis. Delft University of Technology. Delft. 128p+ Appendices.

Bouvet A., Mermoz S., Le Toant., Villard L., Mathieu R., Naidoo L., Asner G.P. 2018. An above-ground biomass map of African savannahs and woodlands at 25 m resolution derived from ALOS PALSAR. Remote Sensing of Environment 206 (2018) 156–173.

Baudena M., Dekker S. C., van Bodegom P. M., Cuesta B., Higgins S. I., Lehsten6 V., Reick C. H.,

Blanc E. 2012. The Impact of Climate Change on Crop Yields in Sub-Saharan Africa. *American Journal of Climate Change*, 2012, 1, 1-13.

Bojang L., Jallow A.O., Mbye B., Loum M.K. 2005. Country study on assessment of vulnerability to climate change in the forest and woodlands ecosystem and to propose adaptation options Consultancy Report Prepared for NAPA Project LDL 2328 2724 4699. Banjul, 21p.

Bojang L. 2016. Vulnerability and Adaptation Assessment for the Tourism Sector of The Gambia. GTBoard contribution towards Third National Communications Project.

Bond B.J. 2000. Age-related changes in photosynthesis of woody plants. Trends in Plant Science. Reviews. August 2000, Vol. 5, No. 8, 349-353.

Bradley D. (1977), Health aspects of water supplies in tropical countries. In *Water, Wastes and Health in Hot Climates* (ed. Feachem R., McGarry M., and Mara D.), pp. 3–17, John Wiley & Sons, London.

Braham C.B. and Corten A. 2015. Pelagic fish stocks and their response to fisheries and environmental variation in the Canary Current Large Marine Ecosystem. In: *Oceanographic and biological features in the Canary Current Large Marine Ecosystem*. Valdés, L. and Déniz‐González, I. (eds). IOC‐UNESCO, Paris. IOC Technical Series, No. 115, pp. 197‐213.

Camara I. I. 2013. Mainstreaming climate change resilience into development planning in the Gambia, London: IIED.

Ceesay A. 2016. Mangrove degradation and its effects on one stuarine fisheris: case study of Tanbi Wetland National Park, The Gambia. Unpublished PhD thesis. Felix Houphet-Boigny University. Abidjan, Banjul, 274p.

Central Bank of the Gambia *(*CBG), 2015. Central Bank of The Gambia Annual Report 2013. Banjul, 92p.

Central Bank of the Gambia *(*CBG), 2016. *Monetary Statistics (unpublished).*

Central Bank of the Gambia *(*CBG), 2017. The Central Bank of Gambia Annual Report and Financial Statement http://www.cbg.gm/archives/pdf/2016%20financial%20Statement.pdf

Cham M.A., Njai S., Barnet L., Bittaye A., Bojang L., Saine A., Sanyang F., Sarr M.B., Jammeh B. and Njie M. 2001. Gambia National Report. GEF MSP Sub-Saharan Africa Project (GF/6010-0016): Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa. National Environment Agency (The Gambia), Banjul, 55p.

Church J.A., Clark P.U., Cazenave A., Gregory J.M., Jevrejeva S., Levermann A., Merrifield M.A., Milne G.A., Nerem R.S., Nunn P.D., Payne A.J., Pfeffer W.T., Stammer D. and Unnikrishnan A.S. 2013: Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker T.F., Qin D., Plattner G.-K., Tignor M., Allen S.K., Boschung J., Nauels A., Xia Y., Bex V. and Midgley P.M. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

CILSS, 2016. *Landscapes of West Africa – A Window on a Changing World*. U.S. Geological Survey. EROS, 47914 252nd St, Garretson, SD 57030, UNITED STATES.

Conkle J.L., White J.R, Metcalfe C.D. 2008. Reduction of pharmaceutically active compounds by a lagoon wetland wastewater treatment system in Southeast Louisiana. Chemosphere 73 (2008) 1741–1748

Cotruvo et al., 2004. *Waterborne Zoonoses: Identification, Causes and Control*. Edited by Cotruvo J.A., Dufour A., Rees G., Bartram J., Carr R., Cliver D.O., Craun G.F., Fayer R. and Gannon V.P.J. Published by IWA Publishing, London, UK. ISBN: 1 84339 058 2.

Cramer W. et al., 2014: Detection and Attribution of Observed Impacts. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. *Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field C.B., Barros HE., Dokken D.J., Mach K.J. and Mastrandrea M.D. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 979-1037.

Cutter S.L. 2010. Social Science Perspectives on Hazards and Vulnerability Science pp 17 -30. DOI 10.1007/978-90-481-3236-2. Springer Dordrecht Heidelberg London New York

DHI, 1982. Banjul second port project: Studies of the effect of a barrage on sedimentation, *Consultancy Report* prepared for the GOTG/GPA, Banjul.

