Measurement of proxy variables to measure livestock productivity in developing countries: experience in three countries

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Abstract

The quality and quantity of livestock data available to developing countries presents a continuing challenge to decisions makers in the public and private sectors. Enumeration and classification has remained the focus of much of the recent and welcome steps taken in the improvement of livestock data collection and presentation. However, measurement of livestock performance has received less emphasis due to the inherent difficulties of periodic production and sale, conversion rates between products at different stages of delivery, conventional avoidance of measurement, and the costs of equipment, staff, training and organisation. Similar comments apply to the measurement of pasture feed resources used by many developing country livestock systems and communities. In this paper, we report on trials of proxy measures of animal productivity in Tanzania (egg and milk production and productivity), Botswana (sheep and goat weight and growth, and pasture quality, quantity and sustainability), and Indonesia (milk production and productivity, and cattle and goat weight and growth). Trials entailed new questionnaire data collection methods' being compared to existing ones, and also to an objective measurement of the variables across a relevant sample. Results are compared, and conclusions are presented about the efficacy of some standard questionnaire-based methods as well as the technical and financial viability of using proxy measures. We also undertake an investigation and discussion of small sample methods in the estimation of lactation curves and age-indexed animal growth profiles, which are then employed as proxy measures of productivity.

Introduction

The quality and availability of agricultural data are vital to various government and non-government stakeholders. In addition to commercial interests, they invigorate efforts toward food security, poverty reduction, disease and natural disaster planning, and aspects of hard and soft infrastructure; and policy more generally (Pica-Ciamarra *et al.*, 2014). A reported decline in these aspects of agricultural data is reported, along with declining capacities in the three key functions of collection, analysis and dissemination (World Bank, FAO and UN, 2010).

Amongst agricultural data, livestock presents particular problems such as such as dynamic herd structures, landless households, opaque ownership, non-sedentary populations. Measurement of production and productivity therefore lags cop counterparts to the extent that livestock production is underrepresented in developing countries GDP estimates (Behnke and Metaferia, 2010).

This paper reports on aspects of a project under the Global Strategy for Improving Agricultural and Rural Statistics,[1] which set out to identify potential improvements in data collection methods for smallholder livestock systems in developing countries, and test new methods. In short, the project entailed a literature review, a "Gap Analysis" in three pilot countries, and the development and implementation of test activities. Recommendations in the form of guidelines for smallholder livestock data collection constituted the final output.[2]

The paper focuses on the testing of proxy measurement methods for difficult- or expensive-to-measure variables, and their synthesis into indicators of use to the stakeholder set outlined above. The first section outlines the approach taken and reports some salient aspects of the Gap Analysis which served to focus the study, and summarises the methods used. The second section presents some results and a discussion of their usefulness in the context of opportunities for improving data collection for smallholder livestock producers in developing

[1] http://gsars.org/en/
[2] Reports from the various stages of the project can be found on the *Global Strategy* website.

countries. A third section extends this discussion to broader aspects of livestock production and productivity measurement, and the opportunities that improvement offers. The final section offers conclusions.

Approach taken

Mobilisation

A user-led approach was employed to identify the most appreciated, or at least the most wished for, indicators, and to allow users to assess the quality of the available data underlying those indicators. Fourteen questionnaire-driven workshops were held in each of Tanzania, Botswana and Indonesia to this end, canvassing the views of 171 stakeholders drawn from extension, livestock services, veterinary authorities, local bodies and various stages of the private sector.

Upon establishing the most important variables, workshop participants scored them on five criteria using a scale of 0 to 5 (5 being perfect). The criteria are drawn from FAO (2004), presented here with the explanations provided as questions to workshop participants:

- Relevance: How close is the data you currently to what you really need?
- Accuracy and Reliability: How accurate and reliable is the information?
- Timeliness and Punctuality: Is it available when you need it and is it up to date?
- Coherence and comparability: Can you understand it properly? Can it be compared?
- Accessibility and Clarity: How difficult is it to get? Is it the format you want?

Survey participants were then asked to comment on the quality of collection methods and to nominate improvements. This included a discussion of collection of proxy variables in place of indicators and variables for which collection was technically or financially infeasible.

Test content

From this analysis, a set of the most important indicators and the alternative collection methods were agreed with national stakeholders. Figures 1 and 2 present the complete list derived from eth workshops, from which selections were made and agreed. Pilot activities were then agreed and trials proceeded in mid-late 2015.

A detailed discussion of the workshop results and proceedings is beyond the scope of this paper, but one notable result is worthy of mention because it was used to guide the approach taken to trials of data collection. This result is, that stakeholders frequently and almost unanimously called for farmer participation in data collection. This unexpected result was borne out during field trials and other stakeholder interactions during the project.

Comparison setting

The set of indicators selected, and key explanatory variables, are presented in table 1. The test method employed compared existing methods (E) with an alternative (A). An unambiguous technical measure ("gold standard", GS) was employed where possible to compare with both E and A. This procedure was not followed in cases where E was not in use (e.g. smallholder dairy production is not recorded in Indonesia; pasture feed quantities and quality are not recorded in Botswana); or where a GS was not readily available (e.g. counting of animal numbers). The details of the field test comparisons are presented in table 2.

