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# How farm practices and antibiotic use drive disease incidence in smallholder livestock farms: Evidence from a survey in Uganda

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ABSTRACT

*Background:* Antimicrobial resistance (AMR) is a growing threat to human and animal health, and the growth in AMR prevalence globally is thought to be partially driven by non-therapeutic antibiotic use in livestock production. However, livestock farms may depend on antibiotics as a prophylactic disease management tool, and reducing antibiotic use in isolation may harm farmers' economic security. In order to help farmers safely reduce their antibiotic use, we must first determine how necessary non-therapeutic antibiotic use is for disease management, and how other farm practices can guard against disease and make antibiotic use reduction safe and feasible.

*Methods:* Using the *Antimicrobial Use in Livestock Production Settings* (AMUSE) tool, a standardised survey tool for investigating attitudes and practices relating to antibiotic use on farms, we investigated the farming practices and animal disease outcomes of smallholder livestock farms in Uganda. We used logistic regression to investigate the effect of prophylactic antibiotic use; as well as of prophylactic vaccination, non-antimicrobial medicines, and on-farm biosecurity measures; on the likelihood of disease outbreaks.

*Findings:* We found that prophylactic antibiotic use did indeed seem to guard against disease outbreaks, underlining the rationality of non-therapeutic antibiotic use in smallholder livestock farms and the need to pair antibiotic use reduction with other interventions in order to mitigate risk. The most effective intervention pairing varied by species, with expanded access to animal health services and the use of prophylactic vaccination demonstrating the greatest potential overall.

*Implications:* These findings echo earlier results generated using the AMUSE survey tool. They should be followed by participatory research in which farmers are consulted to explore intervention options, and subsequently by farm-level intervention trials of combined antimicrobial stewardship interventions to verify their effectiveness.

## 1. Introduction

Antimicrobial resistance (AMR), the capacity of microbial pathogens to survive in the presence of antimicrobials, is an increasingly prominent threat to human and animal health and the focus of much global health policy discourse [1,2]. In particular, the growing resistance of bacterial pathogens to antibiotics threatens a future in which a large portion of bacterial infections become difficult or impossible to treat, and in which procedures such as invasive surgery or chemotherapy for cancer become much riskier and less viable. While AMR exists in nature, the present growth of AMR is driven mainly by the use of antimicrobials [3].

Use of antibiotics in livestock animal production can be for the purposes of treatment, prophylaxis, metaphylaxis or growth promotion; and is one of the most prevalent forms of antimicrobial use (AMU) globally. For this reason, antimicrobial stewardship (AMS) initiatives often aim to reduce the quantity of antibiotics used in livestock production, placing particular emphasis on forms of AMU deemed 'irrational' (e.g. growth-promotion and prophylaxis) and on classes of antibiotics of critical importance to human health [4–6].

However, even non-therapeutic use of antibiotics can improve

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livestock productivity and avert animal disease, and has therefore been important to farmers' livelihoods and to general food security [7]. Where water, sanitation and hygiene (WASH) and biosecurity infrastructure is unaffordable or unavailable, antibiotics may be used to compensate. This question is particularly relevant also to low- and middle-income countries (LMICs), which bear a disproportionate burden of AMR and where lower levels of food security make agricultural productivity particularly important [1]. In addition, simply placing legal restrictions on the use of antibiotics in livestock production may not be politically acceptable, compliance may be difficult to monitor and enforce, and doing so may cause farmers to switch to illegal or counterfeit antibiotics which may worsen the situation.

For these reasons, it is necessary to design interventions which allow farmers to reduce their antibiotic use safely and without concern for increased incidence of animal disease. It is also important to determine how important non-therapeutic antibiotic use is as a disease management tool. We therefore aimed to investigate the determinants of animal disease outbreaks in smallholder livestock farms targeting pigs, small ruminants (sheep and goats) cattle and poultry, using on-farm survey data from Uganda.

We frame AMR here as a One Health issue, in which human health outcomes form part of a network involving food production systems and animal health. Rather than viewing animal antibiotic use as an issue of veterinary medicine alone, we want to see how it interacts with other agricultural practices and animal health infrastructure, allowing us to make recommendations from a cross-sectoral policy lens.

This study forms part of a body of literature using the *Antimicrobial Use in Livestock Production Settings* (AMUSE) survey tool, and aims to add to a body of literature collected using the tool in different contexts. It is closely linked to those previous studies, allowing comparison across settings. To our knowledge, it is first the study to investigate how antibiotic use and other farm practices influence animal disease outcomes in Uganda's smallholder livestock farms.

