STAPLEDON MEMORIAL TRUST TRAVELLING FELLOWSHIP
REPORT TO STAPLEDON MEMORIAL TRUST

LOW-COST ASSESSMENT OF FORAGE QUALITY AND QUANTITY THROUGH THE CALIBRATION OF INDIRECT METHODS

BY

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NORTH WYKE,
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1.0 The Purpose of the Fellowship: In grazing systems, herbage quantity and quality can vary spatially from 15 to 60% relative to the mean value. Among sources of variation are differences in soil fertility, botanical composition, and animal grazing behaviour. These variations have a direct effect on individual intake and individual performance. These variations in forage quantity and quality across space and time represent the main bottleneck for forage management. To surpass this difficulty, managers plan their forage budget on a seasonal base. However, these plans are limited by the amount of data due to cost. The use of non-destructive technologies appears as the tool to quantify both spatial and temporal, inter-annual and seasonal variations in forage quality and quantity. During my fellowship, I carried out studies calibrating two main indirect handheld tools for real-time forage quantity and quality assessment. The specific objectives of my fellowship were to:

1. Familiarise with protocols for on and off-field calibrations of both forage quantity and quality
2. Learn how to obtain and process remote sensing information from worldwide free sources
3. Collaborate on ongoing calibrations which consider both on-and-off-field methods. Some of the on-field equipment used were the Rising Plate Meter, GreenSeeker, and the Radiation Quantum Sensor to achieve the objectives.
4. Ascertain potential applications of these indirect methods of forage evaluation in Nigeria and African grassland in general

2.0 Outline of Work Done During the Fellowship

2.1. Fellowship site

The study site and data collection were from the North Wyke Farm Platform (NWFP) which was established in 2010 at Rothamsted Research's North Wyke site in Devon, UK. The platform consists of three differently managed field farming systems of 21 hectares each, made up of six fields each. The three managed systems are tagged "Red, Blue, and Green". The Blue fields are comprised of grass (perennial ryegrass) in a mixture with white clover, the Green-fields is a permanent pasture dominated by perennial ryegrass, while the Red fields are planted with arable crops, currently under oats. My study and measurements were based on Orchard Dean North and South (Green fields), Higher and Lower Wyke Moors (Blue fields) and Great Field (Red field) (Figure 1).

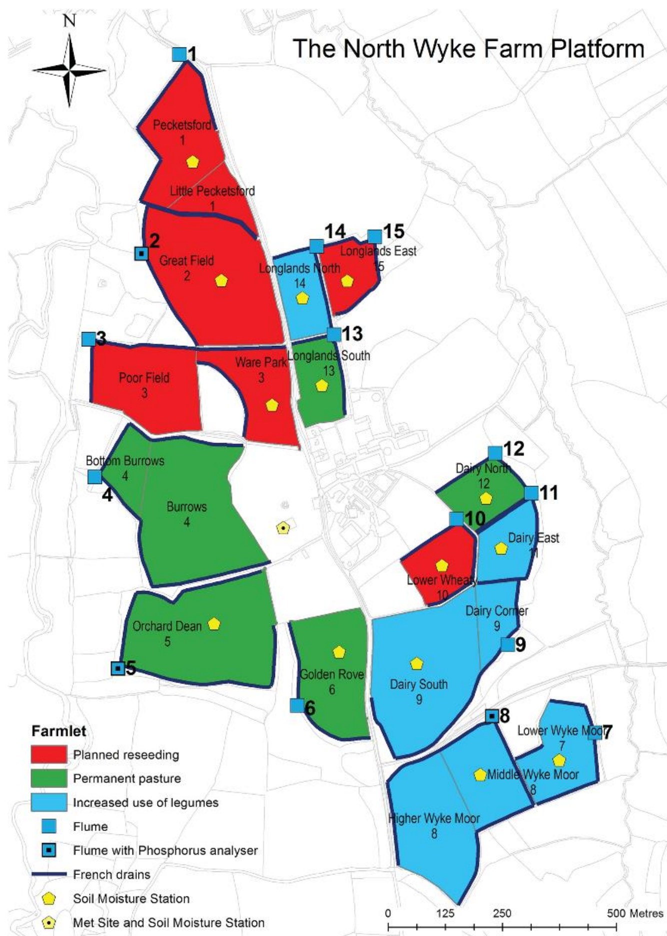


Figure 1. North Wyke Farm Platform, Rothamsted Research, Devon, UK. (https://www.ecologicalcontinuitytrust.org/north-wyke-farm-platform; *Wua et al. 2016*)