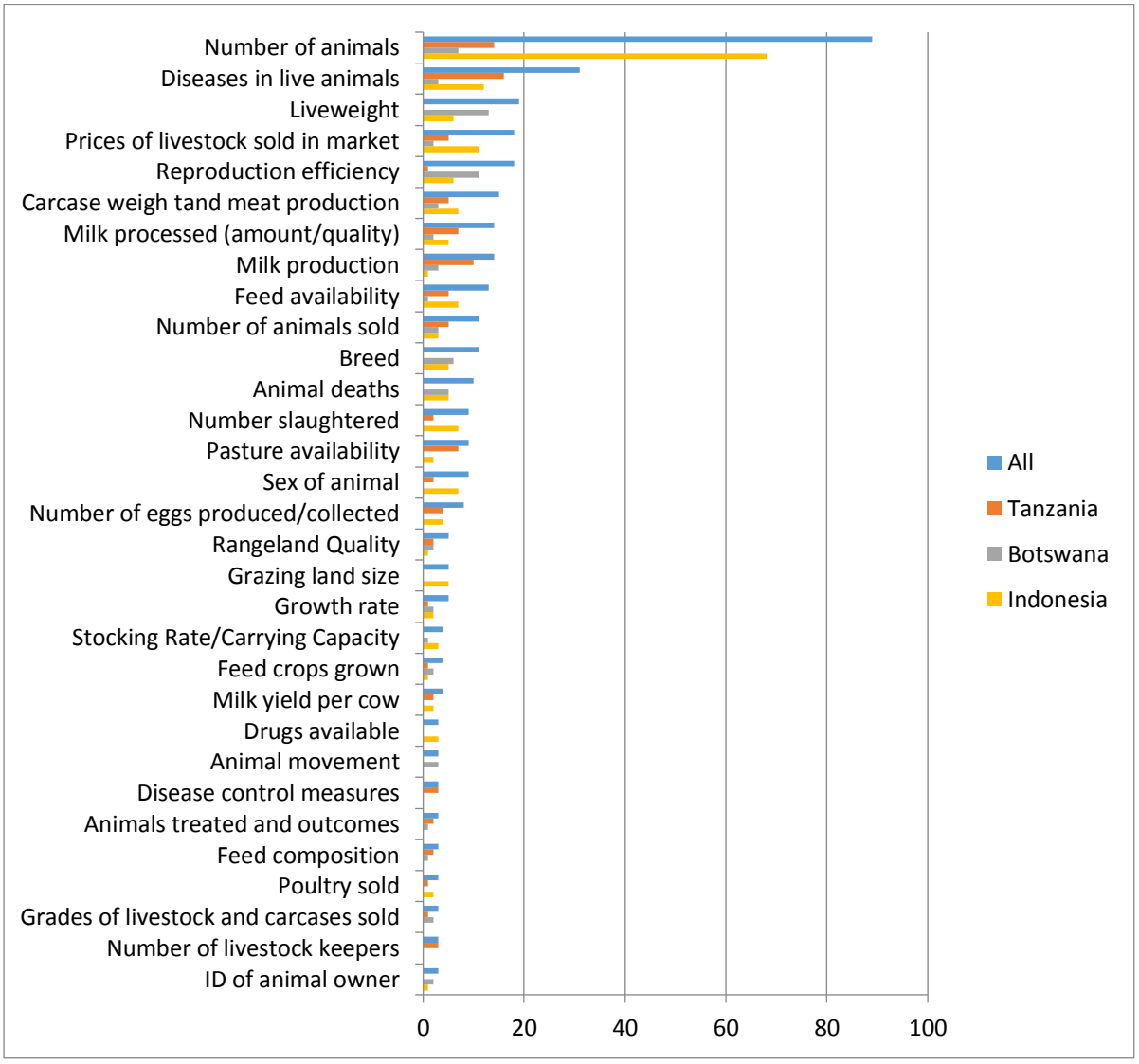


Figure 1. Indicators proposed in workshops for improvements in collection

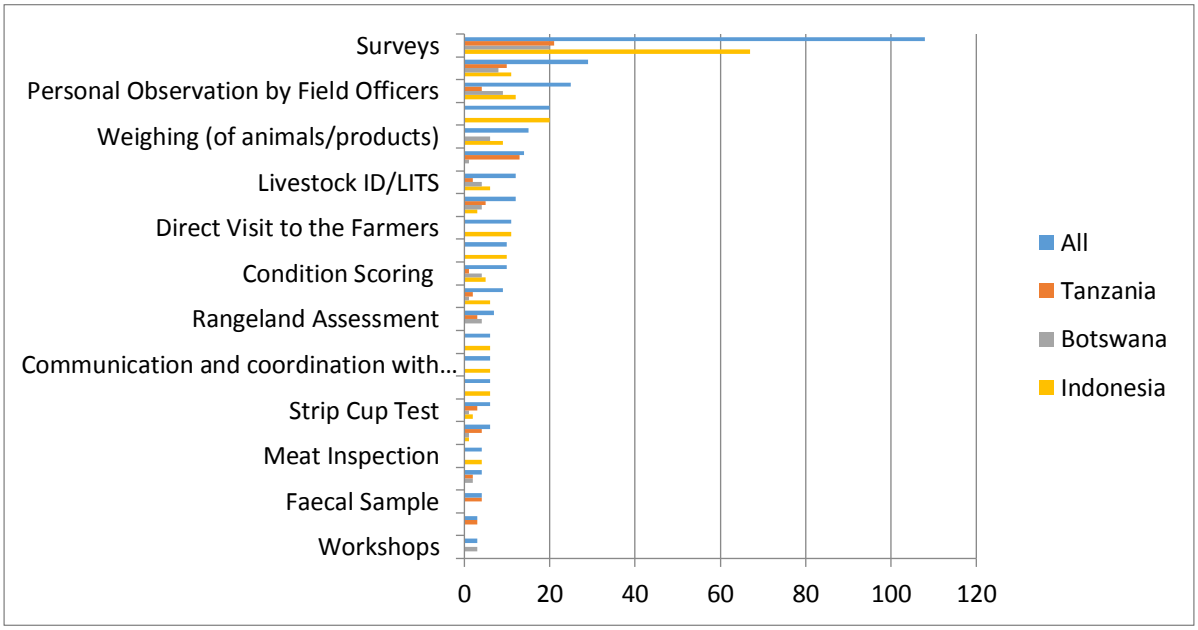


Figure 2. Methods proposed in workshops

Table 1. Indicator selections, test structures

	Tanzania	E	A	GS	**Botswana**	E	A	GS	**Indonesia**	E	A	GS
Animal numbers	Milking cows	✓	✓	✓	Sheep	✓	✓		Cattle		✓	
	Laying hens		✓	✓	Goats	✓	✓		Goats		✓	
Herd dynamics					Sheep	✓	✓					
					Goats	✓	✓					
Animal weight			✓	✓	Sheep	✓	✓	✓	Cattle		✓	✓
			✓	✓	Goats	✓	✓	✓	Goats		✓	✓
Animal growth			✓	✓	Sheep		✓	✓	Cattle		✓	✓
			✓	✓	Goats		✓	✓	Goats		✓	✓
Milk production	Milk production	✓	✓	✓					Milk production		✓	✓
Egg production	Egg production	✓	✓	✓								
Feed availability					Feed purchases	✓	✓	✓	Feed purchases		✓	✓
					Feed crops produced	✓	✓	✓	Feed production		✓	✓
					Pasture availability		✓	✓				
Feed utilisation					Feed uses		✓	✓				