DOF (Department of Fisheries), undated. The common marine and inland fish species in The Gambia. A monograph. Department of Fisheries, Banjul. MOFWR, Banjul, 58pp.

DOF (Department of Fisheries), 2017. Fisheries statistics. Presented at Data Producer-User Forum (2017), GBOS, Banjul.

DOP, 2016. Agricultural statistics. Presented at Data Producer-User Forum (2016), GBOS, Banjul.

Drammeh F. 2013. Assessing and adapting to climate change-induced sea level rise on the southern coastline of The Gambia. United Nations - Nippon Foundation of Japan Fellowship Programme- 2012-2013

DWR (Department of Water Resources), 1983. Groundwater resources of the Gambia: Preliminary report. Ministry of Water Resources and the Environment. Banjul, 92p.

FAO, 2015. Global forest resources assessment 2015: Desk reference. FAO. Rome, 244p.

FAO, 2018. Forest Products Yearbook 2016. ISSN 1020-458X. Rome. 245p

Ferreira, T., 2015. Gap Analysis 1: Climate resilient food and landscapes. Report prepared by Agrer s.a under GCCA Support Project to The Gambia for Integrated Coastal Zone Management and the Mainstreaming of Climate Change (GC3SP). Banjul, 48 pages + Appendices.

Gao H. 2011. Groundwater Modeling for Flow Systems with Complex Geological and Hydrogeological Conditions. Procedia Earth and Planetary Science 3, 23 – 28.

Gascuel D., Labrosse P., Meissa B., MO Sidi T. and Guénette S. 2007 Decline of demersal resources in North-West Africa: an analysis of Mauritanian trawl-survey data over the past 25 years. *African Journal of Marine Science 2007, 29(3): 331–345*.

Gill et al. 2002. Using simple environmental variables to estimate belowground productivity in grasslands. *Global Ecology & Biogeography* (2002) 11, 79–86

Gilman E.L., Ellison J., Duke N.C., Field C. 2008. Threats to mangroves from climate change and adaptation options: A review. Aquatic Botany, 89, 237–250.

Githeko A.K., Ogallo L., Lemnge M., Okia M. and Ototo E.N. 2014. Development and validation of climate and ecosystem-based early malaria epidemic prediction models in East Africa. Malaria Journal 2014 Aug 22; 13:329. doi: 10.1186/1475-2875-13-329.

GOTG, 2018a. National Development Plan (2018 -2021). DDP, MOFEA, Banjul. 319p.

GBOS, 2016a. Special Report on Migration. 2013 Population and Housing Census. NSC. Banjul. 33p.

GBOS, 2016b. Special Report on Youth. 2013 Population and Housing Census. NSC. Banjul. 37p.

GBOS, 2016c. Special Report on Settlements. 2013 Population and Housing Census. NSC, Banjul, 79p.

GBOS, 2016d. Special Report on Economic characteristics. 2013 Population and Housing Census. NSC, Banjul, 92p.

GBOS, 2016e. Special Report on compounds and buildings/structures. 2013 Population and Housing Census. NSC, Banjul, 26p.

GBOS, 2017. Integrated Household Survey 2015/2016: Preliminary Survey Findings.

GBOS, 2019a. The Gambia Multiple Indicator Cluster Survey 2018, Survey Findings Report. Banjul, The Gambia: The Gambia Bureau of Statistics. Banjul. 425p + Appendices.

GBOS, 2019b. Summary Report- Transport Statistics. NSC, Banjul, 12p.

GCAA, 2015. Gambia Civil Aviation Authority 2014 Annual Report. Ministry of Works, Transport and Infrastructure, Banjul, 60p.

Gibba P. 2016 Characterization and projection of extreme precipitation events over Africa, PhD Thesis, Department of Meteorology, Federal University of Technology, Akure (FUTA), 131p.

GOTG, 2003. First National Communication under the UNFCCC. Department of State for Fisheries, Natural resources and the Environment, Banjul, The Gambia, 94p.

GOTG, 2007. Gambia National Adaptation Programme of Action (NAPA). Department of State for Forestry & the Environment, Banjul, 97p.

GOTG, 2012 The Gambia's Second National Communication under the United Nation Convention on Climate Change Ministry of Forestry and the Environment, Banjul, 113p.

GOTG, 2015. Intended Nationally Determined Contributions. Mandatory Report submitted to UNFCCC. Ministry of Environment, Climate Change, Forestry, Water and Wildlife, Banjul, 24p.

GOTG, 2018a. National Development Plan (2018 -2021). DDP, MOFEA, Banjul. 319p.

