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Assessing the impact of a novel strategy for delivering animal health interventions to smallholder farmers

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ABSTRACT

In many countries of the developing world village poultry play a vital role in the rural economy, providing a source of protein and valuable income with relatively small investments. In almost all areas in which village poultry are raised Newcastle disease (ND) is identified as one of the biggest causes of poultry loss, this is often coupled with a lack of knowledge of poultry management practices. Inexpensive and effective vaccines are available that are suitable for use in rural village environments, but in many areas service providers and reliable structures for delivery remain an obstacle to uptake of vaccines. To overcome this, GALVmed has implemented a network for vaccine distribution in which individuals in the villages are trained as vaccinators. The vaccinators purchase ND vaccines from local agro-veterinary stores and sell single doses at market determined prices. Implementation of these networks was preceded by a programme of smallholder sensitisation to increase awareness of diseases and flock management practices. Here we present analysis of the impacts of this scheme on village poultry production. We compare the results of a baseline survey carried out before implementation of the networks, with the results of a survey 16–24 months following implementation. We present results in terms of the uptake of ND vaccine, flock size, consumption of poultry meat, and poultry sales from Gairo district in Tanzania, Mayurbhanj district in India and Banke district in Nepal. In all areas, there was a significant increase in the numbers of flocks that were using ND vaccines, with over 75% uptake in all areas, reaching 98% in India. In all areas flock sizes doubled, the numbers of eggs that were set for hatching and that hatched increased by 25–50% and there was an increase in the frequency with which chicken meat was consumed and chickens were sold. Additionally, farmers reported fewer ND outbreaks, but this is prone to reporting bias and so improvements in production cannot be categorically ascribed to ND vaccination. These results have shown that establishing a market driven approach for the distribution of ND vaccines and community sensitisation on poultry husbandry practices results in a high rate of uptake of the vaccines. The results also suggest a reduction in the number of ND outbreaks and improvements to the livelihoods of rural smallholders.

1. Introduction

In many of the poorest households in rural areas of the developing world poultry play a vital role and have been recognised as making a significant contribution to rural development (Alders and Pym, 2009; Copland and Alders, 2005; Mack et al., 2013). In most developing countries traditional scavenging village poultry form the greatest proportion of the national poultry flock (Mack et al., 2013). Village poultry (usually predominantly comprising domestic chickens (*Gallus gallus*)) are typically kept in flocks of fewer than 50 birds, but flock sizes vary greatly between areas and countries (Guèye, 1998). Birds are typically kept in free-ranging flocks that are owned by known households but are able to mix freely with birds from other flocks. The majority of nutrition is from scavenging and may be supplemented with leftover food, seeds and crops or specialist poultry feed. There may also be some housing, or birds may be left to roost in trees or elsewhere. The investment and input costs are low, making poultry a low risk species to farm (Alders et al., 2010; Conan et al., 2012).

Poultry contribute to the nutritional status of the population by providing a rare source of protein in the form of poultry meat and eggs

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(Bhandari et al., 2016). They are a source of income that can be utilised on an *ad hoc* basis, bartered or sold to pay for school fees, clothes or medicines as needed. In addition they play a key role in the social life of the village – as ceremonial sacrifices, as gifts or to offer meat to greet guests (Gondwe and Wollny, 2007; Kondombo et al., 2003; Thekisoe et al., 2004). The flocks are often managed by women or children, giving women the potential for an independent source of income, and due to their low maintenance requirements poultry can play an important role in sustaining households that are afflicted by HIV/AIDS (Copland and Alders, 2005).

Village poultry production faces a number of constraints such as infectious disease, predation and theft (Aboe et al., 2006; Desta and Wakeyo, 2013; Harrison and Alders, 2010; Olwande et al., 2010). Infectious diseases including fowlpox, Marek's disease, Gumboro (infectious bursal disease) and fowl coryza have high mortality rates, but Newcastle disease (ND) is frequently cited as the infectious disease that is responsible for the greatest proportion of mortality (Aboe et al., 2006; Harrison and Alders, 2010; Otim et al., 2007).