					Pasture quality		✓	✓				
Influences on production and productivity	Egg management	✓	✓	✓	Seasons		✓	✓	Calf management		✓	✓
	Calf management	✓	✓	✓	Sex	✓	✓	✓	Age		✓	✓
	Breed	✓	✓	✓	Breed	✓	✓	✓	Sex		✓	✓
									Breed		✓	✓

Detail of method

Pursuant to the goal of the trial (improved collection), sampling adhered to principles associated with cost (particularly logistics) and demonstration value. Key sampling criteria are presented in figure 3, and sample sizes in figure 4.

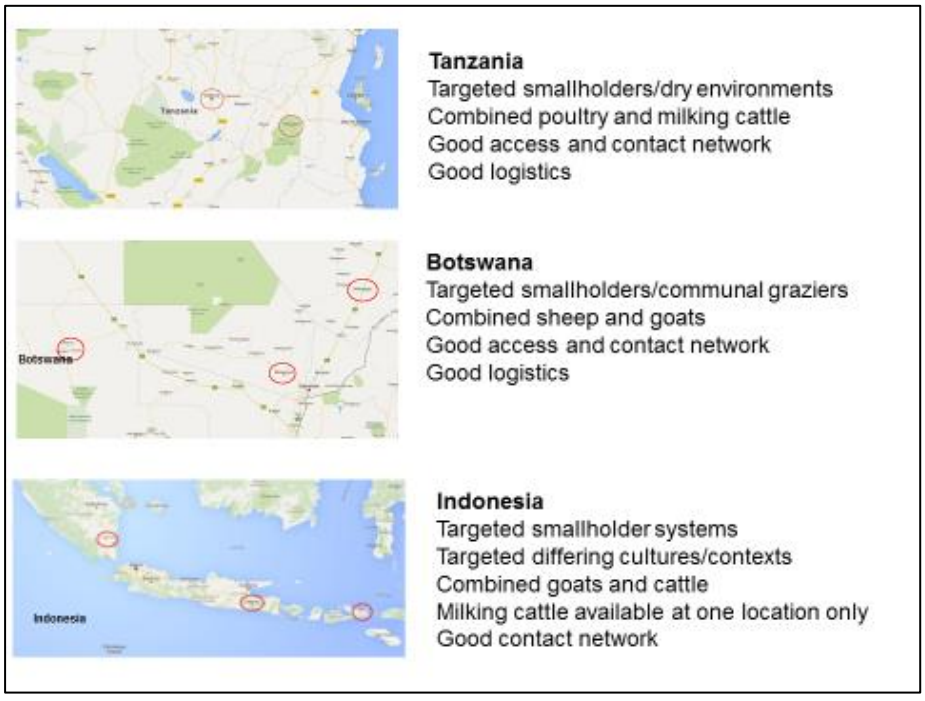


Figure 3. Sampling strategy

Botswana

Sheep and Goats

	Existing	Alternative	Gold Standard
Number of participant farmers ('respondents')	62	61	61
Number of *sheep* observed for measurement	-	-	685
Number of *goats* observed for measurement	-	-	1,600
Average days of observation of *sheep and goats*	Single questionnaire	Single questionnaire	Two observations, approx. four weeks apart

