Supplemental material

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1   Supplemental: Additional details on study locations and approach to qualitative data collection and
2   qualitative interview guides

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7   Narratives of veterinary drug use in northern Tanzania and consequences for drug stewardship

8   strategies in low-income countries

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1. Study Locations

Orbombaward is a part of Longido District, where the district headquarters are located. The main road from Arusha City to Namanga Border (between Tanzania and Kenya) runs through the ward. Longido District is also the center of most businesses in the district and offers reliable transportation to the urban center of Arusha. Sinya is located 30 kms from Longido District headquarters and overlooks the slopes of Mount Kilimanjaro and is also adjacent to a wildlife management area. Gelailumbwa is the furthest of all wards (55 kilometers) from Longido District headquarters bordering Ngorongoro District to the northeast. Very little crop cultivation takes place in this area because of it being at the interface of wildlife conservation. This is almost also the same with Sinya ward where the village is part of a community wildlife management area consortium, meaning wildlife freely roams inside it. This ensures that pastoralists depend heavily on their livestock in Sinya. Maasai in Engarinaibor rely on a more diverse set of economic activities. There is a greater reliance on crop cultivation while the ward is also home to a large ruby mine.

2. Approach to collection of qualitative data

2.1 Interview guides

FGDs and KIIs were concentrated around twelve major themes. The 12 themes related to antimicrobial use (AMU) and antimicrobial resistance (AMR) and included farm management and economic practices, area disease histories, and knowledge, attitudes, and practices relating to AMU and AMR, including use, governance, regulations, policies, and enforcement. The data collection guides were pre-tested and piloted on livestock production systems in Siha District, Kilimanjaro region, on a site resembling proposed Longido pastoral communities between 19 and 21 November 2018. Before the pilot, the research team familiarized themselves with the topic guides and ensured all prompts were translated accordingly. After each field pilot day, the research team re-convened and modified the prompts accordingly. The pilot period also provided an opportunity to further improve the qualitative interviewing skills of the recruited research assistants. See Table S1 for interview guides used during FGDs and IDIs

55   with Maasai. See Table S2 for interview guides used for IDIs with animal health service professionals,

56   including agrovets, livestock field officers, community animal health workers, and veterinarians.

57   **Table S1. Focus group discussion interview guide.** Themes/Domains were developed during a
58   workshop in Nairobi (August 2018), where experts in antimicrobial resistance generated a list of
59   themes/domains impacting antimicrobial use and antimicrobial resistance and probes to assess these
60   themes/domains.

Themes/Domain	Topic and Probes *(in italics)*
Economics / Masuala ya uchumi	1. What livelihood activities does your community engage in? • *What would you consider to be the five-priority livelihood activities based on contribution to household income? List from the most significant to the least* • *Can you estimate the percentage livestock income compared to other enterprise in a year?* • *During the year, when does the income from livestock profitable/ better compared to other enterprise?* • *What are the factors influence livestock process (per specie)? How do you ensure maximum profit?*
Management practices	1. We would like to hear a bit about your animals that you keep. • *What types do you keep and for what purposes?* • *How do you access resources (water & pasture), paying attention to seasonality?* o *Sources of each resources and challenges faced including diseases* 2. Do you keep records of your farm management in general? If yes, how? If not why? • *Probe about productivity, sales, purchases, movement of animals, treatments* • *Probe for the responsibilities of each focusing on gendered roles, in case of the Maasai- age set obligations, clan and household (boma) arrangements*

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Environmental context / Mazingira	1. Can you tell me how the environment you live in climate and weather conditions influence your farming practices? What impact do they have? • *Probe for comparison on changes for the last five years* • *Do you experience interaction with wildlife while grazing, and how has this affect your farming?* • *Compared to other pastoral areas is the geographical position favourable or less favourable for livestock keeping?* • *In relation to population increase and livestock increase how have the farming practices been affected? With a focus of interaction with other livestock* • *Would you say living closely with other farmers or apart increase the chance of cross infections?*

Livestock Diseases	2. Now we are going to talk about health problems that occur in our area, affecting livestock.
	
	 • *Can you tell me about the common diseases that your animals faced in the last year? List these per species.*
	
	      o *For each specie, lets rank from the most significant to the least.*
	
	      o *Where possible, discuss the top three, per season*
	
	      o *For the top three what were the common symptoms?*
	
	 3. For these diseases that you described above, can you tell me where they came from and how the animals were affected?
	 4. Health seeking practices
	
	 • *For each disease/ health condition what did you do?*
	 • Probe on disease identification
	 • *Probe on the treatment options taken*
	      • *Where did you seek help and why?*
	 5. What is your preferred source of animal health information and why?
	
