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Timely and accurate assessment of forage quality during the dry season using earth observation data in Senegalese rangelands

Authors:

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1 FATIMA project

2 Methodological approach

3 key results

01 Presentation of the FATIMA project

FATIMA PROJECT

- **F**odder quality **A**ssessmen**T** in senegalese rangelands based on Sentinel-2 **IMA**ges

- *Duration: Marsh 2023 – Marsh 2024*

Coordinators

Dr Abdoul Aziz Diouf (CSE)

Dr Louise Leroux (Cirad)

Other project members

- Adama LO (CSE)
- Samba Guorgui Mané (CSE)
- Babacar Ndao (Cirad)
- Ibrahima Diedhiou (University of Thiès)
- Torbern Tagesson (University of Lund)
- Rasmus Fensholt (University of Copenhagen)
- Pierre Hiernaux (Pastoralisme Conseil, France)
- Laurent Bonnal (Cirad)
- Anne Mottet (IFAD)
- Mohammed Achab (Mohammed V University, Maroc)

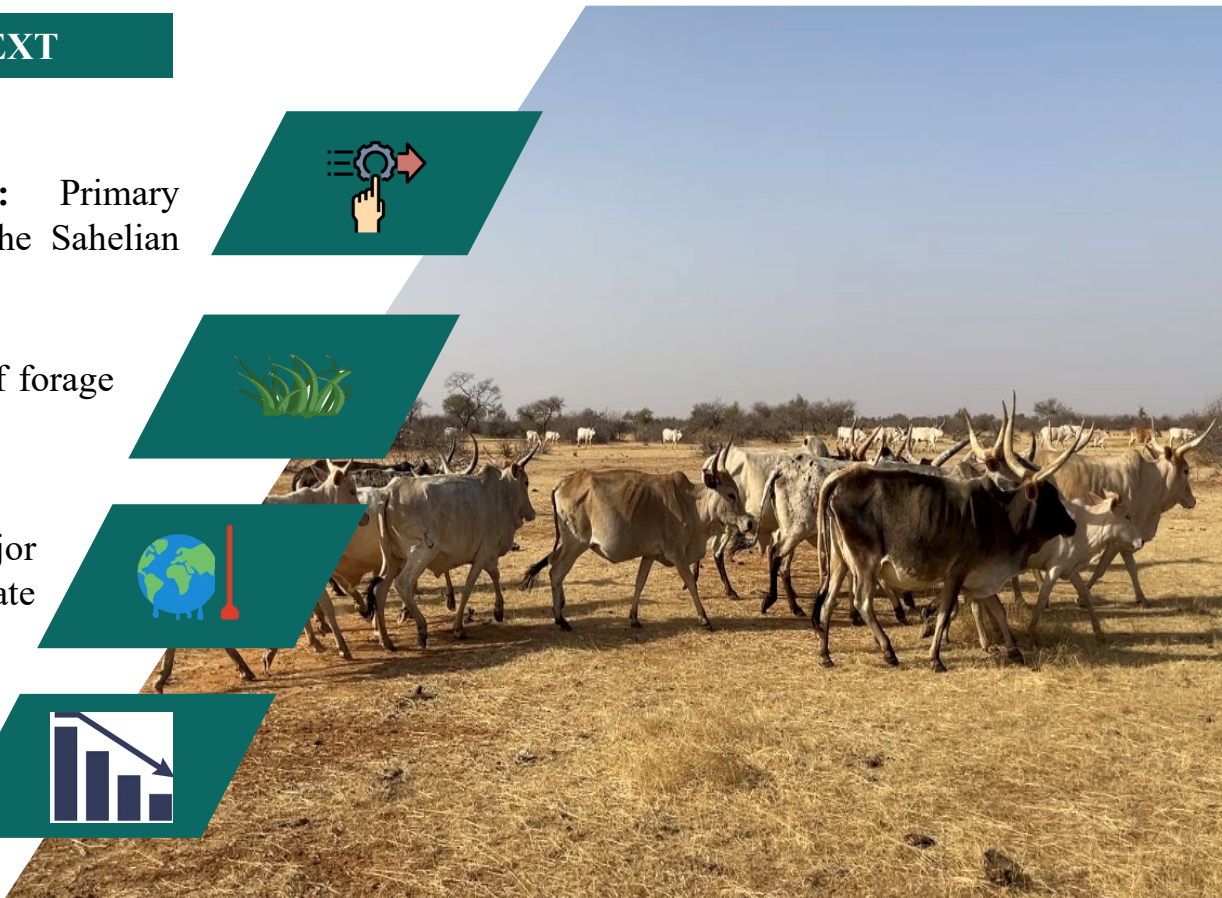**01** **Sahelian livestock farming:** Primary income-generating activity for the Sahelian population