Newcastle disease is caused by infection with the ND virus, a single stranded RNA Paramyxovirus virus of the *Avulavirus* genus. ND viruses can be characterised by the severity of clinical signs and mortality rates among infected birds. The least pathogenic viruses cause subclinical infection, whilst the most pathogenic cause very high mortality, particularly among chicks, where mortality rates can approach 90% and are accompanied by distinctive clinical signs (Alders and Spradbrow, 2001). Among birds that survive there is a period during which the antibody titre is sufficient to protect the bird from further infection. There are a variety of routes of transmission including faecal-oral transmission, transmission through fluid secretions and through corpses of dead birds. Consequently, in an infected village, the disease is characterised by outbreaks in many flocks at the same time. This can be compounded by farmers choosing to sell birds at the start of an outbreak thus spreading infection to neighbouring areas through the movement of latently infected birds (Desta and Wakeyo, 2012; Sambo et al., 2015)

There are a number of both live and inactivated that are licenced and have good efficacy. Thermotolerant live vaccines have been developed that are safe, effective and can be administered by a number of routes including eye drop (Tu et al., 1998) with vaccination once every four months being adequate frequency to protect birds (Alders and Spradbrow, 2001) with clear cost benefits of vaccinating (Henning et al., 2013). However, delivery of ND vaccines to rural village poultry farmers is hampered by the difficulties of ensuring a cold chain and the high-dose formats of many vaccines (Alders, 2014) but a new low-dose tablet format could overcome these difficulties (Lal et al., 2014). This paper describes the impacts on household village poultry flocks of such a vaccine delivery strategy in Nepal, India and Tanzania.

2. Materials and methods

The implementation of this programme was preceded by a sensitisation campaign in which the populations were provided with poultry management related information, details of diseases and the information on the availability of vaccines through poster campaigns, radio broadcasts, video shows, street drama, wall painting and community groups.

The model for product delivery described in this paper is one by which vaccines are distributed to agro-veterinary stores from local distribution hubs, all overseen by local managers. From the agro-veterinary stores, products are either purchased directly by the farmers, or in most cases are purchased by independent vaccinators to sell the products on to farmers. The vaccinators were recruited from among the village population through a process of advertising and interview, and were given 3 days of training in the storage, preparation, administration of the vaccines and maintenance of the cold chain. Thereafter the vaccinators are self-employed but are supported by a local NGO or local distributors with whom they have monthly meetings to discuss issues and monitor sales.

The vaccinators operate as independent businesses, selling vaccines at 100–150 TZS (4–7 US cents) per bird in Tanzania and 2 INR (3 USc) in India, this includes a small profit margin for each vaccine dose that is the vaccinators' fee. As such, the system is entirely farmer funded, the only component that received external funding was the setup, sensitisation and the training of the vaccinators. The first product to be rolled out through this mechanism were ND vaccines in the form of the thermotolerant LaSota in India produced by Hester Biosciences Ltd and I-2 in Nepal and Tanzania produced by the Government of Nepal Central Biological Production Laboratory and the Tanzania Veterinary Laboratories Agency respectively. All vaccines are administered via eye drop. It is the duty of the vaccinators and the distribution chain above them to ensure that the cold chain is maintained, which is also monitored by local managers.

This paper describes the impacts of this programme. This was ascertained through questionnaire surveys that were implemented at initiation of the programme – before the vaccine delivery commenced (baseline) and after 16–24 months (endline). The questionnaires were intended to study the state of health of the poultry systems in the area – the productivity, husbandry practices and income from poultry.

2.1. Questionnaire

The survey was implemented as a questionnaire that comprised a mixture of open and closed questions (the questionnaire is available in Supplementary information S1). The questionnaire was written in English and translated into the local language, with subsequent data entry in English. Prior to survey, the questionnaire was tested and amended in pilot studies. The process of engaging the smallholder and conducting the interview lasted for between 45 and 60 min. Once all interviews were completed, a proportion of survey forms were reviewed by a supervisor. Data were entered into a bespoke database following the completion of each survey.

2.2. Sample sizes

The sample sizes were calculated to give a representative sample of the population with a confidence interval and confidence level of 5%. A further 10% allowance was made to allow for variation within the sample. The actual sample size varied between study areas depending upon the number of poultry-owning households in the study area.

Table 1
Description of the study areas and survey timings.

