European Commission

JRC TECHNICAL REPORTS

Water-Energy-Food-Ecosystems Nexus Project in the Senegal River Basin

Review of literature and analysis of open source data

Umlauf, G., Pastori, M.

2018

DRAFT

Limited distribution

Joint Research Centre

1 Table of Contents

DRAFT

DRAFT

2 Introduction

Water, energy and food are essential for human well-being, poverty reduction and sustainable development. Water, Energy and Food systems are inextricably linked in the Water-Energy-Food Nexus (WEF), and all together are depends on and affect the environment.

Drivers that upset the WEFE Nexus assessment specifically in developing countries are: population growth and change of life quality standards and food demand; urbanization; energy demand increase; increasing competition for water demand by different sectors; climate change and specifically impact on water availability spatially and temporally.

Water resource use and management is a key aspect for all these aspect. Water is a driver for crop production, for intensive cropping system, for livestock and also for the energy sector. Energy production is linked with water management as for example for hydropower system based on water river's availability and on reservoirs. In addition energy is a crucial component for all activities linked with irrigation because of pumping and transport, as well as for water

This report is reporting a summary of the analysis of literature and data availability on the Senegal River basin. This Report is currently based on literature review and open access data and it will be updated as the local data to be collected by project partners will be made available (February 2019).

The 1st section of the report provides an elaboration of the key issues in terms of environmental quality (with special emphasis on water quality) in the SRB. It shall serve to set priorities for the research and training aspects as well as related mitigation concepts concerned within the Water Energy Agriculture Nexus of the WEFE Senegal project

The analysis is done using:

- Country based health statistics released by the World Health Organization (WHO), with special emphasis on environmental health stressors as a starting point
- Country based trade statistics to identify sectors, with presumably impact water quality
- Other databases on industrial activities
- Scientific literature (and data provided by OMVS) about water quality in the SRB in comparison to existing environmental quality standards (EQS).

The 2nd section of the report provides an introduction about main issues related with Nexus by analyzing public available data (Open access data, global dataset, free available data, etc.; See ANNEX 1). This section serve to give an introduction to assessment of the Senegal River Basin for the identification of which sector need to be considered for the Nexus assessment and eventually to identify missing data. This part has to be considered as an ongoing section as it will be updated and populated when local data will be available (local data to be delivered by first months of 2019).

DRAFT

2.1 The Senegal River basin

Senegal river basin is a transboundary basin shared among Senegal, Mali, Mauritania and Guinea (Figure 1).

All these countries needs more energy and more food, and for both at least three of them strongly depend on the flows in the River Senegal. Indeed Guinea share a more limited area of the River Basin and this part is much more linked with environmental issue being included in the Fouta Djalon Massif. Power production in the Senegal river basin is largely hydro based. Climate studies predict a high likelihood of increasing variability of rainfall that need to be considered in combination of increasing demands for multi-purpose usage of water resources.

The Senegal River basin (SRB) is located in the Wester African area, it covers a surface of about 425 000 km^2 drained by the river Senegal (1800 km) and it can be divided in 3 big main regions: the upper basin (from the Fouta Djalon to Bakel), the valley (from Bakel to Dagana), the Delta.

It is shared among 4 countries (Figure 2) and respective shares are (as derived by OMVS, 2012):

- 54% in Mali
- 26% in Mauritania
- 10.5% in Guinea
- 9.5% in Senegal

Figure 1. Senegal River Basin delineation (OMVS).

DRAFT

The Senegal river is the second largest river in West Africa. It is formed by the confluence of three main tributaries: the Bafing, the Bakoye and the Falémé (Figure 3). These three affluents take their sources from the Fouta Djallon highlands in Guinea, a region in the Upper basin which produces more than 80% of the total river basin's contribution.

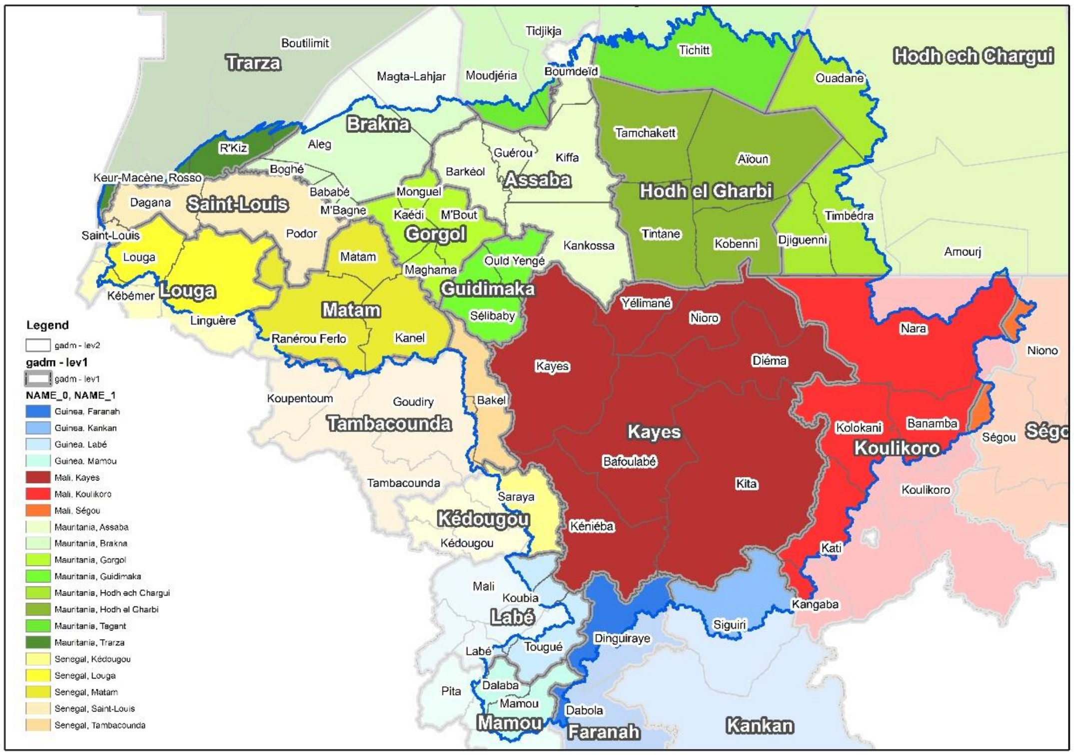


Figure 2. GADM Administrative limits (GADM, 2018) *for within the Senegal River Basin.*

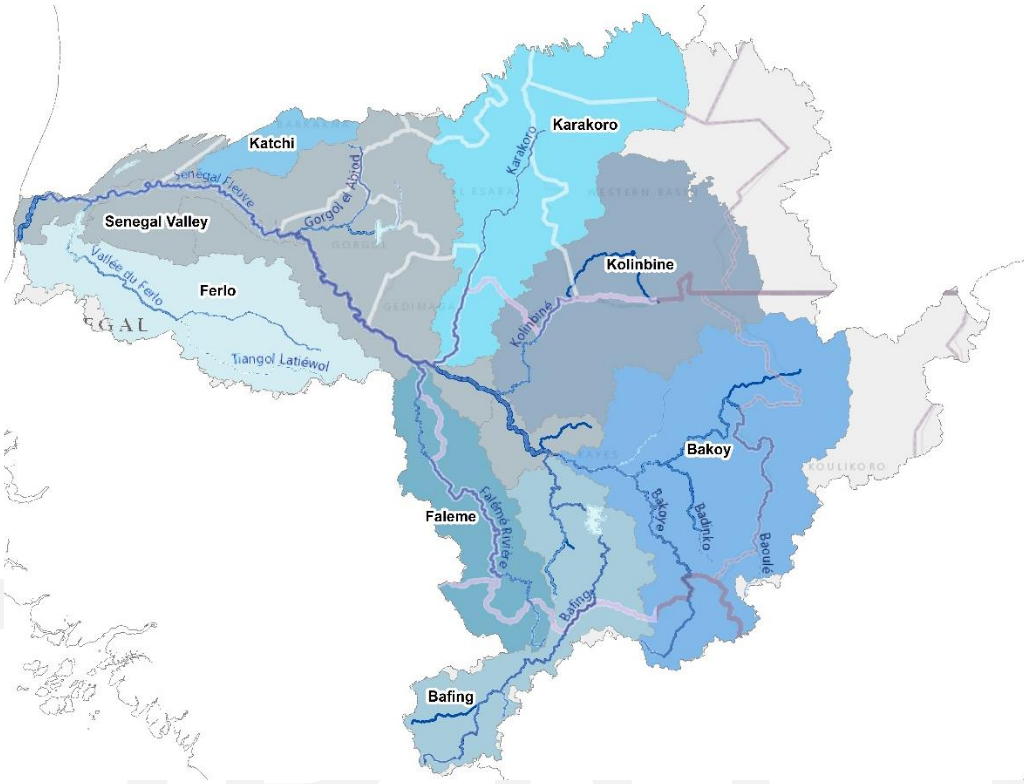


Figure 3 Senegal River Basin, and main tributaries.

DRAFT

3 Water Quality Issues in the Senegal River Basins

3.1 Population distribution and its growth

3.1.1 General trends

Total population living within the hydrological Senegal River Basin (SRB) was about 7 980 000 for year 2015 (JRC and CIESIN, 2015). Total population in the 4 countries (considering also areas outside the SRB) was about 49.3 M in 2015, thus SRB population accounts for 16% of total population. Most populated areas within the SRB are in Mali, specifically in Kayes and Kita regions (red areas in Figure 4) and in Podor (Saint-Louis). In Mauritania most populated areas within the SRB are Selibaby and Kaedi. If we consider population density (see

Figure 5) it is much more clear how population is mainly living nearby the main rivers: see for example all administrative units with high density along the Senegal river in the floodplain and along Bafing, Bakoye and Kolimbiné rivers (

DRAFT

Figure 5). Population statistics across the Senegal River Basin at administrative level are reported in Table 1.

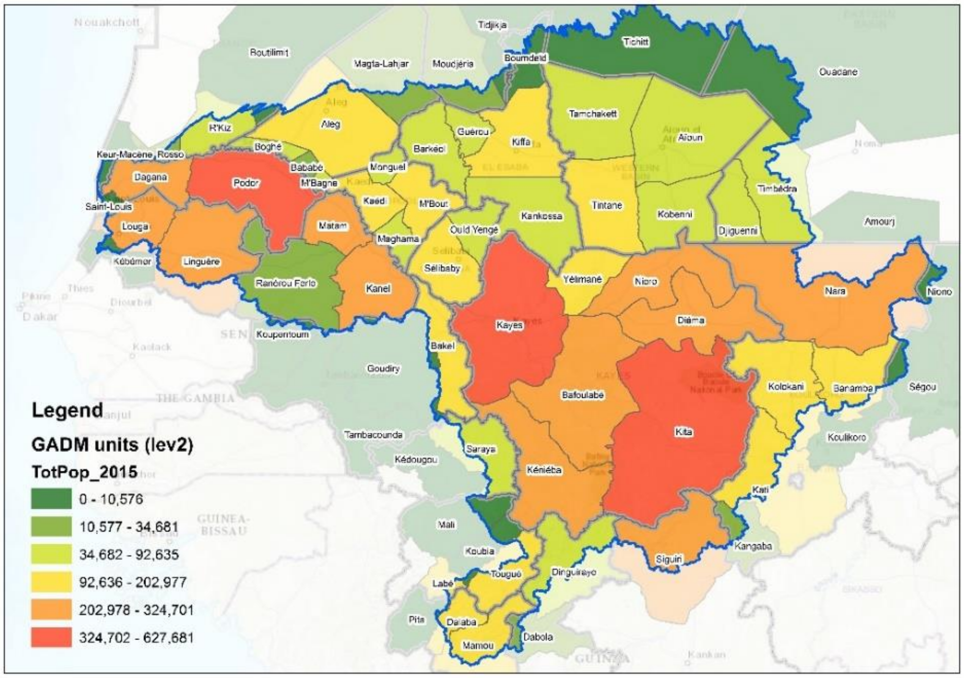


Figure 4. Total population for 2015 as derived by GHS population grid (JRC and CIESIN, 2015)summarized at administrative level 2 of GADM limits (GADM, 2018).

DRAFT

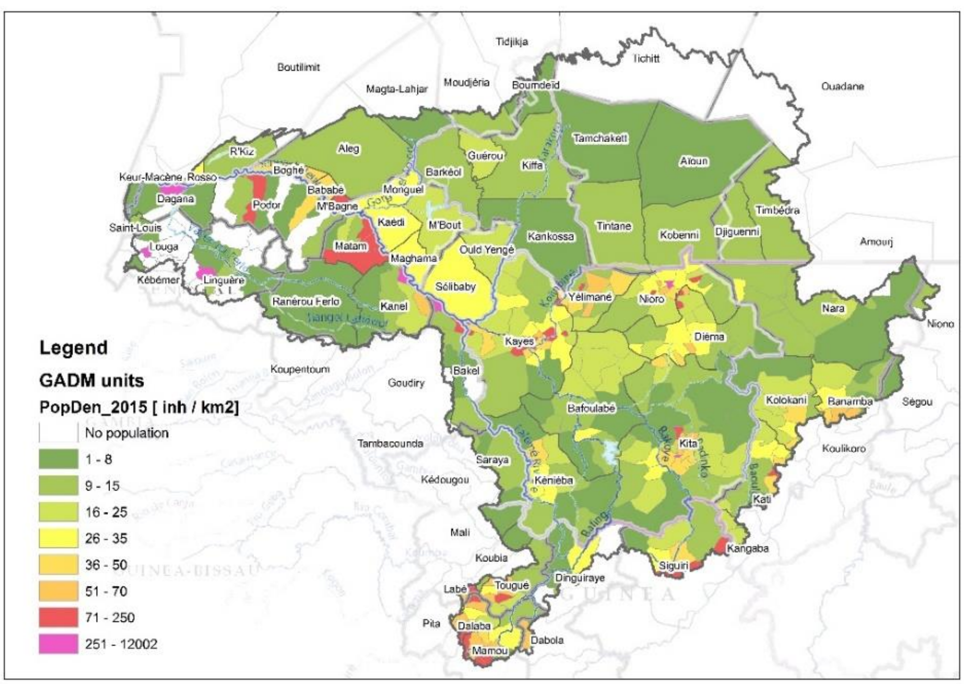


Figure 5. Pop. Density for 2015 as derived by GHS grid (JRC and CIESIN, 2015) at adm. Lev. 4 of GADM (GADM, 2018).

DRAFT

NAME_0	NAME_1	Total Population					Pop. Density (hab/km2)			
		1975	**1990**	**2000**	**2015**	**Areakm2**	**1975**	**1990**	**2000**	**2015**
Guinea	Faranah	45260	50992	64671	89940	7303	6.2	7.0	8.9	12.3
Guinea	Kankan	31139	72793	118074	251337	8721	3.6	8.4	13.5	28.8
Guinea	Labé	144058	201648	270216	269930	8232	17.5	24.5	32.8	32.8
Guinea	Mamou	164840	204354	261105	311422	7249	22.7	28.2	36.0	43.0
Guinea	***Total***	***385297***	***529787***	***714066***	***922629***	***31506***	***12.2***	***16.8***	***22.7***	***29.3***
Mali	Kayes	914829	1199974	1550265	2347141	121818	7.5	9.9	12.7	19.3
Mali	Koulikoro	326036	422416	517263	686605	47562	6.9	8.9	10.9	14.4
Mali	Ségou	632	1084	1606	13431	2038	0.3	0.5	0.8	6.6
Mali	***Total***	***1241497***	***1623474***	***2069134***	***3047177***	***171418***	***7.2***	***9.5***	***12.1***	***17.8***
Mauritania	Assaba	117141	185781	250466	365164	34631	3.4	5.4	7.2	10.5
Mauritania	Brakna	111879	183144	228436	297061	19300	5.8	9.5	11.8	15.4
Mauritania	Gorgol	105980	183624	256166	373791	13796	7.7	13.3	18.6	27.1
Mauritania	Guidimaka	74781	125651	177699	289338	10689	7.0	11.8	16.6	27.1
Mauritania	Hodh ech Chargui	41545	62421	93367	133378	22547	1.8	2.8	4.1	5.9
Mauritania	Hodh el Gharbi	103673	168927	229294	335649	50276	2.1	3.4	4.6	6.7
Mauritania	Tagant	14796	20517	22442	22512	19502	0.8	1.1	1.2	1.2
Mauritania	Trarza	45311	61486	74456	74646	5676	8.0	10.8	13.1	13.2
Mauritania	***Total***	***615106***	***991551***	***1332326***	***1891539***	***176418***	***3.5***	***5.6***	***7.6***	***10.7***
Senegal	Kédougou	14648	31751	35960	51522	5656	2.6	5.6	6.4	9.1
Senegal	Louga	105192	277969	361845	585229	16495	6.4	16.9	21.9	35.5
Senegal	Matam	209051	322951	424660	606181	26917	7.8	12.0	15.8	22.5
Senegal	Saint-Louis	224654	345001	452515	692874	20005	11.2	17.3	22.6	34.6
Senegal	Tambacounda	57313	95435	119973	181610	7982	7.2	12.0	15.0	22.8
Senegal	***Total***	***610858***	***1073107***	***1394953***	***2117416***	***77055***	***7.9***	***13.9***	***18.1***	***27.5***

Table 1. Population statistics across the Senegal River Basin at administrative level (data refer to area within the River Basin)

DRAFT

Population density in the River basin is generally not very high, even if in the last years an important growth was observed Table 1. Average population density (2015) is 29 hab/km^2 in Guinea, 18 in Mali, 11 in Mauritania and 27 in Senegal. Highest density were observed in the following regions: Mamou (43, GUI), Kayes (19, MAL), Gorgol and Guidimaka (27, MRT) and Saint-Louis and Louga (35, SEN).

Population data are available for 1975, 1990, 2000 and 2015: the average annual growth rates for the selected periods is reported in Table 2: the annual growth rate is variable both for the periods and for the countries ranging from 0 to a max of 15%. In Guinea annual growth rate is about 1.7 – 3% and the region where population growth is more pronounced is Kankan. In Mali annual growth rate is about 1.8 – 2.6% and the region where population growth is more pronounced is Ségou, above all in the last years. In Mauritania annual growth rate is about 2.4 – 3.2% and the region where population growth is more pronounced is Guidimaka, above all in the last years. In Senegal annual growth rate is about 2.7 – 3.8% and the region where population growth is more pronounced is Louga and Saint-Louis.

Table 2. Population annual growth rate for 3 periods across the Senegal River Basin.

DRAFT

		Annual growth rate		
NAME_0	***NAME_1***	***75-90***	***90-00***	***00-15***
Guinea	Faranah	0.8%	2.4%	2.2%
Guinea	Kankan	5.8%	5.0%	5.2%
Guinea	Labé	2.3%	3.0%	0.0%
Guinea	Mamou	1.4%	2.5%	1.2%
Guinea	***Total***	**2.1%**	**3.0%**	**1.7%**
Mali	Kayes	1.8%	2.6%	2.8%
Mali	Koulikoro	1.7%	2.0%	1.9%
Mali	Ségou	3.7%	4.0%	15.2%
Mali	***Total***	**1.8%**	**2.5%**	**2.6%**
Mauritania	Assaba	3.1%	3.0%	2.5%
Mauritania	Brakna	3.3%	2.2%	1.8%
Mauritania	Gorgol	3.7%	3.4%	2.6%
Mauritania	Guidimaka	3.5%	3.5%	3.3%
Mauritania	Hodh ech Chargui	2.8%	4.1%	2.4%
Mauritania	Hodh el Gharbi	3.3%	3.1%	2.6%
Mauritania	Tagant	2.2%	0.9%	0.0%
Mauritania	Trarza	2.1%	1.9%	0.0%
Mauritania	***Total***	**3.2%**	**3.0%**	**2.4%**
Senegal	Kédougou	5.3%	1.3%	2.4%
Senegal	Louga	6.7%	2.7%	3.3%
Senegal	Matam	2.9%	2.8%	2.4%
Senegal	Saint-Louis	2.9%	2.7%	2.9%
Senegal	Tambacounda	3.5%	2.3%	2.8%
Senegal	***Total***	**3.8%**	**2.7%**	**2.8%**

It is interesting to note that most areas of the Senegal river basin is not densely populated and generally this is so classified as rural areas (all green areas reported in Figure 6). Rural population is much more dominant in Guinea and Mali areas, where it accounts respectively for 44 and 39% of total population, while Urban is much more dominant in Mauritania and Senegal (Table 3), where it accounts for about 72 and 90%.

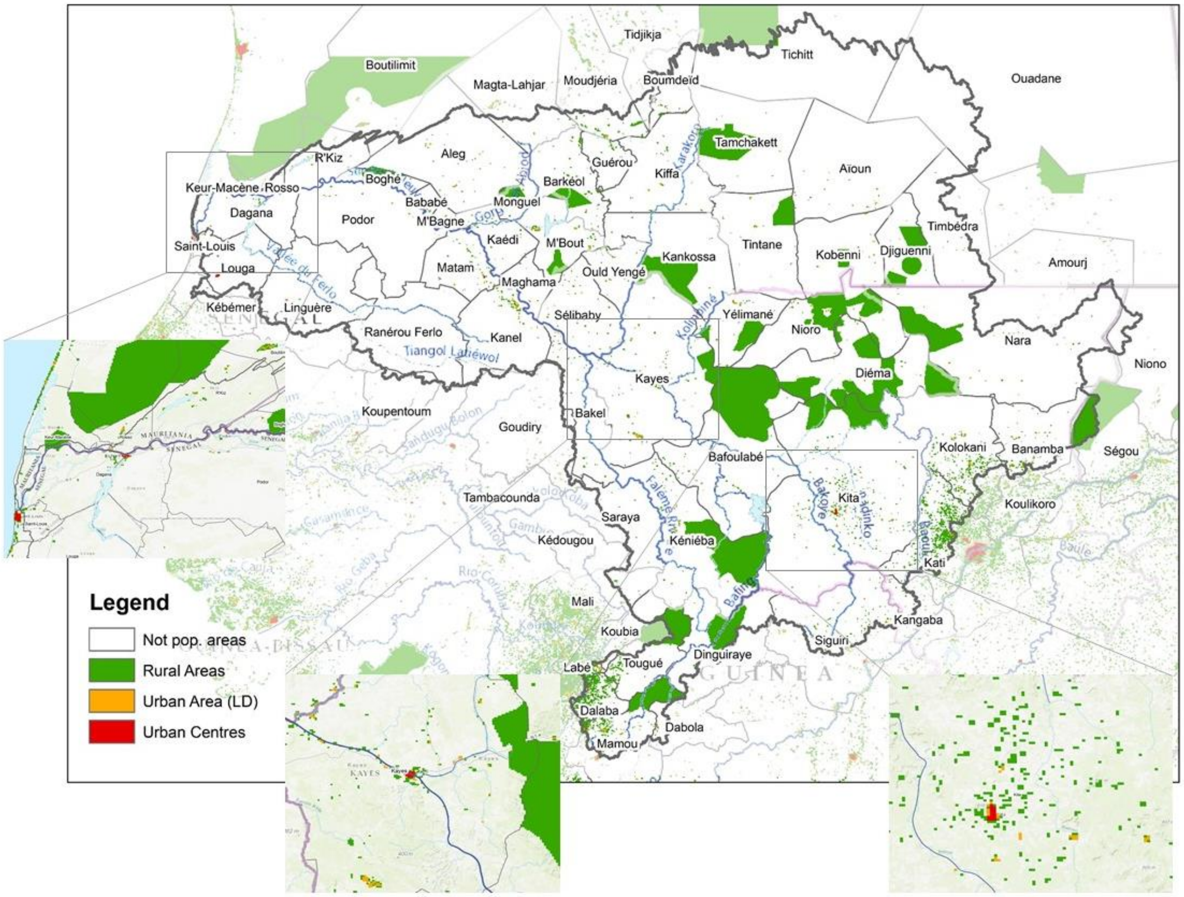


Figure 6. Settlement in the Senegal River Basin. Rural areas in green and urban areas with different density in orange and red (JRC and CIESIN, 2015).

River Basin Area					
Country	***TotPop_Rural***	***TotPop_Urban***	***Total***	***Rural***	***Urban***
Guinea	403373	521378	924,751	43.6%	56.4%
Mali	1208582	1859692	3,068,274	39.4%	60.6%
Mauritania	524211	1346928	1,871,139	28.0%	72.0%
Senegal	222704	1893830	2,116,534	10.5%	89.5%
Total	***2,358,870***	***5,621,828***	***7,980,698***	***29.6%***	***70.4%***

Table 3. Urban and Rural Population for year 2015.

3.1.2 Analysis of Mortality in the SRB countries

This analysis concerns the individual WHO Country profiles of the *Environmental Burden of Disease*, in the SRB countries Senegal, Mauritania, Mali and Guinea, describing the diseases arising from environmental impacts on human health. Estimates are based on national exposure and WHO country health statistics 2004.

The analyses is limited to the environmental impacts on human health, since the mitigation of those impacts falls into the objectives of the WEFE Senegal project supporting an environmentally friendly and sustainable management of the resources concerned in the water-energy-agriculture nexus. This means, that the most important burden of disease (the maternal, neonatal and nutritional cause group) in all four SRB countries, is not considered.

The following table *(*Table 4*)* provides an overview on the WHO estimates about the environmental burden of disease and the main risk factors identified to date in the SRB countries. The indicators are mortality and morbidity in terms of Disability-Adjusted Life Years[1] [DALYs] per 1000 capita. This overview is extracted from SRB Country profiles of Environmental Burden of Disease based on 2004 data.

	Senegal		**Mauritania**		**Mali**		**Guinea**	
	Deaths/y	DALYs /1000 cap /y	Deaths /y	DALYs /1000 cap /y	Deaths/ y	DALYs /1000 cap /y	Deaths/ y	DALYs /1000 cap /y
Overall*	43600 (30%)	119	8900 (28%)	99	71200 (33%)	210	34800 (30%)	132
Selected risk factors								
Water, sanitation (diarrhoea only)	12900	35	2300	24	22600	66	9600	34
Indoor air	6300	17	1200	13	15300	45	5700	20
Outdoor air	1800	1.9	200	0.7	1000	1.3	600	1.0
**The overall environmental burden of disease is higher than the sum of the burden from the individual risk factors, since not all risk factors are listed here (e.g. the burden from vector borne disease)*								

Table 4. Overview on the environmental burden of disease in the SRB countries and the contribution from selected risk factors.

The environmental burden of disease accounts for about one third of the total mortality in all cases, where the water quality related burden of disease clearly dominates the health impacts in all riverine counties, closely followed by the health impacts from poor indoor air quality.

For comparison: The estimates for Switzerland suggest a 13% contribution of environmental burden to the total mortality. However, most interestingly, there is a *zero* mortality from water and indoor air quality risk factors, while the outdoor air quality mortality accounts for 800 deaths per year.

[1] One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.
DALYs for a disease or health condition are calculated as the sum of the Years of Life Lost (YLL) due to premature mortality in the population and the Years Lost due to Disability (YLD) for people living with the health condition or its consequences.
http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/

This comparison clearly highlights the strong vulnerability of the SRB population to environmental stressors and clearly indicates the (entirely different) lines of action to improve environment and health:

While the developed world has left their hygiene and sanitation problems far behind and live in healthy households since centuries, dirty water and smoke from open fire kitchens still kill a vast portion of the people in the SRB.

A look into the overview about the main disease groups in the following table *(*Table 5*),* extracted from SRB Country profiles of Environmental Burden of Disease based on 2004 data, provides a more detailed picture on the specific human health outcomes.

Disease group	**Senegal**	**Mauritania**	**Mali**	**Guinea**
	DALYs /1000 cap /y	DALYs /1000 cap /y	DALYs /1000 cap /y	DALYs /1000 cap /y
Diarrhoea	38	26	69	36
Respiratory infections	21	14	41	20
Malaria	13	12	27	24
Other vector-borne disease	0.7	0.1	2.5	1.7
Lung cancer	0.1	0.1	0.0	0.1
Other cancers	1.4	1.3	1.4	1.4
Neuropsychiatric disorders	1.7	1.6	1.7	1.7
Cardiovascular disease	3.1	2.7	3.2	3.1
COPD#	1.1	0.9	1.1	1.1
Asthma	1.6	1.8	1.7	1.6
Musculoskeletal diseases	0.7	1.8	0.6	0.7
Road traffic injuries	3.3	3.4	4.3	4.2
Other unintentional injuries	6.4	6.4	8.1	7.1
Intentional injuries	1.2	1.2	1.4	1.3
# Chronic obstructive pulmonary disease				

Table 5. Overview on selected disease groups within the environmental burden of disease in the SRB countries.

The disease group clustering reveals the specific issues in three dominant environmental compartments affecting human health in the SRB.

Respiratory disease, the killer no. 1 on the total population level in all 4 countries got a rising trend in three of the four SRB countries. In addition, Malaria is on the rise in Mauritania and Mali, while Diarrhea was a mostly at a stable level between 2000 and 2012 *(*Table 6*)*.

DRAFT

	Respiratory disease#	**Malaria**	**Diarrhoea**
Senegal total&	15.8% stable	8% stable	6.3% stable
Children*	13%	17%	7%
Mauritania total	23.3% rising	6.2% rising	5.8% decreasing
Children	16%	10%	10%
Mali total	10.1% rising	7.6% decreasing	8% stable
Children	16%	14%	11%
Guinea total	12.5% rising	10% rising	6.1% stable
Children	13%	28%	8%
**deaths of children under 5 in 2013, no trend available* & *2012 deaths, trends 2000-2012* # *includes data for tuberculosis in Mauritania*			

Table 6. Trends among the 10 top causes of death in the SRB countries

The **three leading causes for mortality and morbidity** in the SRB countries are:

- Poor microbial **drinking water** quality and sanitation issues causing **Diarrhea**.

- Poor **indoor air** conditions from cooking on open fires causing **respiratory disease** (infection, Lung cancer, COPD, Asthma), affecting particularly women and children.

- Poor **surface water** quality causing Malaria and other **vector borne disease** (such a schistosomiasis).

DRAFT

Considering the main risks for public health documented in the WHO statistics for the four SRB countries, the priorities for further research and development of mitigation strategies are:

1. **Ground and surface waters** used for drinking water and hygiene purpose. Of particular concern is the microbial status with view of the diarrhea problem.
2. **Indoor air** quality affected by cooking on open fire in insufficiently ventilated environments and related respiratory disease.
3. **Surface water** and its biological status concerning breeding conditions of disease vectors transmitting Malaria and Schistosomiasis.

All of these are traditional environmental hazards, while modern environmental Hazards (such as heavy metals, pesticides, ambient air toxics, chemical water contaminants, domestic and hazardous waste and hazards related to production and use of food and consumer products) may affect the environment as well, but are not yet impacting the national health statistics to a significant extent.

This does not mean, that the modern environmental hazards should be neglected, since their significance is growing hand in hand with the modernization in the developing regions (Nweke and Sanders III, 2009)

3.2 Activities presumably impacting the environment in the SRB

Further information can be retrieved from the SRB countries Export statistics. The following diagrams were obtained from the atlas of economic complexity.

See: http://atlas.cid.harvard.edu/

3.2.1 Patterns of exports

3.2.1.1 Senegal exports

Senegal's' exports in 2016 concern mainly the primary sector. They were dominated by raw and processed food products, followed by petroleum products, cement and fertilizers (phosphate and its products). Gold accounts for 7.5 % of the volume.