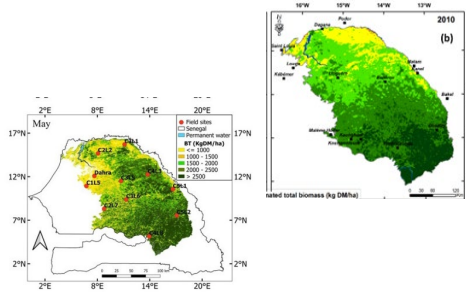**02** **Natural pasture:** Main source of forage for animal feeding

03 **Fragile farming system:** Major crises exarcerbated by climate change

04 **Impact on livestock:** Decrease in their performance, decrease in productivity, …

GENERAL PROJECT CONTEXT

Why dry season?

Necessity to implement innovative methods for regular monitoring of pastoral resources based on remote sensing

- Longest of the year (9 months)
- Lower forage availability
- Decrease in nutrients
- Increase in non-digestible fiber

Existing?

Operational tools of the CSE: Monitoring of forage quantity during the dry and rainy seasons

Need to implement?

Tools for estimating dry-season forage quality

More effective contribution to the national rangeland management framework for productive and sustainable pastoral livestock production, in the current context of global change.

1 Possibility of directing herders to grazing areas with good forage quality.

2 Positive impact on livestock in terms of improving herd health and enhancing their performance

3 Positive impact on farmers' income

4 Improvement in the reliability of forage balance calculation in the Sahel.
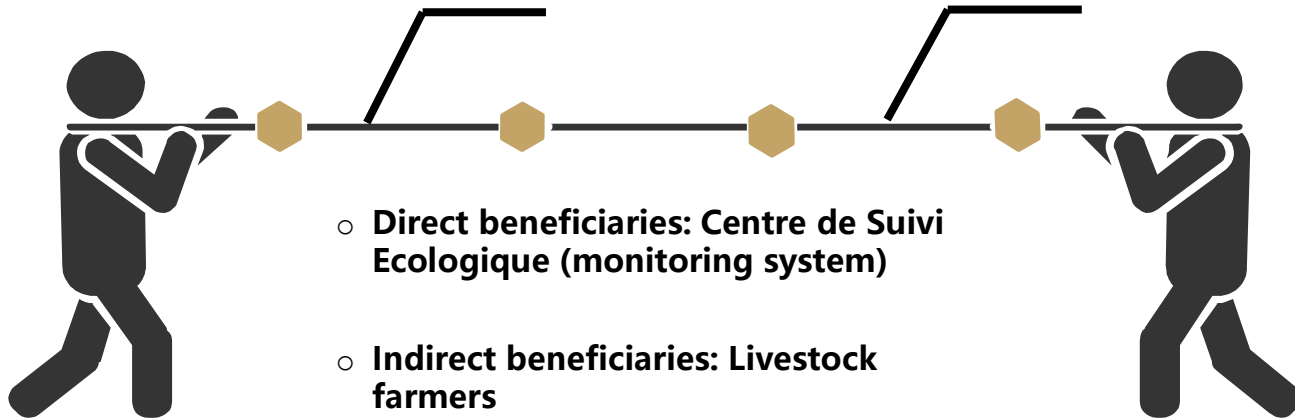
5 Positive impact on carbon balance

The objective of the FATIMA project is to develop models for assessing forage quality during the dry season by combining Sentinel-2 (S2) satellite images with ground data analyzed using Near-Infrared Spectroscopy (NIRS) through statistical modeling techniques.

