Additional Materials –
Livestock exposure to future cumulated climate-related risks in West Africa

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Context

→ Global warming = observed and projected to intensify (*pick your favorite IPCC*);

→ According to future climate and exposure projections, climate change will increase by 8 to 80 million the number of people at risk of hunger by 2050 at global scale (e.g. *Nelson et al. 2018*, *Janssens et al. 2020*);

→ Livestock systems, main sources of income and food production in low-income countries as in West Africa, will be consequently adversely affected (e.g. *Mbow et al. 2019*);

→ Few studies over West Africa have shown that only heat stress intensification itself will *affect* animals husbandry and could result in large production loss (example of dairy production for cattles in *Rahimi et al. 2020*).

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Research questions

→ Nevertheless, no study have investigated the livestock exposure to future climate-related and multiple risks in such vulnerable regions, nor their combination in time and space.

How regional livestock could be exposed to cumulated climate-related risks during the 21st century ?

→ We assess (1) how multiple and cross-sectoral stressors could cumulated according to future climate simulations, and (2) what will be the resulting regional livestock exposure to such cumulated risks (i.e. approaches per species, per indicator and per country)

→ *Paper : Brouillet and Sultan (in press).* ***Livestock exposure to future cumulated climate-related stressors in West Africa.*** *Scientific Reports.*

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Materials and methods

→ A set of 8 climate-related indicators that may affect livestock is selected;

→ Major risk « sectors » are covered and include: food availability, flood, drought and health;

→ Raw variables for indicators calculations are analysed from the Inter Sectoral Impact Model Intercomparison Project (ISIMIP) phase 2b;

→ Simulations are analysed for the historical (1979-2005) and RCP8.5 (2006-2100) scenarios.

Climate-related indicators	Raw variables	Simulations	Model names
Very heavy rainy days **Consecutive dry days** **Temperature-Humidity Index** indicators (3)	daily precipitation ($kg.m^{-2}.s^{-1}$) daily maximum temperature (°C) + surface specific humidity ($kg.kg^{-1}$) + sea-level pressure (hPa)	10 GCMs i.e. 10 simulations (CMIP5)	ACCESS1-0 BNU-ESM CanESM2 CSIRO-Mk3-6-0 GFDL-ESM2M HadGEM2-ES IPSL-CM5A-LR MIROC5 MRI-ESM1 NorESM1-M
High runoff flow **Low runoff flow**	daily runoff ($kg.m^{-2}.s^{-1}$)	5 GIMs × 4 GCMs i.e. 20 simulations (ISIMIP2b)	H08 LPJML MATSIRO ORCHIDEE WATERGAP2 GFDL-ESM2M HadGEM2-ES IPSL-CM5A-LR MIROC5
Leaf Area Index	monthly leaf area index of all plant functional type (no unit)	3 GIMs × 4 GCMs i.e. 12 simulations (ISIMIP2b)	CLM45 ORCHIDEE VISIT GFDL-ESM2M HadGEM2-ES IPSL-CM5A-LR MIROC5

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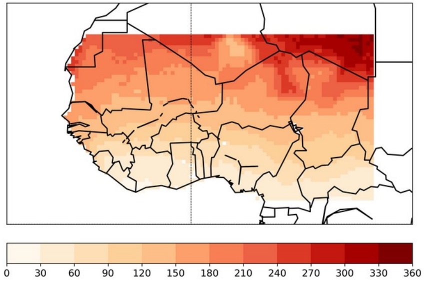
Results: Historical values of various climate-related indicators

(Multi-model median values averaged over 1979-2005)

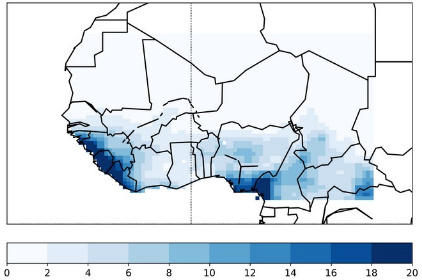
More than 270 consecutive dry days characterize the north of West Africa, whereas less than 60 consecutive dry days characterize the south