Feed

	Existing	Alternative	Gold Standard
Number of participant farmers ('respondents')	62	61	-
Number of *locations* at which observations made	-	-	21 locations across three districts

Tanzania

Eggs

	Existing	Alternative	Gold Standard
Number of participant farmers ('respondents')	67	68	135
Number of *hens* observed for measurement	-	-	356
Average days of observation of *hens*	Single questionnaire	Single questionnaire	Data collection period of 46 days (daily observation) across all observed hens; average observation period *per hen* 13.7 days.

Milk

	Existing	Alternative	Gold Standard
Number of participant farmers ('respondents')	76	68	144
Number of *cows* observed for measurement	-	-	342
Average days of observation of *cows*	Single questionnaire	Single questionnaire	Data collection period of 24 days (daily observation) across all observed cows; average observation period *per cow* 20.2 days.

Indonesia

Cattle and Goats

	Questionnaire	Gold Standard
Number of participant farmers ('respondents')	408	381
Number of *cattle* observed for measurement	-	708
Number of *goats* observed for measurement	-	627
Average days of observation of *cattle and goats*	Single questionnaire	Three observations, approx. three weeks between each observation

Milk

	Questionnaire	Gold Standard
Number of participant farmers ('respondents')	60	60
Number of *cows* observed for measurement	-	120
Average days of observation of *cows*	Single questionnaire	Four observations, approx. two weeks between each observation

Figure 4. Sample sizes

Table 2. Details of field tests

Tests conducted – Tanzania - eggs

	E	A	GS	TESTS
Recall questions				
	monthly egg production per household in the past year			
		Breeds kept		*Improved measure of eggs/hen*
		No. laying hens in the past year		*Improved measure of eggs/household*
		No. clutches per hen		*Incidence of breed*
		No. eggs/clutch		*Influence of breed*
		Period between clutches		*Operationalised productivity measures based around clutches*
	Clutch management practice	Clutch management practice (variant)		*Impact of clutch management on productivity*
			Clutch management practice (variant)	
Communal questions				
		Distribution of egg production during the year		*Indicator of intra-year production distribution* *Enabling point estimation*
Physical measurement				
			Counting eggs/clutch	*Estimation of egg production curve* *Benchmarking productivity* *Examination of recall*
			Measuring length of clutch	
			Measuring period between clutches	
			Tracking of tagged birds	

Tests conducted – Tanzania - milk

	E	A	GS	TESTS
Recall questions				
	Numbers of cows milked in the past year	Numbers of cows milked in the past year, by breed		*Incidence of breed*
	Average milk production per cow per day			
		Average milk production per cow per day over whole lactation, by breed		*Improved recall* *Influence of breed*
		Average milk production per cow per day in 4 lactation periods, by breed		*Improved recall* *Influence of breed*
		Period between calving, by breed		*Improved measurement of annual productivity* *Influence of breed*
	Average number of months cows were milked for			
	Month of highest milk production			
	Month of lowest milk production			
	Calf suckling practice	Calf suckling practice [two variants], by breed		*Implications of influence of suckling practice* *Influence of breed*
	Average daily household consumption of milk	Average daily household consumption of milk		
			Calving dates (last)	*Check on recall for calving interval*
			Calving dates (next)	
			Calf suckling management practice (variant)	*Check on recall for suckling management*
Communal questions				
		Month of highest milk production		*Improved indicator of intra-year production distribution* *Enabling point estimation*
		Month of lowest milk production		
		Shares of milk production in each month of a year		
		Month of greatest pasture availability		*Factors affecting productivity*
		Month of least pasture availability		
Physical measurement				
			Physical measurement of milk production	*Establishment of lactation curve* *Benchmarking productivity* *Examination of recall*
			Tracking of tagged cows	
			Recall on calf management practice	
			Recall on calving dates: last, next	

Tests conducted – Botswana – animal numbers and herd dynamics, liveweight and growth

	E	A	GS	TESTS
Recall questions				
	Number of animals by age group at beginning of specified period	Number of animals by age group on day of survey		*Improved recall*
		Breeds kept, for each age group		*Incidence of breeds*
	Numbers born			
		Numbers born, by season		*Improved recall*
		Main date of lambing/kidding		*Improved knowledge of seasonal influences*
	Numbers died			
	Numbers died by cause of death			
		Numbers died by age category, season, and by cause of death		*Improved information on deaths, causes of death, and seasonal influences*
	Causes of death: young stock			
	Causes of death: other stock			
	Numbers lost/stolen/strayed			
		Numbers sold, by channel and season		*Herd dynamics, influence of season* *Channels for sale and purchase*
		Numbers purchased, by channel and season		
		Numbers given away, by age category and season		
		Numbers slaughtered for home consumption, by age category and season		
		Estimates of weights in three age categories		*Involvement of farmers in data collection*
Communal questions				
Physical measurement				
			Weight	*Estimation of key productivity indicators* *Testing of farmer assessment* *Estimation of relations to proxies*
			Weight difference	
			Shoulder height	*Proxies for weight*
			Heart girth	
			Body condition score	