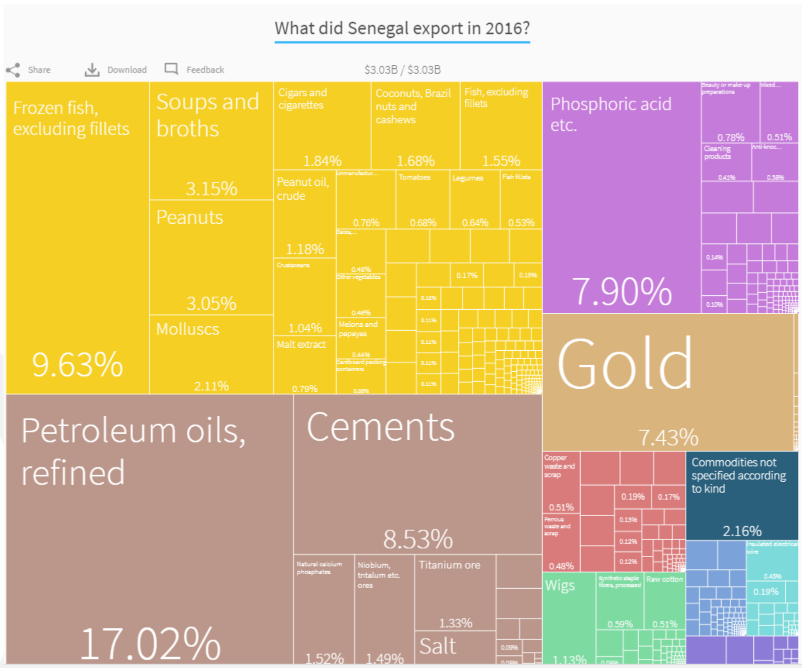


Figure 7: Exports of Senegal in 2016

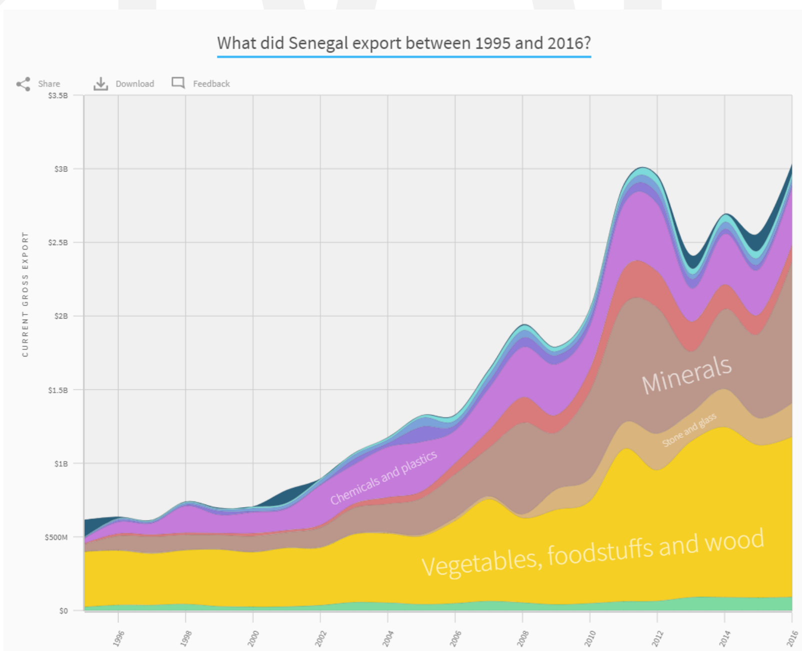


Figure 8: Trends of Exports of Senegal 1995-2016

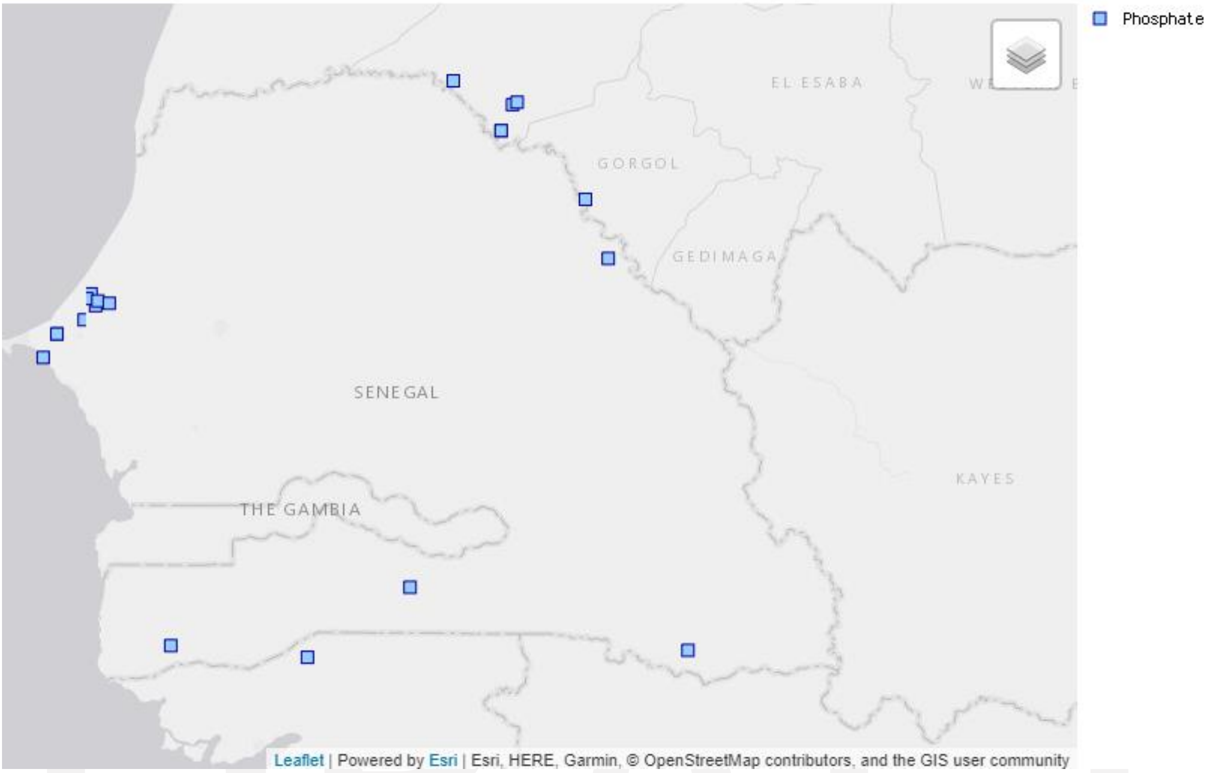


Figure 9. Phosphate mines in the SRB *https://mrdata.usgs.gov/mineral-resources/phosphate.html*

DRAFT

Iron mining, planned at large scale in the Faleme (SRB) region is on hold https://www.reuters.com/article/senegal-arcelormittal/arcelormittal-suspends-senegal-iron-ore-project-idUSL334338820090703

Oil (and gas) mining is done offshore (https://www.rvo.nl/sites/default/files/2017/09/Report-Energy-sector-Senegal.pdf) and got no impact on the SRB.

2016 Gold production in Senegal was 7.5 t. https://www.gold.org/about-gold/gold-supply/gold-mining/gold-mining-map

Gold mining and here in particular **artisanal mining** using Mercury for the amalgamation process is known to contaminate the environment with Mercury and its very toxic organic derivates.

Senegal has only one large-scale gold mine, the Sabodala deposit owned by Canada's Teranga Gold (Figure 10). The currently exploited mining sites do not impact the SRB, but the Gambia River Basin.

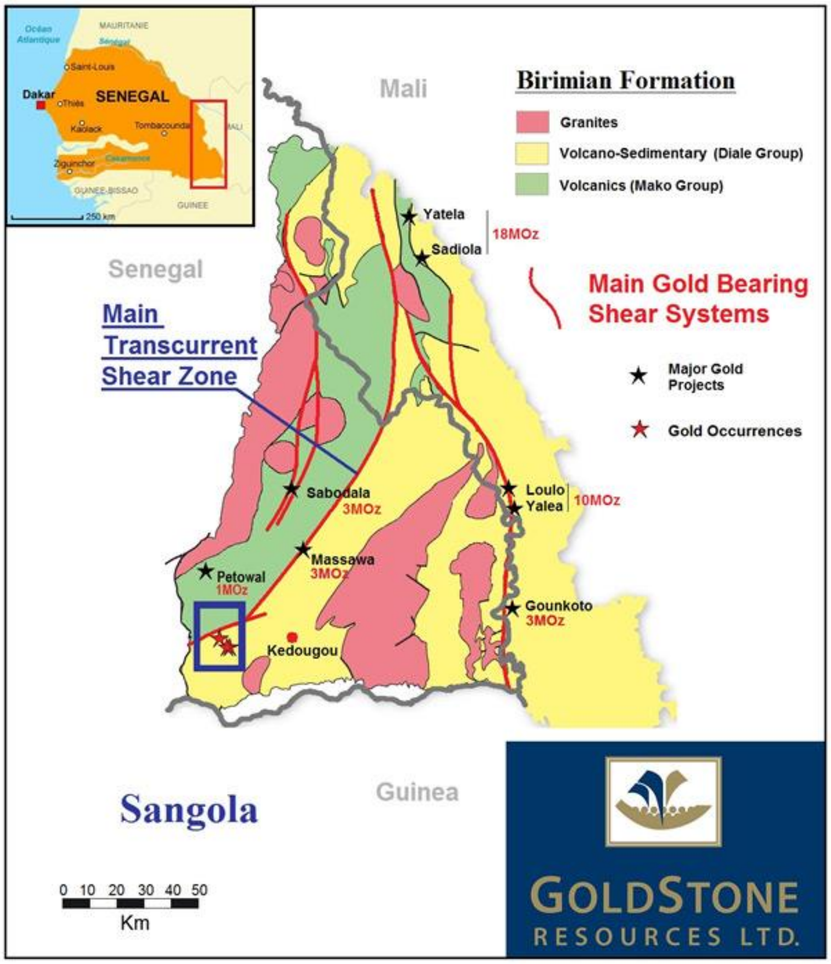


Figure 10. The Sabodala deposit the only large-scale gold mine in Senegal
https://www.google.it/search?q=the+Sabodala+deposit+senegal&source=lnms&tbm=isch&sa=X&ved=0ahUKEwicwI-r0OncAhXKDOwKHUj4CugQ_AUICygC&biw=1584&bih=886#imgrc=GyXxcgy2gqplSM.

Artisanal Gold mining has been practiced traditionally in the country from ancient times, particularly in the southeastern region. The activities have intensified since 2000 (Persaud et al., 2017).

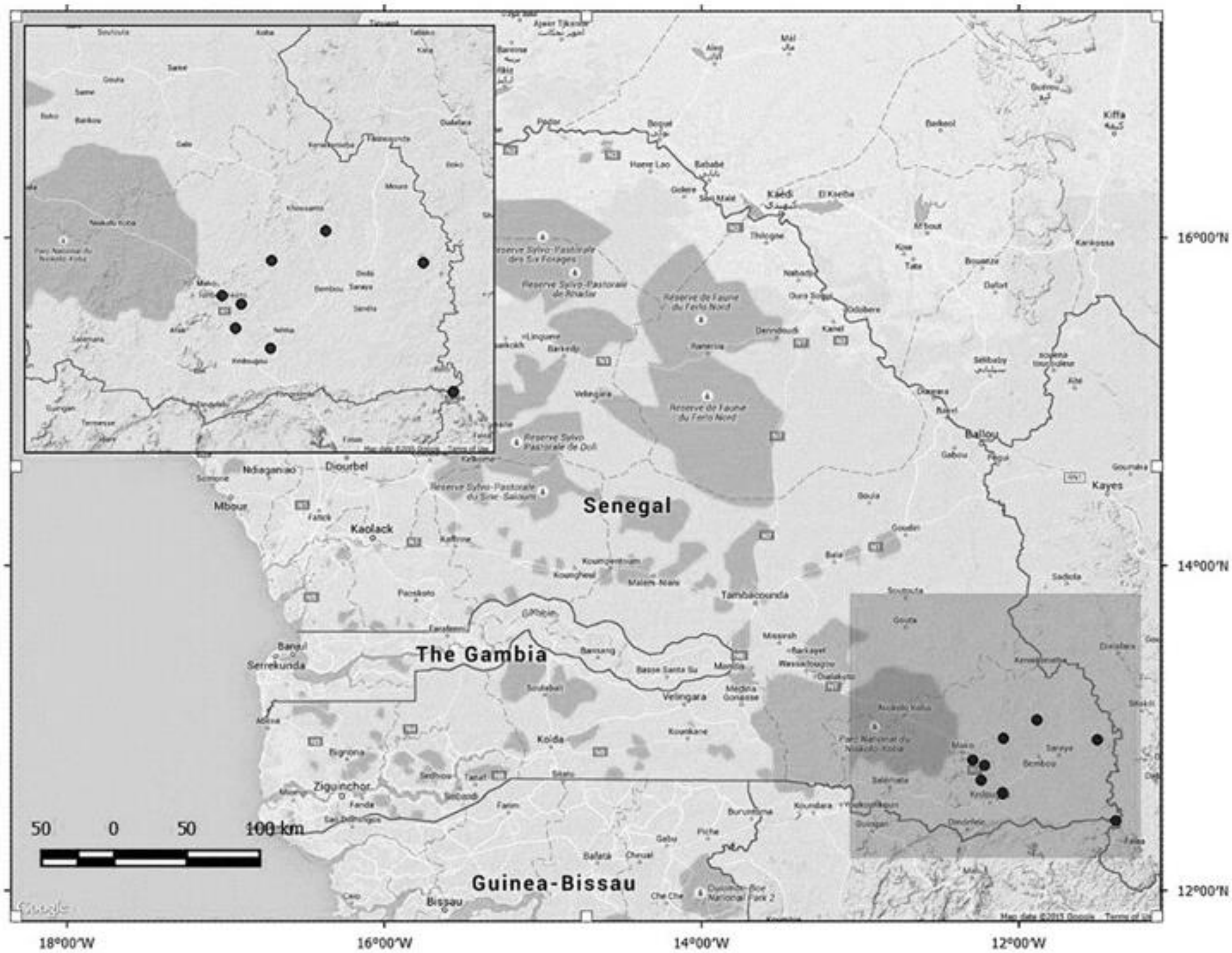


Figure 11: Artisanal mining in the Kedougou region in Senegal (From Persaud et al., 2017).

Hg contamination of water and sediments from artisanal mining has been documented in the Kedougou region. Maximum soil Methylmercury concentrations at Senegalese artisanal mining sites were greater than those observed at all sites except one site in Venezuela (Gerson et al., 2018).

The surface waters at mining sites in Sabodala and Bantako discharge to the Gambia River and got no impact on the SRB (Figure 11).

In contrast, the surface waters at the artisanal mining sites Kharahenna and Kolya are part of the SRB, they discharge into the Faleme River (Figure 12).

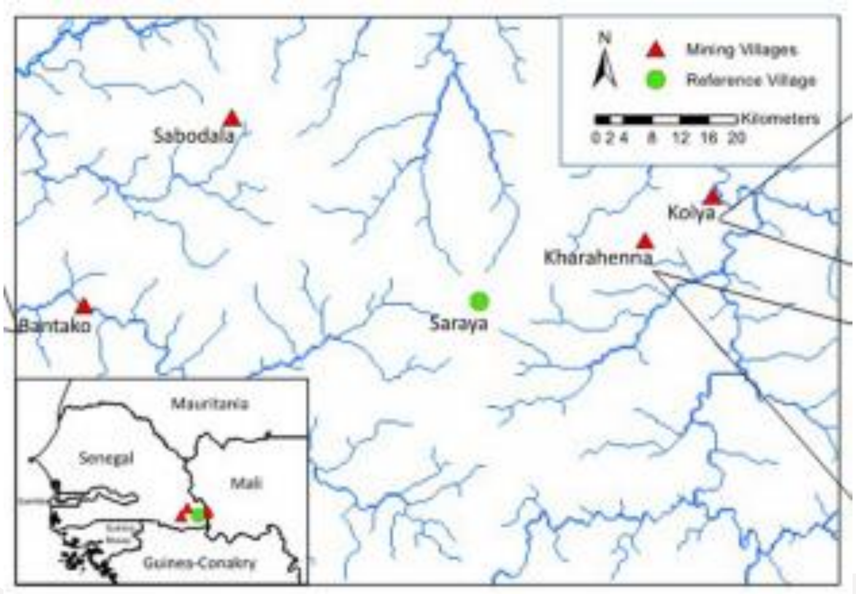


Figure 12. Location of important artisanal gold mining sites in Senegal, part of which affect the SRB (From Gerson et al. 2018).

Limestone mining/cement production occurs mainly in the region of Dakar and got no environmental impacts in the SRB (Figure 13).

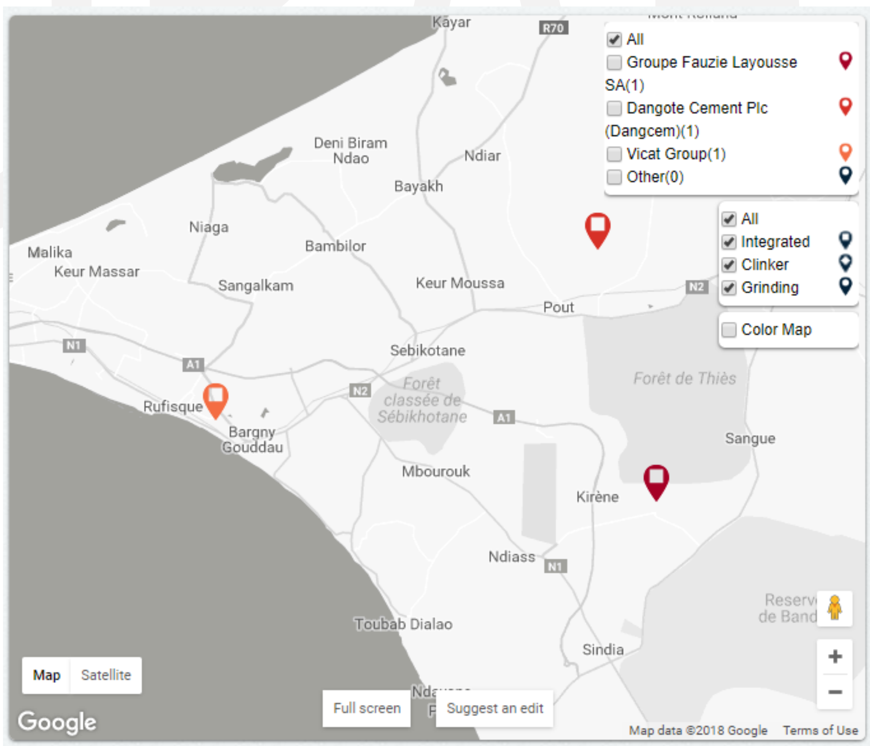


Figure 13. *Cement plants in Senegal* https://www.cemnet.com/global-cement-report/country/senegal

DRAFT

Relevance for the SRB

Export sectors with potential emissions into the environment are Petroleum production, gold and phosphate (fertilizer production) and limestone (cement production) mining.

Senegal a major exporter of phosphate, but it is also looking to develop its iron ore, gold and oil industries.

Phosphate is mainly mined at the coastal zone around Dakar, not affecting the SRB. However, a couple of sites are located along the Senegal River, in Mauritania (Figure 9).

Environmental impacts from Phosphate mining concern rock desertification, poor forest stand structure, loss of biodiversity, aesthetic depreciation of the landscape, and the potential hazard of landslide and ground erosion (Yang et al., 2014).

From Senegal displacement of people, decreasing groundwater levels, and dust and acid leaks are reported. Moreover, untreated production wastes rich in Phosphate are discharged in a non-controlled way and contribute to Eutrophication (https://ejatlas.org/conflict/phosphates-mining-in-the-gardening-zone-of-niayes-mboro-senegal).

DRAFT

3.2.1.2 Mauritania exports

As in Senegal, the primary sector dominates Mauritania's exports with food and minerals (mainly iron) being the main export goods. Gold accounts to about 7% to the total volume, and off shore oil and gas exploitation are coming up (Figure 14, Figure 15 and Figure 16).

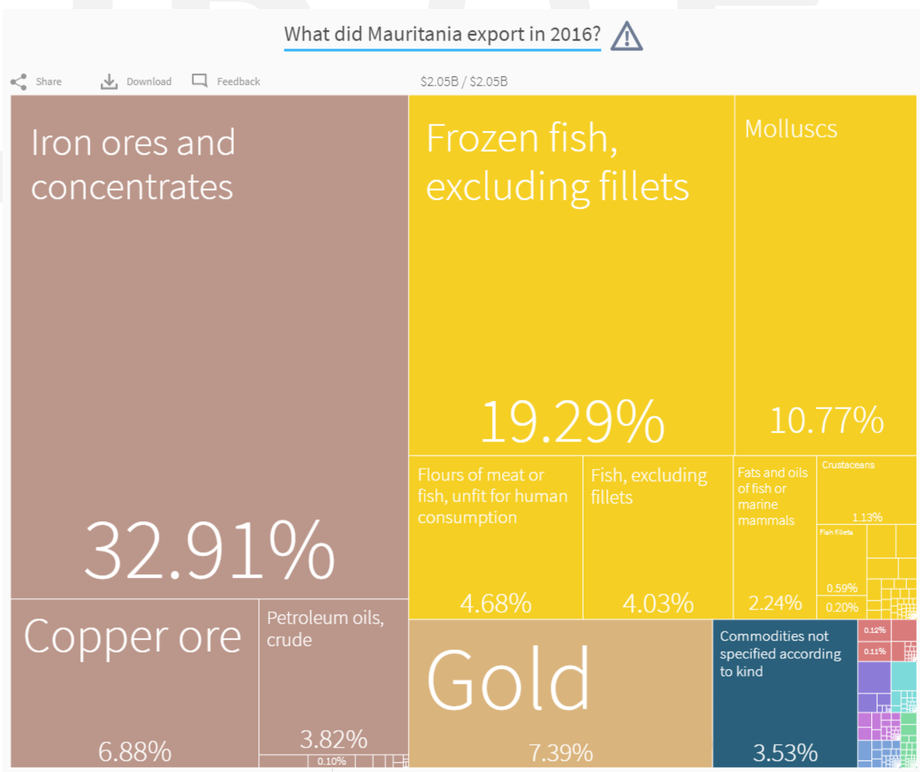


Figure 14: Exports of Mauritania in 2016

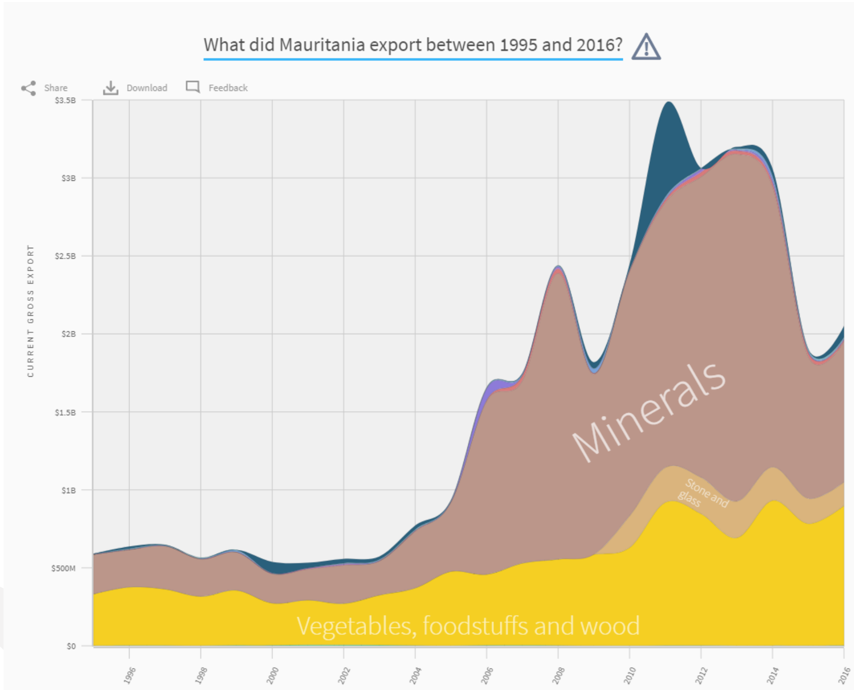


Figure 15: Trends of Exports of Mauritania 1995-2016

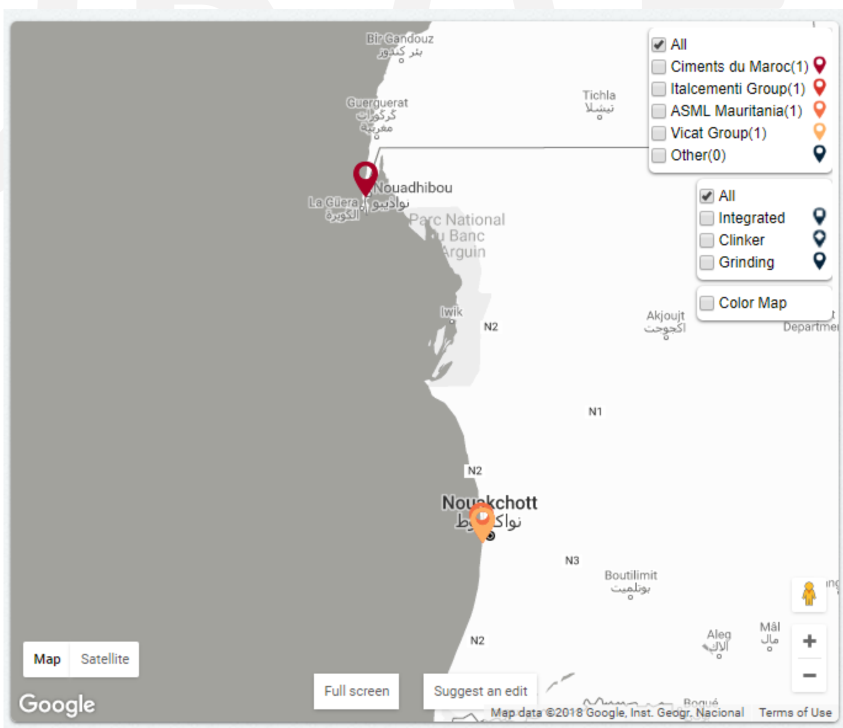


Figure 16. Iron ore mining in Mauritania https://www.cemnet.com/global-cement-repot/country/mauritania

Gold mining in Mauritania has also become a significant economic factor. However, the Mauritania gold deposit is located ca. 150 km East of Nouadhibou, with no hydraulic connection to the SRB. http://spilpunt.blogspot.com/2007/04/mauritania.html

2016 production in Mauritania was 7.4 t. https://www.gold.org/about-gold/gold-supply/gold-mining/gold-mining-map

Relevance for the SRB

As in Senegal, oil production is off shore in Mauritania and does therefore not impact the SRB.

Iron ore mining, which is an important export sector in Mauritania is exclusively done in Nouadhibou and Nouakchott at the Atlantic Coast, not impacting the SRB.

3.2.1.3 Mali exports

Gold, cotton and food were the most relevant export goods produced in 2016 (Figure 17 and Figure 18).

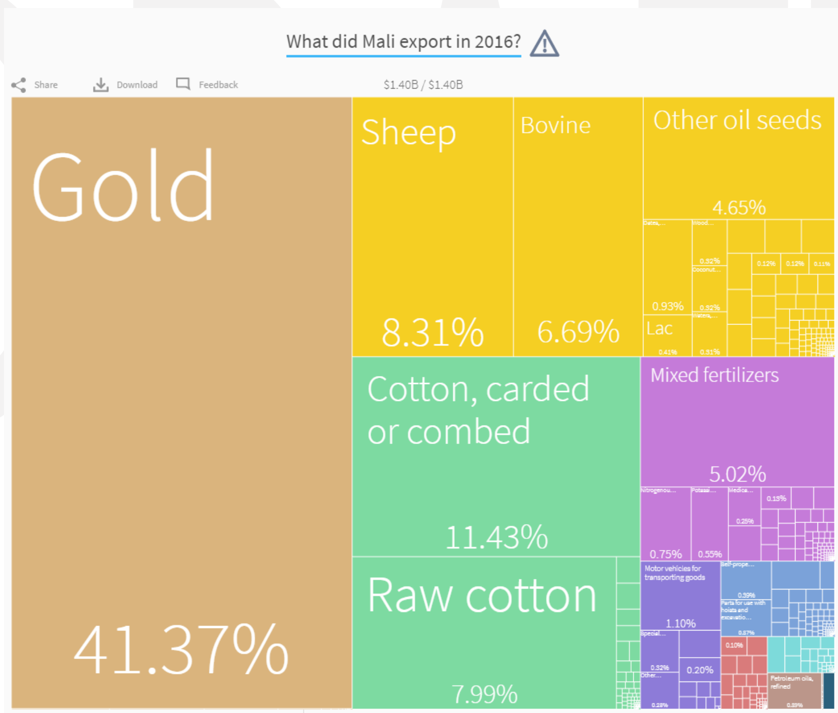


Figure 17: Exports of Mali in 2016

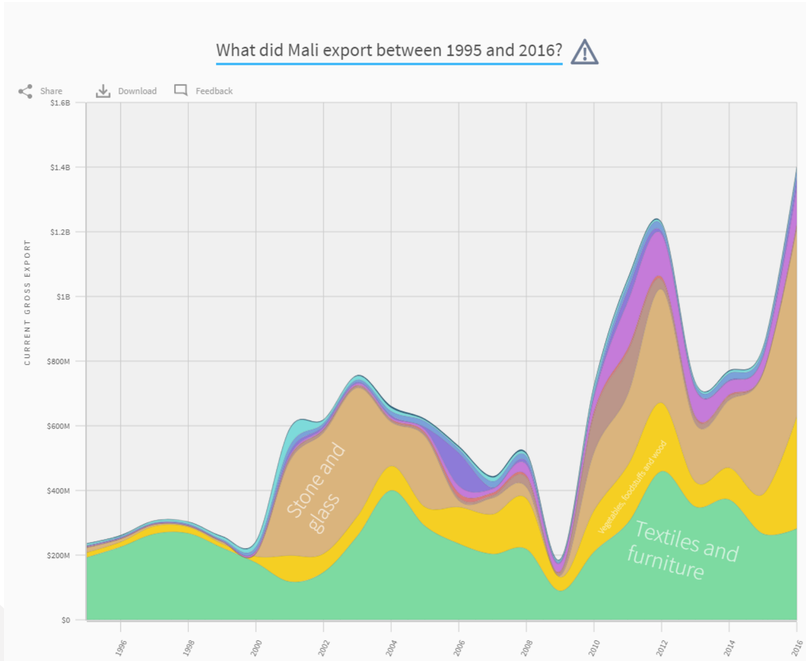


Figure 18: Trends of Exports of Mali 1995-2016

Figure 19. West African Gold region, SRB in the North/West, Niger basin in the South/East.*Link:https://www.google.it/search?q=gold+in+Mali+mining&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj578XPjOrcAhUByqQKHZqPCdEQ_AUICygC&biw=1600&bih=1014#imgrc=696RC-DyB2mcTM:*

DRAFT

Artisanal mines contributed a third of the 70.2 tons of gold Mali exported in 2015. The amount of gold dug up by people working informally in Mali could soon rival official production thanks to demand from domestic refineries.

More than one million artisanal miners work at about 350 sites. The largely unregulated sector is plagued by fatal accidents, smuggling, child labor and environmental damage.

Mali's largest gold refinery, Kankou Moussa, owned by Swiss Bullion Co., can produce 100 kg per day and sources most of its gold from an artisanal mining site in the southwest. https://www.reuters.com/article/us-mali-gold/malis-gold-miners-could-rival-industrial-producers-idUSKBN14328B

Relevance for the SRB

Cotton production is one of the country's leading exports, 40% of the rural population working herein. A broad use of agrochemical is involved, however, this is without relevance for the SRB, since cotton is produced in the Niger catchment.

Gold production in 2016 was 50.1 t. https://www.gold.org/about-gold/gold-supply/gold-mining/gold-mining-map.

Mali is Africa's third-largest gold miner behind South Africa and Ghana. Gold is mined in the SRB catchment in the Faleme and Bafing River basin (Figure 19), this affecting the SRB.