2.2. On-farm protocols for calibration of forage quantity

2.1.1. Handheld Greenseeker™ for Normalised Difference Vegetation Index (NDVI) Readings

GreenSeeker uses multispectral active sensors (8) to determine the real-time normalized differential vegetative index (NDVI) of crop canopies regardless of the time of day or cloud cover (Plate 2 a and b). The sensor emits brief bursts of red and infrared light and then measures the amount of each type of light that is reflected from the plant. The sensors scan an area as long as the trigger remains engaged. It then displays the measured value in terms of an NDVI reading (ranging from 0.00 to 0.99) on its LCD screen. The strength of the detected light is a direct indicator of the health of the crop and the higher the reading, the healthier the plant. NDVI is defined as follows: red and near infrared regions (NIR) of the electromagnetic spectrum

$NDVI = NIR_{(780nm)} - RED_{(660)}/NIR_{780)} + RED_{(660)}$

(a) (b)

Plate 2: Greenseeker (a) and measurements of NDVI values in a Blue field (b) (*Photos: Gonzalo Irisarri*)

2.2.2. The Rising Plate Meter (RPM)

The RPM also allowed repeated estimates of sward biomass over a period of time with minimal sward disturbance (Plate 3). A plate meter measures sward height and uses pre-set equations to convert sward height readings to kg DM/ ha;
kgDM/ha = average compressed sward height (cm) x 140 + 500 (Matthew et al., 1996)
400 is the multiplier and 500 is the adder

Plate 3: Use of RPM in one of the Green Fields (*Photo: Gonzalo Irisarri*)

2.2.3. LI-COR Quantum/Radiation Sensor

The Sensor measures radiation absorption by photosynthetically active tissues (fPAR). The following were measured; total incoming radiation, radiation reflected by the plant canopy surface, radiation within the plant canopy, and the radiation reflected by the soil surface. This enables the calculation of total radiation intercepted by photosynthetic active plant parts. This use is done with a LI-COR Quantum sensor (Plate 4 a and b)

(a) (b)

Plate 4: Use of LI-COR Quantum/Radiation sensor for measuring radiation interception by the plant in a Green field (a) and Red field (b) (*Photos: Gonzalo Irisarri*)

iv). *Calibration of RPM, NDVI, fPAR readings*

Calibration helps to ensure that the measurements more accurately reflect what is in the paddock or field. The GPS-enabled RPM, GreenSeeker, and Quantum sensor (Li-Col) readings were calibrated against actual harvest and oven-dried herbage mass. To calibrate, samples were clipped from an area along the transect after RPM height, fPAR, and NDVI readings were taken in a given location. A sampling grid (30 m X 10 m) consisting of 40 points in each of the Red, Blue, and Green Plots of the farm platform was used for data collection. Weekly readings were taken with the Green Seeker and GPS- enabled RPM for NDVI and plant height, respectively. Readings of radiation Intersection by photosynthetic active plant parts were done with the Quantum sensor (LI-COR) and herbage was cut along the transect every two weeks. These activities were performed from April to early August 2022. Herbage samples were oven-dried in a forced-air dry oven at a temperature of 50ºC for three days and weighed. Calibration was done against the variables using regression equations.

2.2. Obtaining and processing remote sensing information from worldwide free sources

Apart from the indirect on-farm methods of monitoring grassland/vegetation quantity, there are also off-farm techniques that use remote sensing information from worldwide free sources. These sources include Landsat, Sentinel2 and Moderate Resolution Imaging Spectro- radiometer (MODIS) with different Spectral Resolution, Spectral Reflectance, Temporal Resolution and time series. The worldwide sources can be used to obtain vegetative indices such as Normalized Difference Vegetation Index (NDVI), Vegetation Index Number (VIN), Normalized Difference Index (NDI) and Ratio Vegetation Index (RVI). These vegetative indices and a combination of other information such as meteorological data can be used to estimate above-ground net primary forage production and forage quality which are important factors for ecosystem function. The information obtained from these sources will be further regressed against corresponding *in-situ* above-ground biomass yield and weather data to predict forage biomass yield from the satellite.