## 2. Methods

### 2.1. Survey tool

We gathered data using the (AMUSE) survey tool [8], which is designed to collect information about on-farm practices and attitudes relating to antimicrobial stewardship (AMS). This tool has been applied to other settings in a range of countries (Uganda [9], Ethiopia [10], Burkina Faso [11] and Senegal [12]), generating useful insights into the drivers of knowledge, attitudes and practices relating to AMR.

### 2.2. Setting

The study was conducted in Mukono and Lira districts in Uganda. Mukono district is in central Uganda, 40 km from the capital of Kampala, with a population of 596,804 people; among these, 59% are involved in agriculture [13]. Because of the proximity to Kampala, livestock farmers are assumed to have good access to veterinary drugs and other animal health inputs. Lira District is in Northern Uganda, about 300 km from Kampala with an estimated human population of 377,800 in 2010. The economy of the district is mainly based on agriculture, with 81% of the population engaged in subsistence farming, with cattle being the main source of wealth and bulls and oxen being a major source of traction [14]. Piggery has increasingly become an important enterprise with 40% of sub-counties having piggery as a priority enterprise [15]. Due to the scope of the survey, questions on disease occurrence focused on symptoms rather than pathogen species. Animal disease incidence was higher in rural Lira than in peri-urban Mukono, with respiratory complaints being common in the former and digestive issues being common in both settings.

### 2.3. Data collection process

Data collection was led by a research technician and veterinarian, heading a team of eight enumerators who each visited one village and interviewed farmers there. Enumerators were trained on data collection to ensure accurate interpretation of responses, and data were collected on tablets using Open Data Kit (ODK) software between 13 August and 10 September 2018.

Further details on the data collection process can be found in Nohrborg et al. [9], the first study to use this dataset.

### 2.4. Ethical approval

The study was approved by the Uganda National Council for Science and Technology under reference A 583 of 18 June 2018. Informed consent was obtained from all respondents that participated in the study. The full survey tool used, and a copy of the ethical approval given, can be found in the appendix.

### 2.5. Statistical methods

We first present summary statistics of our main variables of interest (Table 1). These are: the use of on-farm biosecurity measures, whether or not a flock or herd experienced a disease outbreak in the two weeks prior to the visit, average annual per-animal expenditure on antibiotics, vaccination and other medicines, access to animal health services, prophylactic antimicrobial use, prophylactic vaccination, and farm size. Here, 'other medicines' refers to vitamins, dewormers and acaricides. Biosecurity measures include fencing, not allowing herds and flocks to mix with each other, avoiding grazing in the morning, maintaining animal hygiene, regular animal health checkups, restricting visitors,

**Table 1**
Summary Statistics.

| | Cattle | Pigs | Small ruminants | Poultry |
|---|---|---|---|---|
| Number of farms with this species (out of 482 farms in the survey) | 216 | 465 | 247 | 326 |
| Portion of farms using biosecurity measures for the species in question | 49/216 (22.7%) | 168/465 (36.1%) | 45/247 (18.2%) | 38/326 (11.7%) |
| Portion of flocks or herds experiencing disease in the last 2 weeks | 47/216 (21.8%) | 92/465 (19.8%) | 52/247 (21.1%) | 44/326 (13.5%) |
| Average annual expenditure on AB per animal in UGX (USD values in brackets[a]) | 10,730 ($3.10) | 3387 ($0.98) | 3369 ($0.97) | 162 ($0.05) |
| Average annual expenditure on vaccines per animal in UGX (USD values in brackets) | 2589 ($0.75) | 1235 ($0.36) | 498 ($0.14) | 282 ($0.08) |
| Average annual expenditure on other medicines per animal in UGX (USD values in brackets) | 20,228 ($5.85) | 11,174 ($3.23) | 5713 ($1.65) | 216 ($0.06) |
| Average flock or herd size (range) | 3.31 (1–14) | 4.92 (1–55) | 4.65 (1–39) | 25.75 (1–700) |
| Portion of farms with access to animal health services | 371/482 (77.0%) | | | |
| Portion of farms using AMU prophylactically | 164/482 (34.0%) | | | |
| Portion of farms using vaccination prophylactically[b] | 427/482 (88.6%) | | | |

[a] The data were collected in 2018. To obtain present-day USD values, the UGX values are converted to USD using the 2018 exchange rate, then inflated to present day using the US GDP deflator

[b] While the majority of vaccination use was prophylactic, we make this distinction because some farmers reported using vaccines to cure existing diseases and for growth promotion

buying only healthy animals, spraying animals, and confinement of sick animals.