Consecutive dry days



in days/year

High annual extreme runoff

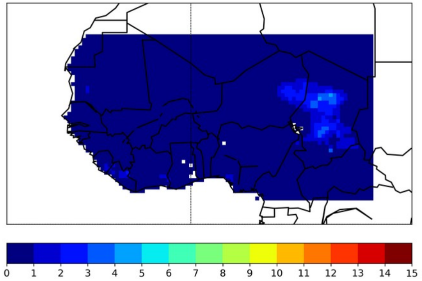


in mm

High annual extreme values of surface + subsurface runoff in southern West Africa, and no runoff on the north (desert)

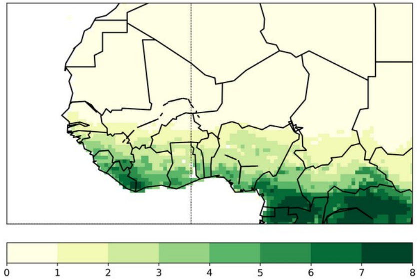
THI index ≥ 89 = *severe* heat stress conditions for animals. No annual days with severe conditions except few within eastern West Africa

Severe heat stress days



in days/year

Mean annual LAI



no unit

High Leaf Area Index (LAI) values along the equatorial band

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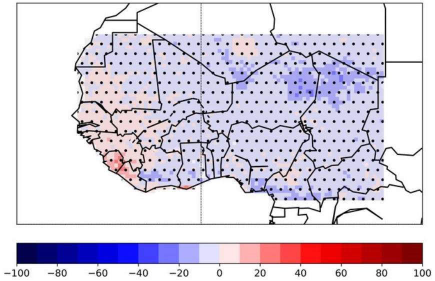
Results: <u>Future projected change</u> in various climate-related indicators

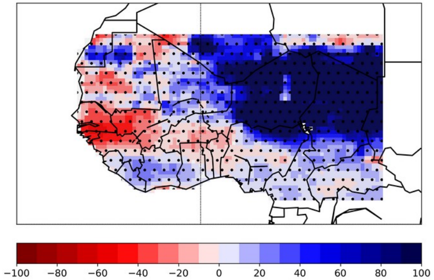
(Multi-model median change between 1979-2005 and 2074-2100 under the RCP8.5 scenario. Provided as the percentage of historical values)

Consecutive dry days

Decrease of consecutive dry days in the eastern part of the region, and increase in western West Africa



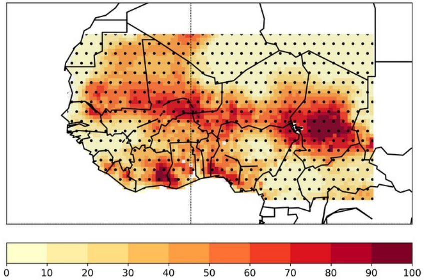
High annual extreme runoff



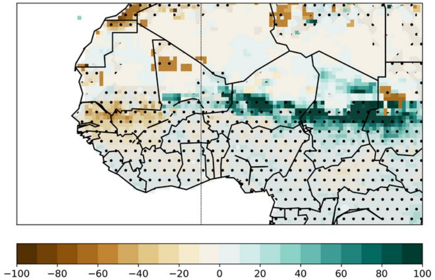
Increase of high annual extreme runoff values within eastern West Africa, and large decrease in the west

Severe heat stress days

Large local increases of annual days with severe heat stress conditions (high combined temperautre and humidity)



Mean annual LAI



Large LAI future increase along the eastern Sahel, and a decrease in the western part of the region

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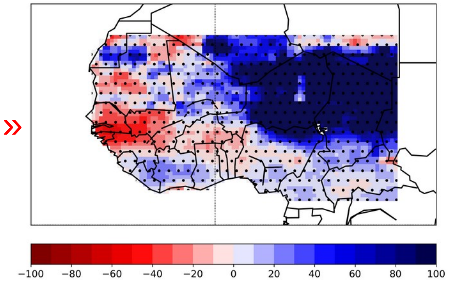
Results: Cumulated multiple climate-related risks

→ A risk (for livestock species) is considered per indicator as an adverse future projected change;

→ We spatially create a mask per indicator with 1 when the future projected change is adverse AND larger than the historical standard-deviation (0 if not). All masks are then added to provide a spatial distribution of cumulated multiple risks.