Tests conducted – Botswana – feeds

	E	A	GS	TESTS
Recall questions				
	Quantities fed to animals of 18 feed types			
	Areas planted (ha) of crops			
		Areas planted (ha) of feed and feed-related crops		*Improved focus on feeds*
		Number of days each crop is fed to age classes of each animal species		*Relationship of feed supply to animal numbers, by species and class*
		Areas (ha) available of each pasture category		*Improved focus on feeds*
		Number of days each pasture type is fed to age classes of each animal species		*Relationship of feed supply to animal numbers, by species and class*
		Rating of extent of overgrazing		*Proxy for feed supply* *Proxy for non-sustainable grazing practices or pressure*
Communal questions				
Physical measurement				
			Incidence and density of indicator weeds for degradation	*Extent of pasture degredation*
			Amount and quality of herbaceous biomass	*Extent of pasture feed availability*
			Incidence and density of selected weeds for dietary quality	*Extent of pasture quality*
			Distribution, density and height of selected weeds	*Extent of pasture quality and degradation*

Table 2. Details of field tests (cont'd)

Tests conducted – Indonesia – cattle numbers and herd dynamics (an initial view)

	E	A	GS	TESTS
Recall questions				
		Number of animals kept by age group on day of survey		*First measure of smallholder cattle numbers*
		Gender of Hh member caring for the animals		*Importance of intra-household labour divisions*
		Number of cattle owned and not owned but cared for by age group on day of survey		*Ownership and placement of animals*
		Use of cattle for draft power		*Uses to which cattle are put* *Non-income reasons for keeping cattle*
		Numbers born		*Herd dynamics*
		Numbers purchased or gifted in, by channel		
		Numbers sold, by channel		
		Numbers died, by casue of death		
		Numbers lost/stolen/strayed		
		Numbers died by age category, season, and by cause of death		
		Changes in all the above since last visit		
Communal questions				
Physical measurement				

Tests conducted – Indonesia – milk

	E	A	GS	TESTS
Recall questions				
		Numbers of cows milked in the past year		*First measure of smallholder milk production*
		Average number of months cows were milked for		
		Average milk production per cow per day		
		Month of highest milk production		*Improved knowledge of seasonal influences*
		Month of lowest milk production		
		Calf suckling practice		*Indicators of influence of suckling practice*
		Share of milk consumed by household		*Nutritional role of dairy*
		Share of milk sold		*Livelihoods role of dairy*
		Share of milk processed into other products		*Value addition by farmers*
		Sales channels used for milk and processed products		*Marketing behaviour*
		Constraints on milk processing		*Indicators of constraints*
			Calving dates (last)	*Check on recall for calving interval*
			Calving dates (next)	
			Calf suckling management practice (variant)	*Check on recall for suckling management*
Communal questions				
Physical measurement				
			Physical measurement of milk production	*Establishment of lactation curve* *Benchmarking productivity* *Examination of recall*
			Tracking of tagged cows, designated HIGH and LOW production	
			Recall on calf management practice	
			Recall on calving dates: last, next	

Tests conducted – Indonesia – cattle and goat weights

	E	A	GS	TESTS
Recall questions				
		Animal numbers and dynamics for cattle and goats		*Factors affecting productivity*
		Feed use		
		Presence of milking cattle and goats		*Uses to which cattle are put* *Non-income reasons for keeping cattle*
		Use of cattle for draft power		
Communal questions				
Physical measurement				
			Weight	*Estimation of key productivity indicators*
			Weight difference	
			Heart girth	*Proxies for weight*
			Body condition score	

For eggs and milk production in Tanzania, farmers collected daily production data following training, and using equipment and recording materials supplied. In Botswana and Indonesia, survey staff weighed animals and conducted all survey interviews. In all cases, at an initial training and familiarisation session the E and A questionnaires were completed, and GS data collection proceeded in subsequent periods.

Trial results (a selection)

Where A methods for data collection entailed changed questionnaire content, structure and method, comparisons with E methods generally revealed statistically significant differences. In some cases, E methods compared favourably with GS data (see figure 5 on Tanzanian eggs, with the disclaimer that GS data was not available on clutch frequency so involved an approximation).