3.2.1.4 Guinea exports

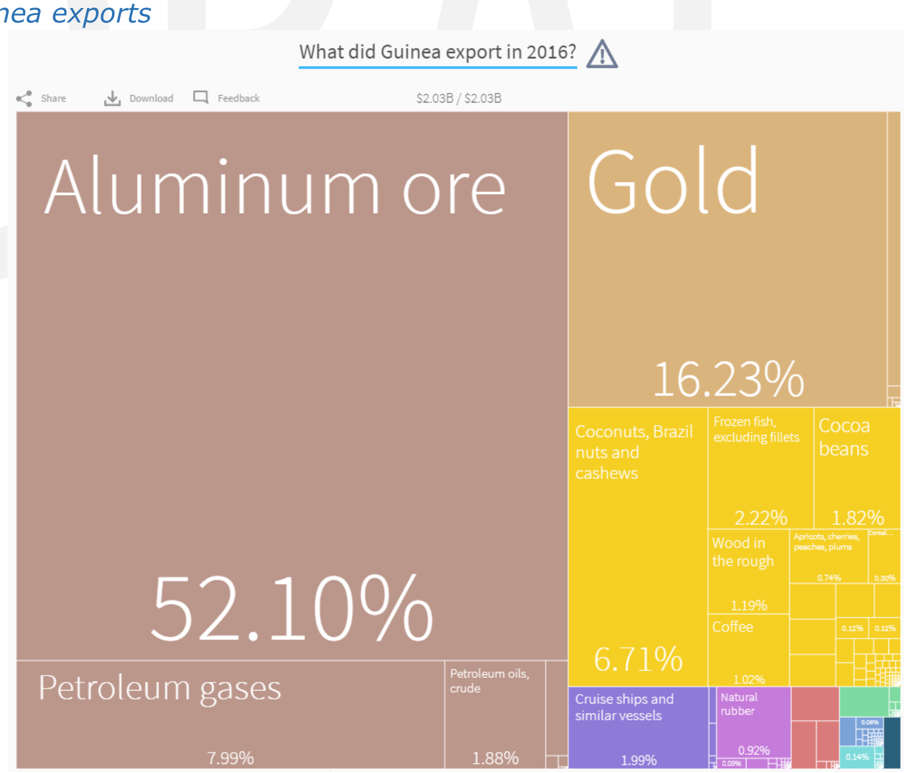


Figure 20: Exports of Guinea in 2016

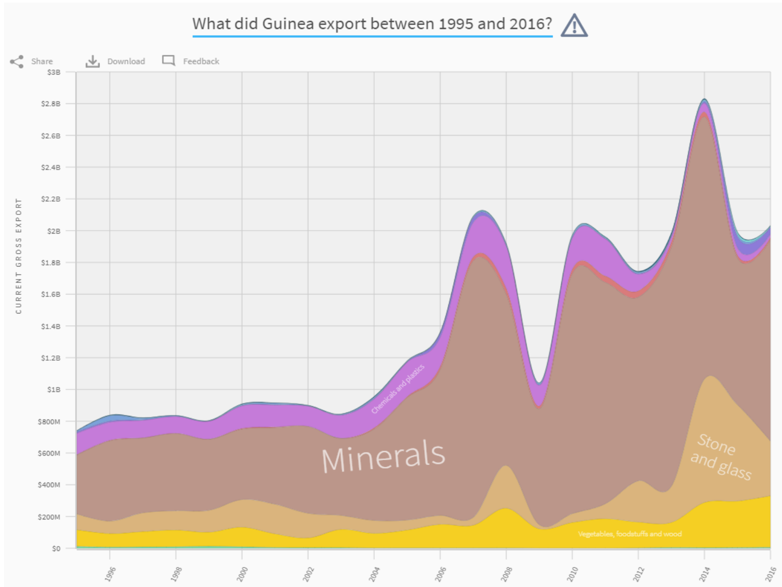


Figure 21: Trends of Exports of Guinea 1995-2016

Mining products, Aluminum and Gold, followed by food and some petroleum products dominate Guinea's exports.

Relevance for the SRB

The **Gold and Bauxite mining** is located outside the SRB and got no relevance (Figure 22)

Oil (and gas) production – as in the other SRB countries, is offshore and does not affect the SRB

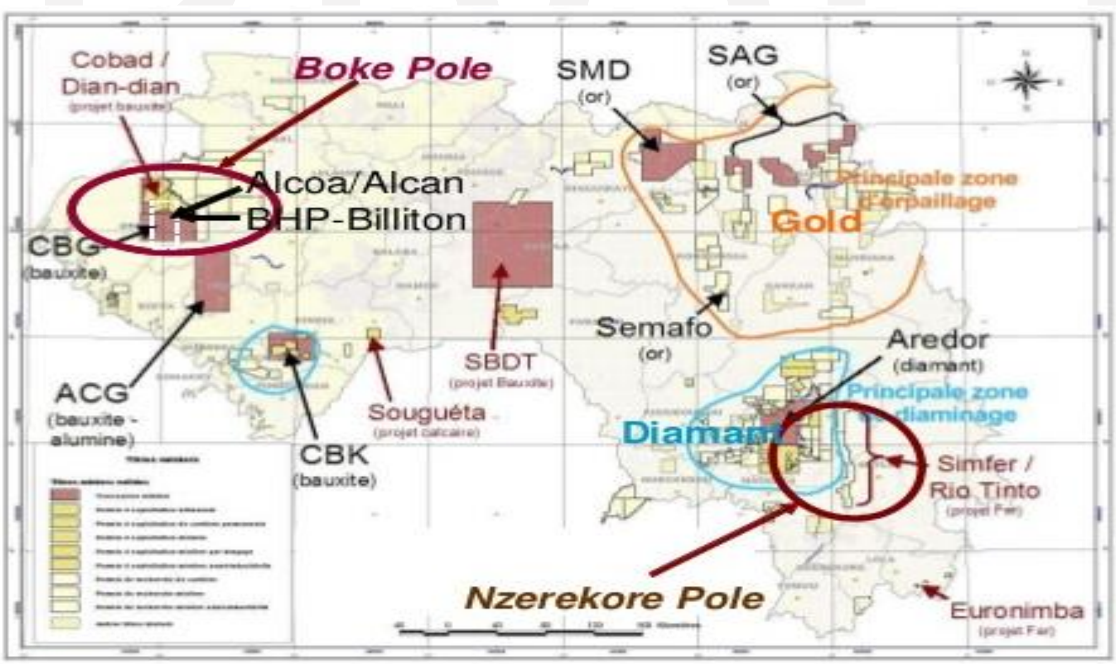


Figure 22. Mining locations in Guinea http://spilpunt.blogspot.com/2007/04/guinea.html

DRAFT

3.2.2 Informal industrial activities

The main types of activities of the Senegalese informal sector which are potentially sources of environmental contamination are mainly recycling related: Artisan smelting plants, lead extraction from motor vehicle batteries, the burning of wastes, Iron extraction from tires, the smoking of skins.

Scrap dealers burn wastes to extract the ferrous or non-ferrous items they contain or to reduce the volume of wastes. Among these wastes there are oil flows, derelict motor vehicles, carcasses of animals, irretrievable electronic equipment, industrial wastes, medical wastes, plastic satchels and bags, used tires, cables etc.

https://ipen.org/sites/default/files/documents/9sen_dioxins_and_informal_sector_in_senegal-en.pdf

The predominately-contaminated compartments are air and land (fills), but also surface waters close by are affected

3.2.3 Solid waste management

Domestic waste management is a severe problem in big cities of developing countries. Rapid population growth produces more and more urban wastes.

This phenomenon is exemplarily documented in Dakar, but concerns all African cities (Kapepula et al., 2007): Mismanaged solid waste dumpsites produce bad sanitary, ecological and economic consequences for the whole population, especially for the poorest urban inhabitants.
Solid wastes are not systematically collected, resulting in dumps that are causes of epidemics and floods (when dumped into river beds and canals).

Hospital and hazardous wastes are another threat to the environment. Although there are licensed hazardous waste collection enterprises, the fate of the waste collected by these agencies is unknown as there are no proper treatment facilities. This situation has resulted to hazardous waste being indiscriminately disposed as part of municipal waste in the Mbeubeuss dumpsite and other dumpsites across the country where thousands of people are working as informal recyclers without proper protective equipment, posing a serious risk to human health and safety and the environment (Ndao, 2018)(Worldbank 2007).

3.2.4 Urban waste water

The absence of urban wastewater treatment affects the surface and ground waters with pathogens such as fecal bacteria and nutrients.

Human exposure to pathogens may occur when surface waters are used as drinking water, and for washing activities. A particular threat is reported form Dakar where many farmers prefer untreated wastewater to irrigate their crops because of its greater availability, reduced fertiliser costs, and higher yields and production. While using such water, few take precautions to protect their health, and 60% are infected with intestinal parasites. The practice poses a risk to public health, as three of the main crops produced (lettuce, tomatoes, and onions) are often or exclusively eaten raw. https://www.cabi.org/cabebooks/ebook/20043115025

3.2.5 Cash crop agriculture

In the construction of the Diama and Manantali Dams, Senegal, constraints to large scale irrigation were not adequately taken into account, while to date planned artificial floods to

DRAFT

assure the continuation of traditional production systems (e.g. recession agriculture, freshwater fish production, estuarine/marine fishery nursery grounds and dry season forage) have been inadequate in both magnitude and duration (Degeorges and Reilly, 2006).

Irrigated agriculture is also a major threat to the water quality in terms of salinization, eutrophication, and chemical pollution. Under hot climates, there is risk of creating habitats for vectors of tropical diseases.

The OMVS, is attempting to execute a shift to irrigated rice production for domestic consumption in the river basin. With the completion of the Manantali and Diama dams, year-round irrigated agriculture is possible in the SRB.

Rice production in the arid river valley (Senegalese & Malian part) has been a financial and social failure. Irrigated rice projects suffer a high rate of abandonment and have intensified the desertification process in the river valley. As an alternate use of the basin's scarce water resources, an agricultural development policy based on village-scale irrigation projects and intensive, irrigated agroforestry projects has been proposed. Village-scale irrigation is dedicated to low-water-consumption cereal grain crops and is managed by traditional sociopolitical structures (Venema et al., 1997).

Drainage from irrigated Sugarcane production affects the nutrient status of Lac de Guiers (Varis et al., 2006).

Intensification of agriculture is also under way in the Malian part of the SRB (FAO, 2018a): The government of Mali considers the development of irrigated agriculture as one of the main lines of action to increase food security and secure incomes. In order to guide irrigation development in the country, Mali prepared the National Strategy for Irrigation in 1999 and revised it in 2008 to better adapt it to the country’s situation. Furthermore, the government of Mali has developed a Small-Scale Irrigation Promotion Programme 2012-2021 (Programme d’Appui au Sous-Secteur de l’Irrigation de Proximité). It aims to fund projects falling into the following categories: (1) Surface water systems from major river systems; (2) Inland valley bottoms/lowlands; (3) the development of ponds; (4) Micro dams, water harvesting systems and water retention works in wadis and oasis; and (5) Irrigated vegetable gardens

The intensification of agriculture goes hand in hand with the use of agrochemicals, such as fertilizers and pesticides. These chemicals affect ground and surface waters in terms of toxicity and eutrophication.

In order to monitor and mitigate the impacts of these ‘modern environmental hazards’ on the ecosystem, the FAO has launched the ‘Integrated Production and Pest Management Programme in Africa’. http://www.fao.org/agriculture/ippm/projects/regional/ep-int-606-gef/en/

3.2.6 Conclusion on sectors potentially impacting the SRB

The secondary sector is not well developed in the four SRB countries except of the processing of marine fish and some petroleum refining. Both activities may affect the coastal zone, but are of little relevance for the SRB.

The primary sector instead is dominant and is composed of agriculture, livestock, forestry, fishing and extractive activities (mining). Impacts from the primary sector concern emission from mining and from irrigated agriculture.

The mining sector that is presumably impacting on the SRB is mainly present around the Faleme and the Bafin River. Especially from the artisanal mining sector in Mali, significant emission of mercury and its derivates can be expected. Apart from direct exposure of mining communities these emissions impact on water quality and the aquatic food chain all along the Senegal River.

The emissions from irrigated agriculture concern nutrients and pesticides. Emissions are expected from the large scale rice cultivation in the lower valley and the Delta, both from Senegal and Mauritania, and from the sugar cane production at Lac de Guiers. Aquatic and food chain toxicity, pathogens, eutrophication can be expected.

Poor management of urban und industrial wastes, together with the lack of wastewater treatment pose a threat to ground and freshwaters in urbanized areas. As above, aquatic and food chain toxicity, pathogens and eutrophication can be expected.

DRAFT

4 Public data analysis of the WEFE sectors by Country

A Nexus assessment requires a participatory approach that helps decision-makers to understand critical situations, where resources (water, land, ecosystem, etc.) are under pressure and at potential risk. Whilst nexus goals need to be defined at the political level by involving all stakeholder, sustainability goals regarding the components of the nexus (water, energy and food) can be defined with quantitative approach thus supporting the process.

The three aspects to be considered, together with their relation with environment, are so:

- Water:
  - Access to water, sustainable use and management, resilience of societies and production system to water risk and disasters
- Energy:
  - Access to modernization, efficient and/or renewable energies
- Food:
  - Food security, availability, self-production, Nutrition, food prices resilience

DRAFT

It's important also to stress that not all the elements and relations are important for all countries and regions all over the World. **According to FAO classification (FAO, 2014) all four countries belonging to Senegal River Basin (SRB) are classified as "Water rich country" and "Agriculture-based economy countries"**. This is because agricultural sector employs more than 20% of total human labor and Renewable water resources is higher than 1500 m^3/inh/yr.

4.1 *WATER SECTOR*

All Senegal River Basin countries can be classified as "water rich" as the total Renewable freshwater Resources (RWR) per capita is high: for example for Senegal in 2014 was 25.8 (Km^3/yr). In Senegal RWR is higher than 15 still when considering just internal water resources; Indeed country dependency ratio (FAO, 2016) is 34%, meaning that **most of its water resources are originating inside the country**.

Average annual precipitation input within the river basin is much variable (Figure 23):

– it ranges from minimum values of about 90 -100 mm in Mauritania areas (Table 7) to much higher quantities in Guinea (average of 1370 mm/yr): the region with the highest precipitation are Mamou and Labe in Guinea (1400), Koulikoro and Kayes in Mali (about 700 mm), Guidimaka and Gorgol in Mauritania (300-380) and Kédougou in Senegal (970).

At country level				
Area	***Type***	***AVG_ANN_RAIN***	***MAX_ANN_PCP***	***MIN_ANN_PCP***
Guinea	Total	1369	2012	811
Mali	Total	699	2041	206
Mauritania	Total	233	550	27
Senegal	Total	448	1331	98
River Basin	Total	704	2041	27

At SubNational level				
Area	***Sub Adm.lev***	***AVG_ANN_RAIN***	***MAX_ANN_PCP***	***MIN_ANN_PCP***
Guinea	Faranah	1326	1696	811
Guinea	Kankan	1154	1383	953
Guinea	Labé	1400	1761	968
Guinea	Mamou	1430	2012	824
Mali	Kayes	694	2041	206
Mali	Koulikoro	727	1185	227
Mali	Ségou	433	608	349
Mauritania	Assaba	228	476	43
Mauritania	Brakna	209	284	87
Mauritania	Gorgol	298	470	190
Mauritania	Guidimaka	374	550	215
Mauritania	Hodh ech Chargui	222	384	47
Mauritania	Hodh el Gharbi	243	477	40
Mauritania	Tagant	97	222	27
Mauritania	Trarza	238	417	104
Senegal	Kédougou	973	1331	770
Senegal	Louga	374	490	165
Senegal	Matam	394	735	247
Senegal	Saint-Louis	272	383	98
Senegal	Tambacounda	617	919	332

Table 7. Average annual precipitation (mm/yr) at National and sub national level (Data source derived by (Ceccherini et al., 2015) *).*

DRAFT

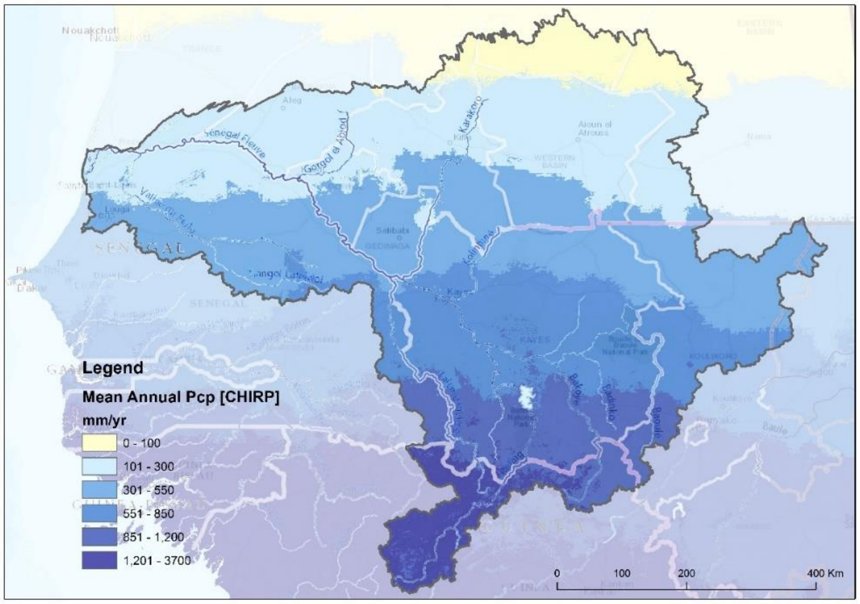


Figure 23. Average annual precipitation (mm/yr) (Data source derived by Ceccherini et al., 2015 *).*

DRAFT

Several data and indicator need to be considered to give a picture of the Water Nexus assessment in the region of study. FAO identifies several indicators, depending on the specific characteristics of the country. Here a list of possible indicators to be calculated:

- Indicator I.1: "*Area under agricultural water management as a % of irrigation potential",*
- Indicator I.2: "Freshwater withdrawal as % of total actual renewable water resources":
- Indicator I.3: "Total internal renewable water resources per capita"
- Indicator I.4: *Water withdrawal/allocation by sector*
- Indicator I.5: *Irrigation intensity*

An example list of the indicators as proposed by FAO is detailed in Table 8

Indicator	Unit	Benchmark
1. Freshwater withdrawal as % of total actual renewable water resources	%	21%
2. Rural population without improved drinking water sources	%	25%
3. Area under agricultural water management as a % of irrigation potential	%	40%

4. Share of monitoring sites in agriculture areas that exceed recommended drinking water limits for nitrates, phosphorous and pesticides in surface water and groundwater	%	29%
5. Total internal renewable water resources per capita	m^3/ab/an	7757.00
6. Amount of food produced per unit of water consumed	m^3/int.$	1.19

Table 8. Example of Indicators for Water (from (FAO, 2014)*)*

4.1.1 Access to Water supply

In the 4 countries belonging to SRB, current water withdrawal is still limited to 3% of total internal water resources, even if it must be noted that this percentages changes a lot across the 4 countries: In Mali and Mauritania it is about 9 %, in Guinea is only 0.3% while in Mauritania is about 340%. As volume it is interesting to note that most of the usage is in Guinea. Anyway we have to consider that those numbers refer to whole country territory and should be refined accounting only the actual usage within the River Basin area. This estimation would be better refined in the second year of the project, after data collection is concluded and models for analysis and assessment would be developed and tuned.

DATA BY COUNTRY (National scale, including all country territory, also outside SRB)

- *Water withdrawal/allocation by sector:*
  - 93% of total water demand in Senegal is from Agricultural sector and 4.5% from Municipal
  - Also in Mali and Mauritania most of water withdrawal is from Agriculture (98% in Mali and 90% in Mauritania), while in Guinea is 51% (39% is from Municipal and 10% from Industrial)
- *Total internal renewable water resources per capita*
  - Data are quite different in the 4 countries: 18000 m^3 per hab. in Guinea 6800 in Mali and only 2600-2800 in Mauritania and Senegal. Benchmark is 7750.
- *Freshwater withdrawal as % of total actual renewable water resources:*
  - In Senegal it is 5.7% to be compared with a benchmark of 21%. In Mali it is 4.3%, 0.3% in Guinea and 12% in Mauritania. As expected water withdrawals levels are not comparable with the ones of more developed countries.
- *Area under agricultural water management as a % of irrigation potential*
  - In Guinea it is 18%, 36% in Senegal, 43% in Mauritania and 110% in Mali; the benchmark is 40 % so only Senegal and Guinea countries are below.
- *Irrigation intensity*
  - about 3-5% of cropped land is equipped for irrigation in Senegal, Guinea and Mali, and 11% in Mauritania . This means that there is potentially an important increase in water demand from agricultural sector, that need to be taken into account for future development and that will impact the Nexus.
- *Amount of food produced per unit of water consumed*

DRAFT

    - Estimation is based on Food Value production and water used for irrigation: only Guinea has low values (0.2) while in other countries it is about 1.8-2.2 (m^3/int.$).
- *Rural population without access to improved drinking water sources (% of rural population)*
    - 39.7% for Senegal, 35% for Guinea, 45.8% for Mali and 52.3% for Mauritania; ref. benchmark is 35%.

DRAFT

4.1.2 Water availability and demands

Water resources

	Precipitation		*Internal renewable fresh. Resources*		*Total renewable fresh. Resources*		Dependency Ratio
	Depth per year	*Volume*	*Volume per year*	*per capita*	*Volume per year*	*per capita*	
	ref: 2014	*ref: 2014*	*ref: 2014*	*ref: 2014*	*ref: 2014*	*ref: 2014*	
Country	*mm*	*Km³*	*Km³*	*m³*	*Km³*	*m³*	*%*
Guinea	1651	406	226	17924	226	17924	0
Mali	282	350	60	3409	120	6818	50
Mauritania	92	95	0	98	11	2802	97
Senegal	686	135	26	1705	39	2576	34
Total	**678**	**985**	**312**	**5784**	**396**	**7530**	**45**

Water withdrawal

	Withdrawal by sector							As % of	As % of
	Industrial		*Irrigation*		*Municipal*		*Total*	*IRWR*	*Tot RWR*
	ref: 2002-2006		*ref: 2002-2006*		*ref: 2002-2006*		*ref: 2002-2006*		
Country	*Km³/an*	*% of tot*	*Km³/an*	*% of tot*	*Km³/an*	*% of tot*	*Km³/an*		
Guinea	0.06	10.5%	0.29	50.9%	0.22	38.6%	0.57	0.3%	0.3%
Mali	0	0.0%	5.08	97.9%	0.11	2.1%	5.19	8.7%	4.3%
Mauritania	0.03	2.2%	1.22	90.4%	0.1	7.4%	1.35	337.5%	11.8%
Senegal	0.06	2.7%	2.07	92.8%	0.1	4.5%	2.23	8.6%	5.7%
Total	**0.15**	**1.6%**	**8.66**	**92.7%**	**0.53**	**5.7%**	**9.34**	**3.0%**	**2.4%**

DRAFT

Irrigation

	Area equipped			% of cultivated land equipped	Irrigation Potential	Actually irrigated	Total agricultural managed area
	by surface	*by groundwater*	*Total*				
	ref: 2001-2008			*ref: 2001-08*			
Country	*1000 ha*	*1000 ha*	*1000 ha*	*%*	*1000 ha*	*1000 ha*	*1000 ha*
Guinea	94.5	0.5	94.9	3.1	520	94.91	94.92
Mali	371.0	0.1	371.1	5.3	566	175.8	621.3
Mauritania	40.3	4.8	45.0	11.0	250	22.84	108.8
Senegal	109.7	10.0	119.7	3.9	409	69	149.7
Total	**615**	**15**	**631**	**5**	**1745**	**363**	**975**

Table 9. Country specific water resources and demands data *(FAO, 2016)*.

DRAFT

4.1.3 Water Quality

4.1.3.1 Summary of key water issues

The currently most prominent water quality associated risks for the population of the SRB come from the biological side. Surface (vectors) and drinking water (pathogens) creates by far more disease at population level than chemicals do.

Poor management of urban wastes, together with improper drinking water in rural areas play an important role in the diarrhea context

Chemical risks instead (apart from exposure of pesticide workers and mercury exposure of artisanal miners, which are not water quality related) concern mainly agrochemicals and mining wastes released into the aquatic and terrestrial ecosystem.

Under consideration of existing environmental quality standards, the impacts from agrochemicals are currently low to moderate, both what concerns pesticides and nutrients.

Emissions from mining (Mercury) and urban activities (Lead) are visible in the ecosystem but, under consideration of existing quality standards, not yet affecting aquatic life and human health at population level.

4.1.3.2 Vector borne diseases

Malaria

Malaria is a major public health problem in the basin. It is the primary reason for consultations in health clinics and the primary cause of death. It causes 90 percent of the cases of fever. It is caused by the parasite Plasmodium falciparum, the most deadly species of Plasmodium, carried by the anopheles mosquito Anopheles gambiae, breeding in stagnant surface waters (OMVS, 2003).

Data on Malaria prevalence are available for Senegal and Mali (Figure 24 and Figure 25) from https://www.linkmalaria.org/country-profiles.

It appears that Malaria in an issue mainly in the middle and upper valley. In so far the situation in Guinea should be similar as in SW of Mali

DRAFT

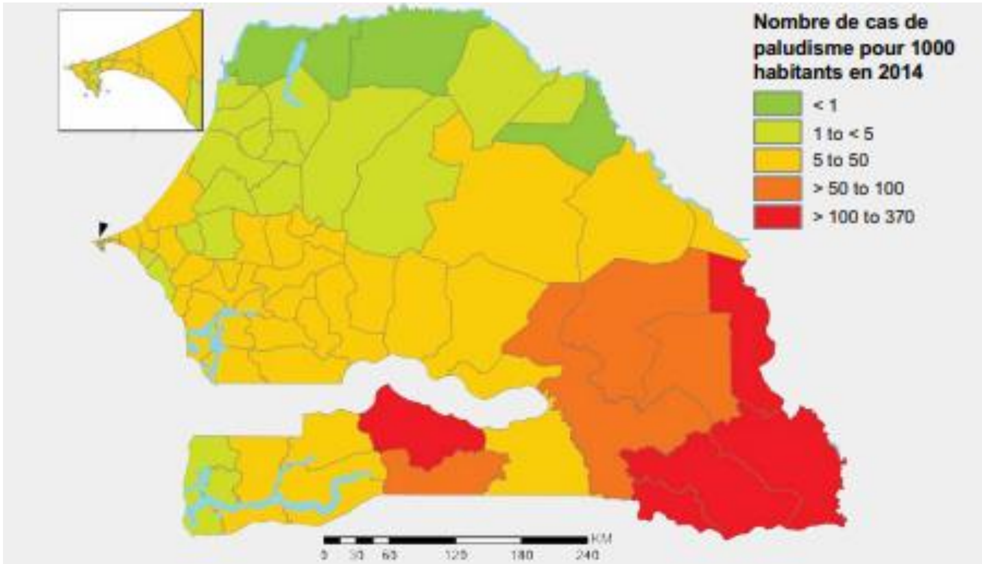


Figure 24. Malaria prevalence 2014 in Senegal
https://www.linkmalaria.org/sites/link/files/content/attachments/2018-02-07/Senegal-French-Poster.pdf

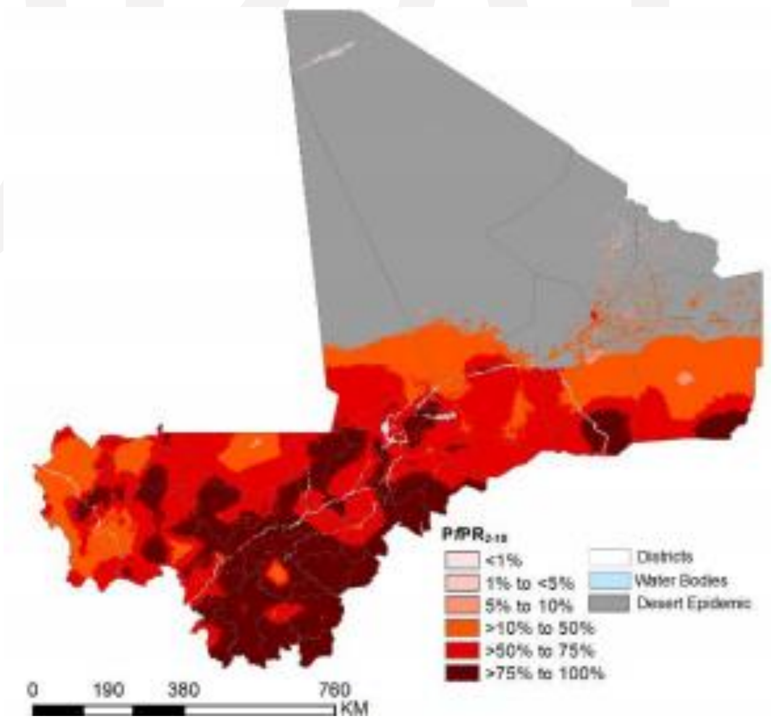


Figure 25. Malaria prevalence 2013 in Mali
https://www.linkmalaria.org/sites/link/files/content/country/profiles/Mali-Malaria-Epi-Profile-Report-2014.pdf

DRAFT

Schistosomiasis

Schistosomiasis, also “snail fever” or “bilharzia”, is an acute and chronic disease caused by parasitic worms hosted by snails living in surface waters. The number of deaths due to schistosomiasis is difficult to estimate because of hidden pathologies such as liver and kidney failure, bladder cancer and ectopic pregnancies due to female genital schistosomiasis. The economic and health effects of schistosomiasis are considerable and the disease disables more than it kills.

Poor and rural communities, particularly agricultural and fishing populations are the most affected. People are infected during their routine agricultural, domestic, occupational, and recreational activities, which expose them to infested water. http://www.who.int/news-room/fact-sheets/detail/schistosomiasis

Infected people continue to excrete schistosome eggs into local water sources (lakes, rivers and canals) where farmers, children and adolescents playing or swimming, and women carrying out domestic tasks can be infected. Thus, reinfection rates remain high, and are likely to continue so if the behaviour associated with disease transmission does not change (Bruun and Aagaard-Hansen, 2008).

Schistosomiasis is considered a neglected tropical disease of poverty and ranks second among the most widespread parasitic disease in various nations in sub-Saharan Africa. It has profound negative effects on child development, outcome of pregnancy, and agricultural productivity, thus a key reason why the “bottom 500 million” inhabitants of sub-Saharan Africa continue to live in poverty. The morbidity and mortality caused by this disease cannot be overemphasized (Adenowo et al., 2015).

According to OMVS (2003)there are two types of human schistosomiasis in the SRB: urinary and intestinal. Intestinal schistosomiasis was unknown before the dams were built, but today is rampant in the valley and delta. The blocking of saltwater intrusion upstream has allowed the snails that host the parasite (Schistosoma mansoni) to proliferate in the desalinated river, lakes and irrigation canals.

Urinary schistosomiasis affects 50 % of the SRB population in the region around Saint Louis, 25 % in Mauritania, in the Trarza, with places where the increase is quite spectacular, and 64% in Mali (2000 assessment). The classic sign of urogenital schistosomiasis is haematuria (blood in urine). Urinary schistosomiasis is diagnosed by looking for worm eggs in the urine.

Intestinal schistosomiasis was unknown in Mauritania before the dams were filled, the first cases were reported in 1993. One year later, schoolchildren in Rosso had an overall prevalence of 32.2 %. In Senegal the situation is even worse, with a 44 %rate of infestation in the Walo flood plain, and with 72 % in the area around Guiers Lake where more than 90 % of the population of the villages are affected. In Mali, this form of schistosomiasis is still present in specific areas, with an infestation rate of 3.34 % in 1997. Diagnosis of intestinal schistosomiasis (S. mansoni and S. japonicum) is generally made by examination of stool specimens.

Prevention is best accomplished by eliminating the water dwelling snails that are the host of the parasite. (Dighe et al., 2009).