	 • *Probe on all possible angles, shops, friends, family, healers, drug peddlers, officials*

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	• *What is your preferred source of medicines for treating livestock and why? Give examples of each*

AMU	1. In your day-to-day life do you talk of diseases caused by different kinds of parasites, such as bacteria's and viruses? (probe on local generally disease causality understanding)
	
	• Can you give examples of the different disease causative agents that you know?
	
	2. In the process of identifying drugs for treating your livestock do you differentiate between antimicrobials and non-antimicrobials?
	
	• How do you do that?
	
	• If not, how do you categorize drugs for treatment
	
	• *Do the options you take always work for you? Give experiences in the past year as far as you can remember*
	
	• Can you name the drugs and the possible diseases they can treat? Please explain how *and the exact measurements as per their understanding*
	
	• *Prompt specifically on the different places these are obtained*
	• *Ask for his opinion on these different sources focusing on issues of quality*
	• *Ask what strategies they use to decide from which source and why? Pay attention to elaborate on differentiating their own preferences and that of farmers*
	• *Prompt for experiences in carrying or storing practices by the farmers, and reasons for this*
	
	3. Is there any difference between vaccines and other drugs including antimicrobials?
	
	• *Can you give me examples of vaccines and when do you use them vaccine (ask for names with examples)*
	
	• *Where do you and farmers source antimicrobials for use in your community?*
	
	4. In your farming practices, when do you normally administer antimicrobials? Probe for triggering actions such as
	
	    a. *Whether during prophylaxis, and why?*
	
	    b. *When an animal is sick with symptoms,*
	
	    c. *If the biosecurity and hygiene conditions are a course for concern*

5

	a. *If time allows probe for reasons behind each use: whether all round costs, simply hygienic reasons, accessibility affecting quality etc* 5. How do you decide how much antibiotic (dose) to give to your animals, and for how long (treatment course) and how often? • *Can you always get the kinds of antimicrobials you want to use? Why / why not?*
AMR	1. Have you experience a situation whereby a drug is not working? • *If yes, please give vivid examples and names of these drugs and what you intended to treat with?* • *How do you tell when a drug or the combination is not working?* • *When this happened what did you do?* • *Probe for all the options taken and why* • *If a combination of drugs was used before or after treatment failure ask for the names of the drugs and the amount of dose given to the animal?* 2. When this drug(s) do not work well as you explain before, how do you call this in your local terms or day-to-day farming practices? • *Probe for any local or vernacular language, or if informed by the local service provider.* • *What do you think contributes/causes the drug not work properly to the extent you resort to other options? Give examples* 3. When you increase dosage of a drug what happens in the body of the animal? • *To your understanding what is the meaning of drug volume or CC?* • *What drugs do you normally start with? What other drugs are given next. Give examples please as per disease* • *Can you explain how the following factors influence prescription and use of AMs? Costs of AMs,* Withdrawal 4. After you treat your livestock and the treatment is not working

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| | • *If you decide to slaughter and consume the meat when can you do that? What treatment is okay to use in the animal and slaughter the same day?*

5. *If you treat a livestock that you are milking what happens with the milk? (Please provide an example and the name of the drug)*

• *How do others in your community behave regarding withrdrawal? (discuss local context meanings and understandings of withdrawal?*

6. Do you normally talk among farmers (or animal health officers) about the relationship between drugs used in animals and whether they can get into humans?

• *If yes, what is the connection and how do you describe it in local lingo?*

• *If they do get into humans what happens in the human body? What do you think is the outcome and why?*

• *If no, do you think the drugs that are treated on livestock can get to humans through milk or meat? What do you think happens?*

7. If antimicrobials stopped working, what would that mean for you and your farm? |
| Summary and any other questions | *(Summarise the main points of the participant checking their agreement and asking if they have anything more to add).*

Are there any points you think I've missed, or any other issues you'd like to talk about relating to AMU and AMR? |

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62 **Table S2. Interview guide for in-depth interviews with animal health service professionals.**
63 Themes/Domains were developed during a workshop in Nairobi (August, 2018), where experts in
64 antimicrobial resistance generated a list of themes/domains impacting antimicrobial use and antimicrobial
65 resistance and probes to assess these themes/domains.