o **Direct beneficiaries: Centre de Suivi Ecologique (monitoring system)**

o **Indirect beneficiaries: Livestock farmers**

02 Methodological approach
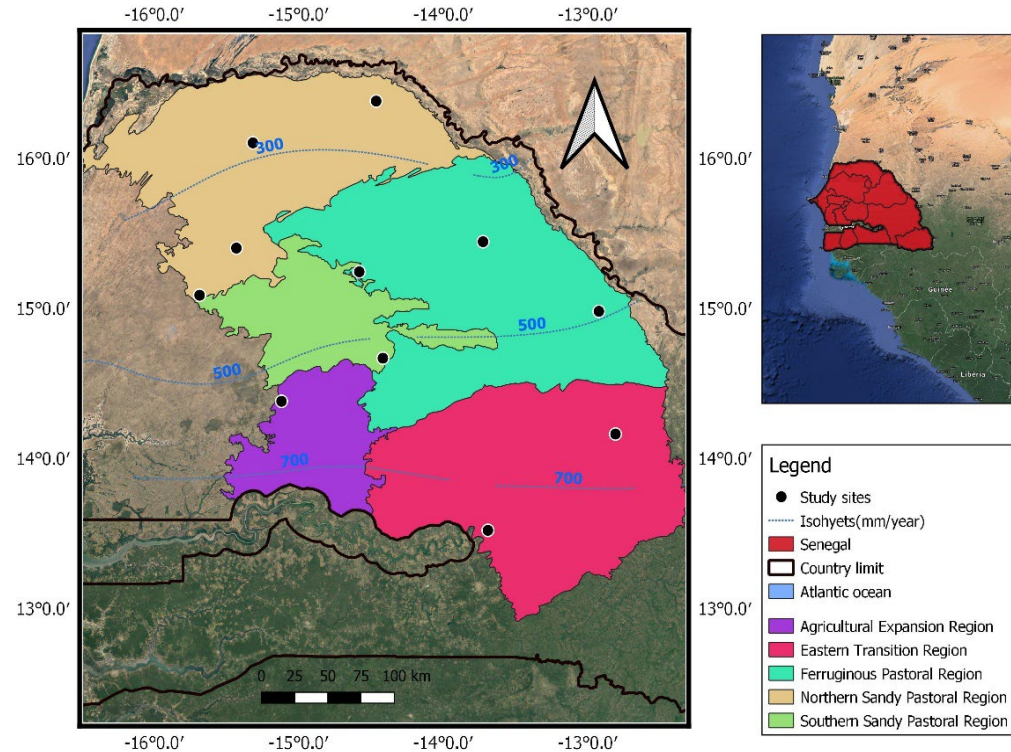
- Sylvopastoral zone (52% of Senegal's total surface area)

- Annual precipitation: 250 to 900mm (North to South)

- Average annual temperature: 25°C

- Selection of sites: based on soil, climate conditions and ecoregions

Collection at 11 (and 24) sites in 3 periods during the 2021 (and 2023) dry season

↓

Herbaceous and woody biomass were collected on a 500m transect.

NIRS ANALYSIS OF SAMPLES

Extraction of nine (9) quality parameters

Good forage quality ↕ Low content of these constituents

- Acid detergent fiber (ADF)
- Neutral detergent fiber (NDF)
- Mineral matter (MM)
- Crude cellulose (CBW)
- Digestibility of organic matter (SMO)
- Lignin (ADL)

Good forage quality ↕ High content of these components

- Dry matter (MS)
- Crude protein(CP)
- Dry matter digestibility (SMS)

OVERALL METHODOLOGICAL APPROACH

geemap — Python package interacting with Google Earth Engine (GEE)

Sentinel-2

Calculation of 17 vegetation indices

NIRS Analysis

9 forage quality parameters

Herbaceous forage quality

Woody forage quality

Selection of explanatory variables and Modelling (MML)

Spatialization of forage quality parameters

Mapping the quality of herbaceous forage in the dry season

Mapping the quality of woody forage in the dry season

EXCECUTION USING A NOTEBOOK

jupyter Python Notebook

Sentinel-2 images with a spatial resolution of 10m and a temporal resolution of 5 days have been downloaded.

03 Key results

Main variables that reflect forage quality

CP
Crude Protein

- Essential for the ruminant diet
- Provide the nitrogen necessary for the metabolism and production of milk and meat of ruminants.