Our main outcome of interest was the probability of disease occurring in the herd / flock. This was a binary variable for whether or not a farmer reported animals in a herd / flock having displayed symptoms of disease in the last two weeks. Disease outcomes were self-reported, and covered respiratory, digestive, dermal and reproductive complaints, as well as parasites, neurological concerns, and mastitis. We investigated which variables were correlated with likelihood of disease for each livestock species using Pearson's correlation coefficient (Table 2).

We then investigated the effect of several farming practices on likelihood of disease using logistic regression (logit), as shown in Table 3. These practices were: prophylactic antimicrobial use, prophylactic vaccination, use of on-farm biosecurity measures, and access to animal health services. All farm practice variables were binary (i.e. whether or not the practice was implemented), as was the variable for accessing animal health services (See Table 3).

Results were first disaggregated by species, and then aggregated across all farm types. When looking at all animal species together, flocks and herds of different species located on the same farm were treated as a separate unit of analysis. All of our regression specifications also controlled for the number of animals in the flock or herd.

Following this, we regressed the likelihood of disease incidence against expenditure on antibiotics, vaccination and other medicines per animal during the past year (in Ugandan Shillings (UGX), omitting extreme outliers (5 SD above the mean[1]). We acknowledge that there may be endogeneity between the outcome and covariates, as farmers may use these medicines in response to disease outbreaks, obscuring any preventative effect that they may have. However, this endogeneity can be minimised by the fact that our covariates concerned average expenditure over the past year, whereas our outcome looked only at disease in the two weeks prior to the survey.

While data were collected from two regions of the country, we did not stratify regressions by region due to small sample size and statistical power concerns, a limitation of this study.

## 3. Results

Each of the four animal species in the sample was present in at least 45% of farms, with most farms having animals of multiple species (Table 1). Most farms had access to animal health services and used prophylactic vaccination, whereas most farms did not use antimicrobials prophylactically and did not implement on-farm biosecurity measures. Average flock and herd size was small, and expenditure on medicines varied greatly between species and medicine type. Farmers generally spent the most per animal on other medicines (acaricides, vitamins and dewormers), followed by antibiotics and then by vaccines.

Using Pearson's correlation coefficient, having a larger flock or herd size was unsurprisingly positively associated with a higher likelihood of disease across all animal species and for the sample as a whole. Expenditure on vaccination was associated with a lower likelihood of disease for the sample as a whole. However, expenditure on vaccination was not associated with likelihood of disease for any individual species, likely due to a smaller sample size when looking at individual species. Prophylactic use of antimicrobials and access to animal health services were both associated with a lower likelihood of disease in pigs and for the sample as a whole, and prophylactic vaccination was associated with a lower likelihood of disease in chickens. None of the practices presented in Table 2 were significantly associated with disease incidence for either small ruminants or cattle.

Having more animals on the farm was associated with a higher likelihood of experiencing disease across all animals considered, with an additional animal increasing the odds of disease by 0.4% (chickens) to 18.9% (ruminants). For cattle and ruminants, none of the farm practices investigated were significantly associated with odds of disease. For pigs, prophylactic use of antimicrobials reduced the odds of disease by 39.3% and access to animal health services reduced the odds of disease by 69%. For chickens, prophylactic use of vaccination reduced the odds of disease by 59.6%. Across all species, prophylactic use of antimicrobials reduced the odds of disease by 33.3%, access to animal health services reduced the odds of disease by 40.7%, and the presence of an additional animal increased the odds of disease by 0.3%.

For cattle, pigs and chickens, expenditure on any kind of medicines (vaccinations, antibiotics and other medicines) was not significantly related to the odds of disease (see Table 4). For ruminants, spending an additional 1000 UGX ($0.29 USD) on non-vaccine and non-antimicrobial medicines per animal per year (including vitamins, acaricides, and dewormer) was associated with a 2.6% *higher* odds of disease. Across all animal species, spending an additional 1000 UGX per animal per year on vaccination was associated with 12.2% lower odds of disease and the same additional spending on other medicines was associated with a 0.8% higher odds of disease. As in the previous specifications, an additional animal was associated with higher odds of disease between 0.4% (chickens) and 21.4% (ruminants).