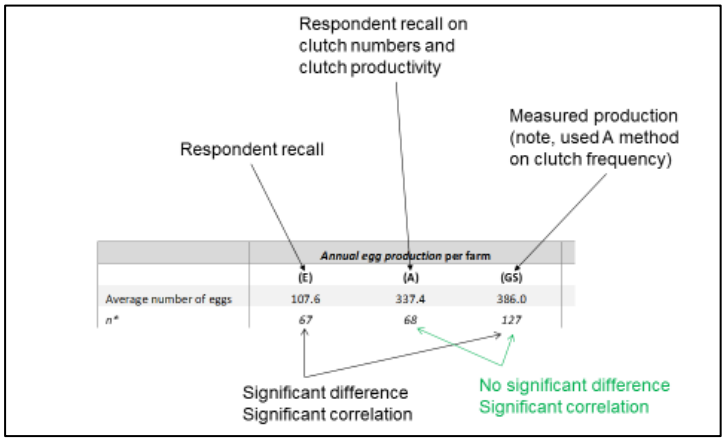


Figure 5. Comparison of E (survey respondent recall on egg numbers), A (survey respondent recall on clutch productivity and frequency) and GS (measured egg production)

In cases where ambitious changes to questionnaires were trialled (e.g. in respondent estimation of animal liveweight), results generally revealed substantial errors on the part of respondents (see table 3 on Botswana's sheep liveweight; see table 5 and figure 6 on Tanzanian milk production).

Table 3. Comparison of A (survey respondent recall) and GS (measured animal liveweight)

	Alternative Questionnaire				Gold Standard Data
Sheep	***3 Months Age***	***6 Months Age***	***12 Months Age***	***12 Months Age or Less***	***12 Months Age or Less***
Weight (kg)	10.2	23.6	41.4	25.1	17.7
Std Dev	5.2	12.2	14.4	10.1	8.7
Min	2.0	5.0	20.0	2.0	2.9
Max	20.0	50.0	75.0	75.0	43.8
Goats	***3 Months Age***	***6 Months Age***	***12 Months Age***	***12 Months Age or Less***	***12 Months Age or Less***
Weight (kg)	6.9	17.1	35.1	19.7	12.5
Std Dev	3.5	9.4	16.3	9.3	7.8
Min	1.0	3.0	11.0	1.0	2.9
Max	13.0	40.0	70.0	70.0	39.3

In cases where ambitious changes to questionnaires were trialled (e.g. in respondent estimation of animal liveweight), results generally revealed substantial errors on the part of respondents (see table 3 on Botswana's sheep liveweight).

Table 4. Comparison of E (survey respondent recall), A (survey respondent recall, with improved questionnaire and reference to separate months of lactation), and GS (measured milk production)

	Daily production: whole of lactation/ annual (E, A, GS)			*Change in daily production during lactation (A)*				*Change in daily production during lactation (GS)*			
	Average Production Per Cow: Last 12 Months (E)	Average Production Per Cow: Whole Lactation (A)	Average Production Per Cow: Whole Lactation (GS)	Average Production Per Cow: First Month of Lactation	Average Production Per Cow: Second Month of Lactation	Average Production Per Cow: Third Month of Lactation	Average Production Per Cow: After Third Month of Lactation	Average Production Per Cow: First Month of Lactation	Average Production Per Cow: Second Month of Lactation	Average Production Per Cow: Third Month of Lactation	Average Production Per Cow: After Third Month of Lactation
Indigenous cows	-	2.11	0.74	2.24	2.05	1.76	1.35	0.76	0.75	0.67	0.74
*n**	-	*67*	*5219*	*67*	*65*	*64*	*65*	*94*	*310*	*636*	*4179*
Improved cows	-	1.91	2.02	2.54	2.01	1.88	1.34	5.62	2.17	2.27	1.80
*n**	-	*28*	*1614*	*28*	*28*	*28*	*28*	*48*	*151*	*235*	*1180*
All cows	2.01	2.05	1.04	-	-	-	-	2.40	1.22	1.10	0.98
*n**	*76*	*95*	*6833*	-	-	-	-	*142*	*461*	*871*	*5359*

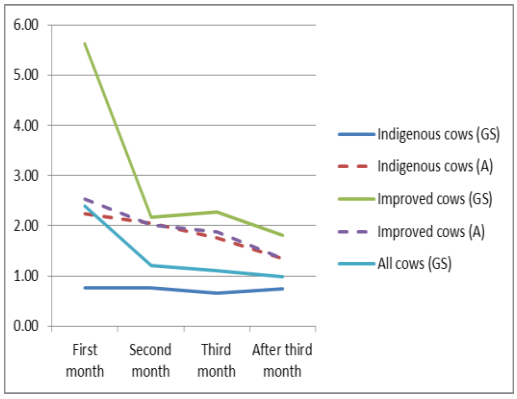


Figure 5. Comparison of A (survey respondent recall) and GS (measured milk production) by month of lactation, taking account of breed effects

Development of proxy measures (a selection)

Dissatisfaction with respondent recall on livestock productivity variables led to further development of the GS data for use in development of proxy measures: use of alternatives to direct measurement, where such direct measurement is technically or financially infeasible. Given the need for calibration of such measures, the field test results and data are proposed as particularly important because they present low-cost methods of GS generation.

Three cases are discussed here:

- use of GS-based lactation curves as a means of estimating milk production from a small number of milk production measurements and a known calving date;
- use of three measures (heart girth, shoulder height and body condition score) on animals to estimate liveweight in sheep and goats
- use of indicator species and observations to estimate rangeland pasture degradation.