ADF
Acid detergent fiber

Cellulose
+
Lignin content

NDF
Neutral detergent fiber

Cellulose
+
Lignin
+
Hemicellulose content

Provide information on the digestibility of the feed biomass

Herbaceous quality

Woody foliage quality

Total forage quality

Variable performance

CP: $R^2 > 70\%$

Fibers: $R^2 > 60\%$

		R²	RMSE (%DM)	RRMSE (%)	Variables explicatives
	CP	0,81	0,41	11%	GRCI + SRI + TCARI + RVI3 + NDI5 + NDI7
HQ	**ADF**	0,70	2,30	4%	SRI + TCARI + RVI3 + NDI5
	NDF	0,47	3,44	4%	B12 + GRCI + TCARI
	CP	0,72	1,44	11%	B2 + NDI5 + TCARI + RVI3
MML **LQ**	**ADF**	0,77	3,39	11%	VARI + GRCI + TCARI + SRI + RVI3 + NDI5 + DFI
	NDF	0,83	3,59	8%	GRCI + TCARI + NDI5 + DFI
	CP	0,70	1,01	12%	B12 + GRCI + B8
HLQ	**ADF**	0,61	2,56	6%	B8 + VARI + RVI3
	NDF	0,6	3,53	6%	TCARI + NDI5

SOME KEY RESULTS
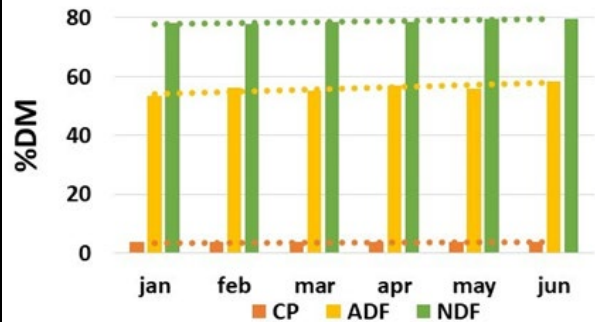
Herbaceous quality
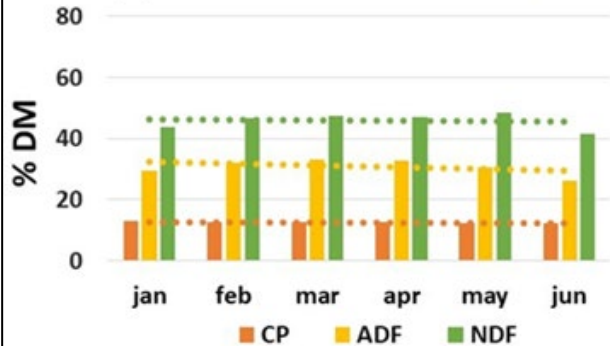
Woody foliage quality