## 4. Discussion

### *4.1. Findings*

Prophylactic AMU, despite often being considered 'irrational', does seem to convey a benefit to smallholder farms, in accordance with studies from other settings using this survey tool [12,16] and with the wider literature [7]. This reaffirms that antibiotic withdrawal must be coupled with other interventions to help mitigate the potential negative effect on animal health; especially in pigs, where prophylactic AMU appeared to be the most effective at preventing disease. This 'intervention pairing' approach has already been successful in medium-sized farms in other contexts [17,18].

Different farm practices were effective in different species, demonstrating the need for a tailored approach when designing interventions to complement AMU reduction. Specifically, animal health services were of the most benefit to pig farms, and prophylactic vaccination was of the greatest benefit to chickens. Surprisingly, on-farm biosecurity did not seem to influence the likelihood of disease; and expenditure on acaricides, vitamins and dewormers seemed positively correlated with the likelihood of disease. However, the level of statistical significance of the latter finding was low, and that result may be due to the modality of these drugs' use (e.g. if acaricides and dewormers are more likely to be used in response to disease rather than prophylactically, which would create endogeneity). There are a number of possible explanations for biosecurity not being associated with the likelihood of disease. In particular, the biosecurity variable that we used covered a broad range of practices, and did not distinguish between farms based on either the number of measures used or by the comprehensiveness of those measures. While expenditure on vaccination was associated with a lower disease incidence overall, we did not see this result when looking at each species individually, likely due to the smaller sample size.

The logistic regressions used here are especially useful because they can provide us with a set of odds ratios with a cardinal real-world interpretation. Looking at our results, we can see that some of the measures considered had a very large impact on the likelihood of disease.

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[1] Although a standard approach is often to remove results 3 standard deviations from the mean, upon inspecting the data we realised that this would mean removing a relatively large number of observations from a small dataset. Because there were many observations only marginally closer to the mean than this, it would also involve removing some data points but keeping nearby data points. Thus, the decision to use a five standard deviation cutoff reflects the underlying variation in expenditure across farms, and only removing results which were truly outliers.

**Table 2**

Correlates of Disease Likelihood by Species (Pearson's correlation coefficient).

Correlates of Disease Likelihood by Species

| | Cattle | Pigs | Small ruminants | Chickens | Whole sample |
|---|---|---|---|---|---|
| Prophylactic AMU | -0.07 | -0.098* | -0.1 | -0.013 | -0.076** |
| Prophylactic vaccination | 0.066 | 0.016 | 0.012 | -0.111* | -0.005 |
| Expenditure on antibiotics | -0.015 | -0.055 | 0.061 | 0.035 | 0.005 |
| Expenditure on vaccination | -0.064 | -0.09 | -0.052 | -0.05 | -0.061* |
| Expenditure on other medicines | 0.046 | -0.069 | 0.094 | -0.002 | 0.023 |
| Use of on-farm biosecurity practices | 0.072 | -0.038 | 0.011 | 0.059 | 0.020 |
| Number of animals | 0.189** | 0.114* | 0.266*** | 0.177** | 0.072* |
| Access to animal health services | -0.107 | -0.204*** | 0.01 | 0.013 | -0.094*** |

*Pearson's correlation coefficient*

*Note: *p < 0.1, **p < 0.05, ***p < 0.01*

**Table 3**

Effect of Practices on Disease Likelihood (Odds Ratio).

| | Dependent variable: | | | | |
|---|---|---|---|---|---|
| | disease | | | | |
| | Cattle | Pigs | Small Ruminants | Chickens | Whole Sample |
| | (1) | (2) | (3) | (4) | (5) |
| Prophylactic AMU | 0.681 | 0.607 | 0.532 | 0.991 | 0.667 |
| | $t = -0.965$ | $t = -1.787$* | $t = -1.588$ | $t = -0.025$ | $t = -2.426$** |
| Prophylactic Vaccination | 1.508 | 0.904 | 1.105 | 0.404 | 0.912 |
| | $t = 0.622$ | $t = -0.262$ | $t = 0.197$ | $t = -2.105$** | $t = -0.409$ |
| Access to Animal Health Services | 0.558 | 0.310 | 1.136 | 1.051 | 0.593 |
| | $t = -1.516$ | $t = -4.324$*** | $t = 0.333$ | $t = 0.123$ | $t = -3.174$*** |
| On-Farm Biosecurity Measures | 1.823 | 0.911 | 1.229 | 0.867 | 1.223 |
| | $t = 1.476$ | $t = -0.338$ | $t = 0.495$ | $t = -0.259$ | $t = 1.157$ |
| Number of Animals in Flock / Herd | 1.173 | 1.058 | 1.189 | 1.004 | 1.003 |
| | $t = 2.511$** | $t = 3.171$*** | $t = 3.498$*** | $t = 2.226$** | $t = 1.922$* |
| Constant | 0.157 | 0.549 | 0.105 | 0.293 | 0.382 |
| | $t = -2.597$*** | $t = -1.462$ | $t = -3.559$*** | $t = -2.420$** | $t = -3.917$*** |
| Observations | 216 | 465 | 247 | 326 | 1254 |
| Log Likelihood | −107.278 | −215.918 | −117.455 | −124.705 | −594.432 |
| Akaike Inf. Crit. | 226.556 | 443.835 | 246.910 | 261.409 | 1200.865 |
| *Note:* | *p < 0.1; **p < 0.05; ***p < 0.01 | | | | |