Milk production

Using fragmentary low-cost GS data (that is, data drawn from a number of cows with known calving dates so as to assemble a composite lactation curve), non-linear estimation of the lactation curves generated profiles shown in figure 6. On-going work[3] involves calibrating the lactation curve results so as to generate key indicators (e.g. whole of lactation production, production at a given lactation stage, and peak lactation productivity) from measured production at a known lactation stage.

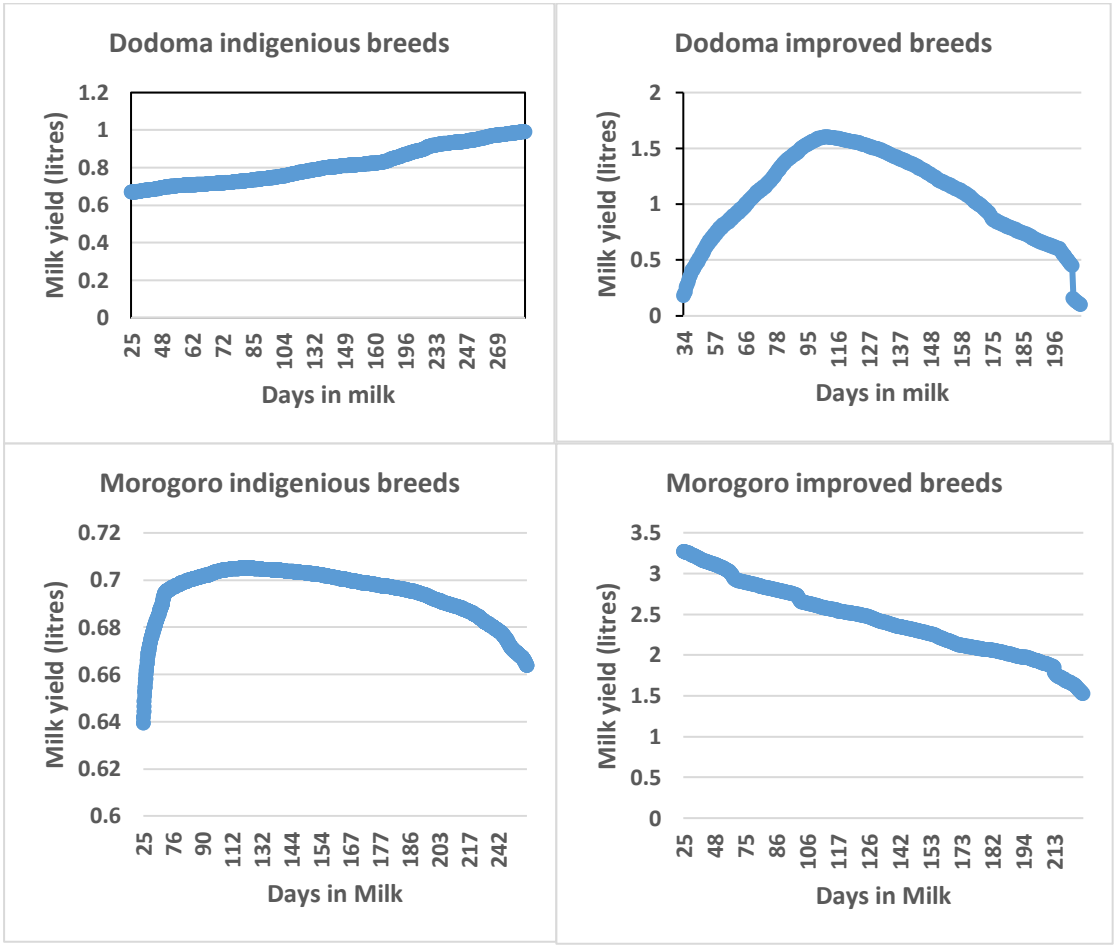


Figure 6. Fragmentary lactation curves estimated using non-linear methods

Animal liveweight

High correlations were received for each of the three proxy measures in relation to liveweight in goats (figure 7) and sheep. An alternative measurement procedure could then involve smallholder livestock producers in proxy measurement. On-going work[3] is employing path analysis to measures on all three proxy measures, so as to achieve improved precision.