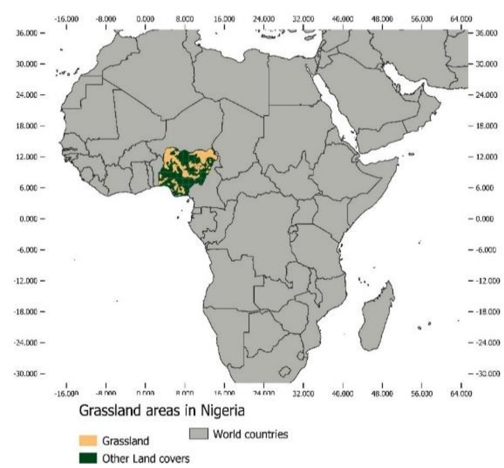


Figure 2: Map of Nigeria in Africa showing grassland and other land covers

During my visit at North Wyke, Rothamsted Research, I familiarised myself with the above mentioned worldwide free sources, how to obtain and process remote sensing data. We are presently generating remote sensing information/data on Nigerian grassland (Figure 2 and 3) using Google Earth Engine (GEE). This is ongoing and part of future collaboration.

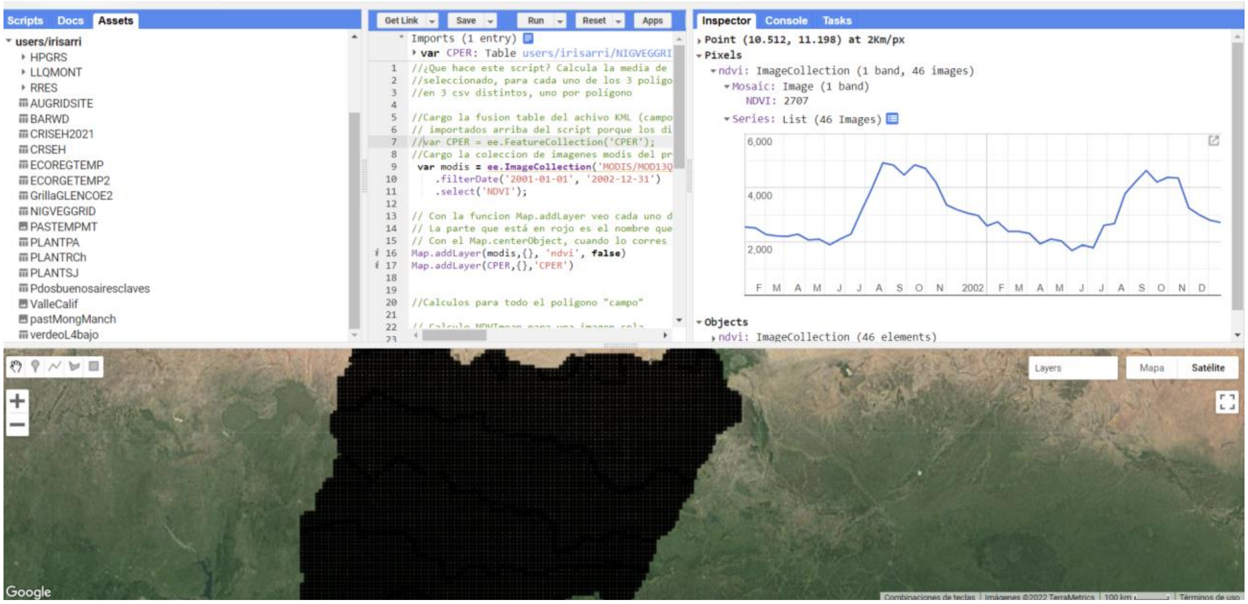


Figure 3: Some of the GEE codes used to obtain NDVI values from remote sensing.