t is the test statistic - a greater size represents a greater degree of statistical significance.

### *4.2. Limitations*

While in this paper we investigated the effect of having some sort of on-farm biosecurity measure(s) in place, future research could consider in more detail the effects of different biosecurity strategies individually as well as combinations of different measures. In addition, the apparent lack of impact of biosecurity measures may be due to the extensiveness or quality of the measures in use on the farms in our sample - it is possible that interventions which use different or more extensive biosecurity measures may yet improve animal health outcomes. In addition, all farms in the sample used antibiotics, and it is possible that biosecurity measures would indeed be effective disease management tools in a context with less antibiotic use.

In terms of assessing the impact of vaccination expenditures, the recorded expenditure only covers vaccines bought by the farmers out of pocket, and not those which were provided by animal health services. Frequency of vaccination may be a more useful indicator to use in future studies, although information on this was not available in this dataset. In addition, the effect of access to animal health services on disease outcomes may thus be partially mediated by vaccination.

When interpreting the results of this paper, we must keep in mind that smallholder farmers exist as part of a complex economic network which includes vets, consumers, drug sellers, creditors, marketeers, landlords, suppliers and others [19]. Interventions targeting AMU in smallholder farms must thus involve the entire network and cannot target farmers in isolation [12,16]. While statistical analyses such as this

**Table 4**

Effect of Expenditures on Disease Likelihood (odds ratio for additional 1000 UGX / 0.29 USD per animal per year).

| | *Dependent variable:* | | | | |
|---|---|---|---|---|---|
| | disease | | | | |
| | Cattle | Pigs | Small Ruminants | Chickens | Whole Sample |
| | (1) | (2) | (3) | (4) | (5) |
| Annual Expenditure on Antibiotics per Animal | 1.005 | 0.996 | 1.021 | 1.292 | 1.006 |
| | *t* = 0.410 | *t* = −0.235 | *t* = 0.885 | *t* = 0.705 | *t* = 0.679 |
| Annual Expenditure on Vaccination per Animal | 0.894 | 0.872 | 0.880 | 0.835 | 0.878 |
| | *t* = −1.502 | *t* = −1.366 | *t* = −1.020 | *t* = −0.844 | *t* = −2.519** |
| Annual Expenditure on Other Medicines per Animal | 1.009 | 0.994 | 1.026 | 0.884 | 1.008 |
| | *t* = 1.584 | *t* = −0.589 | *t* = 1.921* | *t* = −0.291 | *t* = 1.892* |
| Number of Animals in Flock / Herd | 1.194 | 1.036 | 1.214 | 1.004 | 1.004 |
| | *t* = 2.779*** | *t* = 2.147** | *t* = 3.771*** | *t* = 2.580*** | *t* = 2.289** |
| Constant | 0.132 | 0.231 | 0.086 | 0.140 | 0.219 |
| | *t* = −6.176*** | *t* = −8.836*** | *t* = −7.206*** | *t* = −9.992*** | *t* = −18.565*** |
| Observations | 213 | 461 | 244 | 322 | 1240 |
| Log Likelihood | −105.450 | −224.541 | −114.855 | −122.624 | −590.060 |
| Akaike Inf. Crit. | 220.899 | 459.081 | 239.711 | 255.248 | 1190.119 |
| *Note:* | *p < 0.1; **p < 0.05; ***p < 0.01 | | | | |

t is the test statistic - a greater size represents a greater degree of statistical significance.

are useful, they must be coupled with in-depth discussions with farmers about their knowledge, attitudes and practices in order to gain an understanding of what interventions might help them to feel safe in reducing their AMU.