The following figures (Figure 26, Figure 27, Figure 28 and Figure 29) on the prevalence of Schistosomiasis in the four SRB countries are from 'The Global Atlas of Helminth Infections", http://www.thiswormyworld.org/maps accessed on 14.08.2018

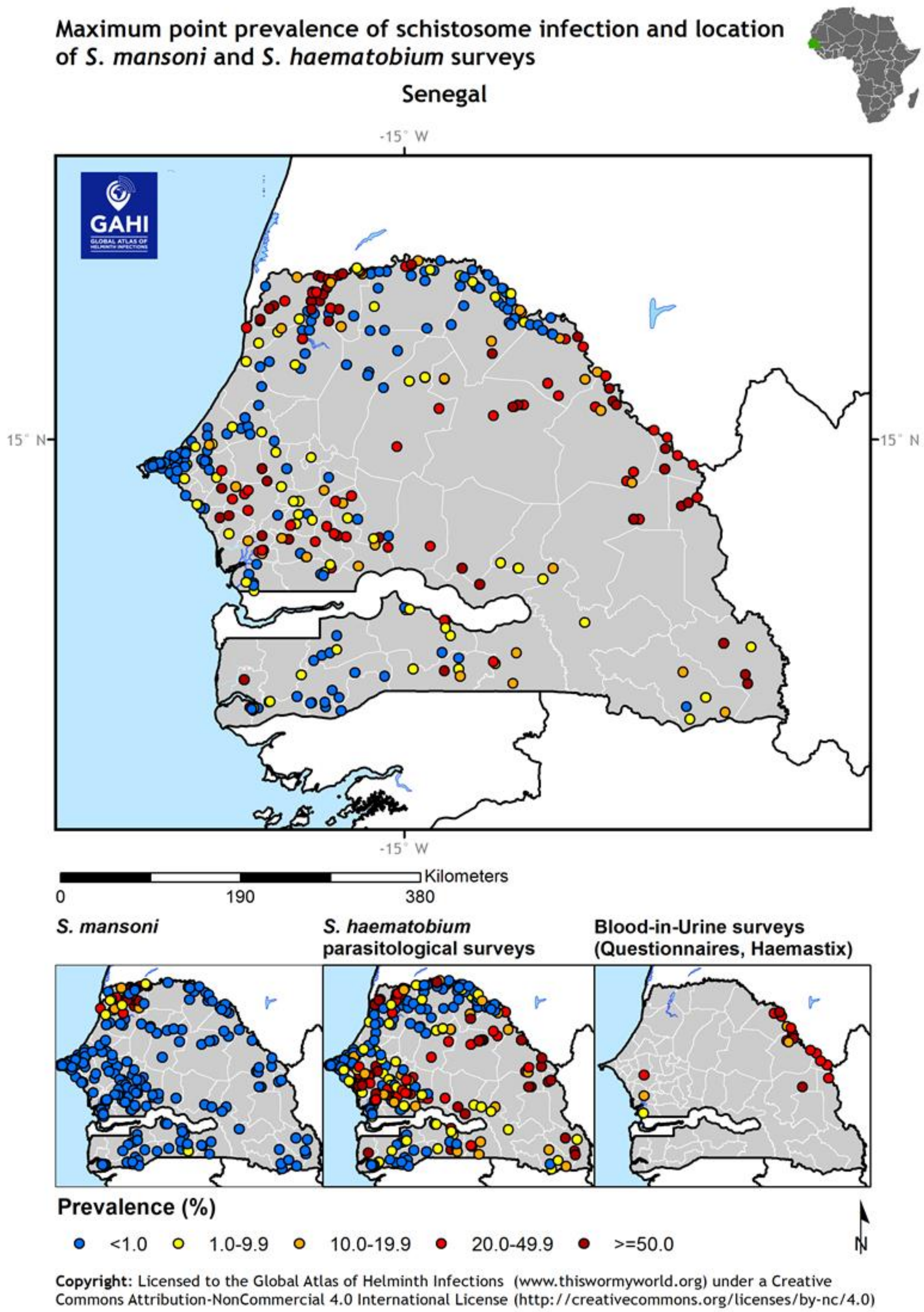


Figure 26. Prevalence of Schistosome infection in Senegal

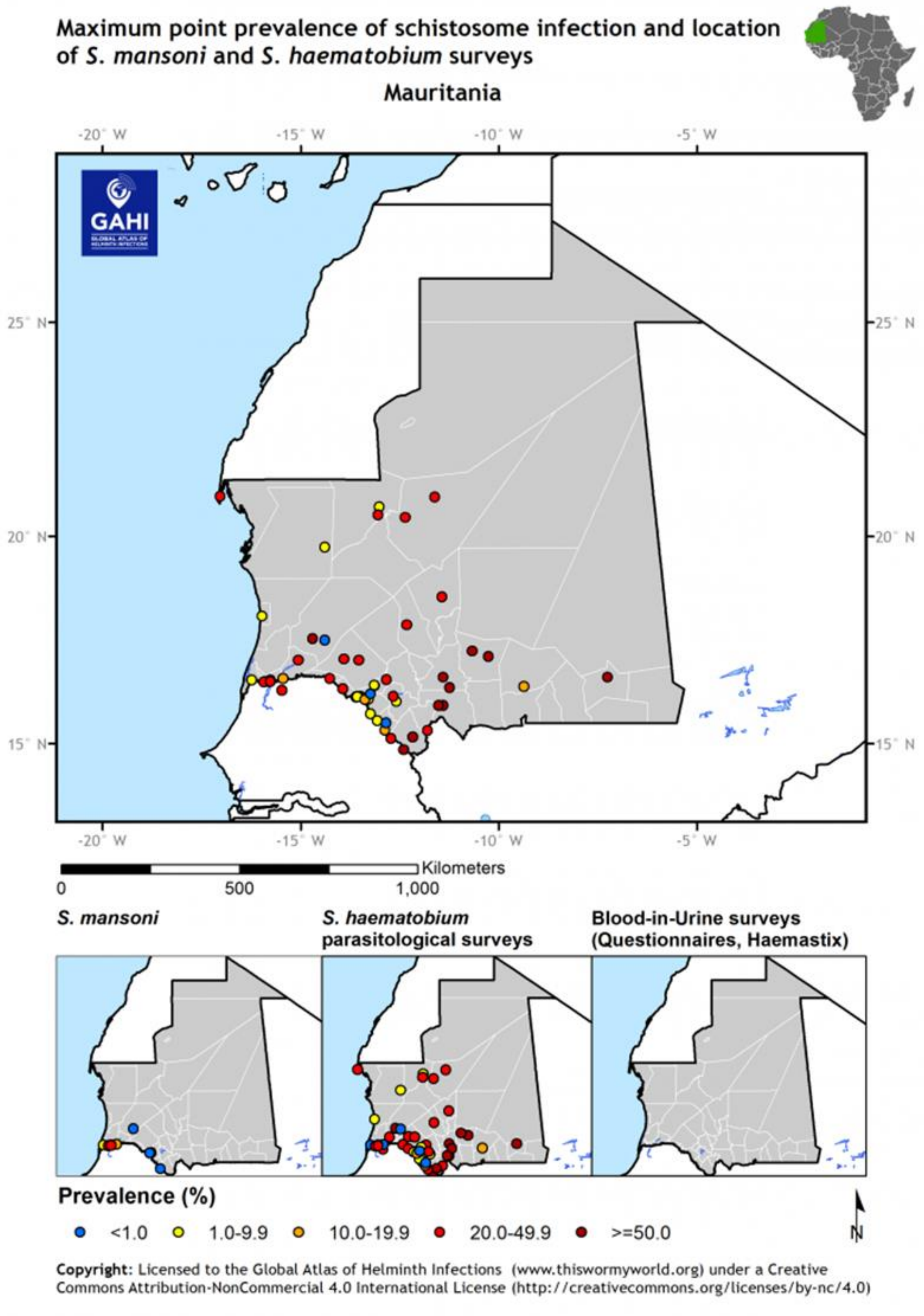


Figure 27. Prevalence of Schistosome infection in Mauritania

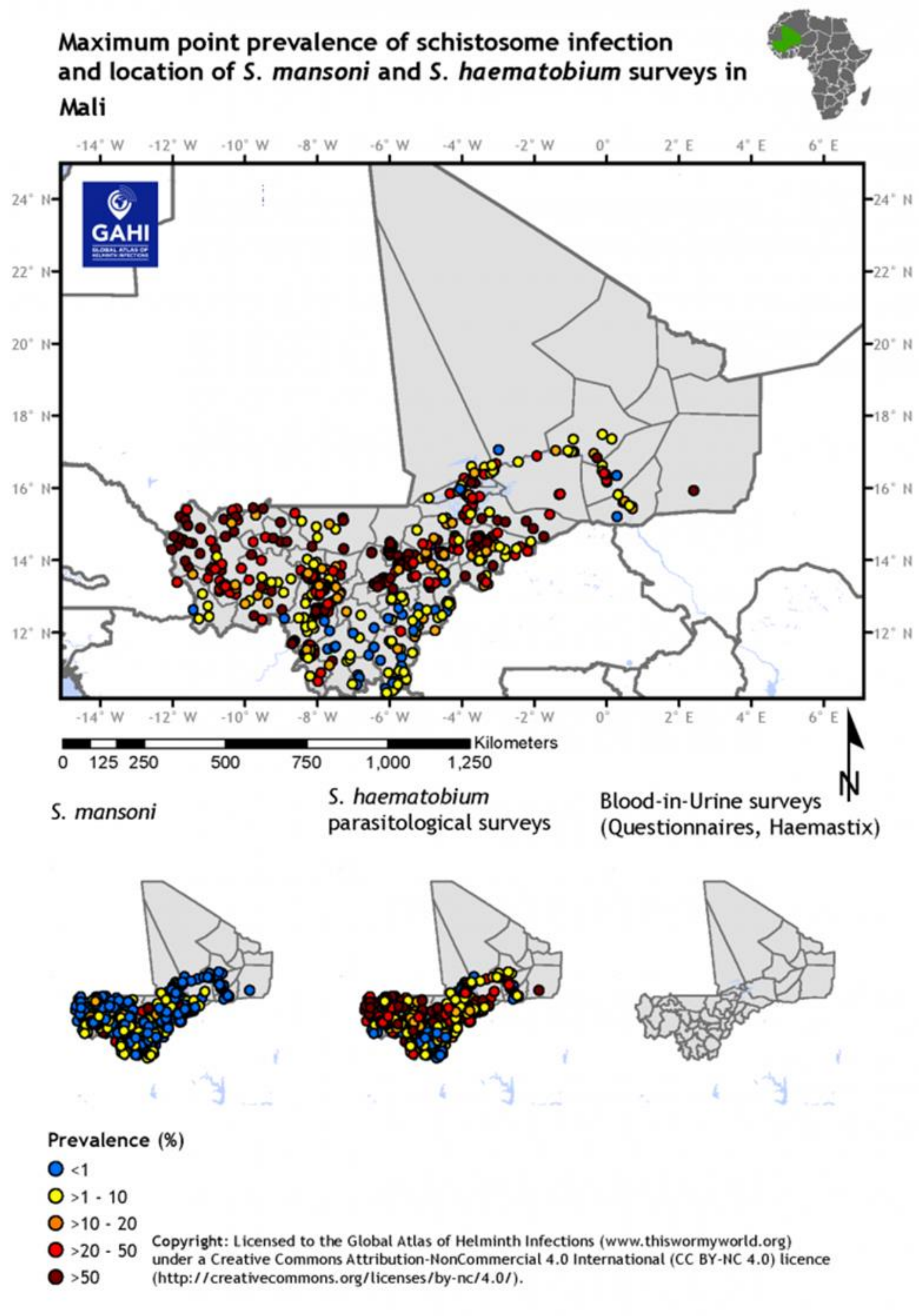


Figure 28. Prevalence of Schistosome infection in Mali

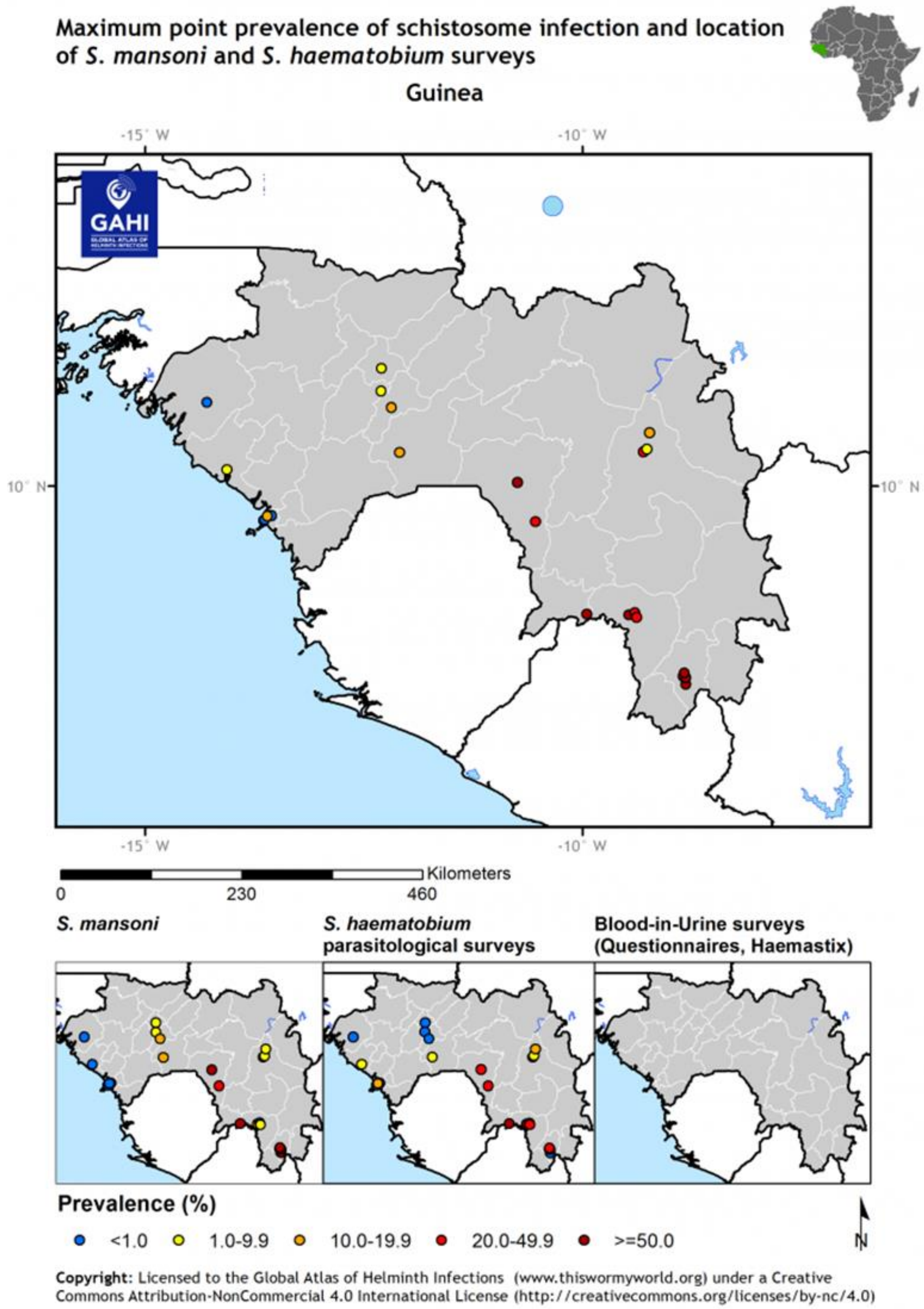


Figure 29. Prevalence of Schistosome infection in Guinea

There are some successful snail control pilots in the SRB, it could be demonstrated, that transmission of human schistosomiasis decreased after restoration of a native river prawn that preys on the snail intermediate host (Sokolow et al., 2015)

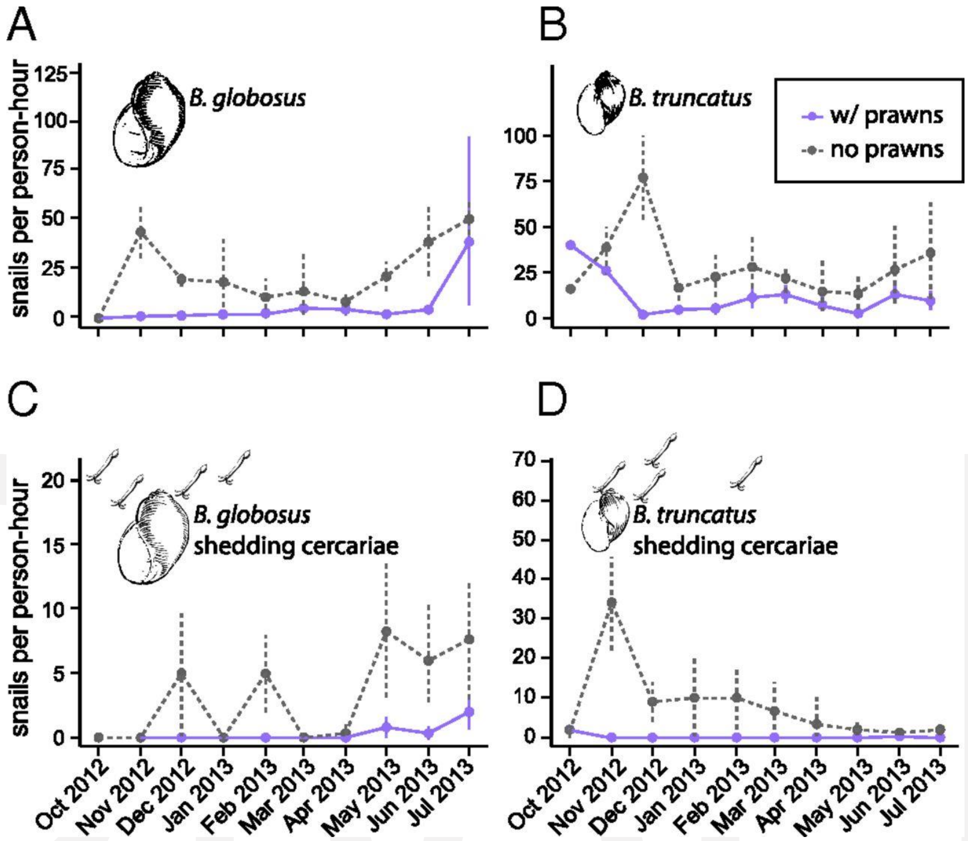


Figure 30. Results from snail control using prawns: Relative density of snails after prawns were installed at the intervention site (w/prawns) and control site (no prawns) from October 2012 to July 2013; (A) total Bulinus globosus, (B) total Bulinus truncatus, (C) B. globosus shedding schistosome cercariae, and (D) B. truncatus shedding schistosome cercariae. Susanne H. Sokolow et al. PNAS 2015;112:31:9650-9655. *(Sokolow et al., 2015)*

Earlier field experiments in Kenya also demonstrated that crayfish reduce snail populations and human reinfection with schistosomiasis (Cheever et al., 1994).

Summary vector borne diseases

Malaria is a major public health problem in the basin and two types of human schistosomiasis are observed in the SRB: urinary and intestinal schistosomiasis (the latter unknown before the dams were built) is rampant in the valley and delta.

Desalination of the River upstream the Diama Dam, eutrophication, stagnant waters in the irrigated areas and the creation of the reservoirs allowed the vectors of the parasites to proliferate.

Mitigation concepts aiming at habitat modification and introduction of natural predators feeding on the vectors do exist, and successful pilot studies were executed in the SRB.

4.1.3.3 Diarrhea and pathogens

Only limited data are available relating to the etiology and epidemiology of diarrhea in The SRB.

A May 2002 study on water quality of the Senegal River Estuary showed larges abundance of fecal bacteria in Saint Louis city and surrounding areas, because of untreated urban sewage inputs. (Troussellier et al., 2004).

A clinical study by Sambe-Ba et al. (2013) carried out on diarrhea patients from March 2009 to December 2010, in the urban region of Dakar, revealed that 29% had bacterial infections (mainly diarrheagenic E. coli and Shigella spp), 21% had viral infections (mainly rotavirus) and 14% had parasitic infections. Co-infection was identified in 17.8% of the patients. There was a seasonal variation of bacterial infections during the study period, with a higher proportion of infections due to Salmonella spp., in particular during the rainy season.

A study in three villages of the Podor district located in northern Senegal revealed a prevalence of Blastocystis sp. of 100% in 93 children with diarrhea. This was the highest prevalence ever recovered worldwide for this parasite (El Safadi et al., 2014).

Safe tap water is an asset to fight diarrheal disease, but also reduces the risk of exposure to vectors when washing in rivers etc. In Gaya, a village in northern Senegal, the introduction of safe tap water caused a significant decline in cases not only of diarrhea but also in bilharzia. https://media.ifrc.org/ifrc/2017/04/28/senegal-fighting-the-spread-of-waterborne-diseases-through-the-provision-of-safe-water-and-toilets/

Pit latrine sanitation standards are the counterpart to improve the hygiene situation in rural areas (Back et al., 2018; Martínez-Santos et al., 2017)

In urban areas Municipal waste water treatment plants are needed.

Summary Pathogens

Although clinical studies and the WHO data on diarrhea mortality are alarming, quasi zero information is available on the actual presence of pathogens in surface and in particular drinking waters.

Only for the Senegal River Estuary surface waters larges abundance of fecal bacteria around Saint Louis are reported. Data from rural areas and from drinking water are not reported.

Safe tap water, proper pit latrine sanitation and treatment of municipal wastewaters are an asset to fight pathogen-induced diarrheal disease

4.1.3.4 Chemicals and Pesticides

On pesticides from agriculture and mosquito control two studies from the SRB were considered.

Anderson et al., 2014:

The scientists from Oregon State University (OSU, Environmental and Molecular Toxicology Department) and the Centre Régional de Recherches en Ecotoxicologie et de Sécurité Environnementale (CERES) in Senegal developed a partnership to build capacity at CERES and to develop a pesticide-monitoring project using passive sampling devices (PSD)s. They published 2002 concentrations in the Senegal River for the following compounds: Alachlor, aldrin, bifenthrin, α-BHC, β-BHC, δ-BHC, γ-BHC (lindane), captafol, captan, chlorobenzilate, cis-chlordane (α-chlordane), trans-chlordane (γ-chlordane), chloroneb, chlorpyrifos, chlorothalonil, dacthal, diallate, dieldrin, dimethoate, 4,4′-DDD, 4,4′-DDE, 4,4′-DDT, endosulfan sulfate, endosulfan I, endosulfan II, endrin, endrin aldehyde, endrin ketone, esfenvalerate, heptachlor, heptachlor epoxide, hexachlorocyclopentadiene (HCCPD), hexachlorobenzene, isodrin, methoxychlor, metolachlor, mirex, trans-nonachlor, propachlor, prophos, cis-permethrin, trans-permethrin, terrazole and trifluralin. PCB-100, PCB-180 and pentachloronitrobenzene

The most abundant pesticides during the winter 2011 sampling in Senegal, Mauritania and Mali, were 4,4′-DDT and the cis- and trans-permethrins. These are Mosquito control agents, not used in agriculture. Agricultural pesticides and industrial chemicals analyzed in the Senegal River were not of concern for the human health and the aquatic ecosystem

However, 4,4′-DDT and metabolites concentrations were 0.05-0.1ppt in Senegal, Mauretania, Mali. Which is 10 fold below (USEPA) maximum concentration of 1 ng/L (ppt) for protection of aquatic life from potential exposure-related effects (US-EPA, 1992). The Environmental Quality Standard (EQS) for inland surface waters in the EU (European Commission, 2008) is 10 ng/L.

The Sum of Endosulfans ranged from 1 to 11 ppt and exceeded the EU PNEC[2] of 5 ng/L (European Commission, 2008)in some sites.

The Permethrins (mosquito control) were highest in Guinea with 0.1-2 ng/L (ppt). A draft chronic criterion for water toxicity has been described and proposed at 2 ng l−1 (ppt) permethrins, which was the maximum concentration measured in this study. In the EU the PNEC for inland surface waters in of 1.5 ng/L (European Commission, 2008).

Dimethoate found in ppb range (μg/L), clearly exceeding the EU PNEC of 10 ng/L (European Commission, 2008).

All of the other pesticides determined in this study were far below existing environmental quality standards. What concerns the Permethrins in Guinea that were determined in concentrations up to the EU EQS, it should be noted that first: an EQS is a protective figure; no effects are expected at his concentrations. Second: Permethrin replaces DDT in mosquito control. The replacement of DDT is a goal of the Stockholm and Basel Convention.

The experience with capacity building is summarized as follows:

The individual site data finally published are exclusively from the OSU extraction and analysis datasets The CERES-analysed dataset was not comparable owing to lack of sensitivity, poor recoveries and an inadequate confirmation process. CERES staff reported analytes as present even when they were not confirmed (false positives). The study concluded that, although considerable investments into instrumentation and formation was done, additional training and practice are necessary for instrument operation and data processing.

DRAFT

[2] PNEC is the Predicted Non Effect Concentration, that is used for risk assessment as long no EQS Standard has been set.

Jepson et al., 2014:

This study from OSU made a risk assessment based on application data for a series of pesticides. The only human health risks identified in this study is dermal uptake during application, mainly due to missing personal protection.

The compounds, locations and crops raising the greatest *human dermal uptake risk* (estimated from use data) are

- Dicofol in Senegal (used in onion, water melon, potato and pimento),
- methamidophos in Niger and Senegal (used in millet, black-eyed peas, rice, maize, water melon, peanut, aubergine, okra, melon and onion),
- dimethoate in Niger and Senegal (used in rice, cabbage, green beans, black-eyed peas, water melon, tomato, maize, peanut, aubergine, okra, melon and onion),
- diazinon in Mali (used in cabbage and okra),
- chlorpyrifos in Niger (used in black-eyed peas) and
- endosulfan in Guinea (used in onion, pimento and tomato).
- Zeta-cypermethrin is suspected for human bystander inhalation risk

The *ecosystem health risks* identified are:

- Propanil for aquatic algal risk,
- Dimethoate for aquatic invertebrate and avian reproductive risk,
- Methamidophos for avian acute risk, earthworm risk and small mammal acute risk,
- Dichlorprop (chlorophenoxy herbicide similar to 2.4-D)for fish reproductive risk

From the three compounds, where risks for the aquatic ecosystem were suggested above, only Dimethoate was actually determined by Anderson et al. above (2014), who found concentrations in the Senegal River fairly above the EU quality standards, thus confirming the risk assessment based on the use data from Jepson and co-workers.

The observation of Jepson et al (2014) that human exposure mainly occurs through application errors and insufficient personal protection is confirmed in a master study from the Mbaye (2017): The study mentions also the problem of observation that pesticides are stored indoor of the habitations, including sleeping rooms. The thesis contains no concentration data, but a detailed study on the application of different pesticides can be found herein.

Summary Pesticides

Significant risks from pesticide application on human health were identified (only) via dermal uptake during inappropriate personal protection during application and storage.

A moderate risk for aquatic ecosystems was predicted for Propanil (aquatic algae), Dimethoate (aquatic invertebrates and avian reproduction), and Dichlorprop (fish reproduction).

Monitoring data reveal only few pesticides close to or exceeding existing PNEC/EQS, i.e the Endosulfans: and permethrins (a mosquito repellant) in Guinea, partially exceeding the EU quality standards

Dimethoate was found in ppb range (µg/L) in the Senegal River was the only agro-pesticide clearly exceeded the EU quality standards for aquatic ecosystems

DRAFT

4.1.3.5 Nutrients

Nutrient contamination pose eutrophication risks in surface waters, in drinking water chronic effects on human health need to be considered.

Troussellier et al., 2004:

Trousellier and coworkers report from a 2002 surface water sampling in the estuary which revealed low inorganic nutrient concentrations while phytoplankton and bacteria abundance were among the highest reported for such ecosystems. They consider the Estuary a very eutrophicated ecosystem, with a quick uptake of nutrients.

While submitted to eutrophication, the fecal contamination of the estuarine water appeared low.

Compared to EU microbiological standards for bathing waters, fecal indicator abundances were near or below the recommended values, except near St Louis city. Eutrophication of the estuary results from some point and many diffuse sewage sources around Staint-Louis.

Ould Med Fadel et al., 2017:

DRAFT

Ould Med Fadel and cowoekers found a high turbidity in the water samples during the 2012 rainy season. Total hardness remained below the value indicated by the WHO 1987 (200 ppm).

Sodium/potassium remained largely lower than the standard of the WHO 1987 (150 mg/L), Calcium/magnesium were consistent with the standards of the WHO 1987: 50mg/L for the magnesium and 270 mg/L for calcium and the Chlorides/sulphates meet the standard set by the WHO 1987 (250 mg/L),

Nitrites recorded during the month of August oscillate between 0.04 and 1.4 mg/L, in September, between 0.1 and 1.4 mg/L. Limit value (drinking water) from WHO 1987 is 3 mg/L.

Nitrates were typically around 1 mg/L, max 1.8 mg/L, clearly below the EQS of 50 mg/L (WHO, EU, UK standards)

At some isolated sites levels of ammonium that exceeded the surface water standard defined by the WHO 1987 (0.5 mg/L), and this is explained by the discharge of wastewaters.

Cogels et al., 2001:

Cogels and coworkers investigated (among other parameters), the inorganic compounds present in the Lac de Guires.

They found the Lac de Guiers impacted with P and N from sugarcane production, mainly through the Taoué canal during the rainy season, with a spatial tendency of P accumulation from the Taoué canal – the northern part of the lake – towards the south and Ferlo. Total P concentrations were between 0.05 and 0.25 mg/L.

The increased P concentrations in the southern region and in Ferlo did not result in increased phytoplankton biomasses, probably as a result of a competition between phytoplankton and the huge macrophyte stands which are characteristics of these areas.

The nitrogen and nitrate concentrations are elevated in the Taoué canal and tend to decrease and stabilize in the lake and Ferlo, from north to south.

The average total N concentrations range from 1 to 2.5 mg/L in the lake and Ferlo, and 6.5 mg/L in the Taoué; whereas average nitrate concentrations never exceed 1 mg/l.

The control of the phosphorus (and eutrophication) input to the lake (draining from the sugar cane) is highlighted as a key objective of the management of eutrophication of the lake.

N'Djaye et al., 2013:

The water of Senegal River displayed a high turbidity during August; corresponding to the rainy season.

The Analysis revealed variation in the values of NH_4+ from 0.01-0.22 mg/L , $PO_4$3- from 0.49-1.70 mg/L SiO_2 from 0.04 - 1.02 mg/L, OM from 1.28-3.84 mg/L, Al from 20- 500 µg/L, Fe from 170- 320 µg/L, Mn from 1- 6 µg/L, Zn from 20-100 µg/L and Pb from 0.5-10.2 µg/L

The following Table 10) gives an overview on data published on the nutrient status of the SRB surface waters, in comparison with, data from the river Danube and existing quality standards for surface and drinking waters.

Table 10. summary of relevant inorganic contaminants analyzed in all studies above

	Senegal River Basin	**River Danube (JDS3)**	**Standards**
NH_4^+	0.01-0.22 mg/L – river*(c)	n.d.	0.5 mg/L (EU surface, UK drinking water)
NO_3^-	around 1 mg/L, max 1.8 mg/L -river *(a)* < 1 mg/L – Lac (b)	0.9 – 3.2 mg/L, up to 5.2 mg/L in tributaries	50 mg/L (EU surface, drinking water)
NO_2^-	0.04 - 1.4 mg/L *(a)*		0.3 mg/L (WHO drinking water
Total N	1 to 2.5 mg/l in the lake and Ferlo, 6.5 mg/l in the Taoué canal *(b)*	1-2 mg/L , up to 6 mg/L in the tributaries	
PO_4^{3-}	0.49-1.70 mg/L - river *(c)*	0.1 mg/L – 0.5 mg/L	5 and 2.2 mg/L (EU surface, UK drinking water)
Total P	Average around 0.1 mg/L. Range: 0.05 and 0.25 mg/L. – Lac *(b)*	0.01- 0.1 mg/L , up to 0.5 mg/L in tributaries	

**with isolated moderate exceedances not reported in this table , most probably sampled in the vicinity of wastewater discharges, a procedure that is not valid for comparison with river water quality standards*
$ Nitrate and nitrite in drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality *http://www.who.int/water_sanitation_health/dwq/chemicals/nitratenitrite2ndadd.pdf*
(a) Ould Med Fadel et al. 2017, (b) Cogels et al. 2001, (c) N'Djaye et al. 2013

Summary nutrients

What concerns nutrients from fertilizers and wastewaters (NH_4, NO_3, PO_4), several studies identified pathogens and aquatic (invasive) vegetation, which can be partially attributed to nutrient loads (salinity changed s in the Delta play in here as well). However, so far is no health and ecosystem risk in relation to EU drinking water standards or surface water EQS although strong eutrophication by macrophytes[3] in the Delta attributed to urban wastewater emission is reported

P and N loads in surface waters reported both in the River and Lac de Guiers are commonly fairly below existing standards and low in comparison with European rivers. However, P is more critical than N.

Nitrites were close to the WHO drinking water limits in the lower Senegal River

Lac de Guiers is impacted with P and N through the Taoué canal during the rainy season (sugar cane).The control of the phosphorus (and eutrophication) input to the lake is a key objective of the management of eutrophication of the lake (stop drainage from the sugar cane cultivation).

4.1.3.6 Heavy metals

Gerson et al., 2018:

Mecury ans its derivates near artisanal mines were found in water and sediments of the Faleme River catchment (upper SRB) by Gerson et al. 2018.