GPA, 2014. Annual report and Financial Statements for year ended 31 December 2013. Ministry of Works, transport and Infrastructure, Banjul, 69p + Annexes.

GPA, 2017. Financial statements and Annual Reports for the year ended 31t December 2015. Banjul. 53 pages + Annexes.

Groover A., 2017. Age-related Changes in Tree Growth and Physiology. In: eLS. John Wiley & Sons, Ltd: Chichester. DOI: 10.1002/9780470015902.a0023924.

GT Board, 2015. Gambia Tourism Board 2013 Annual report. Ministry of Tourism and Culture, Banjul, 61p.

Gu, G., and Adler, R.P., 2004. Seasonal evolution and variability associated with the West African monsoon. *J. Climate*, 17, 3364 – 3377.

Hales S., Kovats S., Lloyd S. and Campbell-Lendrum D. (eds.), 2014: *Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s*. World Health Organization (WHO), Geneva, Switzerland, 115 pp.

Harley C.D.G., Hughes, A.R., Hultgren, K.M., Miner, B.G., Sorte, C.J.B., Thornber, C.S.,, Rodriguez, L,F,, Tomanek, L., Williams. S.L., 2006. The impacts of climate change in coastal marine systems. *Ecol Lett* 9: 228–241.

Head, B.W., and Alford, j., 2013. Wicked Problems: Implications for Public Policy and Management. Administration & Society. XX(X) 1–29. SAGE Publications. DOI: 10.1177/0095399713481601

Henry M., Picard N., Trotta C., Manlay R.J., Valentini R., Bernoux M. & Saint-André L. 2011. Estimating tree biomass of sub-Saharan African forests: a review of available allometric equations. Silva Fennica 45(3B): 477–569.

Hernández-Guerra, A., F. López-Laatzen, F. Machín, D. de Armas, and J. L. Pelegrí, 2001: Water masses, circulation and transport in the Eastern Boundary Current of the North Atlantic Subtropical Gyre. Scien. Mar., 65 (Suppl. 1), 177-186.

Hirani P.2005. Ethnoecological studies of the mangroves of the Tanbi Wetland Complex. Unpublished MSc thesis. Free University of Brussels. 80p + Appendices.

Hope K.R. (2011) "Climate Change in the Context of Urban Development in Africa", in Belinda Yuen and Asfaw Kumssa (eds.) *Climate change and sustainable Urban Development in Africa and Asia,* London and New York: Springer.

http://doi.org/10.3390/hydrology5010014

http://doi.org/10.13189/nrc.2018.060101

http://dx.doi.org/10.4236/ajcc.2012.11001.

http://www.cbg.gm/archives/pdf/2016%20financial%20Statement.pdf

https://www.gbosdata.org/topics/economy/registered-vehicles

https://www.gbosdata.org/topics/housing-and-utilities/electricity

Iheanacho N.N. 2016. Religio-Cultural Foundation and Resources of Human Relations in Africa. Sociology Mind, 2016, 6, 65-74. http://dx.doi.org/10.4236/sm.2016.62005

IPCC. 2001. *Climate Change 2001: The Scientific Basis*. Cambridge: Cambridge University Press, 881p.

IPCC, 2006. *2006 IPCC Guidelines for national Greenhouse Gas Inventories. Mobile Combustion*. *IPCC Guidelines for National Greenhouse Gas Inventories* (pp. 1–78). Geneva: International Panel on Climate Change (IPCC).

IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field C.B., Barros V.R., Dokken D.J., K.J. [Field C.B., Barros V.R., Dokken D.J., Mach K.J., Mastrandrea M.D., Bilir T.E., Chatterjee M., Ebi K.L., Estrada Y.O., Genova R.C., Girma B., Kissel E.S., Levy A.N., MacCracken S., Mastrandrea P.R. and White L.L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

Jaiteh, M., and Saho, A., 2006.The Gambia Atlas of 2003 Population and Housing Census. Gambia Bureau of Statistics, Banjul, The Gambia. x + 7p + Appendices.

Jaiteh, M and Sarr, B., 2011. Climate Change and Development in The Gambia. An ICOBAHRD Consultancy Report for UNDP. Banjul, 55p.

Jallow, B.P., 2016. Technology Needs Assessment - Adaptation Report. Consultancy report for Department of Water Resources (DWR) and UNEP-DTU partnership. Banjul, 82 pages + Annexes.

Jallow B. P. 1997a: Scenarios used in the vulnerability and adaptation assessment in the Gambia, 8 –15. In: GOTG-USCP, 1997. Study on the vulnerability of major socio-economic sectors in the Gambia to climate change and assessment of adaptation measures and options. Study report compiled under the Gambia Climate Change Research Programme. Banjul.