While data were collected from two regions of the country, we did not stratify regressions by region due to small sample size and statistical power concerns, a limitation of this study. While we focused on the influence of farm practices here, we acknowledge that the efficacy of these practices could be modulated by farmers' attitudes and knowledge. As many of our variables were binary, we could not investigate the severity of disease or the quality of veterinary care in detail. Finally, animal disease data captured only a snapshot, and a longer cohort study could have controlled for the disease history on each farm.

### 4.3. Future research and links to other research

Application of the AMUSE survey tool to semi-intensive poultry farms in Dakar and Thiès, Senegal, found that stronger biosecurity aided broiler productivity, as might vaccination (although neither directly influenced disease incidence). The findings of this paper reaffirm the previous finding that smallholder livestock farms have a good rationale for using antibiotics, underscoring the importance of holistic AMS interventions.

The next step should be context-specific in-depth qualitative research in collaboration with smallholder farmers to determine useful interventions to safeguard incomes and facilitate AMU reduction. Subsequently, interventions should be trialled which pair AMU reduction with other interventions in the areas investigated in this paper (especially relating to vaccination and access to animal health services).

### 4.4. Implications

Our findings challenge the conceptualisation of non-curative antibiotic use as irrational, and the idea that antibiotic stewardship efforts should focus on encouraging or requiring individual farmers to reduce or modulate their antibiotic use unilaterally. Smallholder livestock farmers exist as part of a complex network of stakeholders across the One Health spectrum [19], and we draw focus towards creating an environment in which farmers can safely improve stewardship on their own terms without risking incomes and food security. Intervention pairing can facilitate this, and we provide some insights into the best intervention pairings for this context. More broadly, involvement of farmers alongside creditors, suppliers, veterinarians, the public sector and other stakeholders can target stewardship through a whole-system framework [12,16].

## 5. Conclusions

We found that prophylactic AMU was often effective as a disease management tool for smallholder livestock farmers. While there are strong arguments against non-curative antibiotic use in livestock, our findings suggest that it is not always irrational. This highlights the need to combine AMU reduction with other interventions to mitigate any potential loss to animal health and farmers' incomes: prophylactic vaccination and expanded access to animal health services are suitable candidates for this.

These results should be followed by participatory research involving farmers to explore intervention options, followed by trials of combined AMS interventions. Smallholder farms exist as part of an interdependent economic network, and any intervention aiming to reduce AMU in these farms should work across the supply chain.

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## Institutional review board statement

The study was approved by the Uganda National Council for Science and Technology under reference A 583 of 18 June 2018. Informed consent was obtained from all respondents that participated in the study. The full survey tool used, and a copy of the ethical approval given, can be found in the appendix.

## Informed consent statement

Informed consent was obtained from all subjects involved in the study.

## CRediT authorship contribution statement

**Eve Emes:** Conceptualization, Methodology, Software, Validation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Funding acquisition. **Barbara Wieland:** Writing – review & editing. **Ulf Magnusson:** Writing – review & editing. **Michel Dione:** Conceptualization, Investigation, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition.

## Declaration of Competing Interest

The authors declare no conflicts of interest.

## Appendices

*Survey questions.*

To access the full set of survey questions used, please follow this link.