	Survey area				Survey timings		
Country	Region	Study area	Number of households	Target sample size	Baseline	Endline	Duration (months)
India	Odisha State	Mayurbhanj district	100,000	384	June 2014	October 2015	16
Nepal	Mid-Western Region	Banke district	39,826	381	May 2014	December 2015	19
Tanzania	Morogoro Region	Gairo district	34,000	380	February 2014	February 2016	24

Table 2
The numbers of households enrolled in the study, the numbers of the chickens and other poultry species in these households at baseline and endline surveys.

Country	Households enrolled		Villages	Numbers of animals: Chickens		Numbers of animals: Other poultry	
	Baseline survey	Endline survey		Baseline survey	Endline survey	Baseline survey	Endline survey
India	420	440	44	6328	14,780	181	315
Nepal	409	394	28	4179	9101	244	370
Tanzania	494	495	28	10,729	21,045	770	1052

2.3. Study sites

The study was implemented in three countries, details of the specific regions are in Table 1. The baseline and endline surveys represent the surveys prior to and following the initiation of the sensitisation and vaccination activities.

Households were sampled using a stratified methodology whereby villages were selected at random from each lower administrative unit weighted by the number of households in the administrative unit. The same survey structure and questionnaire was used at baseline and endline surveys. In the selected survey households that agreed to participate in the study, the person responsible for looking after the birds was interviewed using the questionnaire. If the household had no poultry or was unwilling to participate in the survey then the next household was selected.

2.4. Metrics for evaluation

The aim of this paper is to evaluate the impact of the programme as a whole, with vaccination against ND being one aspect of the programme. These analyses are a comparison of a number of metrics measured at baseline and endline. Metrics include flock size, consumption of poultry meat, productivity, husbandry practices, use of vaccines and knowledge of poultry rearing. The specific aspects of the programme's impact that were analysed were:

1. The sources of information on poultry health, sources of vaccines, knowledge of diseases, uptake of medicines.
2. Flock size and composition, frequency of consumption of poultry meat, poultry sales, purchasing replacement birds, egg production and uses of eggs.
3. Poultry housing and supplemental feeding.
4. Respondent perceptions regarding the causes of loses and the frequency of ND outbreaks.

Whilst other poultry species were included in this programme (guinea fowl, turkeys, ducks) and were included in the questionnaire, domestic chickens (*Gallus gallus domesticus*) accounted for 94.6% of poultry stock. Due to the different epidemiology of ND in different species (Alexander et al., 2004) and the predominance of chickens on these populations, we focussed exclusively on chickens in these analyses.

2.5. Data processing and statistical analysis

Following entry into the database, data were extracted in a csv format and processed using the R statistical environment (R Core Team, 2016). Data were checked for any anomalies that were verified against the paper questionnaires, respondents that did not own chickens were excluded. The data were analysed by comparing selected indicators between the endline and baseline. Statistical significance of continuous variables was calculated using Student's *t*-test or the Wilcoxon rank sum test depending on whether the variables followed a normal distribution. Binary variables were compared using Pearson's Chi-squared test. All statistical analysis was performed in the R statistical environment (R Core Team, 2016). A number of flocks were surveyed in the baseline and endline surveys and these flocks were matched by respondent details and were analysed separately using linear models in order to compare changes in flock sizes.

Most variables were analysed in the format that they were recorded, but data on the numbers of eggs were recorded as the number of clutches per hen per year and for a typical clutch the numbers that were consumed, sold, set, hatched and the numbers that survived. To combine these metrics, we calculated the numbers of eggs per hen per year by multiplying the numbers of clutches by the uses of the eggs. To correct for some extreme outliers in data on egg production we removed the top 1% of egg producers from analysis of egg production but not the remainder of the analysis. This comprised those that reported 204 or more eggs per hen per year. We also removed the 145 surveys that reported producing no eggs.

Where multiple responses are invited to an individual question, these are analysed separately with equal weight irrespective of the number of responses that were given. Question 17 – "If not vaccinating poultry please provide reasons" included a number of responses that were similar, so this was reduced to four responses: availability, awareness, cost/pack size, effectiveness.

3. Results

3.1. Household enrolment

Similar numbers of households (within 5%) were enrolled during the baseline and endline surveys in all study areas (Table 2). Numbers of chickens owned by the surveyed households varied between study areas with the greatest numbers in Tanzania and the smallest numbers in Nepal (Table 2).