They compared Total Mercury (THg) and Methyl-Mercury (MeHg) concentrations in soil (n = 119), sediment (n = 22), and water (n = 25) from four active artisanal mining villages and one reference village in Senegal. Nearly all samples had THg, MeHg concentrations that exceeded the reference village concentrations and USEPA regulatory standards. The highest median THg concentrations were found in huts where mercury-gold amalgams were burned (7.5 µg/g), while the highest median MeHg concentrations and percent Hg as MeHg were found in river sediments (4.2 ng/g, 0.41%). This study provides direct evidence that Hg from artisanal gold mining is entering both the terrestrial and aquatic ecosystems where it is converted in soils, sediment, and water to the neurotoxic and bioavailable form of MeHg.

Median river water concentrations of THg and MeHg were also elevated compared to values at the reference site (22 ng THg/L, 0.037 ng MeHg/L), but yet not exceeding the quality standard for Mercury and its derivates (THg) in EU inland surface waters (AA-EQS & MAC-EQS of 70 ng/L (*EC 2008)*)

N'Daye et al. 2013:

[3] **Note:** Macrophytes act as an important "natural waste water treatment" by removing nutrients from the water column. In the absence of macrophytes nutrients would be consumed by algae, whose decomposition products pose a risk to drinking water abstraction. In so far the regional attempts to fight the occurrence of Typha should be carefully re-evaluated, as long as no waste water treatment is in place.

N'Daye and coworkers (2013) found Pb in the range of 0.5-10.2 µg/L in the Senegal River about 10 km upstream the Diama Dam during the rainy season, which maximum levels slightly beyond the quality standards for EU inland surface waters (AA-EQS & MAC-EQS of 14 µg/L *(EC 2008))*

Summary heavy metals

On heavy metals, only few studies from the SRB were available, but evidence from export data of mining products and one study on mercury revealed contamination with Mercury and its derivates in water and sediments of the Faleme catchment, with Total Mercury concentrations in the river water not exceeding EU Quality Standards.

Maximum Lead concentration upstream the Diama am were slightly below EU Quality Standards.

DRAFT

4.2 AGRICULTURE SECTOR

Agriculture is the key economic activity for all four countries within the SRB as it account for 53 to 76% of employment resources (Table 11, the highest share is in Mauritania) and also, it is important for its contribution to economy (GDP contribution from agriculture sector is in the range 15-38% in 2017, as reported in Table 12) and for food security. OMVS highlight in its reporting the importance of agriculture as a main driver for economy, as it produces employment for the majority of the population and above all for its importance to reduce poverty and increase food security (OMVS, 2017).

Agriculture accounts for 70 percent of total global freshwater withdrawals, making it the largest user of water. Water is used for agricultural production and along the entire agro-food supply chain, and it is used to produce, transport and use all forms of energy (FAO, 2011a) At the same time, the food production and supply chain consumes about 30 percent of total global energy (FAO 2011b). Energy is required to produce, transport and distribute food as well as to extract, pump, lift, collect, transport and treat water (FAO, 2011b)

Employment in agriculture (% of total employment)

Country	*1990*	*2000*	*2010*	*2017*
Guinea	71	71	70	68
Mali	50	46	57	58
Mauritania	81	79	77	76
Senegal	47	44	53	53

Table 11. Employment percentage for different years as reported by World Bank (The World Bank, 2018).

Country	*Value Added by Sector (% of GDP)*	*1990*	*2000*	*2010*	*2017*
Guinea	*Agriculture, forestry, and fishing*	25	21	17	16
	Industry (including construction)	35	31	32	33
	Manufacturing	5	4		11
	Other Services	36	44	50	40
Mali	*Agriculture, forestry, and fishing*	37	33	33	38
	Industry (including construction)	16	22	23	17
	Manufacturing				
	Other Services	46	46	44	45
Mauritania	*Agriculture, forestry, and fishing*	27	34	20	23
	Industry (including construction)	26	26	39	29
	Manufacturing	9	12	8	

Country	Value Added by Sector (% of GDP)	1990	2000	2010	2017
	Other Services	38	27	33	48
Senegal	*Agriculture, forestry, and fishing*	18	17	15	15
	Industry (including construction)	20	20	20	21
	Manufacturing	14	13	12	11
	Other Services	48	50	52	53

Table 12. Value added by sector to total GDP for different years as reported by World Bank (The World Bank, 2018).

Country	Item	Unit	2010	2016(*2014)
Guinea	Gross Domestic Product	US$	6853	8470
	Value Added (Agriculture, Forestry and Fishing)	% of GDP	17	18
	Value Added (Agriculture, Forestry and Fishing)	US$	1198	1524
	Value Added (Agriculture)	US$		
Mali	Gross Domestic Product	US$	10679	14002
	Value Added (Agriculture, Forestry and Fishing)	% of GDP	32	37
	Value Added (Agriculture, Forestry and Fishing)	US$	3452	5157
	Value Added (Agriculture)	US$		
Mauritania	Gross Domestic Product	US$	4338	4667
	Value Added (Agriculture, Forestry and Fishing)	% of GDP	20	22
	Value Added (Agriculture, Forestry and Fishing)	US$	880	1006
	Value Added (Agriculture)	US$	802	
Senegal	Gross Domestic Product	US$	12926	14605
	Value Added (Agriculture, Forestry and Fishing)	% of GDP	15	15
	Value Added (Agriculture, Forestry and Fishing)	US$	1976	2173
	Value Added (Agriculture)	US$	1652	1711*

Table 13. Macro economics indicator as reported by FAO (FAO, 2018b)..

Agriculture in the Senegal River Basin is mainly practiced in three forms.

1. **Rainfed** ("*pluviale*"): this is the most diffused and it is dominant both for cropland use, work production and total production;
2. **Recession** agriculture ("*décrue*"): this is practiced along the main river in the banks and in the shallow part of the river valley and used surfaces can vary considerably year by year according to river behavior and water balance within the basin;

DRAFT

3. **Irrigated** agriculture (mainly rice paddies, 'post-rainy season cash crops' such as onions, potatoes, fruits and legumes and agro-industry): this sector is particularly important even if currently it is still limited (are equipped for irrigation accounts for about 3-11% of total cropland, Table 9) and effective surface used for irrigation agriculture is less than 50% of total managed area (OMVS, 2017).

Total reported harvested area, within the SRB, as derived by SPAM dataset (2005) is about 14 000 km^2

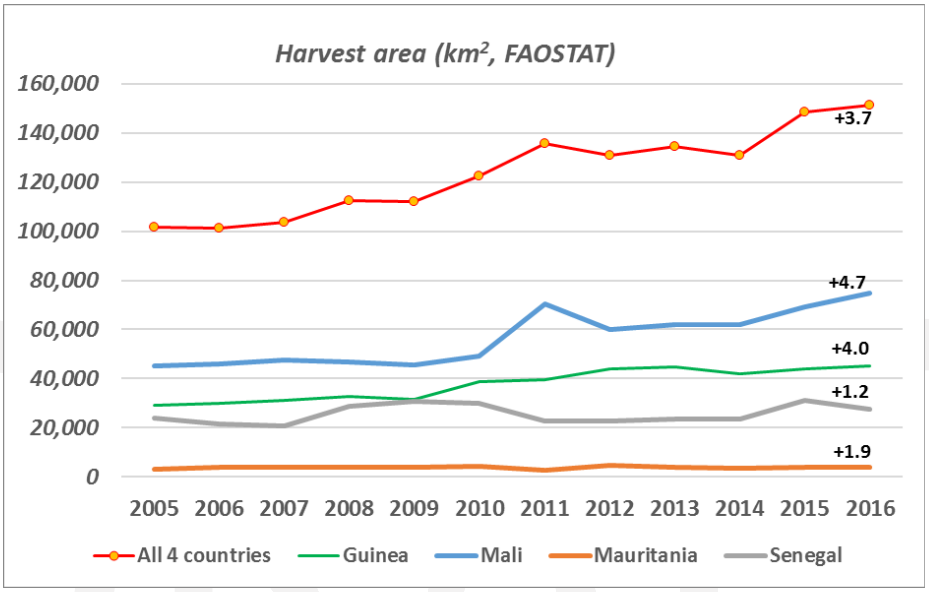


Figure 31. Harvested area at National scale including

Total cropland accounted within the River basin delineation is about 14% of total harvested area in the four countries. It is interesting to note an annual average increase of about 4% in the 4 countries is reported for the four countries for the period extending from 2005 (SPAM reference year) and 2016. The increases reported in FAOSTAT (FAO, 2018b) are higher for Mali and Guinea (4-6%) while less evident for Mauritania and Senegal (1-2%, see Figure 31).

By assuming these average increases are the same all over the country land , we can estimate current (2018) harvested areas (HA) as derived by SPAM in the SRB as 21503 km^2 (+55% if compared with original SPAM values calculated for 2005) and respectively 2204 in Guinea, 12300 in Mali, 3530 in Mauritania and 3472 in Senegal.

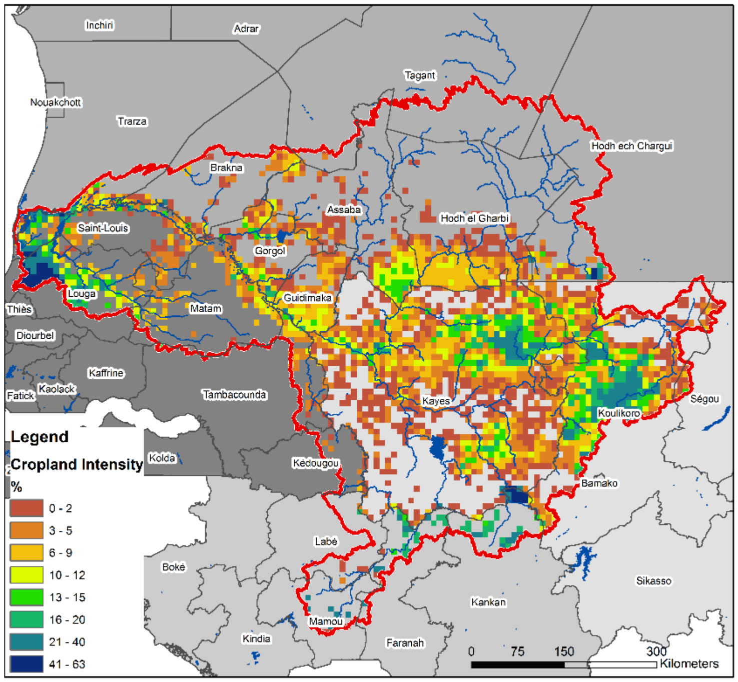


Figure 32. Cropland Intensity: derived as Harvest area reported by SPAM in 2005 divided by total cell area (5' grid resolution).

Largest harvested agricultural areas are located in Mali in Kayes and Koulikoro regions (33% and 16% of total HA, located in central and eastern part of the RB, as showed in Figure 32), in Louga and Saint-Louis regions for Senegal (10 and 7.3% of total HA; in the Delta area of the SRB), in Kankan and Faranah regions for Guinea (5 and 2% of total HA) and in Hodh el Gharbi, Assaba, Gorgol, and Guidimaka for Mauritania (mainly along the main rivers valley).

4.2.1 Landcover in the SRB

Different Lancover products (ESA300m, GLOBCOVER2009, GLOBLAND30m, ESA 20m, etc.) are available for the African continent with different spatial and temporal resolution. At this stage an analysis was developed by using the Global landcover map developed by ESA (ESA, 2017) within the context of the Land Cover project and Climate Change Initiative. The analysis was based on the layer developed for year 2015. The LCC map resulting is showed in Figure 33.

DRAFT

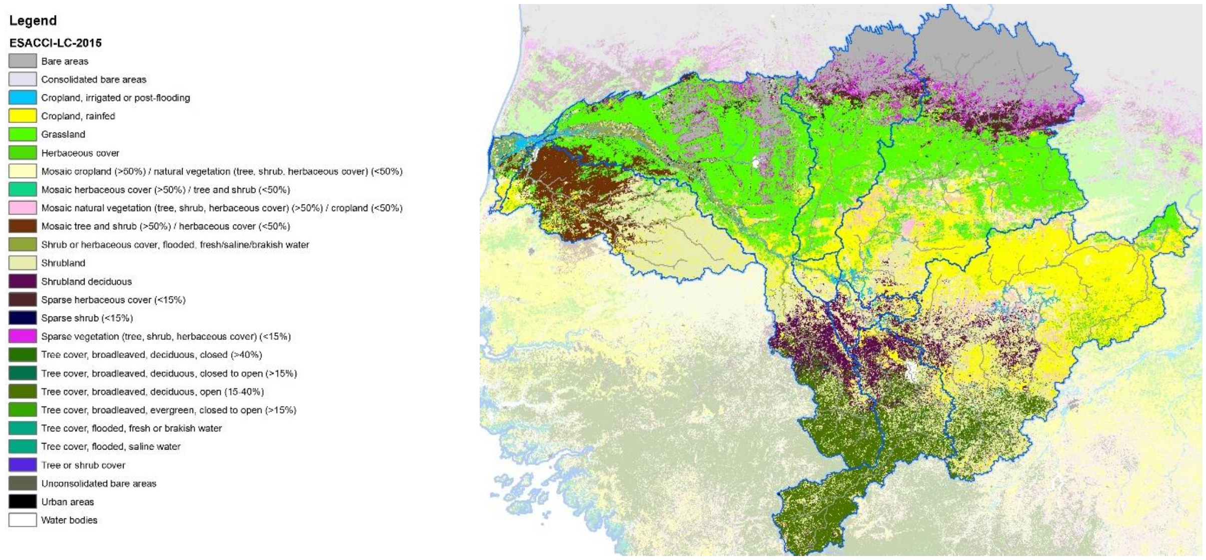


Figure 33. LCC for Senegal River Basin for 2015. Spatial resolution is 300m (ESA, 2014).

DRAFT

By considering the hydrological limit of the SRB derived by Hydroshed (Lehner et al., 2008; WWF, 2018) a total area of about 456 000 km^2 can be considered as the reference total drained area by Senegal river.

The hydroshed limit for Senegal RB was used to spatially clip the administrative boundaries as derived by GADM database (GADM, 2018). It is so possible to calculate for each administrative layer the main land cover with the drained area of the SRB.

At the scale of the whole river basin the dominant landcover are shrubland (35%), mixed shurbaland /trees (23%) and grassland (14%). Rainfed cropland is about 7% (irrigated is an additional 2%) of the total area and other dominant classes are mixed cropland-natural vegetation (8%), forest (5%) and flooded areas (4%) (see Table 14 for more details). By looking the values at national scale (even if just considering the effective drained area) the figures is more diversified:

- Guinea: dominant classes are Forest (70%) and shrubland (24%) while cropland is quite limited (1.5%)
- Mali: dominant classes are Cropland (39%) shrubland (30%) and mixed cropland/natural vegetation (16%)
- Mauritania: dominant classes are Grassland (45%), bare areas (27%) and sparse vegetation, while cropland is about 6%
- Senegal: dominant classes are shrubland (35%), mixed tree/shrub areas (23%) and grassland (114%), while cropland is about 9%

Land Cover Class	***Senegal River Basin***		***Guinea***	***Mali***	***Mauritania***	***Senegal***
			Km^2 31 510	***Km^2 171 415***	***Km^2 176 416***	***Km^2 77 052***
	AREA Km^2	***%***	***%***	***%***	***%***	***%***
Cropland, rainfed	79,056	17.3%	1.5%	37.1%	5.4%	7.2%
Herbaceous cover	3,302	0.7%	0.0%	1.5%	0.3%	0.4%
Irrigated or post-flooding	6,126	1.3%	0.0%	1.9%	0.7%	2.0%

Mosaic cropland/Natural	44,029	9.6%	4.3%	15.6%	5.4%	8.3%
Tree cover	40,378	8.8%	69.6%	8.7%	0.0%	4.6%
Mosaic tree and shrub	18,498	4.1%	0.0%	0.1%	0.5%	22.6%
Shrubland	89,233	19.6%	24.4%	30.0%	1.9%	34.9%
Grassland	97,729	21.4%	0.0%	4.7%	44.5%	14.4%
Sparse vegetation	23,123	5.1%	0.0%	0.0%	12.9%	0.4%
flooded	5,265	1.2%	0.0%	0.0%	1.0%	4.4%
Urban areas	159	0.0%	0.1%	0.0%	0.0%	0.0%
Bare areas	47,735	10.5%	0.0%	0.0%	27.0%	0.0%
Water bodies	1,761	0.4%	0.2%	0.4%	0.3%	0.7%
Total	456,394	100.0%	100.0%	100.0%	100.0%	100.0%

Table 14. Landcover statistics across the Senegal River Basin as derived by Lancover Map for year 2015 (ESA, 2017, 2014).

At subnational level (level 1 of GADM are reported in Figure 2) it is interesting to not that:

- Most of the rainfed and irrigated crop land are in Mali (about 81 of rainfed crop land and 54% of irrigated cropland).
- Irrigation is mostly practiced in Mali and in Saint-Luis region for Senegal and in Trarza and Gorgol for Mauritania
- Forest coverage is maninly in Guinea part (about 51%) and partially in Mali (33%)
- Grassland is mainly in Mali (81%)

In order to have more details at local level it is also possible to calculate % of each class in each subnational region as reported in Table 15 and Table 16.

- Guinea: Kankan region is the only one not dominated by forest and with important shares of cropland and shrubland
- Mali: Segou is the most cropped region (82% and about 90% considering also mixed classes)
- Mauritania: Guidimaka is the region with higher cropland intensity (about 25%), all the areas are dominated by grassland landcover.
- Senegal: Tamacounda and Louga and Saint-Lois areas have important shares of cropland. Kédougou is the only area with high forest cover

CC	***NAME_1***	***Cropland, rainfed***	***Herbac. cover***	***Irrigated post-flooding***	***Mosaic cropland Natural***	***Tree cover***	***Mosaic tree and shrub***	***Shrub-land***	***Grass-land***	***Sparse veget.***	***flooded***	***Urban areas***	***Bare areas***	***Water bodies***
GUN	Faranah	0.1%	0.0%	0.0%	0.7%	14.8%	0.0%	1.1%	0.0%	0.0%	0.0%	0.2%	0.0%	1.3%
GUN	Kankan	0.4%	0.2%	0.1%	0.8%	9.7%	0.0%	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
GUN	Labé	0.0%	0.0%	0.0%	0.3%	15.6%	0.0%	1.9%	0.0%	0.0%	0.0%	12.2%	0.0%	1.5%
GUN	Mamou	0.1%	0.0%	0.0%	1.3%	14.2%	0.0%	1.0%	0.0%	0.0%	0.0%	2.7%	0.0%	0.0%
MLI	Kayes	44.1%	18.2%	38.4%	39.3%	33.5%	0.7%	53.1%	4.9%	0.1%	0.5%	17.5%	0.0%	39.6%
MLI	Koulikoro	34.2%	54.2%	15.4%	21.1%	3.4%	0.0%	4.4%	3.2%	0.1%	0.0%	1.9%	0.0%	0.2%
MLI	Ségou	2.1%	3.1%	0.5%	0.3%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
MRT	Assaba	3.4%	3.7%	2.1%	4.9%	0.0%	1.3%	1.0%	19.0%	16.8%	0.2%	7.7%	12.5%	0.3%
MRT	Brakna	0.1%	0.3%	1.1%	0.0%	0.0%	0.9%	0.9%	10.8%	13.5%	11.2%	7.9%	7.9%	2.3%
MRT	Gorgol	0.6%	2.8%	4.3%	0.6%	0.0%	0.3%	0.3%	10.0%	4.1%	9.5%	19.2%	1.8%	17.2%
MRT	Guidimaka	3.2%	4.3%	2.9%	1.6%	0.0%	0.3%	0.2%	6.6%	1.2%	0.5%	2.0%	0.1%	1.5%
MRT	Hodh ech Chargui	0.5%	0.7%	0.3%	1.4%	0.0%	0.1%	0.1%	10.6%	9.7%	0.0%	0.0%	18.5%	0.0%
MRT	Hodh el Gharbi	3.9%	2.7%	1.1%	13.1%	0.0%	1.4%	0.7%	19.8%	45.6%	0.0%	3.1%	22.0%	0.1%
MRT	Tagant	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.1%	0.6%	4.7%	0.1%	5.1%	36.9%	0.3%
MRT	Trarza	0.1%	0.2%	8.4%	0.0%	0.0%	0.2%	0.4%	3.1%	3.0%	13.6%	1.8%	0.2%	6.4%
SEN	Kédougou	0.0%	0.0%	0.0%	0.1%	7.7%	0.0%	2.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
SEN	Louga	2.6%	7.2%	0.9%	5.4%	0.0%	51.4%	0.5%	1.7%	0.1%	0.7%	6.7%	0.0%	6.2%
SEN	Matam	2.7%	0.2%	2.4%	4.5%	0.0%	7.8%	19.1%	3.0%	0.4%	18.6%	3.2%	0.0%	5.3%
SEN	Saint-Louis	0.1%	0.5%	19.7%	3.2%	0.0%	35.1%	2.1%	6.3%	0.7%	44.5%	7.0%	0.1%	16.1%

CC	NAME_1	Cropland, rainfed	Herbac. cover	Irrigated post-flooding	Mosaic cropland Natural	Tree cover	Mosaic tree and shrub	Shrub-land	Grass-land	Sparse veget.	flooded	Urban areas	Bare areas	Water bodies
SEN	Tambacounda	1.7%	1.6%	2.3%	1.3%	1.1%	0.0%	5.6%	0.4%	0.0%	0.6%	1.9%	0.0%	1.6%

Table 15. Landcover statistics across the Senegal River Basin at SubNational Level (GADM Level 1. (GADM, 2018)) *as derived by Lancover Map for year 2015* (ESA, 2017, 2014)*: percentages refer to the total area in the SRB (that means table may be read in vertical).*

CC	NAME_1	Cropland, rainfed	Herbac. cover	Irrigated post-flooding	Mosaic cropland Natural	Tree cover	Mosaic tree and shrub	Shrub-land	Grass-land	Sparse veget.	flooded	Urban areas	Bare areas	Water bodies
GUN	Faranah	0.9%	0.0%	0.0%	3.9%	81.6%	0.0%	13.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
GUN	Kankan	3.7%	0.1%	0.1%	4.0%	44.9%	0.0%	47.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
GUN	Labé	0.5%	0.0%	0.0%	1.6%	76.6%	0.0%	20.9%	0.0%	0.0%	0.0%	0.2%	0.0%	0.3%
GUN	Mamou	0.7%	0.0%	0.0%	8.1%	79.1%	0.0%	12.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
MLI	Kayes	28.6%	0.5%	1.9%	14.2%	11.1%	0.1%	38.9%	4.0%	0.0%	0.0%	0.0%	0.0%	0.6%
MLI	Koulikoro	56.8%	3.8%	2.0%	19.5%	2.9%	0.0%	8.3%	6.6%	0.0%	0.0%	0.0%	0.0%	0.0%
MLI	Ségou	81.0%	5.1%	1.4%	7.3%	0.0%	0.0%	0.0%	5.2%	0.0%	0.0%	0.0%	0.0%	0.0%
MRT	Assaba	7.7%	0.4%	0.4%	6.2%	0.0%	0.7%	2.5%	53.5%	11.2%	0.0%	0.0%	17.3%	0.0%
MRT	Brakna	0.5%	0.1%	0.4%	0.0%	0.0%	0.9%	4.3%	54.8%	16.2%	3.1%	0.1%	19.6%	0.2%
MRT	Gorgol	3.3%	0.7%	1.9%	1.8%	0.0%	0.4%	2.0%	70.7%	6.8%	3.6%	0.2%	6.2%	2.2%
MRT	Guidimaka	23.8%	1.3%	1.7%	6.8%	0.0%	0.6%	1.7%	60.7%	2.6%	0.2%	0.0%	0.4%	0.3%
MRT	Hodh ech Chargui	1.9%	0.1%	0.1%	2.8%	0.0%	0.1%	0.2%	45.7%	9.9%	0.0%	0.0%	39.2%	0.0%
MRT	Hodh el Gharbi	6.2%	0.2%	0.1%	11.4%	0.0%	0.5%	1.3%	38.4%	21.0%	0.0%	0.0%	20.8%	0.0%
MRT	Tagant	0.1%	0.0%	0.0%	0.1%	0.0%	0.3%	0.7%	3.0%	5.5%	0.0%	0.0%	90.3%	0.0%

CC	NAME_1	Cropland, rainfed	Herbac. cover	Irrigated post-flooding	Mosaic cropland Natural	Tree cover	Mosaic tree and shrub	Shrub-land	Grass-land	Sparse veget.	flooded	Urban areas	Bare areas	Water bodies
MRT	Trarza	1.9%	0.1%	9.1%	0.2%	0.0%	0.7%	5.9%	53.5%	12.3%	12.6%	0.1%	1.6%	2.0%
SEN	Kédougou	0.5%	0.0%	0.0%	1.1%	54.9%	0.0%	43.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SEN	Louga	12.3%	1.4%	0.3%	14.4%	0.0%	57.6%	2.9%	9.9%	0.1%	0.2%	0.1%	0.0%	0.7%
SEN	Matam	7.8%	0.0%	0.6%	7.4%	0.0%	5.4%	63.5%	10.9%	0.4%	3.6%	0.0%	0.0%	0.3%
SEN	Saint-Louis	0.4%	0.1%	6.0%	6.9%	0.0%	32.4%	9.2%	30.7%	0.8%	11.7%	0.1%	0.1%	1.4%
SEN	Tambacounda	16.7%	0.6%	1.7%	7.2%	5.5%	0.1%	62.8%	4.6%	0.0%	0.4%	0.0%	0.0%	0.3%

Table 16. Landcover statistics across the Senegal River Basin at SubNational Level (GADM Level 1. (GADM, 2018)*) as derived by Lancover Map for year 2015* (ESA, 2017, 2014)*: percentages refers to the total area in each subnational region (that means table may be read in horizontal).*

DRAFT

4.2.2 Cropping systems and management

In order to perform an analysis at river basin level, specific data on crop distribution and management are needed at a relevant resolution. Indeed reported statistic on landuse and cropping areas and production are provided at national and subnational level, but these data need to be disaggregated at subabsin level, as river basin delimitation is not consistent with administrative one. Statistical data on crop distribution, harvest areas, and management (fertilization and irrigation, crop calendars, etc.) are provided (if available) at national and sub national scale, but more detailed data (at finer resolution) can be derived by disaggregation analysis (Fritz et al., 2015; You et al., 2014). In this case we used the MapSPAM dataset (You et al., 2018), a spatial allocation model, forced with official statistics reported by FAO at Sub national level, providing several important management data at a resolution of 5’ grid cell.
The data are disaggregated by combing information derived by satellite data and biophysical constraints (landcover maps, suitability maps, soil characteristics, etc). More detailed on the methodology and approach is provided by (You et al., 2017).

Cereals (like Sorghum, Fonio, Millet, and Maize) are the dominant crop type used across the SRB accounting for about 51% of the total harvested area. Maize is representing alone the 8% of total area. Other important crops for surface occupancy are oil crops (16%), pulses (12%), Rice (7%) and Cotton (6%). Crops less diffused, but anyway playing an important rule for food production are vegetables (3%) and fruits (3%).
These statistics are derived considering all the RB, but the figure is not changing much by disaggregating the statistics at country level (portion of the SRB within each country): as reported in Table 17.

- *Guinea (SRB harvest area: 132 000 ha):* Cereals are dominant crops (46%; Maize is 13%) and Rice is very much diffused in the region accounting for about 21% of the total area; other important groups are Fruits, oils (8%) and vegetables and tubers (5-6%).
- *Mali (SRB harvest area: 224 000 ha):* Cereals are dominant crops (58%; Maize is 10%) and oils crop group is also very much diffused in the region accounting for about 20% of the total area; other important crop is Cotton (13%)
- *Mauritania (SRB harvest area: 278 000 ha):* Cereals are dominant crops (53%; 7% Maize) and pulses crop group is also very much diffused in the region accounting for about 34% of the total area; other important crop is Cotton (6%)
- *Senegal (SRB harvest area: 298 000 ha):* Cereals are diffused crops (35%; 2% Maize) and oils and pulses crop groups are also very much diffused in the region accounting respectively for about 27% and 14%of the total area; other important crop are rice and vegetables (11% and 7%)

DOMINANT CROPS WITHIN THE SENEGAL RIVER BASIN

Guinea: → Cereals + Maize + Rice + Oils + Fruits // (Harvested area = 132 000 ha)

Mali: → Cereals + Oils + Cotton // (Harvested area = 224 000 ha)

Mauritania: → Cereals + Pulses + Rice // (Harvested area = 278 000 ha)

Senegal: → Cereals + Oils +Pulses + Rice + Vegetables // (Harvested area = 298 000 ha)

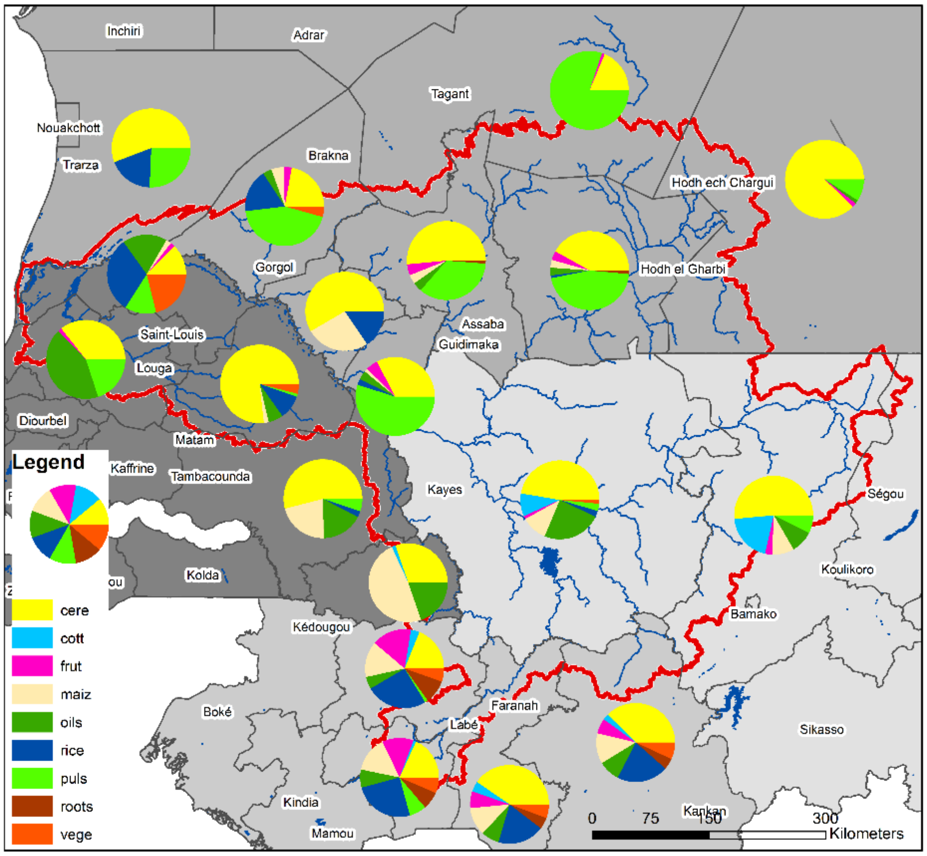


Figure 34. Crop shares by Administrative level (Gadm Level2).

DRAFT

It is important to stress that dominant agriculture used in the region (accordingly to SPAM dataset, 2005) is classified accordingly to SPAM definition as *"Subsistence agriculture"* (about 41% of Total HA): these areas are characterized by rainfed agriculture practiced even if cropland extension is very limited and suitable soils are not present. The 38% of the agriculture is classified as *"Low Input"* (rainfed agriculture, with local varieties and mainly manual labour with no or very limited use of inputs, such as fertilizers, pesticides, etc.), 15% is *"High Input"* (using high-yield crop varieties, some mechanization, use of external inputs and normally produced for the market) and only 6% is "*irrigated"*. Low production system are particularly diffused in Guinea and Mauritania (90 and 92% of total agriculture), while in Mali and Senegal seems high input or irrigated agriculture is more used (High: 22% in Mali and 15% in Senegal; Irrigated: 1% in Mali and 18% in Senegal).
As expected cereals are only rainfed and generally low input (84%). Cotton is the crop with the highest percentage characterized by high input methods (37%). Maize and vegetables are characterized by an important use of input (for about 15-25% of harvest area). Irrigation strategy is particularly relevant for rice (61% of rice area is irrigated,) for sugar crops (99%) and for vegetables (33%). Indeed most of these crop are diffused in the river valley (see for example, rice areas in Figure 35).