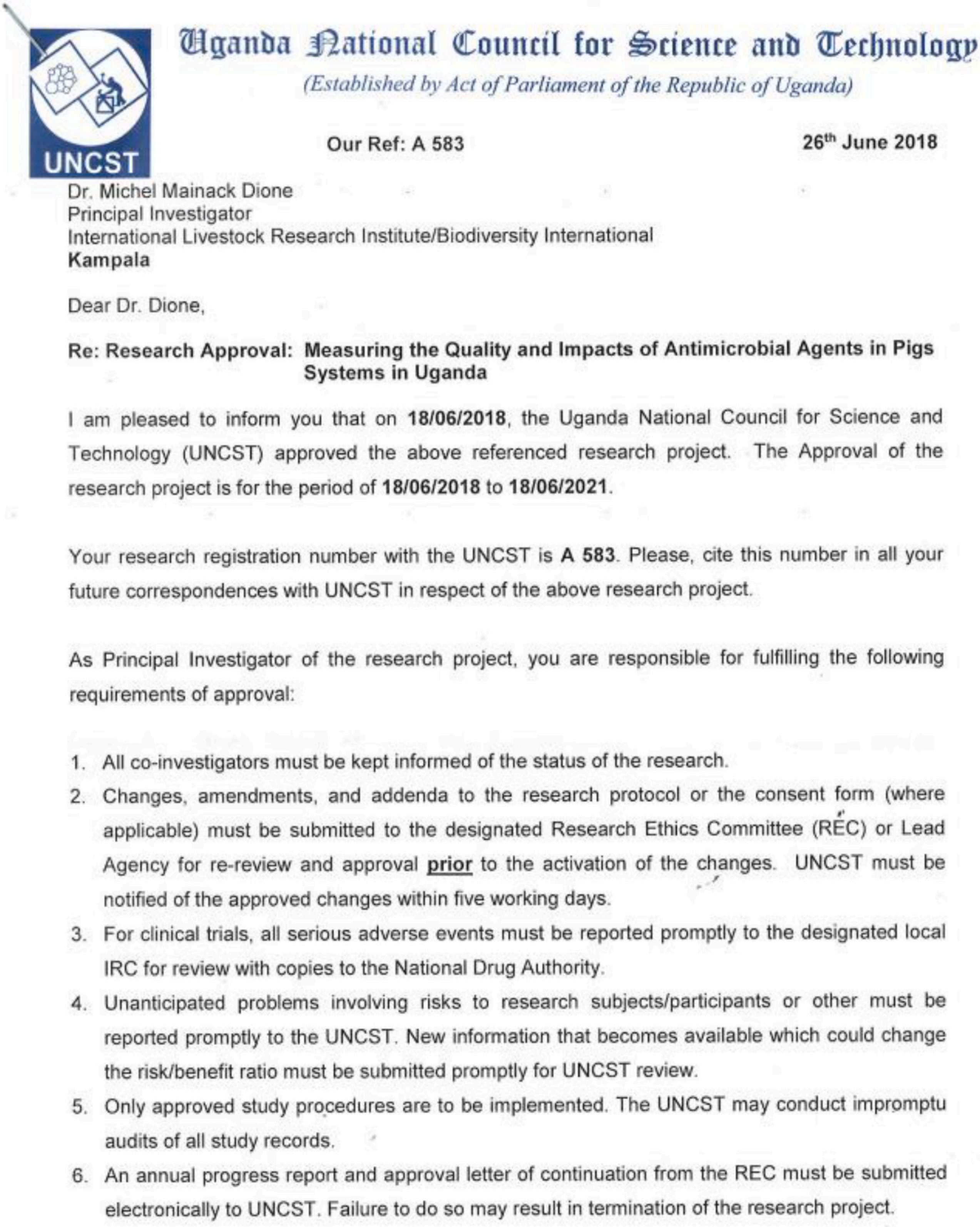
*Ethical approval for the original data collection.*

## Data availability

Data will be made available on request.

## Acknowledgments

The authors express their gratitude towards the farmers who participated in this survey.



UNCST
Uganda National Council for Science and Technology
*(Established by Act of Parliament of the Republic of Uganda)*

**Our Ref: A 583** **26th June 2018**

Dr. Michel Mainack Dione
Principal Investigator
International Livestock Research Institute/Biodiversity International
**Kampala**