3.2. Description of the baseline

Flock sizes varied substantially between study areas (Table 3). A notable difference between the areas was the ratio of hens to chicks, approximately 1:1 in Tanzania, 1:1.75 in Nepal and 1:2.5 in India.

ND and fowlpox were the principal diseases that were perceived by the respondent to be killing birds, but in Nepal, around 50% of households did not know which diseases were killing their poultry

Table 3
The flock sizes across the three study areas at baseline.

Country	Households	Mean (standard deviation): Chicks	Growers	Hens	Cocks	Flock size
India	420	5.94 (5.64)	5.39 (5.94)	2.35 (1.42)	1.38 (1.51)	15.07 (10.79)
Nepal	409	3.65 (4.48)	2.68 (2.91)	2.08 (2.76)	1.81 (2.07)	10.22 (8.67)
Tanzania	494	6.57 (7.76)	6.26 (7.03)	6.50 (5.64)	2.39 (2.46)	21.72 (16.74)

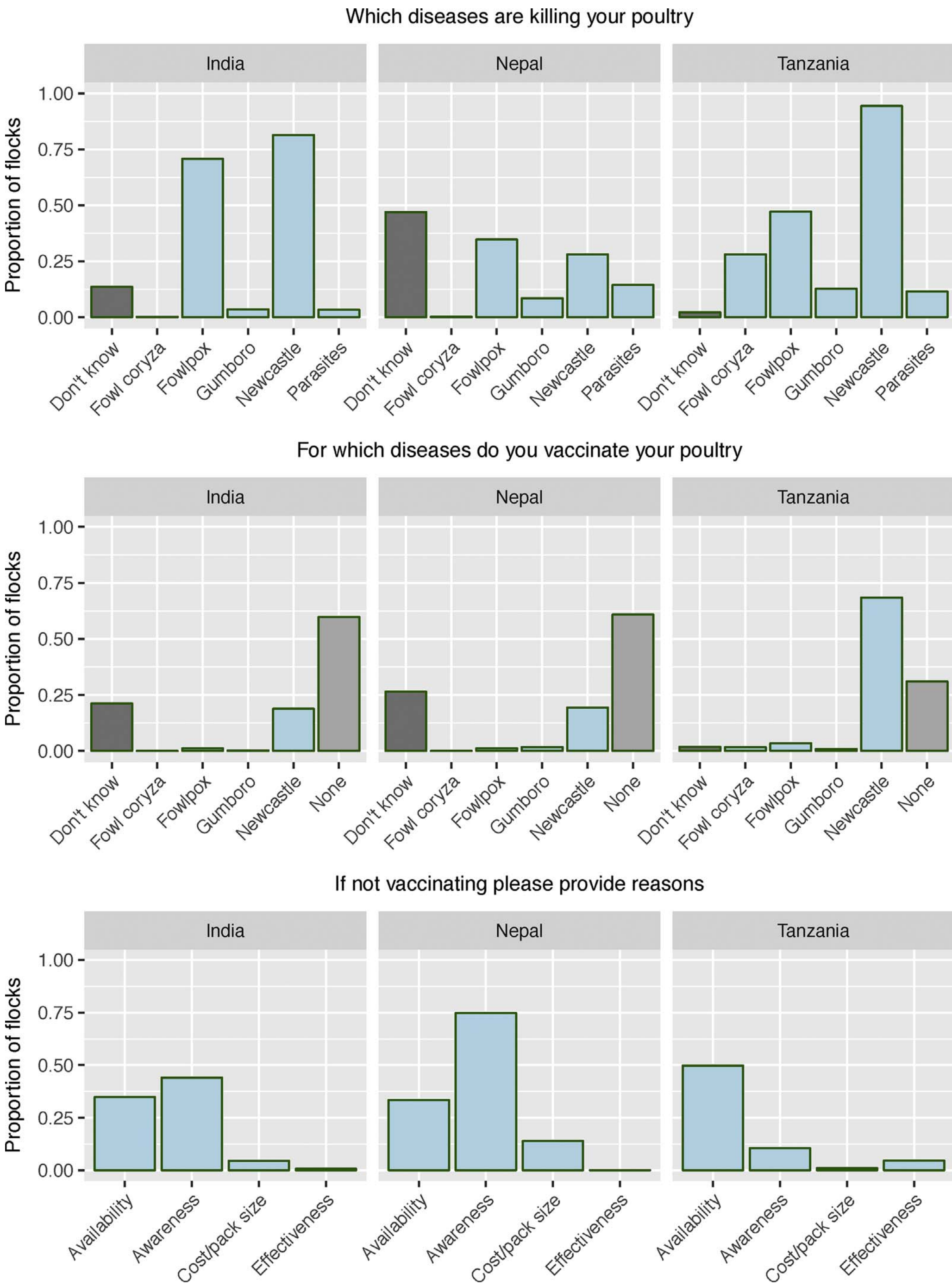

Fig. 1. Barplots of farmer responses to specific questions at baseline. (Top) diseases that were perceived to be killing poultry; (middle) the poultry vaccines that were used and (bottom) the reasons that respondents cited for not vaccinating. The specific question is given as the plot title.

(Fig. 1). In all study areas there was some use of vaccines, this was highest in Tanzania, but in Nepal and India around one quarter of respondents did not know what they were vaccinating against (Fig. 1). Lack of availability and lack of knowledge of the advantages of vaccination were cited as the principal reasons for not vaccinating (Fig. 1).