High annual extreme runoff

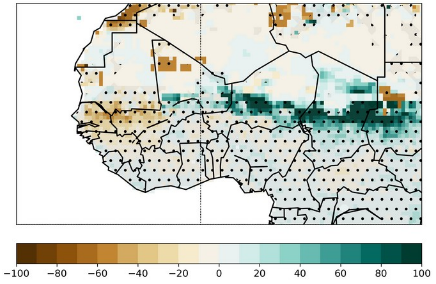
a « benefit »



a risk

Mean annual LAI

a risk



a « benefit »

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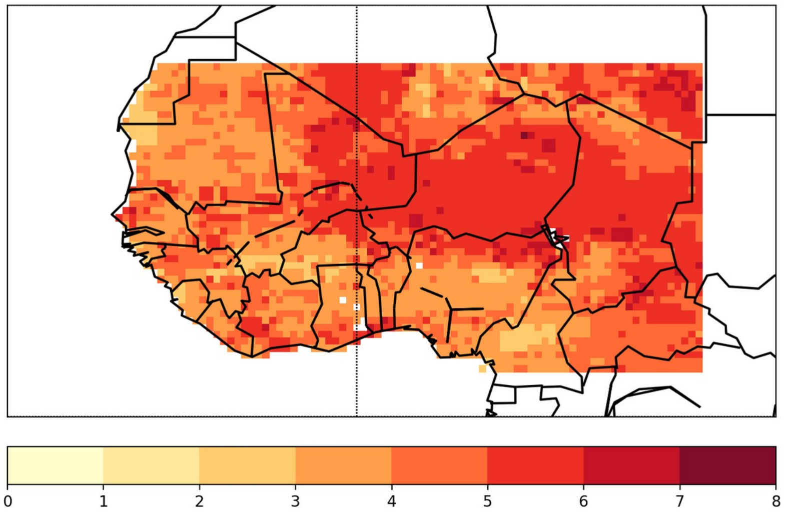
Results: Cumulated multiple climate-related risks

→ A risk (for livestock species) is considered per indicator as an adverse future projected change;

→ The eastern part of West Africa (mostly eastern Mali, Niger and Tchad) is characterized by a pattern of at least 5-6 cumulated multiple indicators that will adversely intensify.

→ Other areas are characterized by 3-4 indicators, mostly driven by the 3 heat stress indicators intensifications (shown in a next slide).



Spatial distribution of cumulated multiple stressors (in number of stressors). A value of 8 means that all of the 8 climate-related indicators are characterized by a multimodel median future adverse change larger than the indicator standard-deviation over 1979-2005.