Dear Dr. Dione,

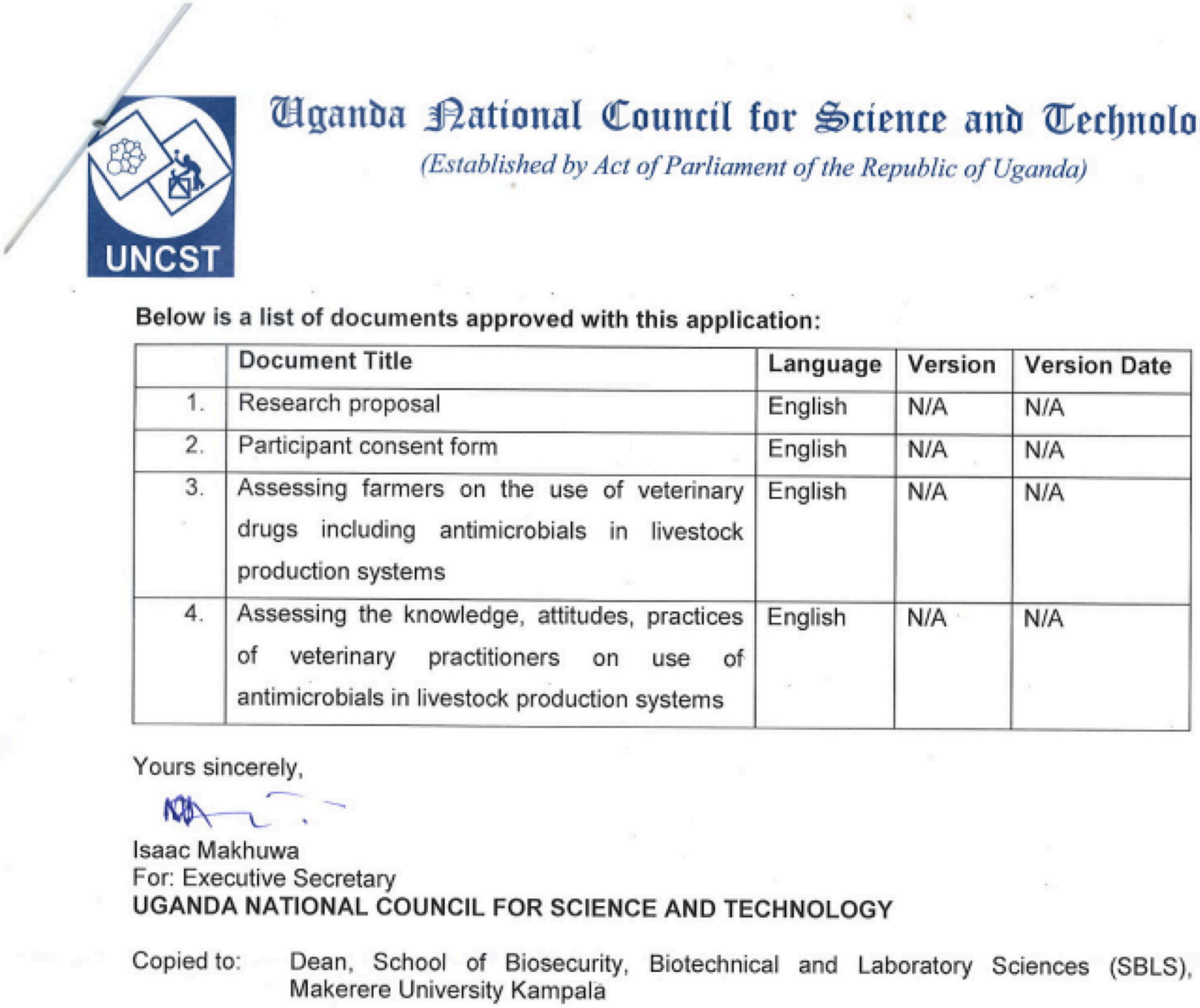
**Re: Research Approval: Measuring the Quality and Impacts of Antimicrobial Agents in Pigs Systems in Uganda**

I am pleased to inform you that on **18/06/2018**, the Uganda National Council for Science and Technology (UNCST) approved the above referenced research project. The Approval of the research project is for the period of **18/06/2018** to **18/06/2021**.

Your research registration number with the UNCST is **A 583**. Please, cite this number in all your future correspondences with UNCST in respect of the above research project.

As Principal Investigator of the research project, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the research protocol or the consent form (where applicable) must be submitted to the designated Research Ethics Committee (REC) or Lead Agency for re-review and approval **prior** to the activation of the changes. UNCST must be notified of the approved changes within five working days.
3. For clinical trials, all serious adverse events must be reported promptly to the designated local IRC for review with copies to the National Drug Authority.
4. Unanticipated problems involving risks to research subjects/participants or other must be reported promptly to the UNCST. New information that becomes available which could change the risk/benefit ratio must be submitted promptly for UNCST review.
5. Only approved study procedures are to be implemented. The UNCST may conduct impromptu audits of all study records.
6. An annual progress report and approval letter of continuation from the REC must be submitted electronically to UNCST. Failure to do so may result in termination of the research project.



Uganda National Council for Science and Technology

*(Established by Act of Parliament of the Republic of Uganda)*

**Below is a list of documents approved with this application:**

| | Document Title | Language | Version | Version Date |
|---|---|---|---|---|
| 1. | Research proposal | English | N/A | N/A |
| 2. | Participant consent form | English | N/A | N/A |
| 3. | Assessing farmers on the use of veterinary drugs including antimicrobials in livestock production systems | English | N/A | N/A |
| 4. | Assessing the knowledge, attitudes, practices of veterinary practitioners on use of antimicrobials in livestock production systems | English | N/A | N/A |

Yours sincerely,

Isaac Makhuwa
For: Executive Secretary
**UGANDA NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY**

Copied to: Dean, School of Biosecurity, Biotechnical and Laboratory Sciences (SBLS), Makerere University Kampala

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