2.3. Evaluation of forage quality through the calibration of indirect method

The HarvestLab™ 3000 is equipment developed by John Deere Company for on-field forage quality estimation. The equipment has sensors and normally mounted to the top of the discharge spout of a forage harvester to measure forage quality parameters as the chopped samples pass through the lenses of the sapphire glass and the spout (Plate 5). The HarvestLab can be put in a stationary mode and used for forage quality evaluation (Plate 6). HarvestLab uses Near Infrared Spectroscopy (NIRS) to evaluate the dry matter, sugar, acid detergent fiber (ADF), neutral detergent fiber (NDF), ash, and crude protein in corn silage, fresh grass, and other forage samples, providing permanent and real-time data compared to wet chemistry method is normally laborious and time-consuming. We were using HarvestLab to determine forage quality variables from the farm platform samples for calibration with wet chemistry analysis. It was going on before I departed for my home country.

Plate 5: HarvestLab being mounted on a spout (http://salesmanual.deere.com/sales/salesmanual)

Plate 6: Working with HarvestLab in a static mode to evaluate forage quality (*Photo: Charlie Morten*)

3.0 Highlight of Results

There was a strong positive linear positive correction between RPM compressed swards surface height (CSSH) and *in-situ* forage dry matter yield for green field (R^2 = 0.7354), blue field (R^2 = 0.5056) and red field (R^2 = 0.6314) (Figure 4). Also, a linear positive relationship existed between calibrated RPM Biomass and yield and fPAR readings for Blue and Green Fields (Figure 5), while a positive quadratic relationship between RPM compressed sward compressed height and NDVI for Green and Blue fields was established (Figure 6).

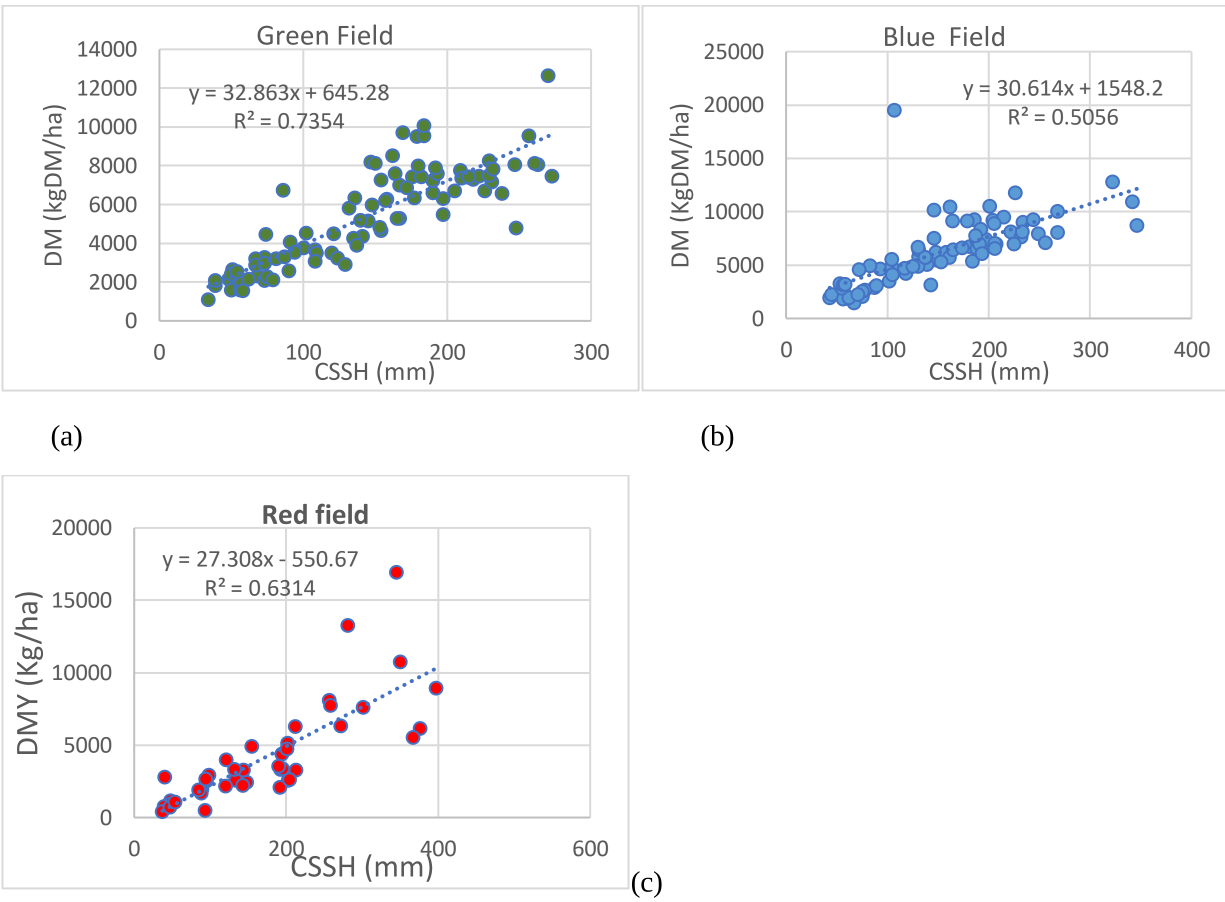
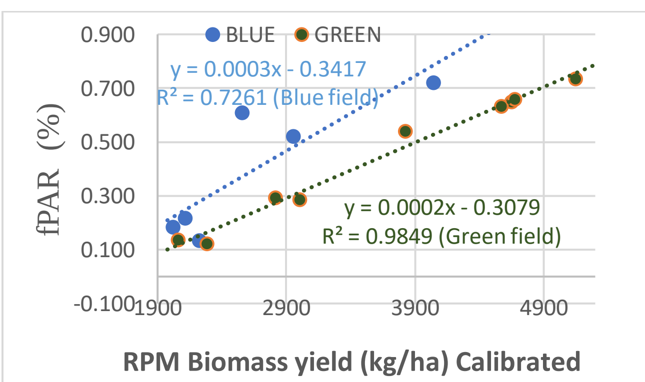