Domain	Topic and Probes *(in italics)*
Warm up	3. I would like to hear a bit about your job. What does it entail?
Management practices	1. What types of animals are kept by the community you serve? • *How are they generally kept? Probe Free range or confines* • *Can you describe the common feeding practices to me?* • *Probe more on ranging systems, if confined how do they source the feeds, quality of feeds, problems with feeds, availability per season, storage practices*

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	2. Can you talk about the general hygiene practices of your farmers?
	   • *How often to they clean their pen?*
	   • *What about disinfection practices? What disinfectants most commonly used?*
	   • *What do you recommend could be the ideal hygiene practices in the context of the farmers you serve?*
	3. Do the farmers you serve keep records?
	   • *Is it something that you encourage or its impractical to implement?*
	   • *For those who keep records, what are the records about?*
	   • *Probe about productivity, sales, purchases, movement of animals or treatment*
	   • *What records of treatment are normally kept? Please explain*

General drug use in the local context	6. Can you tell me the name of common drugs used to treat livestock in your area?
	   • *Probe for the names of diseases and the commonly used drugs*
	   • *Probe about their own dispensing practices and later ask what farmers prefer*
	   • *On whether treatment is categorized basing on different infections such as parasites, fungal or viral, bacteria*

Diseases	7. What are the common livestock diseases in your area? 8. What are the top 5 most significant diseases affecting livestock you serve? Please name per specie 9. Can you rank the most significant to the least? Consider seasonality 10. How do livestock keepers approach you when their animals are sick? Probe on stage of livestock disease

Understanding and categorization of antimicrobial in the local context	11. Can you tell me the commonly used approaches and terms for describing antimicrobials in your work?
	
	   • *Probe for their own understanding of antimicrobials, if they do categorize basing on different infections*
	      o *Ask for specific drug names that are commonly available in the market*
	   • *Probe for detail in how they inform the farmer that a particular drug is an antimicrobial, and if there is really a need to do so, and why?*
	   • *Probe for the specific language, if any, used to communicate antimicrobials to farmers*

Sources and demand for antimicrobials	1. Where do you and farmers source antimicrobials for use in the community?
	   • *Specifically on the different places these are obtained*
	   • *Ask for his opinion on these different sources focusing on issues of quality*

8

	• *Ask what strategies they use to decide from which source and why? Pay attention to elaborate on differentiating their own preferences and that of farmers* • *Probe for experiences in carrying or storing practices by the farmers, and reasons for this*

Practices and experiences of antimicrobial use in community	1. In your practice, when do you normally administer (or advice to farmers) antimicrobials? Probe for triggering actions such as
	  • Whether during prophylaxis, and why?
	  • When an animal is sick with symptoms,
	     o If the biosecurity and hygiene conditions are a course for concern
	  • Do farmers themselves have opinions on what antibiotics to use following your advice?

Understanding of AMR in the livestock value chain	1. In your work have you come across a situation whereby an antibiotics have failed to work, say in the last year? If yes, probe about the following:
	  • *How do you call this phenomenon?*
	  • *In this context have farmers encountered it? How do they refer to it?*
	  • *Do you think AMR is caused by the animal being resistant to the drug? If yes or no, please explain*
	  • *Do you think a micro- organism becoming resistant causes AMR? Explain both answers with examples*
	  • *What else explains best AMR, what causes it, if the answers are different from above?*
	  • *When treatment fails, what do people in the community do?*
	
	2. What kind of activities that are performed by your farmers in the practice of rearing their livestock do contribute to the development of AMR? (Probe on the below statements if the respondent did not mention in his/her answers. Ask for vivid examples on each)
	
	  • *To what extent to you think your farmers contribute to AMR when they give drugs as per your instructions?*
	  • *To what extent do farmers contribute to AMR if drug regimens are not completed, skipped, given doses that are lower than what you recommend*
	  • *To what extent is AMR developed if farmers mix different types of antibioitics?*
	  • *Given the general use of broad spectrum antibiotics, explain how its different uses do relate to AM.R Please give examples*
	  •
	3. Do you encounter situations whereby farmers mix/ combine antibiotics in their animal feed?
	  • *Probe on how often this is a practice? Give examples*
	  • *Probe if they consider such practices as contributing to the development of AMR*

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Summary and any other questions	*(Summarise the main points of the participant checking their agreement and asking if they have anything more to add).* Are there any points you think I've missed, or any other issues you'd like to talk about relating to AMU and AMR?