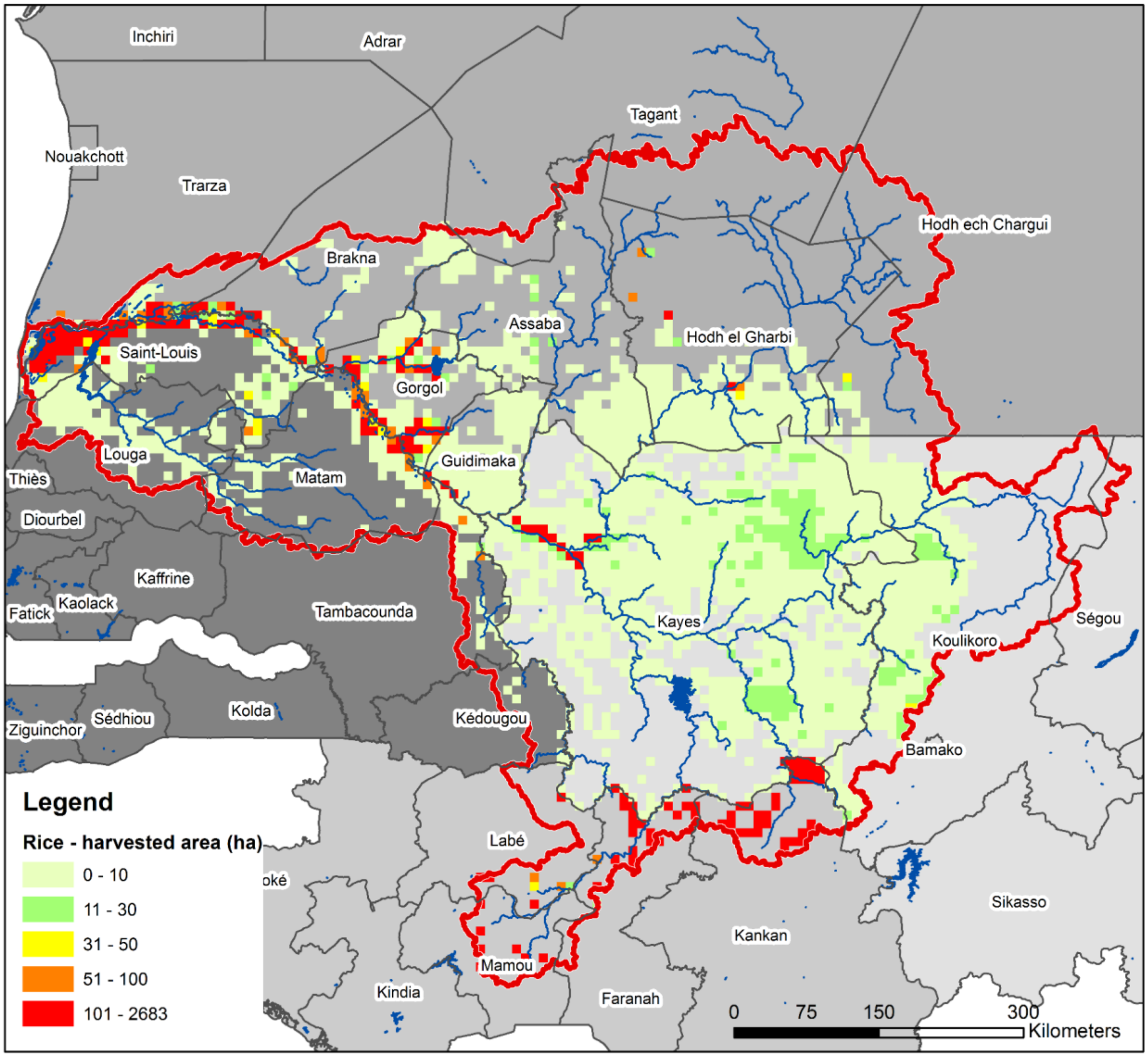


Figure 35. Rice paddy areas in the Senegal RB.

Harvested areas at national level (considering only harvest area belonging to SRB and at river basin scale (derived by SPAM) are summarized in Table 17, Table 18 and Table 19.

Country	Region	Total	Oils		Pulses		Rice		Roots		Vegetables		Other	
Guinea	*Faranah*	30,847	2,250.8	7%	146.5	0%	5,805.4	19%	1,462.9	5%	1,722.6	6%	234.0	1%
Guinea	*Kankan*	72,526	6,304.0	9%	290.4	0%	15,126.4	21%	3,257.8	4%	5,000.8	7%	350.0	0%
Guinea	*Labé*	8,744	432.1	5%	109.3	1%	2,189.0	25%	837.2	10%	466.7	5%	74.5	1%
Guinea	*Mamou*	20,040	1,444.6	7%	1,379.1	7%	4,904.6	24%	1,420.9	7%	1,268.0	6%	463.7	2%
Guinea	***Total***	132,158	10,432	8%	1,925	1%	28,025	21%	6,979	5%	8,458	6%	1,122	1%
Mali	*Kayes*	452,007	108,949.0	24%	13,568.4	3%	10,760.6	2%	2,032.3	0%	6,835.6	2%	2,129.1	0%
Mali	*Koulikoro*	224,033	20,090.8	9%	16,254.6	7%	1,786.2	1%	666.9	0%	1,939.3	1%	664.2	0%
Mali	***Total***	676,040	129,040	19%	29,823	4%	12,547	2%	2,699	0%	8,775	1%	2,793	0%
Mauritania	*Assaba*	63,074	2,381.9	4%	22,108.3	35%	97.1	0%	785.8	1%	77.5	0%	0.0	0%
Mauritania	*Brakna*	21,332	785.6	4%	9,320.4	44%	3,753.9	18%	51.2	0%	913.3	4%	11.8	0%
Mauritania	*Gorgol*	47,680	45.1	0%	3.0	0%	7,347.2	15%	129.3	0%	69.9	0%	2.6	0%
Mauritania	*Guidimaka*	47,170	1,705.8	4%	25,506.5	54%	1,189.8	3%	453.1	1%	131.3	0%	0.0	0%
Mauritania	*Hodh ech Chargui*	9,120	129.4	1%	807.1	9%	59.1	1%	85.7	1%	7.0	0%	0.0	0%
Mauritania	*Hodh el Gharbi*	65,797	2,112.2	3%	29,872.3	45%	691.9	1%	930.7	1%	76.4	0%	1.3	0%
Mauritania	*Tagant*	511	3.6	1%	403.3	79%	0.9	0%	2.5	0%	1.1	0%	0.0	0%
Mauritania	*Trarza*	23,270	128.1	1%	5,843.5	25%	4,217.0	18%	133.7	1%	111.7	0%	0.0	0%
Mauritania	***Total***	277,953	7,292	3%	93,864	34%	17,357	6%	2,572	1%	1,388	0%	16	0%
Senegal	*Kédougou*	2,346	449.0	19%	18.1	1%	10.9	0%	2.8	0%	10.5	0%	21.3	1%
Senegal	*Louga*	138,446	58,718.7	42%	27,400.6	20%	0.0	0%	0.0	0%	76.8	0%	1,097.8	1%
Senegal	*Matam*	39,272	2,355.9	6%	473.1	1%	3,788.4	10%	1.2	0%	1,576.0	4%	324.3	1%
Senegal	*Saint-Louis*	101,356	16,940.5	17%	11,989.6	12%	28,739.1	28%	749.2	1%	19,543.6	19%	7,991.9	8%
Senegal	*Tambacounda*	17,042	2,786.4	16%	842.7	5%	414.7	2%	17.0	0%	14.6	0%	416.8	2%
Senegal	***Total***	298,463	81,251	27%	40,724	14%	32,953	11%	770	0%	21,222	7%	9,852	3%
	River Basin	1,384,614	228,014	16%	166,337	12%	90,882	7%	13,020	1%	39,843	3%	13,783	1%

Table 17. Harvested areas at national level (considering only harvest area belonging to SRB and at river basin scale (derived by SPAM).

DRAFT

Country	Region	Total	Cereals		Cotton		Fruit		Maize	
Guinea	*Faranah*	30,847	12,318.8	40%	1,265.3	4%	2,122.4	7%	3,518.5	11%
Guinea	*Kankan*	72,526	26,965.3	37%	1,776.1	2%	4,531.8	6%	8,923.7	12%
Guinea	*Labé*	8,744	1,637.9	19%	306.5	4%	1,416.6	16%	1,274.2	15%
Guinea	*Mamou*	20,040	3,555.5	18%	207.1	1%	2,522.1	13%	2,874.7	14%
Guinea	***Total***	132,158	44,478	34%	3,555	3%	10,593	8%	16,591	13%
Mali	*Kayes*	452,007	211,967.2	47%	42,150.1	9%	5,736.6	1%	47,878.1	11%
Mali	*Koulikoro*	224,033	112,799.7	50%	43,598.0	19%	6,387.7	3%	19,845.6	9%
Mali	***Total***	676,040	324,767	48%	85,748	13%	12,124	2%	67,724	10%
Mauritania	*Assaba*	63,074	32,457.0	51%	0.0	0%	2,801.1	4%	2,364.9	4%
Mauritania	*Brakna*	21,332	4,715.7	22%	0.0	0%	695.2	3%	1,085.2	5%
Mauritania	*Gorgol*	47,680	27,695.8	58%	0.0	0%	1.6	0%	12,385.1	26%
Mauritania	*Guidimaka*	47,170	15,247.7	32%	0.0	0%	2,265.7	5%	670.1	1%
Mauritania	*Hodh ech Chargui*	9,120	7,878.6	86%	0.0	0%	152.8	2%	0.0	0%
Mauritania	*Hodh el Gharbi*	65,797	27,505.8	42%	44.1	0%	2,460.0	4%	2,102.1	3%
Mauritania	*Tagant*	511	94.3	18%	0.0	0%	5.5	1%	0.0	0%
Mauritania	*Trarza*	23,270	12,689.8	55%	0.0	0%	146.1	1%	0.0	0%
Mauritania	***Total***	277,953	128,285	46%	44	0%	8,528	3%	18,607	7%
Senegal	*Kédougou*	2,346	690.2	29%	35.5	2%	4.1	0%	1,103.8	47%
Senegal	*Louga*	138,446	49,059.6	35%	0.0	0%	2,067.4	1%	25.5	0%
Senegal	*Matam*	39,272	29,620.5	75%	0.0	0%	349.1	1%	783.9	2%
Senegal	*Saint-Louis*	101,356	11,709.0	12%	0.0	0%	1,708.9	2%	1,984.2	2%
Senegal	*Tambacounda*	17,042	8,867.4	52%	117.7	1%	74.8	0%	3,489.8	20%
Senegal	***Total***	298,463	99,947	33%	153	0%	4,204	1%	7,387	2%
	River Basin	1,384,614	597,476	43%	89,500	6%	35,450	3%	110,309	8%

Table 18. Harvested areas at national level (considering only harvest area belonging to SRB and at river basin scale (derived by SPAM).

DRAFT

COUNTRY	GROUP	%	Harvested area (Ha)	Subsistence	High Input	Low Input	Irrigated
Guinea	cereals	52%	1,520,358	62%	4%	31%	4%
	fibres	1%	37,335	0%	34%	66%	0%
	fruits	10%	303,845	88%	0%	10%	1%
	oilcrops	18%	514,381	15%	8%	76%	1%
	others	0%	13,627	11%	21%	21%	47%
	pulses	2%	71,731	25%	35%	40%	0%
	roots&tubers or starchy roots	7%	192,306	69%	0%	30%	0%
	stimulat	3%	77,181	0%	19%	79%	2%
	sugar crops	0%	5,182	0%	35%	65%	0%
	vegetables	6%	181,530	38%	38%	19%	5%
	Guinea Total		2,917,476	52%	8%	38%	3%
Mali	cereals	70%	3,225,266	37%	19%	35%	9%
	fibres	12%	529,414	0%	35%	65%	0%
	fruits	1%	63,892	1%	0%	99%	0%
	oilcrops	8%	354,271	30%	15%	54%	1%
	others	0%	18,939	20%	40%	40%	0%
	pulses	7%	303,061	70%	0%	30%	0%
	roots&tubers or starchy roots	0%	17,682	58%	5%	37%	0%
	stimulat	0%	975	0%	0%	100%	0%
	sugar crops	0%	4,649	0%	0%	0%	100%
	vegetables	1%	63,032	40%	40%	20%	0%
	Mali Total		4,581,181	34%	19%	40%	7%
Mauritania	cereals	63%	213,304	81%	0%	10%	9%
	fibres	0%	44	0%	36%	64%	0%
	fruits	3%	9,463	2%	3%	96%	0%
	oilcrops	2%	8,118	1%	12%	87%	0%
	others	0%	16	32%	4%	54%	9%
	pulses	30%	102,489	70%	0%	30%	0%
	roots&tubers or starchy roots	1%	3,098	77%	0%	23%	0%
	vegetables	0%	1,606	17%	18%	8%	57%
	Mauritania Total		338,138	73%	0%	20%	6%
Senegal	cereals	50%	1,132,877	47%	13%	32%	8%
	fibres	2%	42,024	0%	20%	80%	0%

DRAFT

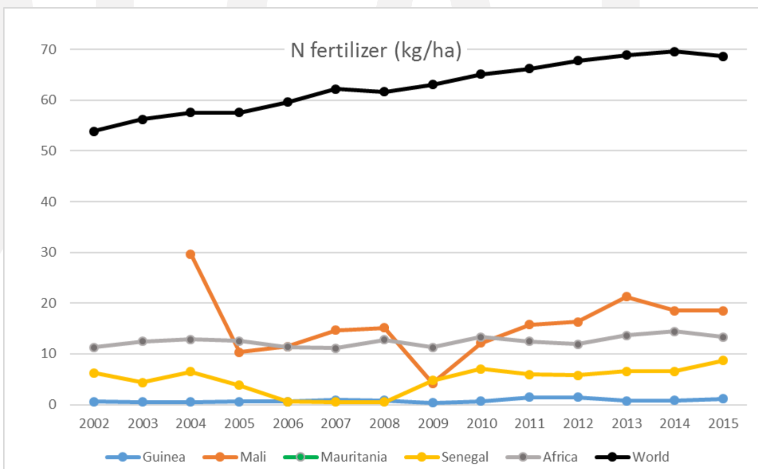
fruits	2%	38,350	1%	3%	96%	0%
oilcrops	34%	765,528	37%	22%	42%	0%
others	1%	20,499	19%	38%	38%	5%
pulses	9%	202,049	70%	0%	30%	0%
roots&tubers or starchy roots	2%	36,412	89%	0%	10%	1%
stimulat	0%	0	0%	0%	100%	0%
sugar crops	0%	7,114	0%	0%	0%	100%
vegetables	1%	24,354	17%	17%	9%	57%
Senegal Total		2,269,205	44%	15%	36%	5%

Table 19. Agriculture production system for dominant crops at National scale.

DRAFT

4.2.3 Agricultural Input

Use of mineral and organic fertilization in the four countries is very limited as evident by data reported by FAO (FAO, 2018b) and showed in Figure 36 to Figure 40.



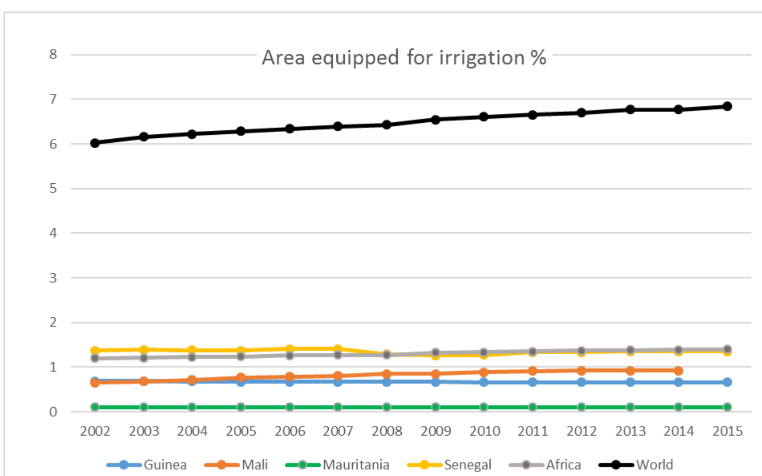


Figure 36. N fertilizer use at national level and area equipped for irrigation. Derived from FAOSTAT Agri-environmental Indicators.

Average fertilization rate are generally low if compared with World average (black line) and also with Africa average (grey line). Mali is the country with the highest fertilization rate.

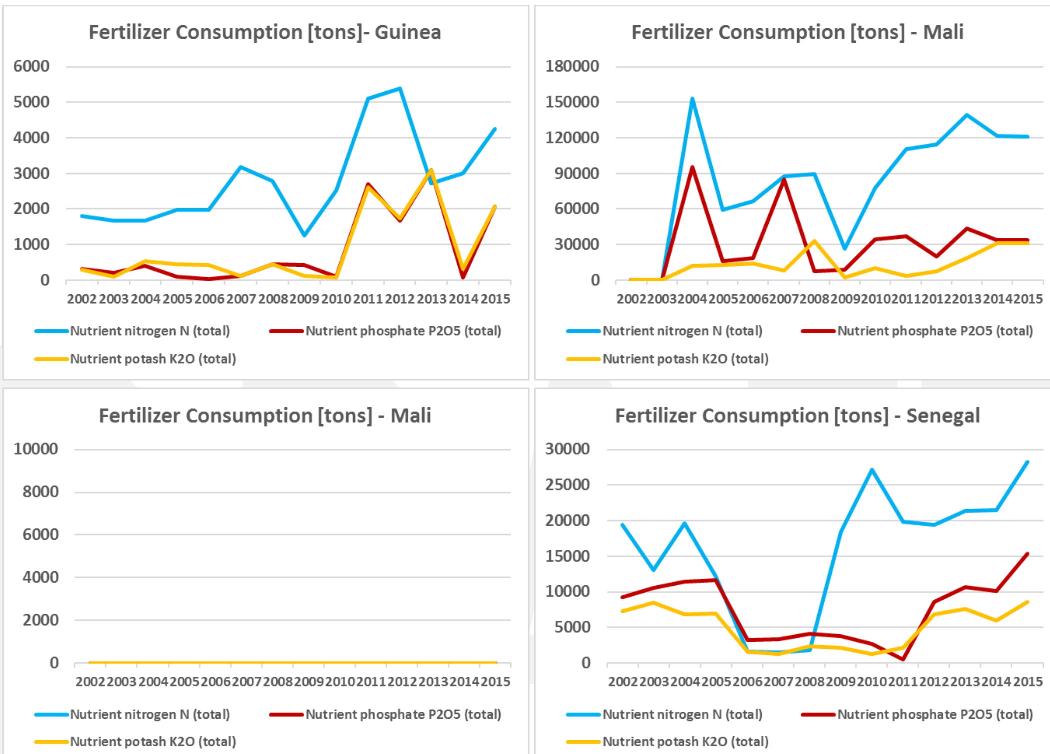


Figure 37. Total Nutrient Agricultural use in tons per year. Derived from FAOSTAT Agri-environmental Indicators.

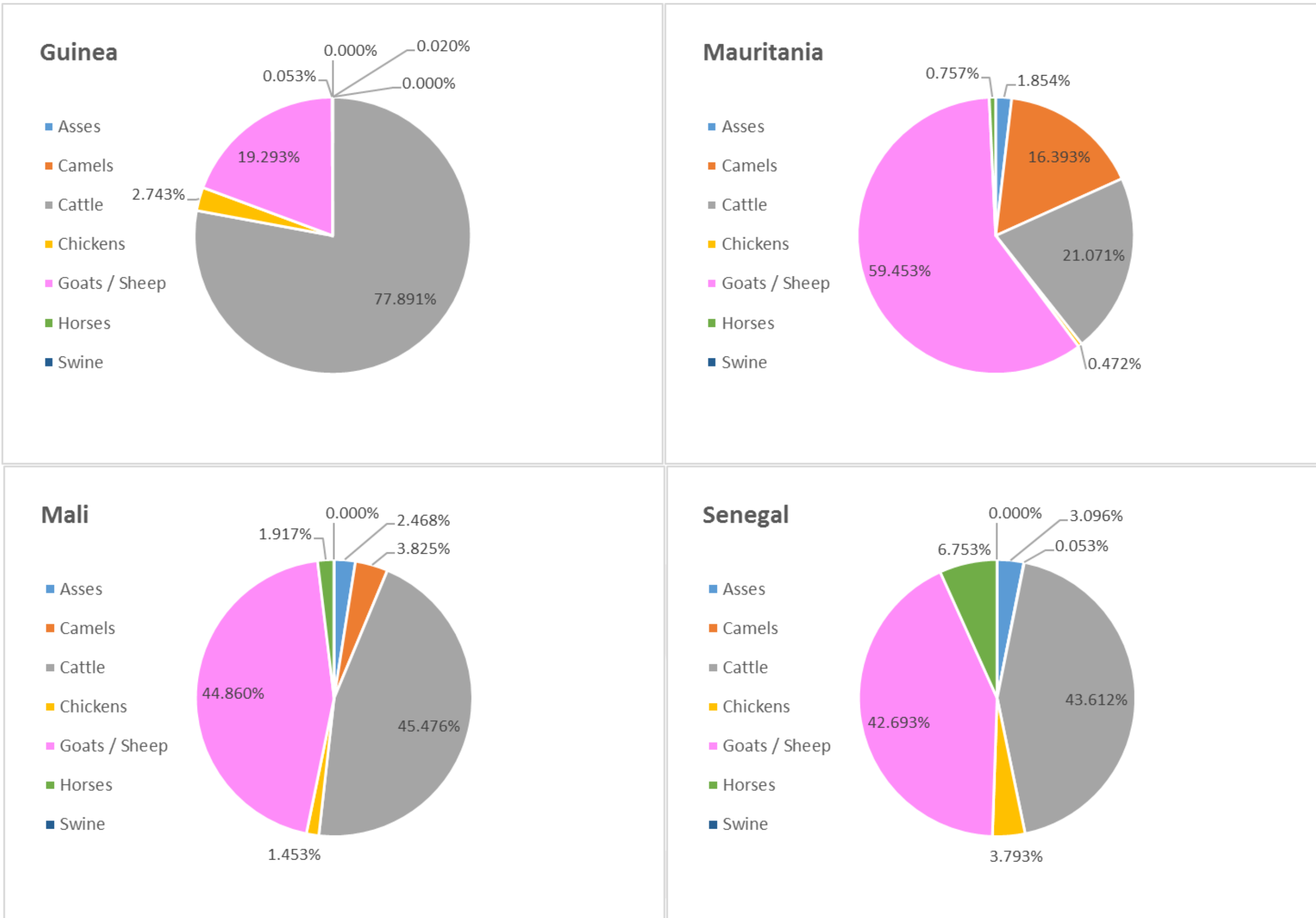


Figure 38.Source of manure left to pasture and forage areas (as percentage)

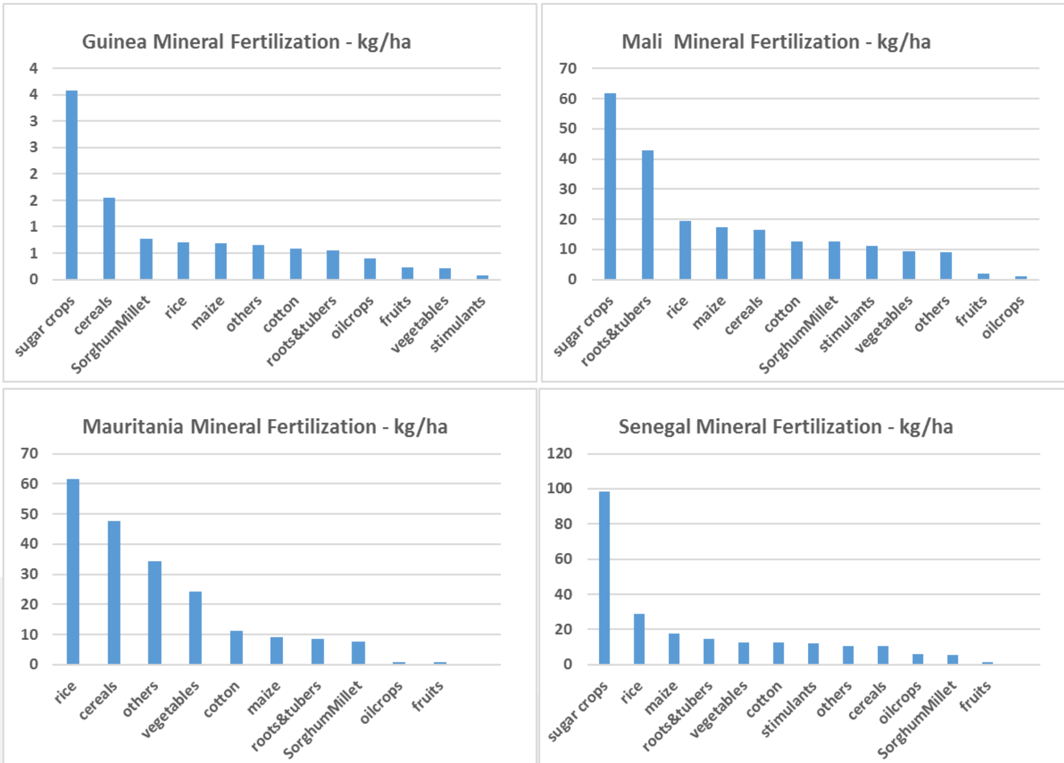


Figure 39. Average Fertilization Input by crop in the SRB for the 4 countries. Data estimated by SPAM harvested areas and FAOSTAT reported fertilization use. (Malagó et al., 2016)

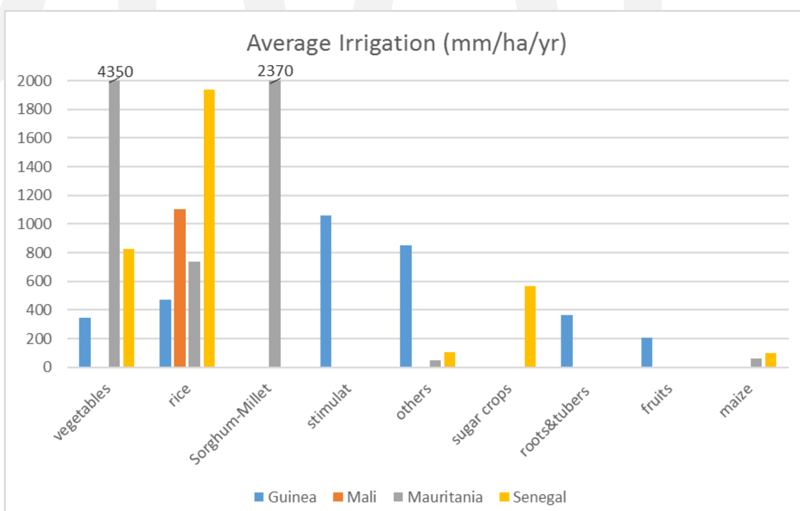


Figure 40. Average Irrigation Input by crop in the SRB for the 4 countries. Data estimated by SPAM irrigated areas and FAOSAT reported volumes.

DRAFT

4.2.4 Livestock

In general Livestock density in the SRB is not very high across different areas and countries. If we consider maximum cattle density it ranges from a minimum of 1.7 heads/km^2 in Mauritania (Tagant) region to a maximum of 463 heads/km^2 in Senegal (Louga) region. The average cattle density in the SRB is about 14 with a minimum in Mauritania (7.6 animals/km^2) and a maximum of 24.2 in Guinea.

Other important animals category in the SRB are goats, sheeps and poultry as reported in the

Table 20.

NAME_0	***NAME_1***	***Cattle***	***Goats***	***Sheep***	***Pigs***	***Poultry (1000)***
Guinea		3,653,898	1,418,118	1,125,506	70,561	16,059
Mali		7,691,591	12,412,977	8,737,573	72,401	30,694
Mauritania		1,578,340	4,951,096	8,908,350	414,098	3,963
Senegal		3,033,283	4,186,586	4,711,799	267,115	45,895
NAME_0	***NAME_1***	***Cattle***	***Goats***	***Sheep***	***Pigs***	***Poultry (1000)***
Guinea	Boké	589,321	197,340	148,635	10,301	2,198
Guinea	Conakry	19,565	2,751	1,035	241	29
Guinea	Faranah	338,246	215,598	165,632	8,923	2,292
Guinea	Kankan	614,887	432,774	347,862	21,643	4,616
Guinea	Kindia	760,879	131,952	122,743	6,507	1,589
Guinea	Labé	572,312	140,774	103,150	7,353	1,566
Guinea	Mamou	506,444	103,228	77,587	4,853	1,231
Guinea	Nzérékoré	252,240	193,698	158,859	10,736	2,538
Mali	Bamako	2,583	2,931	4,813	7	15
Mali	Gao	228,015	1,079,558	958,820	0	212
Mali	Kayes	1,209,102	1,138,815	658,738	1,053	2,901
Mali	Kidal	5,327	123,858	135,380	0	681
Mali	Koulikoro	1,304,699	1,881,675	1,221,665	10,960	4,167
Mali	Mopti	1,588,879	2,910,205	2,111,326	6,397	4,457
Mali	Ségou	1,313,001	2,286,775	1,615,595	29,437	5,185
Mali	Sikasso	1,481,534	1,023,195	649,599	24,531	12,746
Mali	Timbuktu	558,448	1,965,962	1,381,633	12	329
Mauritania	Adrar	48	825	41,216	150	125
Mauritania	Assaba	420,833	371,010	1,517,236	139,311	838
Mauritania	Brakna	8,030	82,253	159,579	96	274
Mauritania	Dakhlet Nouadhibou	0	0	0	409	33
Mauritania	Gorgol	134,335	307,477	972,980	990	243
Mauritania	Guidimaka	373,759	766,939	2,292,324	4,095	196

DRAFT

NAME_0	***NAME_1***	***Cattle***	***Goats***	***Sheep***	***Pigs***	***Poultry (1000)***
Mauritania	Hodh ech Chargui	219,139	2,200,059	1,103,507	995	462
Mauritania	Hodh el Gharbi	399,195	737,256	1,238,642	48,465	377
Mauritania	Inchiri	22	1,064	4,113	77	24
Mauritania	Nouakchott	77	364	25,590	24	714
Mauritania	Tagant	977	147,969	605,736	68,271	296
Mauritania	Tiris Zemmour	0	0	342	226	36
Mauritania	Trarza	21,919	335,875	947,079	150,984	345
Senegal	Dakar	3,779	19,812	9,893	0	712
Senegal	Diourbel	121,850	345,590	298,905	13,312	2,789
Senegal	Fatick	163,564	298,388	176,575	58,030	4,116
Senegal	Kaffrine	227,356	375,524	268,802	4,271	4,173
Senegal	Kaolack	128,535	227,524	181,768	6,309	2,507
Senegal	Kédougou	165,968	63,019	108,643	21	947
Senegal	Kolda	384,357	161,418	86,065	75,674	4,042
Senegal	Louga	523,451	765,064	1,201,633	35	3,918
Senegal	Matam	321,218	594,280	760,579	2,031	1,722
Senegal	Saint-Louis	124,532	305,525	402,248	253	1,719
Senegal	Sédhiou	221,939	192,256	211,864	86,176	3,423
Senegal	Tambacounda	452,431	395,714	301,938	141	3,943
Senegal	Thiès	97,572	315,929	217,593	17,743	4,922
Senegal	Ziguinchor	96,724	126,538	485,286	3,113	6,962

Table 20. Livestock heads by type, (Robinson et al., 2014) *.*

4.2.5 Food security

As reflected in Sustainable Development Goal 2 (SDG 2), one of the greatest challenges the Africa faces is how to ensure that a growing global population - projected to rise to around 2.5 billion by 2050 (+109% of 2015) – has enough food to meet their nutritional needs.