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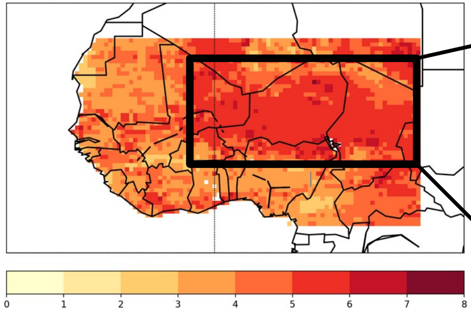
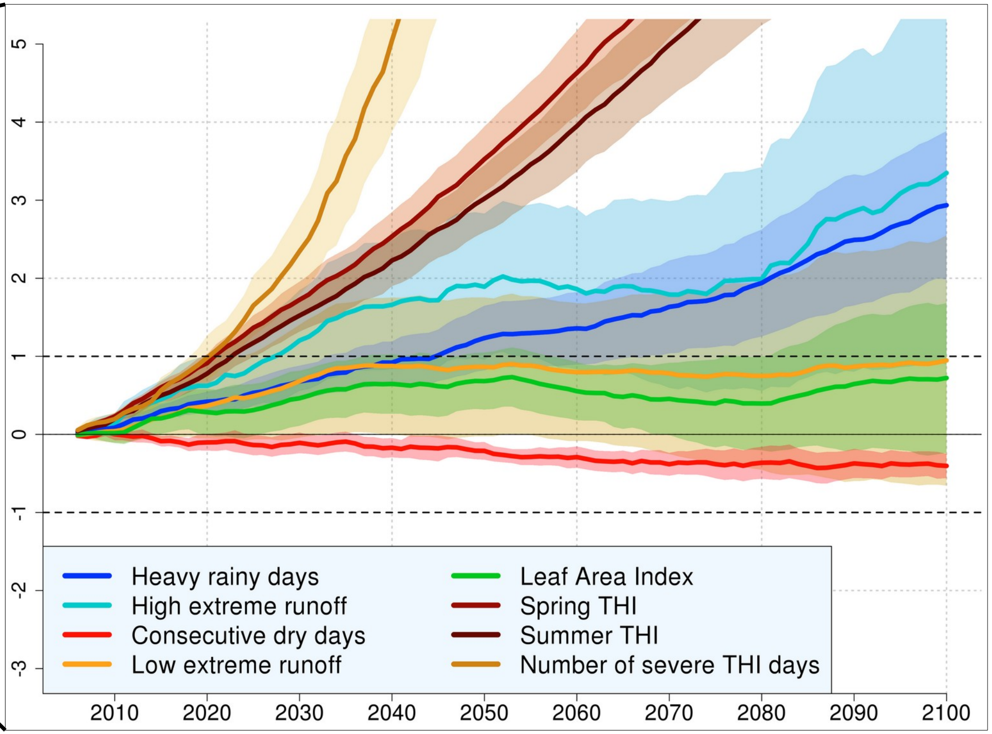
Results: Timing of cumulated climate-related risks





→ First significance is reached by heat stress indicators (THI) between 2020 and 2025, then by high extreme runoff around 2027 and by very heavy rainy days around 2042;

→ Low extreme runoff, LAI and consecutive dry days both positively change during the 21st century for that location, but these changes do not exceed one historical standard-deviation.

Timeseries of the normalized 8 selected climate-related stressors between 2005 and 2100. For each indicator and for each year, values are obtained by dividing the corresponding 20-y upcoming projected change compared to the 1979-2005 period by the 1979-2005 standard-deviation. Per indicator, solid lines indicate multi-model medians and shaded colors display the confidence intervals among the models.

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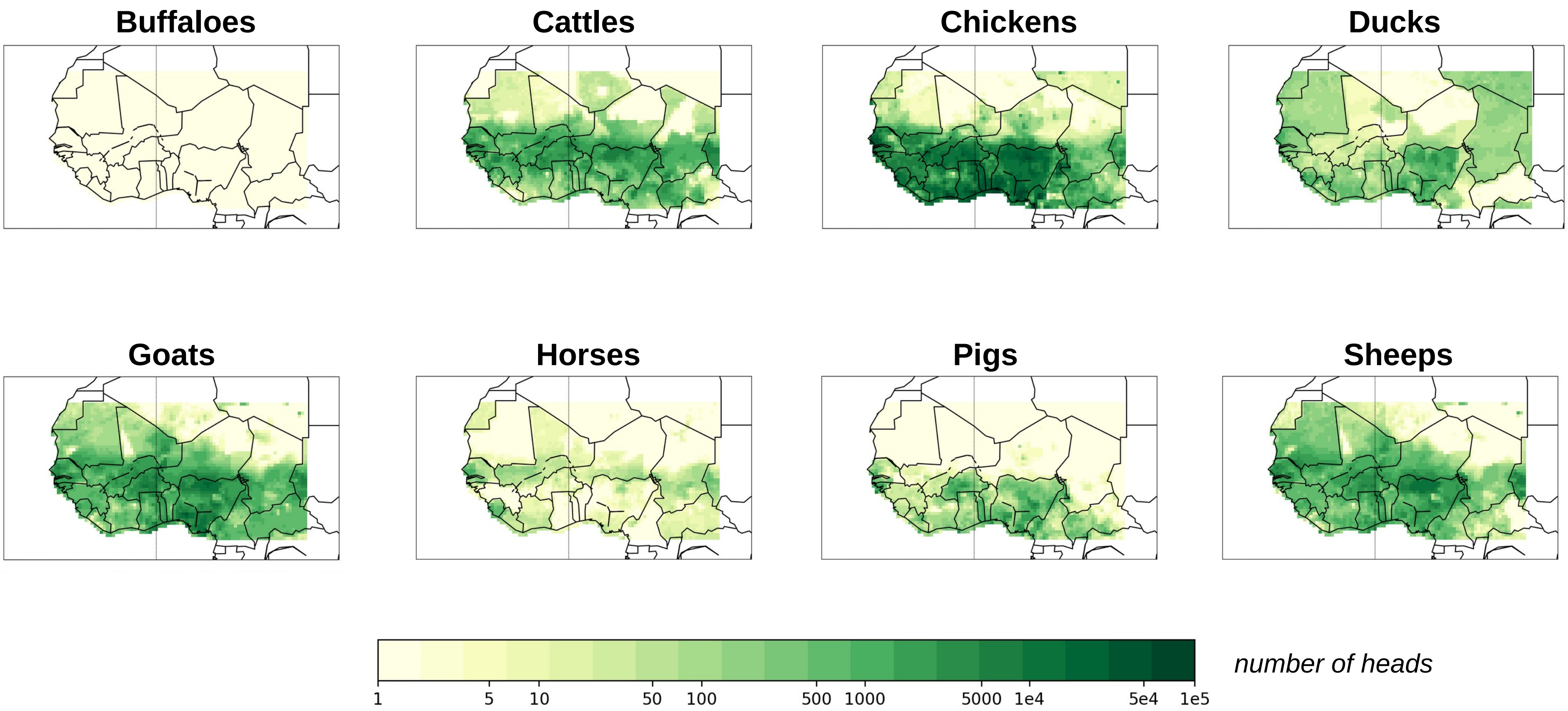
Results: Livestock gridded data in 2010 (Gilbert et al. 2018)