Figure 4: Relationship between Real harvest oven-dried herbage yield and RPM compressed swards surface height (CSSH) of Green, Blue and Red Fields



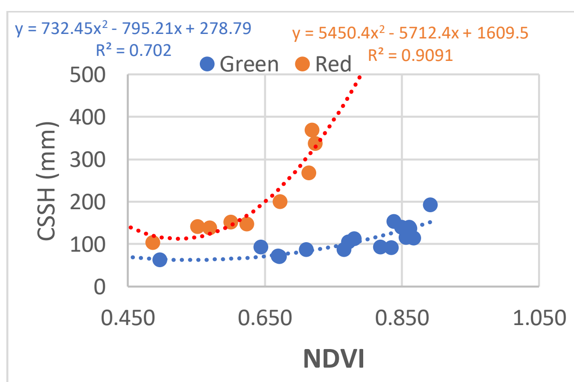


Figure 5: Relationship between Calibrated RPM Biomass and fPAR readings for Blue and Green Fields

Figure 6: Relationship between Platemeter compressed and yield height and NDVI for Green and Blue fields

2.3 Other Engagements while at Rothamsted Research, North Wyke

i).**Project Title:** The use of NuAdvent+ feed supplement to support healthy methanogenesis reduction in sheep.
This Project was performed at the BioControl pens of the Robert Orr Small Ruminant Facility (SRF) of Rothmsted Research, North Wyke to investigate the effect of NuAdvent+ (a feed additive) in ruminants for GHG emissions, feed conversion efficiency, lightweight gain, and body condition score. Funding was from Environmental Futures & Big Data Impact Lab and the period of the project was eight (8) weeks (from 29/04/2022 to 15/07/2022). I was involved in feeding and data collection among other activities (Plate 7).