Jallow B. P. 1997b: Assessment of the impacts of climate change to rangelands and livestock, 109 – 136. In: GOTG-USCP, 1997. Study on the vulnerability of major socio-economic sectors in the Gambia to climate change and assessment of adaptation measures and options. Study report compiled under the Gambia Climate Change Research Programme. Banjul.

Jallow S.B.O, 1989. Monitoring of organochlorine pesticides in the Gambia. Internal Report. Department of Water Resources. Banjul. 16p.

Jarra A. 2002. Water quality assessment study and chlorination of flood affected drinking water supply points in North Bank and Central River Divisions (The Gambia). Internal report, Department of Water resources, The Gambia, Banjul, 27p.

Jiang, B., and Yao, X., 2010. Geospatial Analysis and Modeling of Urban Structure and Dynamics: An Overview in Geospatial Analysis and Modelling of Urban Structure and Dynamics, Bin Jiang and Xiaobai Yao (eds). DOI 10.1007/978 90 481 8572 6

Jimenez J.A., Lugo A.E., Cintron G. 1985.Tree Mortality in Mangrove Forests', BIOTROPICA 17(3): 177-185 1985

Joly and Voldoire, 2008. Influence of ENSO on the West African Monsoon: Temporal Aspects and Atmospheric processes. Journal of climate. Vol. 22, 3193-3210.

Kirkpatrick S.W. 1993. Groundwater Survey of the Gambia (Phase II) –Geophysical Surveys. Volume 1. Consultancy Report prepared on behalf of GOTG/DWR.

Knox, J. et al 2012 Climate change impacts on crop productivity in Africa and South Asia. Environ. Res. Lett. 7 034032

Komiyama A., Ong J.E., Poungparn S. 2008. Allometry, biomass, and productivity of mangrove forests: A review. Aquatic Botany, 89, 128–137.

Komoroske LM., Connon RE., Lindberg J., Cheng BS., Castillo G., Hasenbein M., Fangue NA. (2014) Ontogeny influences sensitivity to climate change stressors in an endangered fish. *Conserv Physiol* 2: doi:10.1093/conphys/cou008.

Korte L.F., Brummer GJ.A., van der Does1M, Guerreiro C.V., Hennekam R., van Hateren J.A., Jong D., Munday C.I., Schouten S. and Stuut JB.W. Downward particle fluxes of biogenic matter and Saharan dust across the equatorial North Atlantic. Atmos. Chem. Phys., 17, 6023–6040, 2017/ doi:10.5194/acp-17-6023-2017

Krauss K.W., Lovelock C.E., McKee K.L., Lo´ pez-Hoffman, L., Ewe S.M.L., Sousa W.P. 2008. Environmental drivers in mangrove establishment and early development: A review. Aquatic Botany, 89, 105–127.

Lance F. W. Lesack 1984. Transport of carbon, nitrogen, phosphorus, and major solutes in the Gambia River, West Africa'. Limnol. Oceanogr. 29(4), 1984, 8 16-830

Lavender and Matthews, 2009. Response of the West African Monsoon to the Madden–Julian Oscillation. Journal of Climate. Vol. 22, 4097-4116.

Leandro Medina, Andrew Jonelis, and Mehmet Cangul, 2017. The Informal Economy in Sub-Saharan Africa: Size and Determinants. IMF WP/17/156. New York, 31p.

Lee, V., Tobey, J., Castro, K., Crawford, B., Dia, I.M., Drammeh, O., and Vaidyanathan, T., 2009, Marine Biodiversity Assets and Threats Assessment, Gambia-Senegal Sustainable Fisheries Project, Coastal Resources Center, University of Rhode Island. 50p.

Le Houerou, H.N. 1980. "The rangelands of the Sahel." *Journal of Range Management* 33:41-45

Lewandowsky S., Ballard T. and Pancost R.D. 2015. Introduction: Uncertainty as knowledge. Philosophical Transactions: Mathematical, Physical and Engineering Sciences, Vol. 373, No. 2055, pp.1-11.

Linsley R. K., Kohler, M. A. and Paulhus J.L.H., 1983 Hydrology for engineers. Third edition. McGraw-Hill Inc. 508p.

Long S.P., Ainsworth E.A., Leakey A.D.B., Josef Nösberger, Donald R. Ort, 2006. Food for Thought: Lower-Than-Expected Crop Yield Stimulation with Rising CO2 Concentrations. Science, Vol 312, 1918-1921

Lugo A.E., Brown, S., and Brinson, M.M., 1988. Forested wetlands in freshwater and salt-water environments. Limnol. Oceanogr., 33(4, part 2), 1988, 894-909 0 1988, by the American Society of Limnology and Oceanography, Inc.