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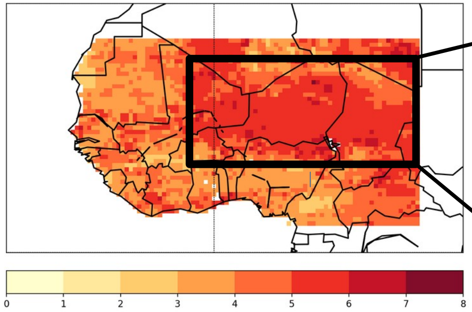
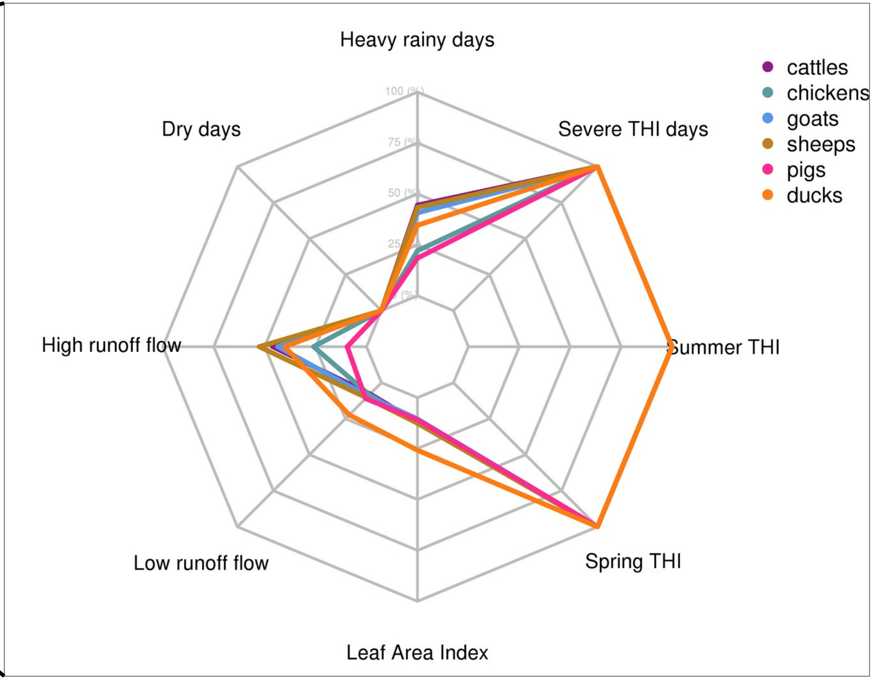
Results: Livestock exposure to cumulated climate-related stressors