Plate 7: BioControl Facility with GreenFeed attached at the Robert Orr Small Ruminant Facility. (*Photos: Paulo De Meo Filho*)

ii). **Achieving Sustainable Agricultural Systems (ASSIST) now the Rowden Experiment**
The project was established in 2018 and jointly funded by Biotechnology and Biological Sciences and Research Council (BBSRC) and NERC. The aim was to develop and test innovative farming systems that aim to maintain or increase crop productivity and resilience to future perturbations, while reducing the environmental and ecological footprint of agriculture. To achieve the aim, the following objectives were addressed:
a). Quantify biophysical limitations on arable and grassland yields from field to national scales, and develop integrated models to forecast limitations under future environmental change
b). Accurately predict the potential impacts of current and future agricultural intensification on the wider environment, including natural capital and associated ecosystem services
c). Develop models to predict the vulnerability of agro-ecosystems to environmental perturbations and design strategies to make them more resilient


Plate 8: Aerial view of Rowden experiment (*https://www.ecologicalcontinuitytrust.org/rowden-plots*)

d). Implement a study farm network to test combinations of nature-based and agri-tech solutions that reduce negative environmental impacts and enhance agricultural production and
e). Build a synthesising spatial framework for planning future land use that optimises these benefits to food production while minimising trade-offs and conflicts with other ecosystem services at the farm- and landscape-scales
For the grassland component of the project, three sward types were tested: a) nature-based approaches; b) agri-tech approaches c) permeant pasture, with 12 plots in total. Half of the plots were managed under cell grazing and the other half under continuous stocking. Plate 8 shows the aerial view of the project.

My activities at Rowden were:
a). Measurements of pasture swards yield using RPM (weekly measurement of forage biomass accumulation, Pre and post graze biomass of the cell-grazed plots and as well as biomass of whole plots)
b). Collection of soil emission samples using Static Chamber from all the plots (Plate 9)
c). Took 10 soil cores from each plot using soil corer for evaluation (Plate 10)

Plate 9: Collecting soil emissions from a Static Chamber

Plate 10: Taking a Soil Core (*Photos: Fabiana Pereyra*)

Plate 11: Taking GPS points at a location of a Static Chamber

iii). The Techno grazing Project

This project was established in 2018 to evaluate and compare two grazing systems. TechnoGrazing/cell grazing and set stocking for herbage production, dairy x beef cattle performance, and soil variables. Cell grazing is an approach where paddocks are divided into lanes and these lanes are sub-divided into precisely equal parts (cells). Animals are rotated for grazing from one cell to another for a period of one to two days. The concept, which originates from New Zealand is currently not practiced in Africa and is not widely concept practiced in the UK as well as in other parts of the world but it is gaining relevance. The summary aim of this study was to evaluate the forage production, cattle live weight gain, soil properties, and nutrient distribution under the two contrasting grazing systems (TechnoGrazing and set stocking). My role at the time of the visit was to evaluate herbage mass/cover using the RPM for an informed decision on stocking rate and I also took herbage snips samples for quality assessment.

iv) British Society of Animal Science Conference 2022

I attended the British Society of Animal Science Conference (BSAS), 12th - 14th, April, 2022, which held at EMCC, University of Nottingham, Great Britain. Theme: *The role of Animals in Human and Planetary Health.* The sponsorship came from the Livestock Grazing Systems Cluster of Net Zero and Resilient Farming Science Directorate, Rothamsted Research.

Plate 12: 2022 BSAS conference, Nottingham

3. Potential application of the indirect methods for Nigeria evaluation in Nigeria

Forage yield and quality evaluation with the use of on-farm methods where the above-mentioned equipment are deployed have been valuable in the temperate grassland for more than two decades. These on-farm methods are easily employed due to the nature of growth temperate forage species which are normally shorter and low in biomass compared to tropical species. The tropical species are much taller sometimes more than 3 meters in some species with high biomass, up to 40 tDM/ha (Plate 13 a and b) compared to a typical grass sward (Plate 13 c) in the temperate region. In this regard, the application of RPM and GreenSeeker may be suitable only during the early part of plant grass growth and trailing legumes for yield estimation and calibration to predict growth rate. However, it will not be feasible to estimate yield and quality at later stages of growth and calibration will not be possible at this stage. Most RPM are approximately 100 cm in height and the GreenSeeker tends to be saturated for values above the value of 1. This means the quantity of forages will be underestimated at the later stages of forage crops in most tropical species. A more viable option is the calibration of fPAR values from Quantum Sensor for forage growth and yield prediction (Fig. 4 a and b). However, values could be obtained from the Harvest Lab of John Deere and calibrated using the wet chemistry values for quality in a real-time manner.