Temporal analysis
Low protein content in forage compared to fiber was observed throughout the dry season.
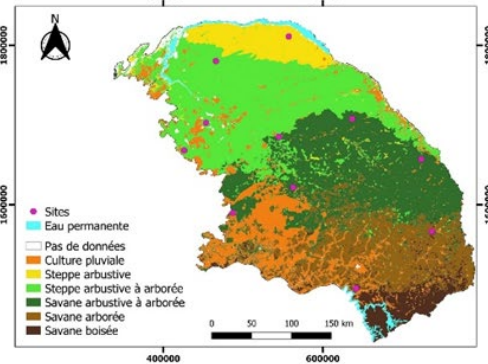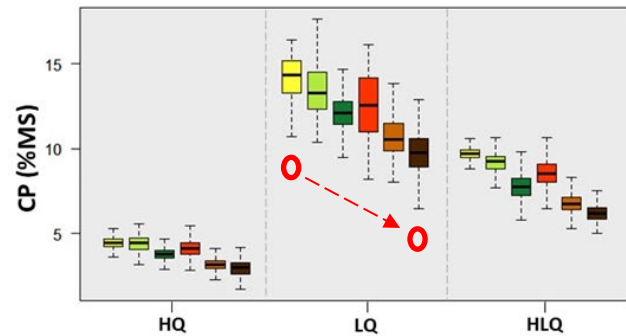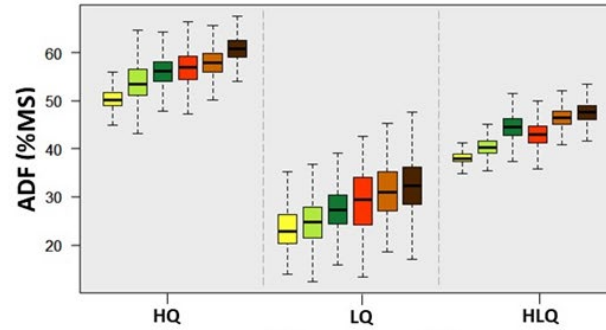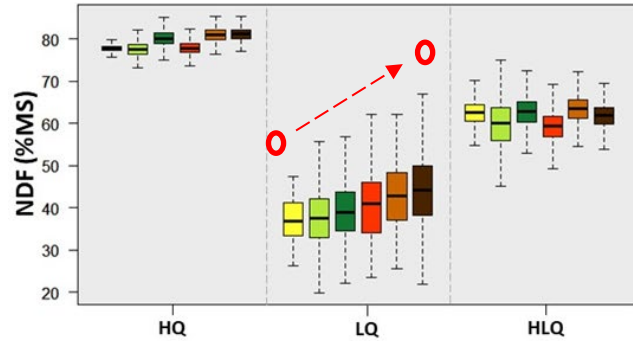
Trend
A decrease in protein content is observed throughout the season, whatever the type of vegetation (herbaceous, woody forage)

Observation

% CP in herbaceous stratum does not exceed 4% which is below the critical threshold of 8% for weight gain in animals

SOME KEY RESULTS

Spatial analysis

High CP content in steppe rather than savannah areas

Explanation

- Poorly developed soil in the south, therefore very low mineralization
  Maignien (1965)

- High proportion of legumes in the north (80% in the north to 11% in the south)
(Grouzis et Diédhiou (1998))

The use of Sentinel-2 L2A data combined with NIRS data allowed to obtain satisfactory results on the mapping of forage quality

The multilinear model proved to be more effective in assessing dry-season forage quality when a year of data collection is considered

The herbaceous forage quality during dry-season is not sufficient to cover the need of the animals in our study area (low crude protein and high level of fiber). We think woody plants could provide an additional source of forage at this critical time of year

The results obtained can be used as a foundation to develop a decision support tool for land managers, to predict forage quality through the silvopastoral zone of Senegal.

This study was conducted based on a single year of field observations and the accuracy of the model could possibly be improved and consolidated by further calibration from including additional years of field forage quality data.

Knowledge of quality of the forage resources in the study area is expected to improve the management of resources for livestock in the silvopastoral zone of Senegal and Sahel. Such information will support improved distribution and density models of livestock, as well as the reliability of the calculation of the fodder balance that hitherto only takes into account the availability of fodder and not the quality of the fodder.
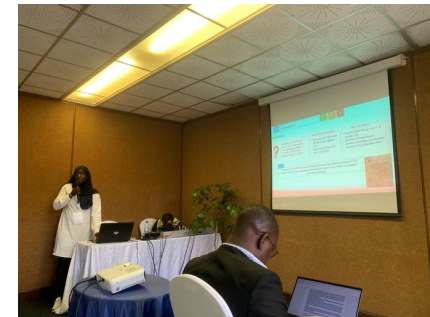
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Original Research

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Adama Lo [1,2,*], Abdoul Aziz Diouf [1], Louise Leroux [3,8,9], Torbern Tagesson [4,5], Rasmus Fensholt [4], Anne Mottet [6], Laurent Bonnal [7], Ibrahima Diedhiou [2]
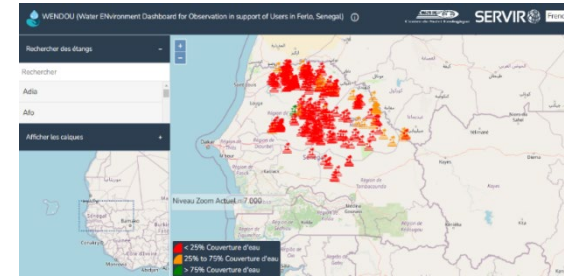
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THANK YOU FOR YOUR ATTENTION

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