Radarchart of livestock species exposed to each sectoral stressor (in%). Per indicator, 100 % means that the total regional species will be exposed to a significant and adverse projected change (under the RCP8.5 scenario)

→ All livestock species are characterized by a 100 % exposure to adverse change in heat stress metrics, none for consecutive dry days, few for vegetal cover

→ Combine exposure and indicator variabilities

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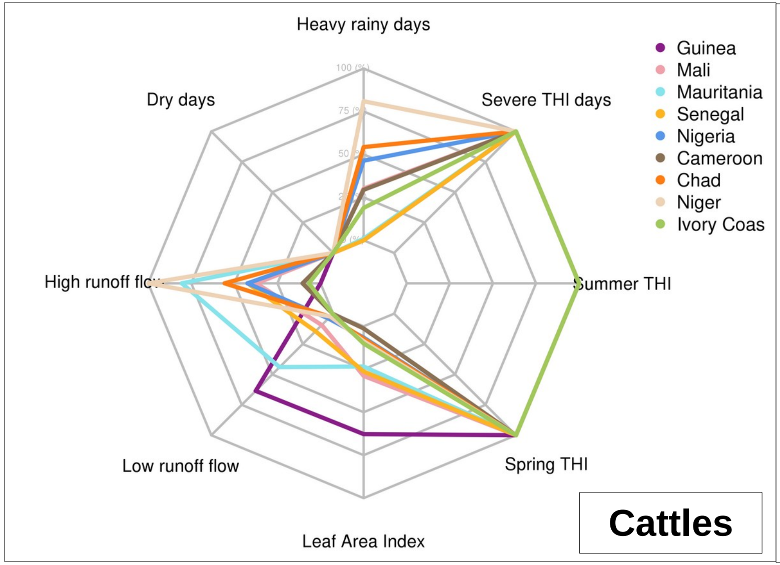
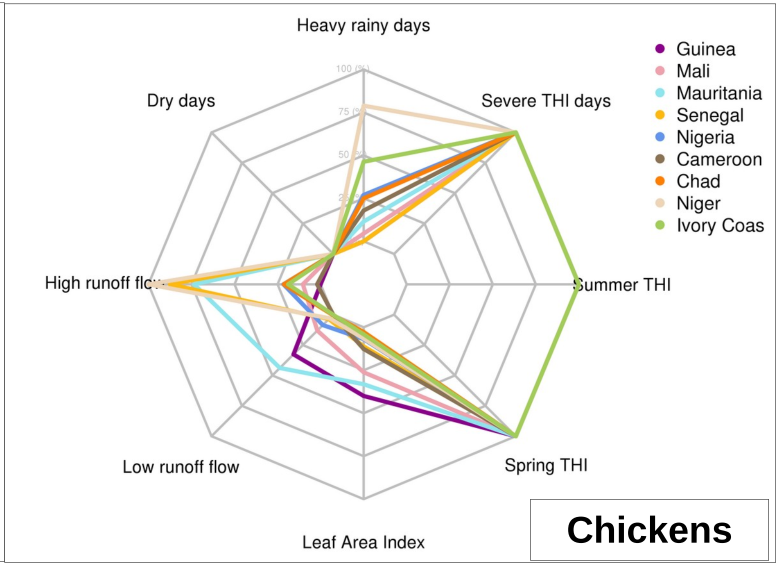
Results: Livestock exposure per country

→ Some countries such as Niger, Senegal and Mauritania are characterized by similar exposures among all the four main livestock species, but specific location/species combinations result in most severe exposures

→ As examples, in Niger, 75 to 100% of each species are projected to be exposed to at least 5 cumulated stressors (flood risks and heat stress intensifications). More than 60% of cattles are exposed to high runoff increase in Guinea, whereas only 30% of chickens are projected to be affected