Plate13 a: *Pennisetum purpureum* (https://www.istockphoto.com/search/2/image?phrase=pennisetum+purpureum)

Plate 13 b: *Andropogon gayanus* *(https://www.google.com/search?q=andropogon%20gayanus&tb)*

Plate13 c:Pernnial ryegrass sward, Rising Plat Meter and Handheld GreenSeeker (*Photo: Gonzalo Irisarri*)

4. Experience gained or contacts made that will be of particular value for me or my organisation

I have gained experience in various ways that are valuable to me and my organization. Rapid and real-time estimation of forage biomass yield and quality through the calibration of indirect methods especially the on-fields have been significant for farmers in terms of forage budgeting in temperate regions. Even though not all the on-farm techniques for low-cost assessment of forage growth and subsequent yield can be applied to Nigerian grassland due to the nature of forage species, knowledge and skills in all the methods available at North Wyke allowed me to learn the on and off-farm procedure for forage quantification and calibration. This will enable me to apply those methods that will be useful in tropical grasslands. My experience at North Wyke, Devon was not limited only to the low-cost assessment of forage quality and quantity using the calibration of indirect methods, but I was also exposed to modern facilities during my participation in other projects as stated above. Overall, the knowledge, approach, and skills in grassland research for short and long-term projects at Rothamsted Research are of great value to me. This will be translated to my home institution for training and research on sustainable grassland improvement. Valuable contacts have been made for future collaboration on sustainable grassland production.

5. Follow-up and future plans from the Fellowship.

i) Collaboration on the calibration of forage quality readings from HarvestLab of John Deere with wet chemistry analysis.
ii) Aiming to have a manuscript on the work carried out.
iii) We are currently generating remote sensing data on Nigeria grassland
iv) Would like to develop and collaborate on agronomic trials to investigate different multispecies mixtures, NIRS calibration, soil emissions, silage value, and in vitro assessment of methane emissions both in Nigeria and the UK.

6. Acknowledgement

My appreciation goes to the Board of Trustees and the entire staff for of Stapledon Memorial Trust for finding my proposal worthy to be selected and awarded for the 2022 Travelling Fellowship. My deep appreciation also goes to my immediate Supervision (Dr. Gonzalo 1risarri) as we worked closely and the line Manager of Grazing Livestock Systems (Dr. Jordana Rivero) who accepted to be my host Supervisor/line manager during my stay at Rothamsted

Research. I'm grateful to Prof. Adrian Collins, the Strategic Science Director - Net Zero and Resilient Farming, Rothamsted Research for the approval and to the entire staff of the Research Institute for the cooperation at various times during my stay at the Institute.

Plate 14. Myself and some staff of Rothamsted Research, North Wyke, Devon, UK (*Photo during Rothamsted Staff Celebration of the Queen's Platinum Jubilee*)

Plate 15. L-R, Dr. Jordana Rivero, Myself and Dr. Gonzalo Irisarri
(*Photo: Gonzalo Irisarri*)

References

Matthew, C. Hernandez-Garey, A. and Hodgson, J. (1996). Making sense of the link between tiller density and pasture production. Proceedings of the New Zealand Grassland Association. Pp: 83-87.

Wua, L., Zhanga, X., Griffitha, B.A. and Misselbrooka, T.H. (2016). Sustainable grassland systems: a modelling perspective based on the North Wyke Farm Platform. European Journal of Soil Science. 67: 397–408 https://doi.org/10.1111/ejss.12304

APPENDIX

Summary of Schedule of Activities carried out at Rothamsted Research, North Wyke, Devon, UK