Expected population growth in the four countries belonging to SRB is reported in

Figure 41 (United Nations, 2017). Annual growth rate of total population in the 4 countries is about 2.4% and specifically 2.3 in Guinea, 2.7 in Mali, 2.2 in Mauritania and 2.4% in Senegal (period 2015-2050, 35 years). To feed another 65 million people in 2050, food production will need to increase by 50 percent globally.

Country	Total population, both sexes combined (milions)					
	2015	2018	2020	2025	2030	2050
Guinea	12.1	13.1	13.8	15.6	17.6	26.9
Mali	17.5	19.1	20.3	23.5	27.1	44.0
Mauritania	4.2	4.5	4.8	5.4	6.1	9.0
Senegal	15.0	16.3	17.2	19.6	22.1	34.0
Total	49	53	56	64	73	114

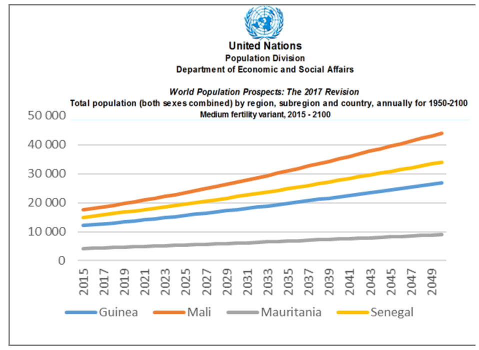


Figure 41. Population prospects from 2015 to 2050.

Currently, the linkage between food security and agriculture is particularly strong in SRB countries as population diet is very much dependent on agricultural food commodities such as cereals, roots and tubers: indeed share of Dietary Energy Supply derived from cereals, roots and tubers is 52% for Mauritania, about 60% for Guinea and Senegal and 67% for Mali (Data for 2011-2013, (FAO, 2018c)).

Food supply for each item food is reported in Figure 42.

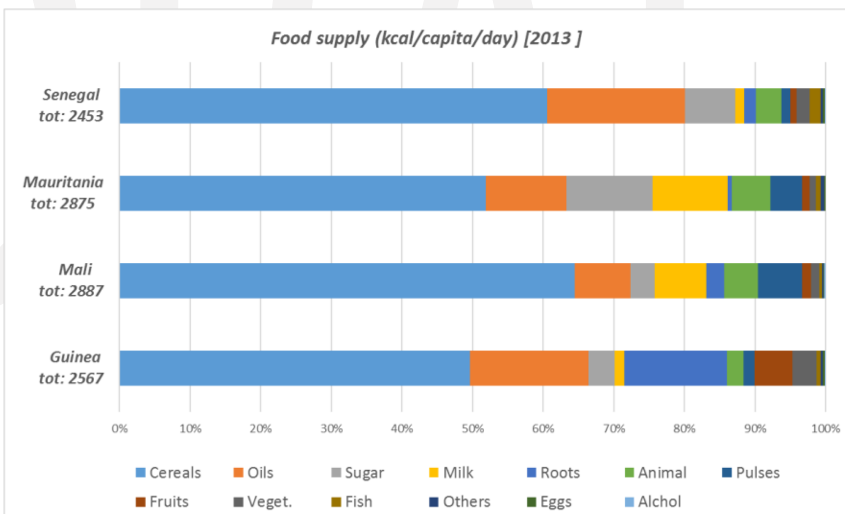
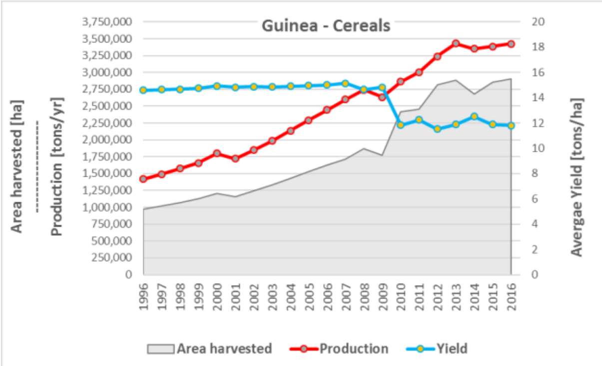
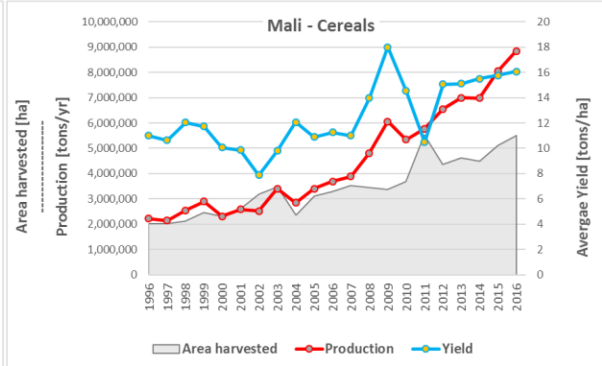
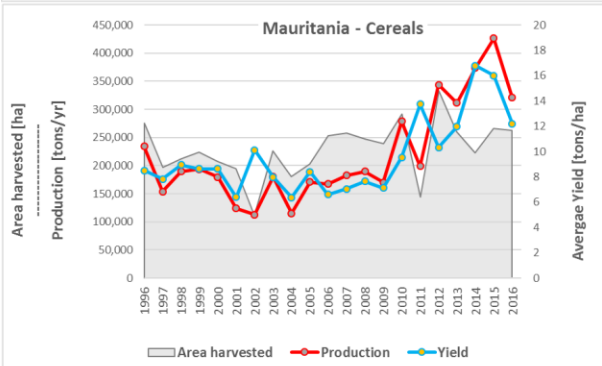


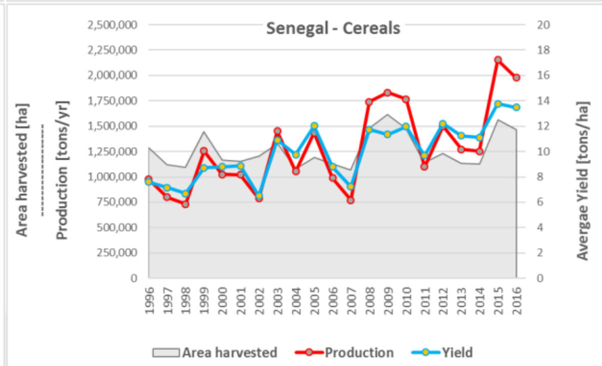
Figure 42. Food supply per capita for different food items, (FAO, 2018b).

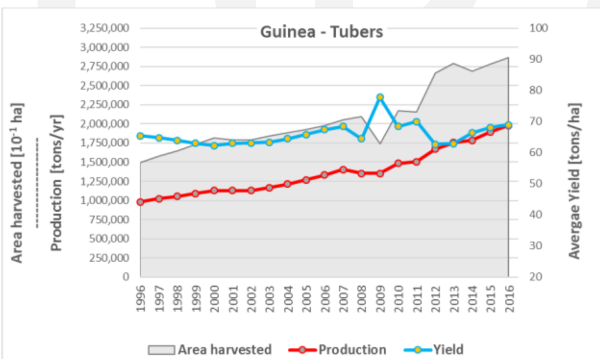
DRAFT

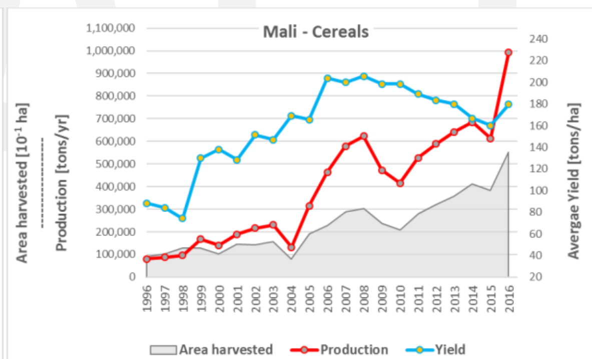

Guinea - Cereals
Area harvested [ha]
Production [tons/yr]
Avergae Yield [tons/ha]
Area harvested
Production
Yield

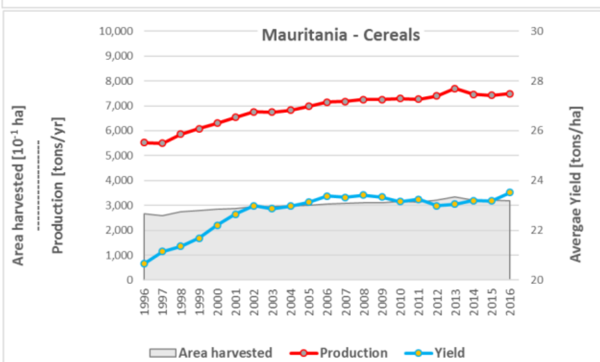

Mali - Cereals
Area harvested [ha]
Production [tons/yr]
Avergae Yield [tons/ha]
Area harvested
Production
Yield

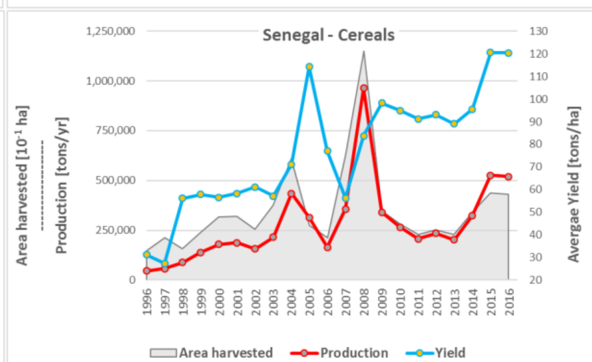

Mauritania - Cereals
Area harvested [ha]
Production [tons/yr]
Avergae Yield [tons/ha]
Area harvested
Production
Yield


Senegal - Cereals
Area harvested [ha]
Production [tons/yr]
Avergae Yield [tons/ha]
Area harvested
Production
Yield


Guinea - Tubers
Area harvested [10⁻¹ ha]
Production [tons/yr]
Avergae Yield [tons/ha]
Area harvested
Production
Yield


Mali - Cereals
Area harvested [10⁻¹ ha]
Production [tons/yr]
Avergae Yield [tons/ha]
Area harvested
Production
Yield


Mauritania - Cereals
Area harvested [10⁻¹ ha]
Production [tons/yr]
Avergae Yield [tons/ha]
Area harvested
Production
Yield


Senegal - Cereals
Area harvested [10⁻¹ ha]
Production [tons/yr]
Avergae Yield [tons/ha]
Area harvested
Production
Yield

Country	Food group	Food supply quantity (kg/capita/yr)	Pop [2017]	Total Need	Total Production	Self sufficency Ratio [1]
		kg/capita/yr	total	tons/yr	tons/yr	
Guinea	*Cereals*	134.82	12,717,176	1,714,530	3,425,886	**100%**
Guinea	*Tubers - Roots*	132.3	12,717,176	1,682,482	1,978,287	**18%**
Guinea	*Pulses*	4.19	12,717,176	53,285	58,400	**10%**
Guinea	*Vegetables*	49.37	12,717,176	627,847	555,698	**-13%**
Guinea	*Fruit*	86.68	12,717,176	1,102,325	1,275,456	**16%**
Mali	*Cereals*	214.94	18,541,980	3,985,413	8,849,690	**122%**
Mali	*Tubers - Roots*	29.27	18,541,980	542,724	993,189	**83%**
Mali	*Pulses*	18.77	18,541,980	348,033	352,028	**1%**
Mali	*Vegetables*	56.59	18,541,980	1,049,291	1,748,926	**67%**
Mali	*Fruit*	28.7	18,541,980	532,155	1,385,850	**160%**
Mauritania	*Cereals*	172.11	4,420,184	760,758	320,644	**-137%**
Mauritania	*Tubers - Roots*	8.11	4,420,184	35,848	7,489	**-379%**
Mauritania	*Pulses*	13.79	4,420,184	60,954	52,145	**-17%**
Mauritania	*Vegetables*	34.05	4,420,184	150,507	4,540	**-3215%**
Mauritania	*Fruit*	11.35	4,420,184	50,169	26,125	**-92%**
Senegal	*Cereals*	175.71	15,850,567	2,785,103	1,977,006	**-41%**
Senegal	*Tubers - Roots*	16.16	15,850,567	256,145	519,656	**103%**
Senegal	*Pulses*	3.24	15,850,567	51,356	61,521	**20%**
Senegal	*Vegetables*	54.38	15,850,567	861,954	741,012	**-16%**
Senegal	*Fruit*	21.65	15,850,567	343,165	512,951	**49%**

[1] Calculate as Indicator=IF(TotalNeed>TotalProduction THEN 1-TotalNeed/TotalProduction ELSE (1-TotalProduction/TotalNeed)*-1)

Positive percentages means that production is higher than need, negative means national production is not enough and Country need to import food to satisfy demand. This assuming all production can be used for local needs

Figure 43. Food supply, total production and total need comparison. Analysis at national level for most important crops for diet and agricultural production.

In the context of project an analysis of food self-sufficiency will be assessed by integrating results from crop modelling and social data. As these data (and models) are not yet available a first exploratory assessment has been implemented by considering global data at National scale. This analysis is not tailored on the River scale and doesn't take into account important factors (such as post harvest losses, transport of good, import and exports, etc.) but anyway give a first picture of the production capacity of each countries versus food demand.

Current crop yields production are only partially meeting current food demand in the 4 countries: for example the comparison of food supply and food demand (considering population in 2017) is reported in Figure 43: Mauritania is the country with the highest negative balances for basically all the crop items. Senegal has some negative balances for cereals and vegetables and also pulses and fruits and close to 0 (considering no loss is considered, and even no market export). Vegetables negative balance is also present in Guinea and for pulses it is very close to 0 for Mali. This is clearly reflected also in the total quantities of food items imported: for example in Mauritania imported cereals account for about 160% of total cereals production, and even more (500-700%) for fruit/vegetables and tuber (Table 21).

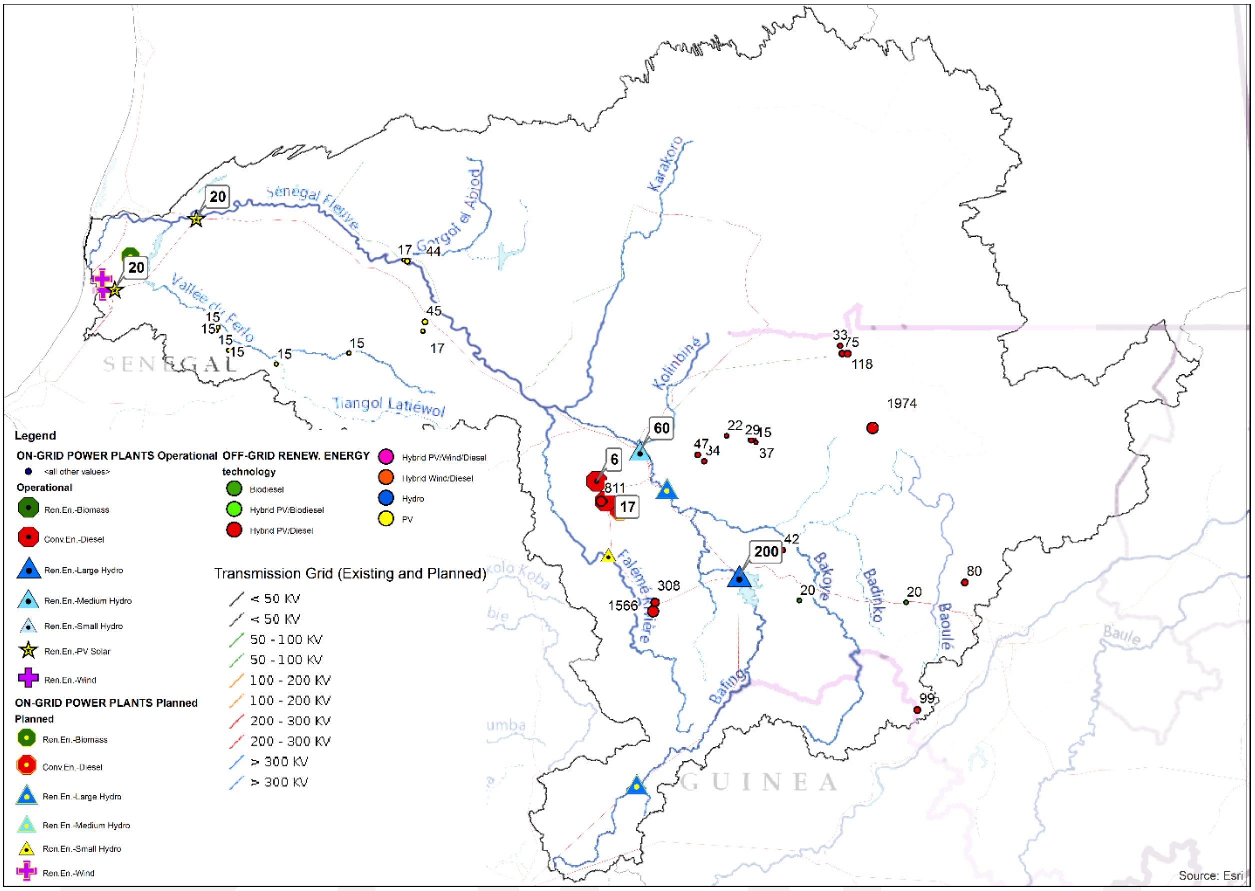
	Item	***Production***	***Export***	***Import***	***Imp/prod***
Guinea	*Cereals*	3,425,886	4,399	993,043	29%
Mali		8,849,690	6,779	567,667	6%

	Item	Production	Export	Import	Imp/prod
Mauritania		320,644		503,348	157%
Senegal		1,977,006	153,985	1,804,870	91%
Guinea	*Pulses*	58400		146	0%
Mali		352028	1709	4980	1%
Mauritania		52145		2365	5%
Senegal		61521	1429	12459	20%
Guinea	*Fruit/Veget.*	1831154	38816	72964	4%
Mali		3134776	75724	144693	5%
Mauritania		30665	476	205342	670%
Senegal		1253963	100245	372893	30%
Guinea	*Tubers*	1978287	5	2442	0%
Mali		993189	20980	30894	3%
Mauritania		7489		37784	505%
Senegal		519656	4538	83270	16%

Table 21. Production vs Import and Export quantities in 2016 in the 4 countries of SRB as reported by FAOSTAT (FAO, 2018b)

DRAFT

4.3 ENERGY SECTOR



Power plants and distribution networks in the Senegal River Basin (data modified from Ecowrex, 2018).

4.3.1 Main Indicators

Country	Access to electricity			Access to clean fuels and technologies for cooking	Renewable energy consumption	Renewable electricity output	Electric power consumption (kWh per capita)	Electricity Production*	Electricity Consumption*	Electricity Production - SOURCE*		
	Total	Urban	Rural	Total						%		
	(% of sp. pop.)			(% of pop.)	(% of total final energy consumption)	(% of total final energy output		billion kWh	billion kWh	Fossil	Hydro electric	Other ren.
Guinea	33.5	82.2	6.9	1.2	76.3	78.8	79.0	1.0	0.9	50.0	49.7	
Mali	35.1	83.6	1.8	1.0	61.5	43.5	115.0	2.2	2.0	67.8	31.2	
Mauritania	41.7	81.0		46.6	32.2	13.4	295.0	1.2	1.1	63.8	23.5	16.7
Senegal	64.5	87.7	38.3	31.7	42.7	10.4	223.4961633	3.7	3.0	88.5	7.8	8.2
World Bank Indicators								*https://www.cia.gov/				

Figure 44. Energy Indicators.

4.3.2 SRB Country energy Profiles

4.3.2.1 Senegal

In 2017, Senegal had a population of 15.85 with a total consumption of about 190 kWh per capita.

Senegal's source for electricity generation is overwhelmingly diesel and gas, which both need to be imported. Power demand has been growing throughout the last decade and it is expected to increase further in the next few years. Installation of new coal and diesel generation and exploitation of newly discovered offshore gas reserves is foreseen to keep up with rising demand. In addition, there is political will to have 15% of generation capacity from renewables by 2020 (RECP, 2018).

Senegal's national electricity access rate of 55% is relatively high with over 90% in urban centres, but estimated to less than 30% in rural areas.

Rural electrification runs on a concessions program whereby ten distinct rural electrification concession areas can be awarded to bidders in a competitive tender. To date, six of the ten concessions have been awarded and three are up and running.

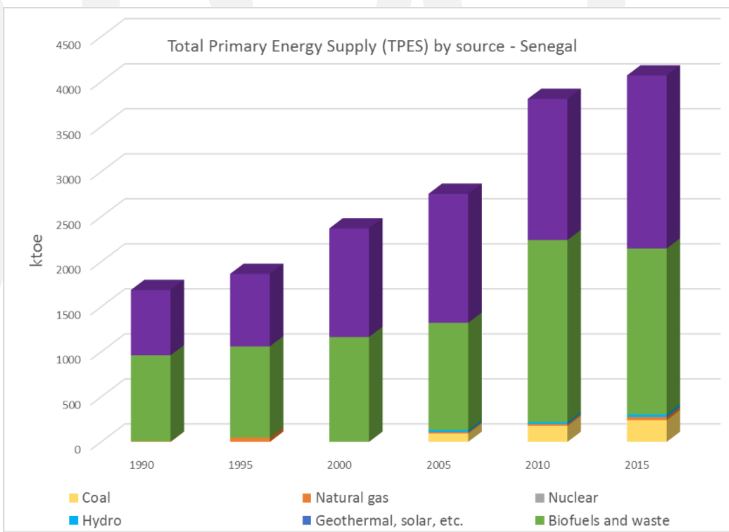


Figure 45. Total Primary Energy Supply. Source: IEA World Energy Balances 2017 - https://webstore.iea.org/world-energy-balances-2017

Energy consumption in Senegal is dominated by wood fuels (53% of total).

Traditional biomass accounts for 54% of Senegal's primary energy supply, oil products for 40% and other resources, including coal and hydro power, for the remaining 6%. All oil products are imported, making Senegal's trade balance very vulnerable to oil price volatility. The only renewable-based electricity injected into the grid is from the Manantali hydro power plant in Mali, as part of the Western African Power Pool project.

Hydro

Senegal has about 3 billion cubic meters per year of renewable groundwater resources, excluding those groundwater resources that overlap with surface water. Total water withdrawals in 1987 were 1.4 billion cubic meters, of which 92% is for agriculture, 3% for industry and 5% for domestic use. The Senegal River represents a significant hydroelectric potential estimated at 1,200 MW and partially exploited at Manantali plant (200 MW) commissioned in 2002, providing electricity to Senegal, Mali and Mauritania via a 225 KV interconnection line.

For Mali, Mauritania, Guinea data for energy sector still need to be harmonized.

4.3.3 Biomass Energy source and its health impacts

Although there are no specific studies in the SRB, it has been sufficiently demonstrated, that the use of traditional stoves (usually open cooking fires), which is still the most prevalent way of cooking in the developing countries, bares risks associated to human health and the environment (inefficiency/deforestation/erosion, etc.) (Arthur et al. 2010: Agrawal and Yamamoto 2015).

Indoor open fires are associated with an increase of respiratory infections, including pneumonia, tuberculosis and chronic obstructive pulmonary disease, low birthweight, cataracts, cardiovascular events, and all-cause mortality both in adults and children.

According to WHO, an estimated 4.3 million people a year die prematurely from illness attributable to the household air pollution caused by the inefficient use of solid fuels (Accinelli et al 2014, from 2012 data). The high prevalence of these diseases in the four SRB countries has been evidenced by the WHO statistics discussed above.

Firewood still plays an important role in the national energy demand. The 2001 assessment revealed a share of 96 % in Mali, 20% in Mauritania, 80% in and Guinea 67 % in Senegal (OMVS 2007)

However, there is a big potential of mitigation. It has been demonstrated, that the implementation and exclusive utilization of improved kitchen stoves improves a series of health implications, baring the side effect that improved cook stoves impact on households' economy, deforestation and global climate change. (Accinelli et al 2014)

A study in China found that adoption of improved cookstoves reduced fuel wood consumption, wood collection time, and tree felling by 40.1, 38.2 and 23.7%, respectively (De Wan et al. 2013).

Cooking on open fires in bad ventilated kitchens is a serious health issue in the SRB.

Moreover, fire wood acquisition plays an important households' economy, and inefficient fuel use impacts upon deforestation, erosion, biodiversity, greenhouse gas emissions, etc.

Mitigation of the related health, environmental and socioeconomic is suggested by employing cleaner and more efficient cook stoves, a strategy, which has proven success in many developing countries.

DRAFT

5 Conclusions

This report is reporting a summary of the analysis of literature and data availability on the Senegal River basin. This Report is currently based on literature review and open access data and it will be updated as the local data to be collected by project partners will be made available (February 2019).

The elaborated chapters provides an analysis of the key issues in terms of environmental quality (with special emphasis on water quality) in the SRB. It shall serve to set priorities for the research and training aspects as well as related mitigation concepts concerned within the Water Energy Agriculture Nexus of the WEFE Senegal project

The analysis is done using:

- Country based health statistics released by the World Health Organization (WHO), with special emphasis on environmental health stressors as a starting point
- Country based trade statistics to identify sectors, with presumably impact water quality
- Other databases on industrial activities
- Scientific literature (and data provided by OMVS) about water quality in the SRB in comparison to existing environmental quality standards (EQS).
- Free Open Access Data

This report has to be considered as an ongoing working document as it will be updated and populated when local data will be available (local data to be delivered by first months of 2019).

DRAFT

References

WHO statistics

Senegal: Country health profile, Geneva 2012.
http://www.who.int/gho/countries/sen.pdf?ua=1

Senegal: Country profile of Environmental Burden of Disease. Public Health and the Environment. Geneva 2009.
http://www.who.int/quantifying_ehimpacts/national/countryprofile/senegal.pdf?ua=1

Senegal: Country profile Malaria, Geneva 2016.
http://www.who.int/malaria/publications/country-profiles/profile_sen_en.pdf?ua=1

Senegal: urban health profile.
http://www.who.int/kobe_centre/measuring/urban_health_observatory/senegal.pdf

Mali: Country health profile, Geneva 2012: http://www.who.int/gho/countries/mli.pdf

Mali: Country profile of Environmental Burden of Disease. Public Health and the Environment. Geneva 2009.
http://www.who.int/quantifying_ehimpacts/national/countryprofile/mali.pdf?ua=1

Mali: Country profile Malaria, Geneva 2016.
http://www.who.int/malaria/publications/country-profiles/profile_mli_en.pdf?ua=1

Mali: urban health profile, Geneva 2014.
http://www.who.int/kobe_centre/measuring/urban_health_observatory/mali.pdf

Mauritania: Country health profile, Geneva 2012. http://www.who.int/gho/countries/mrt.pdf

Mauritania: Country profile of Environmental Burden of Disease. Public Health and the Environment. Geneva 2009.
http://www.who.int/quantifying_ehimpacts/national/countryprofile/mauritania.pdf?ua=1

Mauritania: Country profile Malaria, Geneva 2016.
http://www.who.int/malaria/publications/country-profiles/profile_mrt_en.pdf?ua=1

Mauritania: urban health profile.
http://www.who.int/kobe_centre/measuring/urban_health_observatory/mauritania.pdf

Guinea: Country health profile, Geneva 2012.
http://www.who.int/gho/countries/gin.pdf?ua=1

Guinea: Country profile of Environmental Burden of Disease. Public Health and the Environment. Geneva 2009.
http://www.who.int/quantifying_ehimpacts/national/countryprofile/guinea.pdf?ua=1

Guinea: Country profile Malaria, Geneva 2016.
http://www.who.int/malaria/publications/country-profiles/profile_gin_en.pdf?ua=1

Guinea: urban health profile.
http://www.who.int/kobe_centre/measuring/urban_health_observatory/guinea.pdf

DRAFT

Swizerland, Country profile of Environmental Burden of Disease. Public Health and the Environment. Geneva 2009
http://www.who.int/quantifying_ehimpacts/national/countryprofile/switzerland.pdf?ua=1

Documentation

Adenowo AF, Oyinloye BE, Ogunyinka BI, Kappo AP (2015). Impact of human schistosomiasis in sub-Saharan Africa. Braz. J. Infect. Dis. 19(2):196–205

Accinelli RA, Llanos O, López LM et al. (2014). Adherence to reduced-polluting biomass fuel stoves improves respiratory and sleep symptoms in children. BMC Pediatrics 14:12

Agrawal S, Yamamoto S (2015). Effect of indoor air pollution from biomass and solid fuel combustion on symptoms of preeclampsia/eclampsia in Indian women. Indoor Air 25: 341–352

Anderson, K.A., Seck, D., Hobbie, K.A., Traore, A.N., McCartney, M.A., Ndaye, A., Forsberg, N.D., Haigh, T.A., Sower, G.J., 2014. Passive sampling devices enable capacity building and characterization of bioavailable pesticide along the Niger, Senegal and Bani Rivers of Africa. Philos. Trans. R. Soc. B Biol. Sci. 369, 20130110–20130110. https://doi.org/10.1098/rstb.2013.0110

Arthur MFSR, S. Zahran S, Buccini G (2010). On the adoption of electricity as a domestic source by Mozambican households. Energy Policy 38 7235-7249

Back, J.O., Rivett, M.O., Hinz, L.B., Mackay, N., Wanangwa, G.J., Phiri, O.L., Songola, C.E., Thomas, M.A.S., Kumwenda, S., Nhlema, M., Miller, A.V.M., Kalin, R.M., 2018. Risk assessment to groundwater of pit latrine rural sanitation policy in developing country settings. Sci. Total Environ. 613–614, 592–610. https://doi.org/10.1016/J.SCITOTENV.2017.09.071

Bruun, B., Aagaard-Hansen, J., 2008. The social context of schistosomiasis and its control. An introduction and annotated bibliography. WHO. https://doi.org/10.2471/TDR.08.978

Ceccherini, G., Ameztoy, I., Hernández, C., Moreno, C., Ceccherini, G., Ameztoy, I., Hernández, C.P.R., Moreno, C.C., 2015. High-Resolution Precipitation Datasets in South America and West Africa based on Satellite-Derived Rainfall, Enhanced Vegetation Index and Digital Elevation Model. Remote Sens. 7, 6454–6488. https://doi.org/10.3390/rs70506454

Cheever, A.W., Macedonia, J.G., Mosimann, J.E., Cheever, E.A., 1994. Kinetics of egg production and egg excretion by Schistosoma mansoni and S. japonicum in mice infected with a single pair of worms. Am. J. Trop. Med. Hyg. 50, 281–95.

Cogels, F.-X., Fraboulet-Jussila, S., Varis, O., 2001. Multipurpose use and water quality challenges in Lac de Guiers (Senegal). Water Sci. Technol. 44, 35–46. https://doi.org/10.2166/wst.2001.0335

Degeorges, A., Reilly, B.K., 2006. Dams and large scale irrigation on the Senegal River: Impacts on man and the environment. Int. J. Environ. Stud. 63, 633–644. https://doi.org/10.1080/00207230600963296

DeWan A, Green K, Li X, Hayden D (2013). Using social marketing tools to increase fuel-efficient stove adoption for conservation of the golden snub-nosed monkey, Gansu

DRAFT

Province, China. Conserv .Evid. 10 32-36

Dighe, N.S., Pattan, S.R., Bhawar, S.B., Thakur, D., Gaware, V.M., Hole, M.B., Laware, R.B., 2009. A REVIEW ON: SNAIL FEVER, Pharmacologyonline.

Ecowrex, 2018. ECOWAS observatory for Renewable Energy and Energy Efficiency [WWW Document]. URL http://www.ecowrex.org/page/maps (accessed 9.14.18).

El Safadi, D., Gaayeb, L., Meloni, D., Cian, A., Poirier, P., Wawrzyniak, I., Delbac, F., Dabboussi, F., Delhaes, L., Seck, M., Hamze, M., Riveau, G., Viscogliosi, E., 2014. Children of Senegal River Basin show the highest prevalence of Blastocystissp. ever observed worldwide. BMC Infect. Dis. 14, 164. https://doi.org/10.1186/1471-2334-14-164

ESA, 2017. ESA CCI-LC database. Source: Land Cover project. © ESA Climate Change Initiative - Land Cover led by UCLouvain (2017).

ESA, 2014. ESA—European Space Agency, 2014. CCI Land Cover Product User Guide version 2.4, ESA CCI LC project.

European Commission, 2008. DIRECTIVE 2008/105/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council (OJ L 348, 24.12.2008, p. 84).