Mahé, G and J.C. Olivry, 1995. *Variations des précipitation et des écoulements en Afrique de l'Ouest et centrale de 1951-1989*. Sécheresse, 6 (1) (1995), pp. 109-117.

Manneh, M., Ceesay, E., Sallah, A., Mbaye, B. and Jallow, B.P., 2015. Third National Greenhouse Gas inventory report (NIR): 2001 – 2010. Contribution to the Third National Communications of The Gambia to the United Nations Framework Convention on Climate Change. Banjul, 112p.

Mendy A. 2002. Trends in Gambian Fisheries and Fisheries Statistics. *Actes du symposium international*, Dakar (Sénégal), 24-28 juin 2002, p69-78.

Mingguo Z., Qiangguo C. and Hao C. 2007. Effect of vegetation on runoff-sediment yield relationship at different spatial scales in hilly areas of the Loess Plateau, North China. Acta Ecologica Sinica, 2007, 27(9), 3572−3581.

Mitchell, J and Faal, J. 2007. Holiday package tourism and the poor in the Gambia. *Development Southern Africa* Volume 24, Number 3, 445 – 464.

M'koumfida B., Yaffa S. and Bah A. 2018, The Impacts of Saline-Water Intrusion on the Lives and Livelihoods of Gambian Rice-Growing Farmers. Res. Rev. J Ecol. Environ. Sci. Volume 6, Issue 1, January- March, 2018, pp1-7

MOBSE, 2016. Education sector policy 206-2030). Banjul, 45p.

Molesworth A.M., Cuevas L.E., Connor S.J., Morse A.P., and Thomson M.C. Environmental Risk and Meningitis. Epidemics in Africa. Emerging Infectious Diseases • Vol. 9, No. 10, October 2003. Pp1287-1293.

Mosha A.C. (2011) "The Effects of Climate Change on Urban Human Settlements in Africa" in B Yuen and A Kumssa (eds.) *Climate change and sustainable Urban Development in Africa and Asia*, London and New York: Springer.

MEDD (Ministere de l'environnement et du developpement durable), 2015. *Troisieme communiciation a la Convention Cadre des Nations Unies sur les Changements Climatiques.*

MOFEA, 2019. The 2018 Annual Progress Report (APR) of The Gambia National Development Plan (2018-2021). Banjul, 158p.

MOTIE, 2013 http://www.gambiatradeinfo.org/external-trade

MSU, 1985. Terrestrial ecology and GRB development. Report prepared for USAID & OMVG. 337p + Appendices. MSU. Contract No. 685-0012-C-00-2158-00. USAID/OMVG. 1985.

Mylène R., 2002. The Gambia Today. First editions. Publications Jaguar. 248p

NDMA (National Disaster Management Agency), 2014. Local hazard and risk zoning exercise in The Gambia. Office of the President. Banjul, 88p + Appendices

Ndoye, S., X. Capet, P. Estrade, B. Sow, D. Dagorne, A. Lazar, A. Gaye, and P. Brehmer (2014), SST patterns and dynamics of the southern Senegal-Gambia upwelling center, J. Geophys. Res. Oceans, 119, 8315–8335, doi:10.1002/2014JC010242

NEA (National Environment Agency), 2010. State of the Environment Report –The Gambia (SER –TG). National Environment Agency (NEA), MOFEN., Banjul, The Gambia, 263p.

Niguse A., Aleme A. (2015) Modeling the Impact of Climate Change on Production of Sesame in Western Zone of Tigray, Northern Ethiopia. J Climatol Weather Forecasting 3: 150. doi:10.4172/2332-2594.1000150

NIRAS, 2013. Groundwater monitoring and network design. . National Water Sector Reform Studies. MOF&WR, Banjul, The Gambia, 1 pages + Annexes

NIRAS, 2014a. Hydrogeological map of The Gambia. Consultancy Report. Project ID number: 5600 15500 2201 Financing Agreement Ref: P-GM-EAZ-01

NIRAS, 2014b. Establishment of new groundwater monitoring network and initial results on groundwater occurrence. Project ID number: 5600 15500 2201 Financing Agreement Ref: P-GM-EAZ-01

NIRAS, 2015a. National Water Resources Assessment and Management Strategy. Consultancy Report. Project ID number: 5600 15500 2201 Financing Agreement Ref: P-GM-EAZ-01

NIRAS, 2015b. Installation of Hydrological Equipment. National Water Sector Reform Studies. MOF&WR, Banjul, The Gambia, 27 pages + Annexes

Njie M. 2002. Second Assessment of Climate Change induced vulnerability in the Gambian Water Resources Sector and Adaptation Strategies. Consultancy Report for National cleat Committee (The Gambia), Banjul. 71p

Njie M. 2003. National Water Security in the first half of the 21st Century. Report prepared under GAM/93/003 as a contribution towards Gambia's National Water Resources Management Strategy, UNDP/DWR, Banjul, 24p.