Week	Date	Activities Performed
Arrival	8th April, 2022	
Week 1	**11th -17th April, 2022**	
Monday	11th /04/2022	Took Measurements with Rising Plate Meter (RPM) and GreenSeeker (GS) at Green Field
Tue - Sat	12th – 17th/04/2022	Attended BSAS Conference in Birmingham
Week 2	**18th – 24th/04/2022**	
Tue-Wed.	19th -20th /04/2022	Safety Induction with various safety units and officers
Thur	20th /04/2022	Took measurements at green fields using RPM,GS.
Fri.	21st/04/2022	Dried forage samples in herbage lab.
Week 3	**24 th – 29th/04/2022**	
Tues	26th/04/2022	Took measurements at Red fields with RPM,GS and fPAR. Did Laboratory Induction
Wed.	27th/04/2022	Took measurements at Green fields with RPM, GS and fPAR and took herbage samples. Weighed Sheep with farm Staff
Thurs	28th/04/2022	Took measurements at Blue fields with plate meter, GreenSeeker and fPAR and took herbage samples. Weighed Sheep with farm Staff
Fri.	29th/04/2022	Took measurements at Red fields with RPM,GS and fPAR and took herbage samples.
Week 4	**2nd- 6th/05/2022**	
Wed	5th /05/2022	Took Plate meter readings at Rowden experiments/fields
Fri	6th/05/2022	Oven-dried herbage samples from Red, Blue and Green fields
Week 5	**9th - 15th/05/2022**	
Mon	9th/05/2022	Weighed Oven-dried herbage samples from Red, Blue and Green fields
Tue.	10th/05/2022	Took measurements from Techno Experiments
Wed	11th/05/2022	Took postgraze readings with plate meter at Rowden experiments
Fri.	13th /05/2022	Took readings from Green field with RPM, GS and harvest herbage samples and oven dried herbage samples Work at Small Ruminant Facility (SRF)
Fri. & Sat.	14th – 15th/05/2022	Fed animals and work at SRF
Weeks, 6, 7, 8, 9, 10, 11, 12 13	**16th/05/2022 to 15th/07/2022**	**Mondays:** Measurements of pregraze cells at Rowden experiment **Tuesdays:** Took measurements at Red, Blue and Green fields with RPM,GS and fPAR and took herbage samples **Wednesdays:** Measurements of postgraze cells and all 12 plots at Rowden experiment **Thursdays:** Measurements at Red, Blue and Green fields with RPM,GS and fPAR and took herbage samples **Fridays:** Biomass measurements at Techno Grazing with RPM Fed animals at SRF **Saturdays and Sundays.** Fed animals and work at SRF -Took herbage snips samples at Techno every four weeks -Perform other activities such as harvest, oven-drying, freeze-drying and weighing of samples at various days The activities at the SRF used to alternate within days of the week.

Weeks, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	**18th/07/2022 to - 03th/092022**	**Tuesdays:** Took measurements at Blue and Green fields with RPM,GS and fPAR and took herbage samples **Wednesdays:** Biomass measurements of permanent pasture plots at Rowden experiment **Thursdays:** Measurements at Blue and Green fields with RPM, GS and fPAR and took herbage samples **Fridays:** Biomass measurements at Techno Grazing with RPM. -Took soil cores with soil corer at Rowdem experiments on different days within the period Set up Static Chambers for soil emissions measurements at Rowden experiments at different times within this period -Took soil emission gasses at Rowden Plots at different times within this period -Took herbage snips samples at Techno every four weeks -Perform other activities such as harvest, oven-drying freeze-drying and weighing of samples
Week 24 and 25	7th September, 2022	**Wednesdays-**Took herbage cover for the permanent pasture at Rowden experiment with RPM -Install Static Chambers at Rowden experiment for soil emission measurements
	8th September, 2022	**Thursdays:** Evaluated nutritive value of samples from Green and Blue fields with Harvest Lab of John Deere,
	9th September, 2022	**Fridays:** Took samples from Static Chamber at Rowden plots
	10th September, 2022	**Saturdays**: Took herbage biomass cover at Techno grazing experiment
Week 26	11th to 18th Sept., 2022	Evaluated nutritive value of samples from Green and Blue fields, oat hay and forage snips from Techno Grazing experiment with HarvestLab of John Deere,
Week 27	19th to 24th Sept. 2022	Report writing and departure to home country