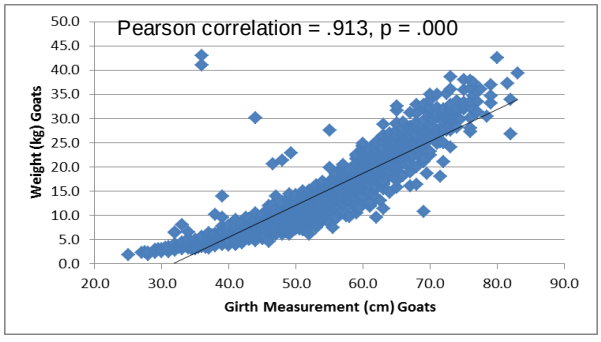


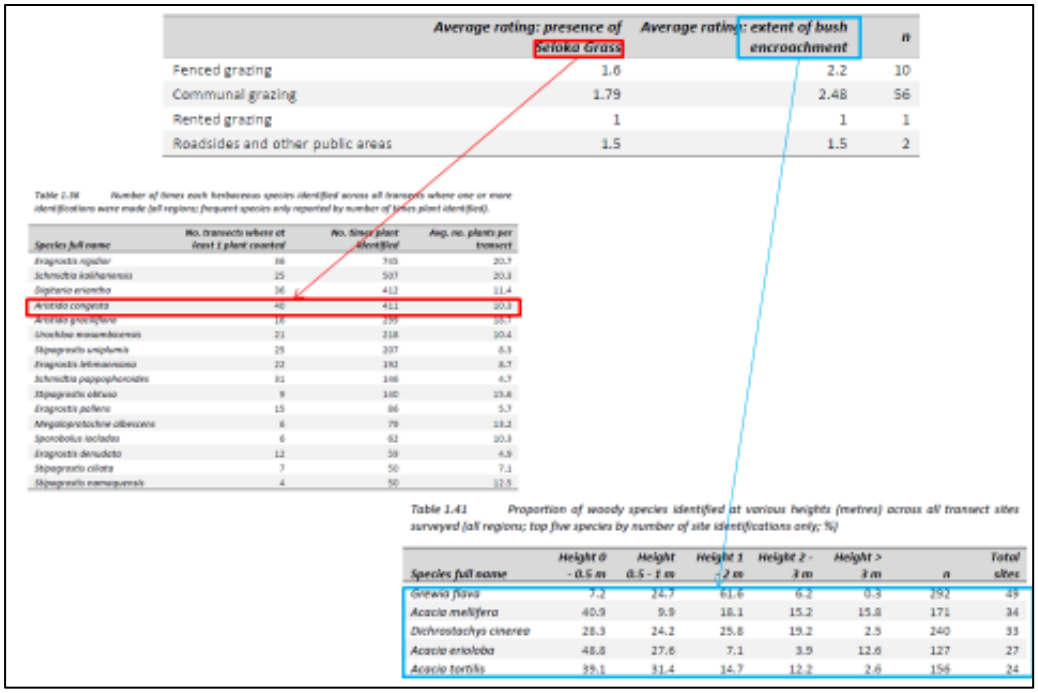
Figure 7. Girth measurement as a proxy for liveweight in goats

Pasture degradation

Respondent-generated scores on presence of an indicator species (Seloka Grass in Tanzania) and bush encroachment were trialled a proxy for pasture degradation in communally grazed rangeland. These were compared to transact-based observations by rangeland scientists in a related experiment. On-

[3] Information available from the authors.

going work[3] entails the feasibility of training the communities utilizing such rangelands so as to develop better methods of identifying feed shortages for herds earlier, and for anticipating pastruire and rangeland degradation.



	Average rating: presence of Setaka Grass	Average rating: extent of bush encroachment	n
Fenced grazing	1.6	2.2	10
Communal grazing	1.79	2.48	56
Rented grazing	1	1	1
Roadsides and other public areas	1.5	1.5	2

Table 1.41 Proportion of woody species identified at various heights (metres) across all transect sites surveyed (all regions; top five species by number of site identifications only; %)

Species full name	Height 0 - 0.5 m	Height 0.5 - 1 m	Height 1 - 2 m	Height 2 - 3 m	Height > 3 m	n	Total sites
Grewia flava	7.2	24.7	61.6	6.2	0.3	292	49
Acacia mellifera	40.9	9.9	18.1	15.2	15.8	171	34
Dichrostachys cinerea	28.3	24.2	25.8	19.2	2.5	240	33
Acacia erioloba	48.8	27.6	7.1	3.9	12.6	127	27
Acacia tortilis	39.1	31.4	14.7	12.2	2.6	156	24

Figure 8. Proxy measures of pasture degradation

Conclusions

Improved quality and quantity of livestock data is recognised as a priority for a diverse set of stakeholders. Improved data collection, and an enhanced set of variables' being collected, are recognised by a sample of stakeholders in Botswana, Tanzania and Indonesia as a vital aspect of improving both data quality and data quantity. Pursuant to the problems and opportunities identified as part of the current study, a trial of new collection methods was conducted.

In general, respondent recall was found to be unreliable measures. However, in many cases livestock productivity is expensive, difficult, or time consuming – or all three – so proxy measures have been discussed here as a viable alternative. In some cases this entails improved questions that while still employing respondent recall are a more focused approach. The elements of egg production provide one example, and the use of indicator species and scoring methods is another, for which promising results have been obtained. In other cases an indicative objective measure is taken, and compared to a reference set based on so-called Gold Standard data. Milk production and animal liveweight are examples examined here.

Use of proxy measures requires referencing and calibration, and so presumes the availability of a Gold Standard data set. Such data sets are expensive to obtain and maintain, and are subject to definitional and sampling strictures that require a pragmatism that may be interpreted as counter-intuitive to the logic of a Gold Standard. The current study employs gold standard data having collected it in a manner governed by resource and time constraints, and demonstrates the utility of using such a pragmatically-defined Gold Standard.

On-going work is examining low cost methods of data collection extending from the current study. In addition, private sector participation in advancing proxy measures of livestock production and productivity is being developed. This extends to employment of advanced sensing technologies and communication methods.

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