Njie M., Gomez B.E., Hellmuth M.E., Callaway J.M., Jallow B.P. and Droogers P. 2008. Making economic sense of adaptation in upland cereal productions systems in the Gambia. In: Leary *et al.* (eds.) *Climate Change and Adaptation*, Earthscan Publications, pp.131 – 146.

Njie M., 2009. IWRM roadmap for the Gambia. *Consultancy Report* prepared for the UCC-Water/DHI, Banjul, 39p + appendices.

Njie M. and Jarjusey O.D. 2011. An assessment of investments and financial flows to address climate change in the Gambian water sector. Consultancy report prepared for UNDP Bureau of Development Policy, New York, USA.

Njie, M., 2013. Reflections on the Gambia's Second National Communication under the UNFCCC. Discussion Paper prepared for Department of Water Resources. Banjul, 27p.

Njie, 2014. Physical setting of the Gambian coastal zone. Refresher ICZM Training Course. GCCA Support Project to The Gambia for Integrated Coastal Zone Management and the Mainstreaming of Climate Change (GC3SP). NEA, Banjul.

Njie, 2015a. Gap Analysis 2: Low emissions and resilient economy. Report prepared by Agrer s.a under GCCA Support Project to The Gambia for Integrated Coastal Zone Management and the Mainstreaming of Climate Change (GC3SP). Banjul, 36 pages + Appendices.

Njie, M., 2015b. Management Plan for a Gambian Coastal Zone Management Organisation. Consultancy report prepared for NEA under GCCA Support Project to the Gambia for ICZM[26] and mainstreaming Climate Change (GC3SP). Banjul, 78 pages + Appendices.

26 Integrated Coastal Zone Management

Njie, M., 2017. Climate change mitigation technologies in the Gambian energy, transport and waste sectors. Consultancy report for Department of Water Resources (DWR) and UNEP-DTU partnership. Banjul, 45 pages + Annexes.

Nutt C., Adams P. Zika in Africa—the invisible epidemic? The Lancet. Vol 389 April 22, 2017

Oakland J., Marosszeky M. 2006. Total Quality in the Construction Supply Chain. Published by Elsevier Ltd. London. 527p. ISBN-13: 978-0-7506-6185-0

O'Connor T.G., Haines L.M. and SNYMAN H.A. 2001, Influence of precipitation and species composition on phytomass of a semi-arid African grassland. *Journal of Ecology*2001 89, 850–860

Oke T. R., 1973. City size and urban heat island. *Atmospheric Environment* PergamonP ress1 973. Vol. 7, pp. 769-779.

Oke T.R. 1982. The energetic basis of the urban heat island. Quart J.R. Met. Soc. (198Z), 108, pp. 1-24.E
Oluwatobi, O.O., 2018. Integration of climate change education into the national curriculum of The Gambia. Unpublished MSc thesis. University of The Gambia. Banjul, 96p.

Ouillon S. and Caussade B. 1990. *Modelisation mathematique de l'hydro-dynamique et du transport d' un constituant passif dans l' estuaire du fleuve Gambie a l'interpretation d'images satellitaires*, IMFT, Rapport Hydre n° 1, Toulouse, 1990.

Ouillon S. and Caussade B. 1991 Numerical simulation and remote sensing: two techniques applied to the River Gambia estuary in Computer Methods and Water Resources 2, Vol. 3, 309 -220. Ben Sari, Brebbia, Ouzzar (eds.),

PCA (The Portland Cement Association), 2002. Types and Causes of Concrete Deterioration.

Pender, D., and Callaghan D.P.J., 2016. An evaluation of methods available for quantifying extreme beach erosion. Ocean Eng. Mar. Energy (2015) 1:31–43. DOI 10.1007/s40722-014-0003-1.

Penn State. "Dry Season Brings On Measles In Sub-Saharan Africa." ScienceDaily. ScienceDaily, 7 February 2008. <www.sciencedaily.com/releases/2008/02/080206131643.htm>.

Perry B., McDermott J., Randolph T. 2001 Can epidemiology and economics make a meaningful contribution to national animal-disease. Preventive Veterinary Medicine, Volume 48, Issue 4, 29 March 2001, Pages 231-260.

Philips et al., 2010. Drought-mortality relations for tropical forest. New Phytologist (2010) 187: 631–646 doi: 10.1111/j.1469-8137.2010.03359.x.

Prek M. 2006. Thermodynamical analysis of human thermal comfort. Energy 31 (2006) 732–743.