Radarchart of livestock species exposed to each sectoral stressor (in %). Per indicator, 100 % means that the total species of the country will be exposed to a significant and adverse projected change (under the RCP8.5 scenario)

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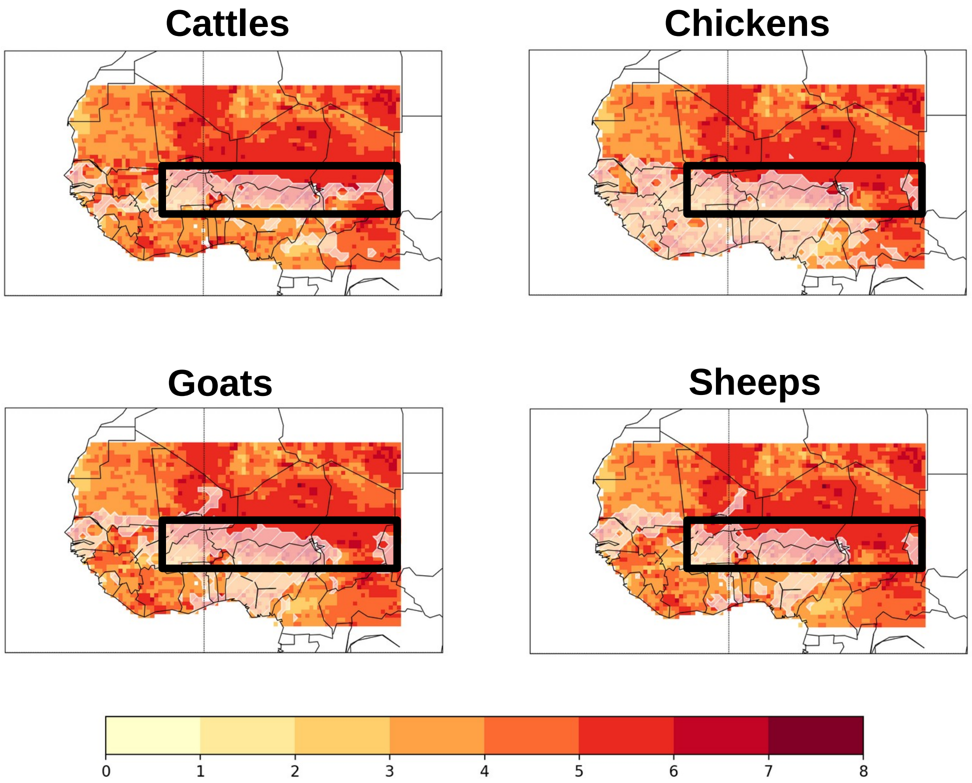
Results: Livestock exposure to cumulated climate-related risks

(spatial distribution of cumulated multiple stressors is superimposed with livestock densities of at least 1000 heads)



→ A total of 7 961 677 animals is expected to experience at least 5 projected cumulated cross-sectoral risks, i.e. 28% of total 2010's livestock in West Africa;

→ It includes :

38% of total cattles of the region (i.e. 890 960 heads)

23.9% of the chickens (i.e. 4 219 029)

35% of the goats (i.e. 1 433 954)

39% of the sheeps (i.e. 1 175 420)

→ Locally, livestock could experience more than 6 cumulated risks: 3.4% of total cattles, 2% of chickens, 2.4% of goats and 4.2% of sheeps.

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Conclusions and discussions

Take-home messages

→ According to ISIMIP2b (and CMIP5), a large part of West Africa will be affected by at least 5 to 6 cumulated multiple climate-related risks during the 21st century;

→ One third of the total western african livestock will be exposed to these cumulated 5-6 stressors, including sheeps, cattles, chickens and goats (between 23% and 39% of each species regional distribution);

→ This exposed livestock will be first affected by a significant intensification of severe heat stress conditions from early 2020s, then by large flood risk in the following decades.

Limitations and ongoing work

→ No future evolution nor dynamic of animal species (e.g. seasonal move of pastures)

→ No quantification of multi-model uncertainties (and only RCP8.5)

→ We could extend this analysis to other areas/global scale and to other exposures (e.g. population, ecosystems).