FAO, 2018a. Food and agriculture data [WWW Document]. URL http://www.fao.org/faostat/en/ (accessed 7.18.18).

FAO, 2018b. FAO, Food security indicators. [WWW Document]. URL http://www.fao.org/economic/ess/ess-fs/en/ (accessed 8.1.18).

FAO (2018) http://www.fao.org/in-action/aicca/country-activities/mali/irrigation-technologies/en/

FAO, 2016. AQUASTAT website. Food and Agriculture Organization of the United Nations (FAO). [WWW Document]. URL http://www.fao.org/nr/water/aquastat/main/index.stm (accessed 7.16.18).

FAO, 2014. Walking the Nexus Talk: Assessing the Water-Energy-Food Nexus in the Context of the Sustainable Energy for All Initiative. Rome, Italy.

FAO, 2011a. The State of the World's Land and Water Resources for Food and Agriculture, Food and Agriculture Organization of the United Nations; London: Earthscan. https://doi.org/10.4324/9780203142837

FAO, 2011b. Energy-smart food for people and climate - ISSUE PAPER.

Fritz, S., See, L., Mccallum, I., You, L., Bun, A., Moltchanova, E., Duerauer, M., Albrecht, F., Schill, C., Perger, C., Havlik, P., Mosnier, A., Thornton, P., Wood-Sichra, U., Herrero, M., Becker-Reshef, I., Justice, C., Hansen, M., Gong, P., Abdel Aziz, S., Cipriani, A., Cumani, R., Cecchi, G., Conchedda, G., Ferreira, S., Gomez, A., Haffani, M., Kayitakire, F., Malanding, J., Mueller, R., Newby, T., Nonguierma, A., Olusegun, A., Ortner, S., Rajak, D.R., Rocha, J., Schepaschenko, D., Schepaschenko, M., Terekhov, A., Tiangwa, A., Vancutsem, C., Vintrou, E., Wenbin, W., van der Velde, M., Dunwoody, A., Kraxner, F., Obersteiner, M., 2015. Mapping global cropland and field size. Glob. Chang. Biol. 21, 1980–1992. https://doi.org/10.1111/gcb.12838

DRAFT

GADM, 2018. GADM maps and data. V 3.6 [WWW Document]. URL https://gadm.org/index.html (accessed 8.28.18).

Gerson, J.R., Driscoll, C.T., Hsu-Kim, H., Bernhardt, E.S., 2018. Senegalese artisanal gold mining leads to elevated total mercury and methylmercury concentrations in soils, sediments, and rivers. Elem Sci Anth 6, 11. https://doi.org/10.1525/elementa.274

Jepson, P.C., Guzy, M., Blaustein, K., Sow, M., Sarr, M., Mineau, P., Kegley, S., 2014. Measuring pesticide ecological and health risks in West African agriculture to establish an enabling environment for sustainable intensification. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 369, 20130491. https://doi.org/10.1098/rstb.2013.0491

JRC, CIESIN, 2015. GHS population grid, derived from GPW4, multitemporal (1975, 1990, 2000, 2015). European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/jrc-ghsl-ghs_pop_gpw4_globe_r2015a.

Kapepula, K.-M., Colson, G., Sabri, K., Thonart, P., 2007. A multiple criteria analysis for household solid waste management in the urban community of Dakar. Waste Manag. 27, 1690–1705. https://doi.org/10.1016/J.WASMAN.2006.07.009

Lehner, B., Verdin, K., Jarvis, A., 2008. New Global Hydrography Derived From Spaceborne Elevation Data. Eos, Trans. Am. Geophys. Union 89, 93. https://doi.org/10.1029/2008EO100001

Malagó, A., Bouraoui, F., Ferrario, I., Grizzetti, B., 2016. Scenarios of Nutrient Management for Cleaner Seas: Application on the Mediterranean. Luxembourg: https://doi.org/doi:10.2760/51281

Martínez-Santos, P., Martín-Loeches, M., García-Castro, N., Solera, D., Díaz-Alcaide, S., Montero, E., García-Rincón, J., 2017. A survey of domestic wells and pit latrines in rural settlements of Mali: Implications of on-site sanitation on the quality of water supplies. Int. J. Hyg. Environ. Health 220, 1179–1189. https://doi.org/10.1016/J.IJHEH.2017.08.001

Mbaye, S., 2017. La biosecurite face a l'usage des pesticides agricoles au Lac der Guiers: Etude de cas de la commune de Ngnith. Memoire de Master. Universite Gaston Berger de Saint Louis, Anne academique 2016-2017.

N'Djaye, D., El Kory, M., Ould Kankou, M.O.S.A., 2013. Water quality assessment of Senegal River in Mauritania by turbidity and chemical parameters analysis during rainy season. Issues Biol. Sci. Pharm. Res. 1.

Ndao, O., 2018. Senegal - AFRICA- P161477- Senegal Municipal Solid Waste Management Project - Procurement Plan.

Nweke, O.C., Sanders III, W.H., 2009. Modern Environmental Health Hazards: A Public Health Issue of Increasing Significance in Africa. Environ. Health Perspect. 117, 863–870. https://doi.org/10.1289/ehp.0800126

OMVS, 2017. Plan d'action regional pour l'amelioration des cultures irrigues du bassin du fleuve Senegal. Dakar.

OMVS (2007). Analyse Diagnostique Environnementale Transfrontalière du Bassin du Fleuve Sénégal, Syntherse Regional, Synthèse Régionale, Juin 2007 http://www.sadieau.org/document/analyse-diagnostique-environnementale-transfrontaliere-bassin-fleuve-senegal-synthese?language=fr

OMVS, 2003. Chapter 20. Senegal River Basin, Guinea, Mali, Mauritania, Senegal., in:

UNESCO (Ed.), Water Fo Peaple Water for Life. The United Nations World Water Development Report. UNESCO Publishing, pp. 447–463.

Ould Med Fadel K, Taouil H, Elamza S et al. (2017). Physicochemical water from the right bank of the Senegal River in Mauritania. Journal of Materials and Environmental Sciences (JMES), 8, 2956-2966.

Persaud, A.W., Telmer, K.H., Costa, M., Moore, M.-L., 2017. Artisanal and Small-Scale Gold Mining in Senegal: Livelihoods, Customary Authority, and Formalization. Soc. Nat. Resour. 30, 980–993. https://doi.org/10.1080/08941920.2016.1273417

RECP, 2018. The Africa-EU Renewable Energy Cooperation Programme (RECP) [WWW Document]. URL https://www.africa-eu-renewables.org/

Robinson, T.P., Wint, G.R.W., Conchedda, G., Van Boeckel, T.P., Ercoli, V., Palamara, E., Cinardi, G., D'Aietti, L., Hay, S.I., Gilbert, M., 2014. Mapping the Global Distribution of Livestock. PLoS One 9, e96084. https://doi.org/10.1371/journal.pone.0096084

Sambe-Ba, B., Espié, E., Faye, M.E., Timbiné, L.G., Sembene, M., Gassama-Sow, A., 2013. Community-acquired diarrhea among children and adults in urban settings in Senegal: clinical, epidemiological and microbiological aspects. BMC Infect. Dis. 13, 580. https://doi.org/10.1186/1471-2334-13-580

Senabou Mbaye (2017). La biosecurite face a l'usage des pesticides agricoles au Lac der Guiers: Etude de cas de la commune de Ngnith. Memoire de Master, Universite Gaston Berger de Saint Louis, Anne academique 2016-2017)

Sokolow, S.H., Huttinger, E., Jouanard, N., Hsieh, M.H., Lafferty, K.D., Kuris, A.M., Riveau, G., Senghor, S., Thiam, C., N'Diaye, A., Faye, D.S., De Leo, G.A., 2015. Reduced transmission of human schistosomiasis after restoration of a native river prawn that preys on the snail intermediate host. Proc. Natl. Acad. Sci. U. S. A. 112, 9650–5. https://doi.org/10.1073/pnas.1502651112

Troussellier, M., Got, P., Bouvy, M., M'Boup, M., Arfi, R., Lebihan, F., Monfort, P., Corbin, D., Bernard, C., 2004. Water quality and health status of the Senegal River estuary. Mar. Pollut. Bull. 48, 852–862. https://doi.org/10.1016/J.MARPOLBUL.2003.10.028

United Nations, 2017. World Population Prospects: The 2017 Revision, DVD Edition.

US-EPA, 1992. Framework for Ecological Risk Assessment. EPA/630/R-92/001.

Varis O, Stucki V, Fraboulet-Jussila S (2006). UNDP Human Development Report. The Senegal River case. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.422.5430&rep=rep1&type=pdf

Veneam HD and Schiller EJ (1995). Water Resources Planning for the Senegal River Basin. Water International 20, 2 https://doi.org/10.1080/02508069508686451

WHO (2008). The social context of schistosomiasis and its control. An introduction and annotated bibliography by Birgitte Bruun and Jens Aagaard-Hansen. .http://www.who.int/tdr/publications/documents/social-context-schistosomiasis.pdf

WHO (1987). Global pollution and health results of related environmental monitoring. Global Environment Monitoring system, WHO, UNEP. 7

Worldbank (2007). Senegal Municipal Solid Waste Management Project (P161477) http://documents.worldbank.org/curated/pt/581531500995135875/pdf/ITM00184-

DRAFT

P161477-07-25-2017-1500995132357.pdf).

World Bank, 2018. World Development Indicators [WWW Document]. URL https://datacatalog.worldbank.org/dataset/world-development-indicators (accessed 7.7.18).

WWF, 2018. Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales [WWW Document]. URL http://www.hydrosheds.org/ (accessed 8.28.18)

Yang Y-Y, Wu H-N, Shen S-L et al. (2014). Environmental impacts caused by phosphate mining and ecological restoration: a case history in Kunming. China Nat. Hazards 74 755–770

You, L., Wood-Sichra, U., Fritz, S., Guo, Z., See, L., Koo, J., 2018. Spatial Production Allocation Model (SPAM) 2005 v3.2. [WWW Document]. URL http://mapspam.info. (accessed 6.27.18).

You, L., Wood-Sichra, U., Fritz, S., Guo, Z., See, L., Koo, J., 2017. Spatial Production Allocation Model (SPAM) 2005 v3.2. February 5, 2018.

You, L., Wood, S., Wood-Sichra, U., Wu, W., 2014. Generating global crop distribution maps: From census to grid. Agric. Syst. 127, 53–60. https://doi.org/10.1016/J.AGSY.2014.01.002

DRAFT

ANNEX I - LISTE DES DONNEES PUBLIQUES DISPONIBLES

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
National Elevation Dataset	USGS	Topography	elevation	http://ned.usgs.gov/	U.S. Geological Survey, Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD
Global Land Survey Digital Elevation Model (GLSDEM)	GLCF - Global Land Cover Facility	Topography	DEM	http://glcf.umiacs.umd.edu/data/	
ASTER Global Digital Elevation Map	ASTER GDEM Version 2	Topography	DEM	http://asterweb.jpl.nasa.gov/gdem.asp	
Hydrosheds River Network, Subabsin and River Basin limit	WWF - Hydrosheds	Topography	HydroSHEDS Drainage Basin and rivers from DTM at 30s	https://www.hydrosheds.org/page/hydrobasins	Lehner, B., Grill G. (2013): Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrological Processes, 27(15): 2171–2186. Data is available at www.hydrosheds.org.
Soil Survey Geographic Database (SSURGO)	Natural Resources Conservation Service	Soil	soil properties (structural and hydrological);	http://soils.usda.gov/survey/geography/ssurgo/	Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for [Survey Area, State]. Available online at http://soildatamart.nrcs.usda.gov . Accessed [month/day/year].

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
Digitial General Soil Map of the United States (STATSGO2)	Natural Resources Conservation Service	Soil	same variables as SSURGO, but covers everywhere in US at coarser resolution	http://soils.usda.gov/survey/geography/ssurgo/ description_statsgo2.html	Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. U.S. General Soil Map (STATSGO2). Available online at http://soildatamart.nrcs.usda.gov . Accessed [month/day/year]
Harmonized World Soil Database	IIASA - International Institute for Applied Systems Analysis (IIASA)	Soil	soil mapping units, soil propertie	http://www.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/SupplementaryData.html	Fischer, G., F. Nachtergaele, S. Prieler, H.T. van Velthuizen, L. Verelst, D. Wiberg, 2008. Global Agro-ecological Zones Assessment for Agriculture (GAEZ 2008). IIASA, Laxenburg, Austria and FAO, Rome, Italy.
CONUS-SOIL	Soil Information for Environmental Modeling and Ecosystem Management	Soil	soil properties, based on STATSGO data	http://www.soilinfo.psu.edu/index.cgi?soil_data&conus	Miller, D.A. and R.A. White, 1998: A Conterminous United States Multi-Layer Soil Characteristics Data Set for Regional Climate and Hydrology Modeling. Earth Interactions, 2. [Available on-line at http://EarthInteractions.org]
Global Country Boundaries	Administrative areas GADM v.2.0	Management	boundaries	http://www.gadm.org/	
Inland waters and infrastructures	Digital Chart of the World	Management	Rivers, canals, and lakes	http://www.diva-gis.org/	

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
DAMS_FAO_Aquastat	FAO	Management	DAMS	http://www.fao.org/nr/water/aquastat/dams/index.stm	FAO. 2016. ***AQUASTAT website*. Food and Agriculture Organization of the United Nations (FAO).**
The Digital Water Atlas	GWSP	Management	DAMS	http://atlas.gwsp.org/	GWSP IPO is sponsored by the Federal Ministry of Education and Research
A global map of Accessibility	JOINT RESEARCH CENTRE	Management	Travel time	http://forobs.jrc.ec.europa.eu/products/gam/description.php	Uchida, H. and Nelson, A. Agglomeration Index: Towards a New Measure of Urban Concentration. Background paper for the World Bank's World Development Report 2009.
LandScan Datasets	Oak Ridge National Laboratory	Management	Population	https://landscan.ornl.gov/	This product was made utilizing the LandScan (insert dataset year)™ High Resolution global Population Data Set copyrighted by UT-Battelle, LLC, operator of Oak Ridge National Laboratory under Contract No. DE-AC05-00OR22725 with the United States Department of Energy
GHSL datasets	JOINT RESEARCH CENTRE	Management	Population, Settlements, Built-Up presence, Built-Up Quality,	https://ghslsys.jrc.ec.europa.eu/datasets.php	Langhammer, P., Butchart, S. H. M. and Brooks, T. M. (2018) Key Biodiversity Areas. Encyclopedia of the Anthropocine. https://doi.org/10.1016/B978-0-12-809665-9.09829-3
Water Mask	GLCF - Global Land Cover Facility	LULC	water mask	http://glcf.umiacs.umd.edu/data/	
Harvested Area and Yield for 175 Crops year 2000	EarthStat - geographic data sets	LULC	harvested areas and yields	http://www.earthstat.org/harvested-area-yield-175-crops/	Monfreda, C., N. Ramankutty, and J. A. Foley (2008), Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000, Global Biogeochem. Cycles, 22, GB1022, doi: 10.1029/2007GB002947.
Cropland and Pasture Area in 2000	EarthStat - geographic data sets	LULC	Cropland and Pasture Area	http://www.earthstat.org/cropland-pasture-area-2000/	Ramankutty, N., A.T. Evan, C. Monfreda, and J.A. Foley (2008), Farming the planet: 1. Geographic distribution of global

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
					agricultural lands in the year 2000. Global Biogeochemical Cycles 22, GB1003, doi:10.1029/2007GB002952.
Climate Variation Effects on Crop Yields for Maize, Soybean, Rice, and Wheat	EarthStat - geographic data sets	LULC	Climate Variation Effects on Crop Yields for Maize, Soybean, Rice, and Wheat	http://www.earthstat.org/climate-variation-effects-crop-yields-maize-soybean-rice-wheat/	Ray DK, JS Gerber, GK MacDonald, PC West. 2015. Climate variation explains a third of global crop yield variability. Nature Communications. doi: 10.1038/ncomms6989
Croplands in West Africa	EarthStat - geographic data sets	LULC	LULC	http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html	
1992 Croplands Dataset	SAGE WISC - Center for Sustainability and the Global Environment at University of Wiconsin-Madison	LULC	croplands	https://nelson.wisc.edu/sage/data-and-models/1992-croplands/index.php	Ramankutty, N. and J.A. Foley (1998). Characterizing patterns of global land use: an analysis of global croplands data. Global Biogeochemical Cycles 12(4), 667-685
Global Potential Vegetation Dataset	SAGE WISC - Center for Sustainability and the Global Environmen	LULC	potential vegetation	https://nelson.wisc.edu/sage/data-and-models/1992-croplands/index.php	Global Potential Vegetation Dataset

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
	t at University of Wiconsin-Madison				
Crop Physical Area	MapSPAM - Spatial Production Allocation Model	LULC	physical area (20 crops)	http://mapspam.info/	You, L., S.Crespo, Z. Guo, J. Koo, W. Ojo, K. Sebastian, M.T. Tenorio, S. Wood, U. Wood-Sichra. Spatial Produciton Allocation Model (SPAM) 2000 Version 3 Release 2. http://MapSPAM.info
GlobCover Land Cover	GeoServer	LULC	land cover	http://geoserver.isciences.com:8080/geonetwork/srv/en/ metadata.show?id=228&currTab=simple	
UMD Land Cover Classification	Global Land Cover Facility	LULC	land cover	http://glcf.umiacs.umd.edu/data/landcover/	Hansen, M., R. DeFries, J.R.G. Townshend, and R. Sohlberg (1998), UMD Global Land Cover Classification, 1 Kilometer, 1.0, Department of Geography, University of Maryland, College Park, Maryland, 1981-1994.; Peer reviewed: Associated Peer-Reviewed Publication: Hansen, M., R. DeFries, J.R.G. Townshend, and R. Sohlberg (2000), Global land cover classification at 1km resolution using a decision tree classifier, International Journal of Remote Sensing. 21: 1331-1365.
Global Maps of Urban Extent	SAGE - Center for Sustainability and the Global Environment	LULC	urban extent	http://sage.wisc.edu/people/schneider/research/data.html	Schneider, A., Friedl, M., Potere, D., 2009, A new map of global urban extent from MODIS data. Environmental Research Letters, vol. 4, article 044003. ; Schneider, A., Friedl, M., Potere, D., 2010, Monitoring urban areas globally using MODIS 500m data: New methods and datasets based on 'urban ecoregions'. Remote Sensing of Environment, vol. 114, p. 1733-1746

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
Gridded Population of the World	GRUMP - Global Rural-Urban Mapping Project	LULC	periurban extent (derived from this data set according to section 2.1.1 in paper cited in NOTES)	http://sedac.ciesin.columbia.edu/gpw	CIESIN & CIAT (2009) Global Rural-Urban Mapping Project (GRUMP). Center for International Earth Science Information Network (CIESIN), Columbia University; and Centro Internacional de Agricultura Tropical (CIAT). Available at: http://sedac.ciesin.columbia.edu/gpw.
Spatial Production Maps	MapSPAM - Spatial Production Allocation Model	LULC	physical area (20 crops)	http://mapspam.info/	You, L., S.Crespo, Z. Guo, J. Koo, W. Ojo, K. Sebastian, M.T. Tenorio, S. Wood, U. Wood-Sichra. Spatial Produciton Allocation Model (SPAM) 2000 Version 3 Release 2. http://MapSPAM.info
C-CAP Regional Land Cover and Change	NOAA Coastal Change Analysis Program	LULC	land cover	https://coast.noaa.gov/digitalcoast/data/ccapregional.html	National Oceanic and Atmospheric Administration, Office for Coastal Management. "Name of Data Set." Coastal Change Analysis Program (C-CAP) Regional Land Cover. Charleston, SC: NOAA Office for Coastal Management. Accessed Month Year at www.coast.noaa.gov/ccapftp.
3D Land Mapping	NASA & Caltech - Jet Propulsion Laboratory	LULC	canopy height & biomass	http://lidarradar.jpl.nasa.gov/	
Amazon and Central Africa Forest Change Products	GLCF - Global Land Cover Facility	LULC	forest type / deforestation / degraded forest	http://glcf.umd.edu/data/	
Paraguay Forest Change Product	GLCF - Global Land	LULC	forest type / forest loss	http://glcf.umd.edu/data/	

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
	Cover Facility				
Coastal Marsh Health Index	GLCF - Global Land Cover Facility	LULC	coastal marsh health index	http://glcf.umd.edu/data/	
Vegetation Index (NDVI)	GLCF - Global Land Cover Facility	LULC	NDVI	http://glcf.umd.edu/data/	
MODIS Vegetation Continuous Fields	GLCF - Global Land Cover Facility	LULC	vegetation type	http://glcf.umd.edu/data/	
MODIS Vegetative Cover Conversion	GLCF - Global Land Cover Facility	LULC	land cover change	http://glcf.umd.edu/data/	
Tree Cover Continuous Fields	GLCF - Global Land Cover Facility	LULC	tree cover	http://glcf.umd.edu/data/	
Global Inventory Modeling and Mapping Studies (GIMMS)	GLCF - Global Land Cover Facility	LULC	NDVI	http://glcf.umd.edu/data/	
Global Production Efficiency Model (GloPEM)	GLCF - Global Land	LULC	NPP	http://glcf.umd.edu/data/	

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
	Cover Facility				
Burned Areas in Russia	GLCF - Global Land Cover Facility	LULC	burned area	http://glcf.umd.edu/data/	
National Biomass and Carbon Dataset	WHRC - Woods Hole Research Center	LULC	canopy height, above ground biomass, carbon stock	http://www.whrc.org/mapping/nbcd/index.html	Kellndorfer, J., Walker, W., LaPoint, E., Bishop, J., Cormier, T., Fiske, G., Hoppus, M., Kirsch, K., and Westfall, J. 2012. NACP Aboveground Biomass and Carbon Baseline Data (NBCD 2000), U.S.A., 2000. Data set. Available on-line at http://daac.ornl.gov from ORNL DAAC, Oak Ridge, Tennessee, U.S.A. http://dx.doi.org/10.3334/ORNLDAAC/1081.
Geo-Referenced Field Photos	Earth Observation - Geo-referenced field photo library	LULC	field images to use as land cover	http://www.eomf.ou.edu/photos/map/	
Corine Land Cover 2000 (CLC2000)	EEA - Corine Land Cover	LULC	corine land cover	http://www.eea.europa.eu/data-and-maps/data/ corine-land-cover-2000-clc2000-100-m-version-12-2009	
Global Lakes and Wetlands Database	GWSP Digital Water Atlas Project	LULC	location of lakes and wetlands	http://atlas.gwsp.org/index.php?option= com_content&task=view&id=183	Lehner B, Döll P (2004) Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology 296: 1–22.
Global Land Survey (GLS)	GLCF - Global Land Cover Facility	LULC	remote sensing imagery (no particular variable)	http://glcf.umiacs.umd.edu/data/gls/	

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
Land Cover Type Yearly L3 Globa0 500 m SIN Grid	Land Processes Distributed Active Archive Center	LULC	land cover type	https://lpdaac.usgs.gov/dataset_discovery/ modis/modis_products_table/mcd12q1	NASA LP DAAC, 2015
Global Land Use Database	SAGE WISC - Center for Sustainability and the Global Environment at University of Wiconsin-Madison	LULC	potential natural veg, cropland extent, grazing land extent, built-up land extent, 18 major crops extent, land suitability for cultivation	http://www.sage.wisc.edu/iamdata/	
Soil Survey Geographic Database (SSURGO)	Natural Resources Conservation Service	LULC	vegetation canopy cover and type(in Component Canopy Cover Table)	http://soils.usda.gov/survey/geography/ssurgo/	Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for [Survey Area, State]. Available online at http://soildatamart.nrcs.usda.gov . Accessed [month/day/year].
Land Use and Land Cover	Harmonized World Soil Database	LULC	land cover types (included different kinds of cultivated land)	http://webarchive.iiasa.ac.at/Research/LUC/ External-World-soil-database/HTML/ LandUseShares.html?sb=9	

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
Major River Basins of the World	GRDC - Global Runoff Data Centre	Hydrology	rivers, river basins, river discharge	http://www.bafg.de/GRDC/EN/Home/homepage_node.html	Global Runoff Data Centre (2007): Major River Basins of the World / Global Runoff Data Centre. Koblenz, Germany: Federal Institute of Hydrology (BfG).
Watershed Boundaries of GRDC Stations	GRDC - Global Runoff Data Centre	Hydrology	watersheds	http://www.bafg.de/GRDC/EN/Home/homepage_node.html	Lehner, B., Verdin, K., Jarvis, A. (2008): Hydrological data and maps based on Shuttle elevation derivatives. U.S. Geological Survey. - online resource: http://hydrosheds.cr.usgs.gov/
Hydro 1k	Hydro 1k	Hydrology		https://lta.cr.usgs.gov/HYDRO1K	Data available from the U.S. Geological Survey.
Water Depletion and WaterGap3 Basins	EarthStat - geographic data sets	Hydrology	available renewable water consumptively used by human activities	http://www.earthstat.org/water-depletion-watergap3-basins/	Brauman, KA, BD Richter, S Postel, M Malby, M Flörke. (2016) "Water Depletion: An improved metric for incorporating seasonal and dry-year water scarcity into water risk assessments." Elementa: Science of the Anthropocene. Doi: http://doi.org/10.12952/journal.elementa.000083
Crop Allocation to Food, Feed, Nonfood	EarthStat - geographic data sets	Food	Total kilocalories produced for usage as food, feed and nonfood	http://www.earthstat.org/crop-allocation-food-feed-nonfood/	Cassidy, E. S., West, P. C., Gerber, J. S., & Foley, J. A. (2013). Redefining agricultural yields: from tonnes to people nourished per hectare. Environmental Research Letters, 8(3), 34015. http://iopscience.iop.org/article/10.1088/1748-9326/8/3/034015/meta
ECOWAS OBSERVATORY FOR RENEWABLE ENERGY AND ENERGY EFFICIENCY	ECOWAS observatory	Energy	Renewable Energy Resources, Clean Energy Mini-grids	http://www.ecowrex.org/mapView/index.php?lang=eng	

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
Global current monthly climate	WorldClim Version2	Climate	Temperature min/max/mean. Precipitation. Solar radiation, Wind Speed, Water vapour pressure	http://www.worldclim.org/	Fick, S.E. and R.J. Hijmans, 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology
Global current WorldCil BioClimatic variables	WorldClim Version2	Climate	19 Bioclimatic Variables	http://www.worldclim.org/	Fick, S.E. and R.J. Hijmans, 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology
Downscaled Global Climate Model Data	CIAT	Climate	future max monthly temp	http://ccafs-climate.org/download_allsres.html	Ramirez, J.; Jarvis, A. 2008. High Resolution Statistically Downscaled Future Climate Surfaces.
Downscaled Global Climate Model Data	CIAT	Climate	future min monthly temp	http://ccafs-climate.org/download_allsres.html	Ramirez, J.; Jarvis, A. 2008. High Resolution Statistically Downscaled Future Climate Surfaces.
Downscaled Global Climate Model Data	CIAT	Climate	future monthly total precip	http://ccafs-climate.org/download_allsres.html	Ramirez, J.; Jarvis, A. 2008. High Resolution Statistically Downscaled Future Climate Surfaces.
Global Aridity and PET Database	CGIAR CSI - Consultative Group on International Agricultural Research, Consortium	Climate	PET (annual and monthly averages) and aridity index (annual average)	http://www.cgiar-csi.org/	Trabucco A, Zomer RJ (2009) Global Aridity Index (Global-Aridity) and Global Potential Evapo-Transpiration (Global-PET) Geospatial Database. CGIAR Consortium for Spatial Information. Published online, available from the CGIAR-CSI GeoPortal at: http://www.csi.cgiar.org/.

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
	on Spatial Information				
TRMM Multi-Satellite Precipitation Analysis	NASA	Climate	daily precipitation	http://disc.gsfc.nasa.gov/datacollection/ 3B4XRT_V7.shtml	Dataset Originator/Creator: Tropical Rainfall Measurement Mission Project (TRMM) Dataset Title: Experimental Real-Time TRMM Multi-Satellite Precipitation Analysis (TMPA-RT): 3B4XRT Version: 7
Daily Gridded Precipitation Analysis	NOAA - Climate Prediction Center, National Integrated Drought Information System (NIDIS	Climate	daily & weekly precipitation	http://www.cpc.ncep.noaa.gov/products/ GIS/GIS_DATA/	
Daily Gridded Temperature Analysis	NOAA - Climate Prediction Center, National Integrated Drought Information System (NIDIS	Climate	daily temperature (max and min)	http://www.cpc.ncep.noaa.gov/products/ GIS/GIS_DATA/	

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
Global Sea Surface Temperatures	NOAA - Climate Prediction Center, National Integrated Drought Information System (NIDIS	Climate	sea surface temperature + SST anomaly	http://www.cpc.ncep.noaa.gov/products/ GIS/GIS_DATA/	
Climate Data Archives	Willmott, Matsuura and Collaborators' Global Climate Resources	Climate	monthly precip, water budgets, moisture etc	http://climate.geog.udel.edu/~climate/	Willmott, C. J. and K. Matsuura (2001) Terrestrial Air Temperature and Precipitation: Monthly and Annual Time Series (1950 - 1999), http://climate.geog.udel.edu/~climate/html_pages/README.ghcn_ts2.html.
Precipitation Reconstruction Dataset	NOAA	Climate	historical monthly precip	http://www.esrl.noaa.gov/psd/data/gridded/ data.prec.html	Chen, M., P. Xie, J. E. Janowiak, and P. A. Arkin, 2002: Global Land Precipitation: A 50-yr Monthly Analysis Based on Gauge Observations, J. of Hydrometeorology, 3, 249-26
VASClimO 50-year Precipitation Data Set	Weather and Climate - Deutscher Wetterdienst	Climate	monthly precip	https://oasishub.co/dataset/global-precipitation -climatology-centre-50-year-precipitation-data-set	Beck, C., J. Grieser and B. Rudolf (2005): A New Monthly Precipitation Climatology for the Global Land Areas for the Period 1951 to 2000 (published in Climate Status Report 2004, pp. 181 - 190, German Weather Service, Offenbach, Germany)
IPCC Tier-1 Global Biomass Carbon Map for the Year 2000	CDIAC - Carbon Dioxide Information Analysis Center	Carbon	Cabon biomass	http://cdiac.ornl.gov/	Ruesch, Aaron, and Holly K. Gibbs. 2008. New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000. Available online from the Carbon Dioxide Information Analysis Center [http://cdiac.ornl.gov], Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
IPCC Default Soil Classes	ISRIC WISE (World Inventory of Soil Emission Particles)	Carbon	Soil Class	http://www.isric.org/data/ipcc-default-soil-classes-derived-harmonized-world-soil-data-base-ver-11	http://www.isric.org/isric/Webdocs/Docs/ISRIC_Report_2009_02.pdf
Map of Life	Mapping Life	Biodiversity	species distributions for 46,000 species (all described birds, mammals and amphibians)	http://www.mappinglife.org/	Jetz, W., McPherson, J. M., and Guralnick, R. P. (2012). Integrating biodiversity distribution knowledge: toward a global map of life. Trends in Ecology and Evolution 27:151-159. DOI:10.1016/j.tree.2011.09.007
Key Biodiversity Area (KBA)	BirdLife International	Biodiversity	Biodiversity Areas	http://www.keybiodiversityareas.org/site/requestgis	
Nutrient Application for Major Crops	EarthStat - geographic data sets	Agriculture	Fertilizer application rate and consumption	http://www.earthstat.org/nutrient-application-major-crops/	Mineral Fertilizer: Mueller, ND, JS Gerber, M Johnston, DK Ray, N Ramankutty, and JA Foley. 2012. Closing yield gaps through nutrient and water management. Nature doi: 10.1038/nature11420. 490:254-257. Manure and Atmospheric Deposition: West, PC, JS Gerber, ND Mueller, KA Brauman, KM Carlson, ES Cassidy, PM Engstrom, M Johnston, GK MacDonald, DK Ray, and S Siebert. 2014. Leverage points for improving food security and the environment. Science. 345:325-328. doi: 10.1126/science.1246067.
Global Livestock Production SYstems	GLW - Gridded Livestock of	Agriculture	livestock production systems	http://www.fao.org/AG/againfo/resources/en/glw/home.html	

Dataset name	Datasource name	Variable category	Variables	LINK	Reference
	the World (FAO)				

DRAFT

DRAFT

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

DRAFT