ProPAG, 2013. Analytical Note on 2014 Budget laid before the National Assembly of the Gambia. PPAG/SER/AN/GMB Budget/01, Pro-Poor Advocacy Group Publications, Bakau Newtown, 29p.

Qasim M., Porembski S., Sattler D., Stein K., Thiombiano A. and Lindner A. 2016. Vegetation Structure and Carbon Stocks of Two Protected Areas within the South-Sudanian Savannas of Burkina Faso. Environments 2016, 3, 25; doi:10.3390/environments3040025.

QUT (Queensland University of Technology), 2010. Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009, Report for the National Climate Change Adaptation Research Facility, Gold Coast, Australia.

Queiroga FR., Vianna RT., Vieira CB., Farias ND. and da Silva PM. 2015. Parasites infecting the cultured oyster Crassostrea gasar (A danson, 1757) in Northeast Brazil. Parasitology (2015), 142, 756–766. doi:10.1017/S0031182014001863.

Rieger F. and Wong-Rieger D. (1990). Organization and culture in developing countries: a configuration model. In: Management in developing countries. Jaeger A.M. and Kanungo R.N. (eds.). Rutledge Publishers, New York. pp: 101 – 127.

Rotmans J., Kemp R., van Asselt M. 2001.More evolution than revolution: transition management inpublic policy foresight/ vol.03, no.01, feb.01.

Sanogo S.2015 Empirical analysis of the recent rainfall recovery in West Africa, PhD Thesis, Department of Meteorology, Federal University of Technology, Akure (FUTA), 162p.

Sarré A., Krakstad JO., Brehmer P. and Mbye E.M. 2018. Spatial distribution of main clupeid species in relation to acoustic assessment surveys in the continental shelves of Senegal and The Gambia.
Aquat. Living Resour. 2018, 31, 9

Savage, 2017 Livestock Statistics. Presented at Data User-Producer (2017) Forum. GBOS, Banjul

Scardua MP., Vianna RT., Duarte SS., Farias ND., Correira MLD., dos Santos, HTA and da Silva PM., 2017. Growth, mortality and susceptibility of oyster *Crassostrea* spp. to *Perkinsus* spp. infection during on growing in northeast Braz. J. Vet. Parasitol., Jaboticabal, v. 26, n. 4. p401-410, oct.-dec. 2017.

Schlenker W. and Lobell DB. (2010) Robust negative impacts of climate change on African agriculture. Environmental Research Letters 5: 014010. 8p.

Sillah B. 2013. Agriculture and growth nexus in Gambia. Journal of Economic & Financial Studies, Vol. 01, No. 01, 74-86.

Sillah, J.S. 1999. Forest resources and plantations of the Gambia. Report produced under the EC-FAO Partnership Programme (1998-2002) – Project. GCP/INT/679/EC. EC-FAO Partnership Programme. DOF, Banjul. 29p

Sima, F., 2010. Climate Change Report. Department of Water Resources, Banjul, 14p.

Simöes et al., 2011. A review of low-level air pollution and adverse effects on human health: implications for epidemiological studies and public policy. CLINICS 2011;66(4):681-690. DOI:10.1590/S1807-59322011000400025

Sogreah Ingenierie, Hydroconsult International and SCET-Tunisie, 1999. Gambia River Basin Hydraulic Master Plan, Main Report. Consultancy Report prepared for OMVG. Dakar.

Sowe, M.M., 2016. Health sector statistics from HMIS. Presented at Stistics Data User-Producer Forum, December 2016.

Stafford, G., 2019. The Gambia Annual Climate Report: 2018. Department of Water Resources, Banjul, 44p.

Sultan et al. 2003. The West African Monsoon Dynamics. Part I: Documentation of intra-seasonal variability. Journal of climate. Vol. 16, No. 21, 3389-3406

Sultan and Janicot, 2003. The West African Monsoon Dynamics. Part II: The ''Pre-onset'' and ''Onset'' of the Summer Monsoon Journal of climate. Vol. 16, No. 21, 3407-3427

Sylla A. 1994. *La philosophie more des Wolofs.* Second edition. IFAN, UCAD. 219p.

Tourre Y.M., Lacaux JP, Vignolles C., Ndione JA, Lafaye M. 2017. Mapping of zones potentially occupied by *Aedes vexans* and *Culex poicilipes* mosquitoes, the main vectors of Rift Valley fever in Senegal. *Geospatial Health 3(1), 2008, pp. 69-79*

Sylla et al., 2012. West African Monsoon in State-of-the-Science Regional Climate Models. West African Monsoon in State-of-the-Science Regional Climate Models. 2013. doi/10.5772/55140

Tait R.V. and Dipper F.A. 1998. Elements of marine ecology. Fourth edition. Butterworth-Heinemann. 412p.