66

67 *2.2 Examining themes*

68   Following transcription and translations of the interviews, the translated transcripts were uploaded

69 into Nvivo Version 8 for organization and coding by PM and supported by MN. Themes were developed

70 from an initial pre-determined theme named Livestock diseases from which most results presented in this

71 paper emanated. This was followed by prompts about "health seeking behaviour". Sub themes emerged

72 following prompts from the interview guides. In each sub-theme, corresponding responses were

73 categorized as "lower codes" to the sub-themes, that is, responses that elaborated and enriched the coded

74 sub theme. See Table S3 for a summary of theme development.

75 **Table S3. Example of theme development for "health seeking behavior" theme.**

Livestock Diseases care seeking	
Sub-themes	**Lower level codes**
Symptom identification & recognition	Starts with family members at the household level
	Disease syndrome confirmation: by head of household
	Disease recognition support from age set members and neighbors
Household level veterinary Drug option deliberations	Antimicrobial hoarding: Drug sourced from the house
	Antimicrobial sourced from neighbors
	Antimicrobial sourced from drugstores
	Discussed and agreed by the head of household
Antimicrobial application responsibilities	Head of household (if available)
	Eldest age member of household

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	Wife/ mother
Drug workings observation & confirmation of healing	Normally - 1 -2 days
	Symptoms subsiding observed (e.g. Cough stops, change in hair lustre)
	Animal ability to walk, eat pasture, drink water
	Confirm capabilities and other family learns
	Drug container kept for future reference
Case of Drug Failure/ did not work 1	Neighbors or friends suggest alternative that worked
Drug Failure/ did not work-2	Animal health profession is consulted
	Agrovet or Veterinary doctor (consulted for a better drug only)
	Veterinary consulted for investigation and drug application
	If all of above fails, the animal can also be sold to the market
Drug failure 3	Animal is slaughtered and consumed (household and neighbors)

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77   *2.3 Focus Group Discussions*

78   FGD participants were selected from different villages forming the wards. See Table S4 for the

79 number of FGDs conducted by ward and Table S5 for demographics of FGD participants. FGD participants

80 were purposefully identified by village elders (through respective village hamlet leaders) ensuring that each

81 hamlet (hamlets form villages) was represented in the discussion. After each round of discussions and

82 interviews the research assistants met with the research team (led by authors XXX) and discussed the data

83 and themes and sub-themes of interests that arose and summarised the information on specialized contact

84 summary forms (See Supplementary B). The summarised information was then used to discuss and improve

85 the quantitative KAP survey tool.

86   Importantly, two FGDs for women were not conducted during the first round of data collection.

87 The first one could not take place because the required number of participants did not suffice and had to

88 be cancelled. The second, due to a miscommunication, only men showed up. As a result, only one FGD

89 was conducted in that community.

90   In addition to interviewing, observations were conducted on three conveniently selected bomas in

91 Orbomba Village. The local animal health service providers sent word to livestock keepers who were

92 willing to be observed as they applied treatment to their livestock. During observations, questions were

93 posed, and notes/pictures were taken.

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94 **Table S4. Number of focus group discussions (FGDs) conducted per ward.**

Ward Name	Village name	Male	Female
Orbomba	Orbomba	1	-
Sinya	Ildonyo	1	1
Gelailumbwa	Gelailumbwa	1	-
Engarinaibor	Mairowa	1	1
Total		4	2

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96 **Table S5. Demographic information of Maasai focus group discussion (FGD) participants by ward.**
97 Wards are in the first row with totals across wards in the final column.

	GELAILUMBWA		ENGARENAIBOR		ORBOMBA		SINYA		Total	
	N	%	N	%	N	%	N	%	N	%
Sex										
Female	0	0	13	81.25	0	0	9	52.94	22	40.00
Male	12	100	3	18.75	10	100	8	47.06	33	60.00
Education level										
No education	3	25.00	12	75.00	1	10	11	64.71	27	49.09
Primary	8	66.67	4	25.00	9	90	4	23.53	25	45.45
Secondary	1	8.33	0	0	0	0	2	11.76	3	5.45
Age-group										
20 - 40	2	16.67	12	75.00	3	30	9	52.94	26	47.27
41 - 70	10	83.33	4	25.00	7	70	8	47.06	29	52.73
Marital status										
Married	12	100	11	68.75	10	100	13	76.47	46	83.64
Single	0	0	2	12.50	0	0	2	11.76	4	7.27
Widow	0	0	3	18.75	0	0	2	11.76	5	9.09

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99 *2.4 In-Depth Interviews*

100   In-depth interviews were conducted with Livestock Field Officers (LFOs), agrovets, Community
101   Animal Health Workers and Influential/Opinion shapers, who were usually elderly Maasai men. See
102   Table S4 for the number of IDIs per ward and Table S5 for demographic characteristics of interviewed
103   persons.