Tappan, G. G., Cushing, W.M., Cotillon, S.E., Mathis, M.L., Hutchinson, J.A., and Dalsted, K.J., 2016, West Africa Land Use Land Cover Time Series: U.S. Geological Survey data release, http://dx.doi.org/10.5066/F73N21JF

TerrAfrica, 2009. Land and Climate: The Role of Sustainable Land Management (SLM) for Climate Change Adaptation and Mitigation in Sub-Saharan Africa (SSA), NEPAD. Johannesburg, 110pp**.**

Touray, K.S., Loum, B., Njie, M., Yaffa, S., Sonko, K.N., Fatty, L.M.K., Nyangado, L., Sawaneh, M., Jammeh, M.E., Kassama, M.L., Jobe, N.F., Touray, O., Keita, S., 2014. *Gambia Sustainable Land management Investment Framework (GAMSIF) 2016 – 2020*. Ministry of Agriculture, Banjul, 62pages + Appendices

Tourre Y.M., Lacaux JP, Vignolles C., Ndione JA, Lafaye M. 2017. Mapping of zones potentially occupied by *Aedes vexans* and *Culex poicilipes* mosquitoes, the main vectors of Rift Valley fever in Senegal. *Geospatial Health 3(1), 2008, pp. 69-79*

Trawalley D.N.A. 2016. Modelling heat stress impact on maize productivity in the Northern Region of Ghana, Unpublished PhD thesis. KNUST, Kumasi, Ghana. 137p.

UNDESA, 2017. Framework for the Development of Environmental Statistics (FDES) 2013. UN Statistics Division. UN Publication ST/ESA/STAT/SER.M/92, New York. 228p.

UNDP, 2018. Human Development Indices and Indicators: 2018 Statistical Update. http://hdr.undp.org/en/countries/profiles/GMB

UNECA, 2017. Country Profile 2016- The Gambia. UNECA. Addis Ababa, Ethiopia. 33p. www.uncerca.or/publications

Urquhart, P., 2016. National Climate Change Policy of The Gambia. Final Draft. *Consultancy Report prepared by Agrer s.a.* for MECCNAR, Banjul, 63p.

Van der Ent R. J., Wang-Erlandsson L., Keys P.W. and Savenije H. H. G., 2014. Contrasting roles of interception and transpiration in the hydrological cycle – Part 2: Moisture recycling. Earth Syst. Dynam., 5, 471–489, doi:10.5194/esd-5-471-2014

Van Vuuren et al, 2011. The representative concentration pathways: an overview. Climatic Change (2011) 109:5–31. DOI 10.1007/s10584-011-0148-z

Verhoeven J.T.A., Meuleman A.F.M. 1999. Wetlands for wastewater treatment: Opportunities and limitations. Ecological Engineering 12 (1999) 5–12.

Verkerk M.P. and van Rens, C.P.M 2005. Saline intrusion in Gambia River after dam construction: Solutions to control saline intrusion while accounting for irrigation development and climate change. Research Report, University of Twente (The Netherlands), 64p

Wei J., Su H., Yang ZL. 2014. Impact of moisture flux convergence and soil moisture on precipitation...: a case study for the southern United States with implications for the globe. Clim Dyn. Springer. DOI 10.1007/s00382-015-2593-2

WenHong MA., YuanHe Y., JinSheng HE., Hui Z. & JingYun F. 2008. Above- and belowground biomass in relation to environmental factors in temperate grasslands, Inner Mongolia. *Sci China Ser C-Life Sci.,* vol. 51, no. 3, 263-270

World Bank, 2016. World Development Indicators. Available at http://data.worldbank.org/ data-catalog/world-development-indicators.
https://data.worldbank.org/indicator/BX.TRF.PWKR.CD.DT?locations=GM

WTO, 2003. Proceedings of the 1st International Conference on Climate Change and Tourism Djerba, Tunisia, 9-11 April 2003. WTO, Madrid, 55p.

Xu X., Medvigy D., Ignacio Rodriguez-Iturbe. Relation between rainfall intensity and savanna tree abundance explained by water use strategies**.** *Proceedings of the National Academy of Sciences*, 2015; 201517382 DOI:

Yade S. 2015. Gap Analysis 3: Climate resilient people. Report prepared by Agrer s.a under GCCA Support Project to The Gambia for Integrated Coastal Zone Management and the Mainstreaming of Climate Change (GC3SP). Banjul, 24 pages + Appendices

Zhou Y.; Gencturk B.; Willam K.; and Attar A. Carbonation-Induced and Chloride-Induced Corrosion in Reinforced Concrete Structures. Journal of Materials in Civil Engineering · November 2014
DOI: 10.1061/(ASCE)MT.1943-5533.0001209.