104   Livestock field officers (LFOs) were purposefully selected, in collaboration with the district
105   veterinary officer since they report to him. Most of the LFOs (4) were interviewed at the district
106   headquarters. The interviews with the livestock field officers aimed to shed light on the experiences of
107   animal care seeking by the Maasai including understanding the modes of interactions between the two.
108   LFOs were interviewed during the first round of data collection.

109   Agrovets were purposefully selected from registered drug shops in the district. Agrovets, in the
110   absence of animal health professional are often the first point of contact when seeking care beyond
111   households. Agrovets were interviewed during the second round of data collection when the KAP survey
112   was underway.

113   IDIs with influencers and opinion shapers were implemented to further unpack nuanced drug use
114   patterns in relation to broader social, cultural and historical underpinnings that were held by older
115   community members. These interviews were conducted at elders and leaders' respective villages.

116   Community animal health workers (CAHWs) became an interest group worthy of interviewing
117   when fieldwork was ongoing. It occurred to the researchers that certain community members during the
118   initial FGDs were somewhat vested with issues pertaining to veterinary drugs. After inquiry they
119   informed us there was a programme by an international NGO that was active 6 years ago that trained
120   village para-veterinaries to address the gap from the lack of animal health service professionals in the
121   district. However, since the program ended they have not been as active, although these CAHWs are
122   occasionally used by fellow community members to address animal health issues. We inquired about their
123   presence and asked for interviews when we visited the next ward.

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124   **Table S6. The number of in-depth interviews conducted per ward/village.**

Ward Name	Village name	Agrovets Collected 2nd rd	CAHWs Collected 2nd rd	Influential persons Collected 1st rd
Orbomba	Orbomba	2	2	2
Sinya	Ildonyo	-	-	4
Gelailumbwa	Gelailumbwa	1	1	3
Engarinaibor	Mairowa	2	1	1
Total				10

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126   **Table S7. Demographic information of key informant in-depth interview participants by key**
127   **informant role.** Key informant roles are in the first row with totals across roles in the final column. For
128   roles, CAHW refers to "Community Animal Health Worker", Influential refers to Maasai who are opinion
129   shapers in the community, LFO refers to "Livestock Field Officers", AGVET refers to "agrovet". For
130   Influential people interviewed, questions were not asked on work experience or training as they held no
131   officially recognized animal health position within the community.

	CAHW		INFLUENTIAL		LFO		AGVET		Total	
	N	%	N	%	N	%	N	%	N	%
Age group										
20 - 40	0	0.00	4	40	5	100	4	80	13	45.0
41 - 80	4	100	6	60	0	0	1	20	11	55.0
Gender										
Female	1	25	0	0	0	0	2	40	3	12.5
Male	3	75	10	100	5	100	3	60	21	87.5
Education level										
None	0	0	3	30	0	0	1	20	4	16.67
Primary	3	75.0	5	50	0	0	2	40	10	41.67
Secondary	1	25	2	20	5	100	2	40	10	41.67
Work experience										
1-5 years	1	25	-	-	1	20	5	100	7	50.0
6–12 years	3	75	-	-	4	80	0	0	7	50.0
Ward										
Engarenaibor	1	25	0	10	0	0	2	40	4	16.67
Gerailumbwa	1	25	2	30	0	0	1	20	5	20.83
Orbomba	2	50	2	20	4	80	2	40	10	41.66
Sinya	0	0	1	40	1	20	0	0	5	20.83
Training										
None	0	0	-	-	0	0	3	60	3	21.43
Certificate	4	100	-	-	0	0	2	40	6	42.86
Diploma	0	0	-	-	3	60	0	0	3	21.43

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| Bachelor | 0 | 0 | - | - | 2 | 40 | 0 | 0 | 2 | 21.43 |

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