3.3. Programme impacts – uptake of vaccines

In all study areas, a proportion of flocks were vaccinated against ND at baseline. This was the majority of flocks in Tanzania (68%) but fewer than 20% of flocks in India or Nepal. At endline, over 75% of flocks reported vaccinating in all areas and this was over 98% in India (Fig. 2).

There was a significant increase in the proportion of respondents that vaccinated against ND, and in India there was also an increase in use of vaccines against fowlpox (Fig. 3). In all areas, village vaccinators were included under the title of community animal health workers (CAHWs) and this category was primarily responsible for selling vaccines (Fig. 3).

3.4. Programme impacts – on poultry production

In all study areas, there was a statistically significant increase in the numbers of chickens of all types (Fig. 4 and Table 4) and the number of chicks per hen increased, in India to 4.38 chicks per hen, 1.59 in Tanzania and 1.92 in Nepal.

This approximate doubling in flock sizes (Table 4) was also seen when we analysed those flocks that were sampled twice (Fig. S1). In India, 105 households were surveyed under both baseline and endline

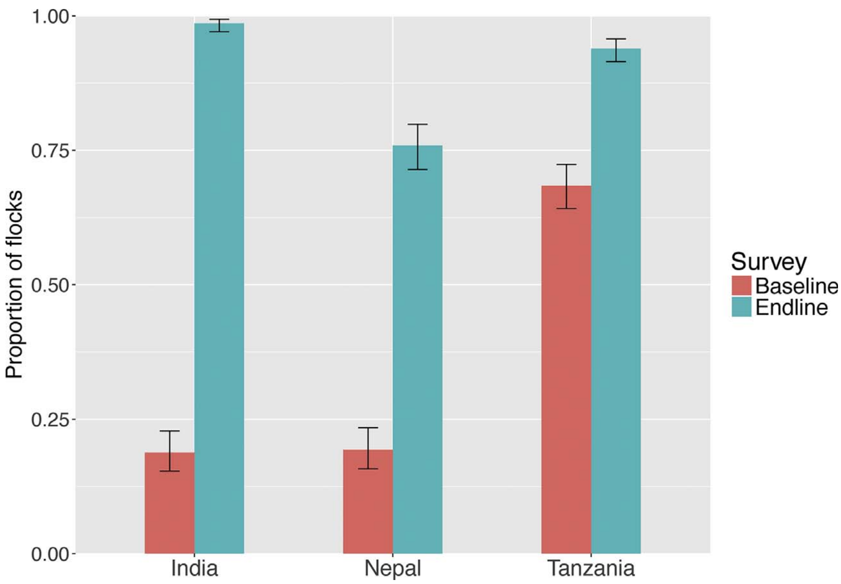

Fig. 2. Barplot with 95% confidence intervals of the proportion of flocks vaccinating against ND at baseline and at endline.

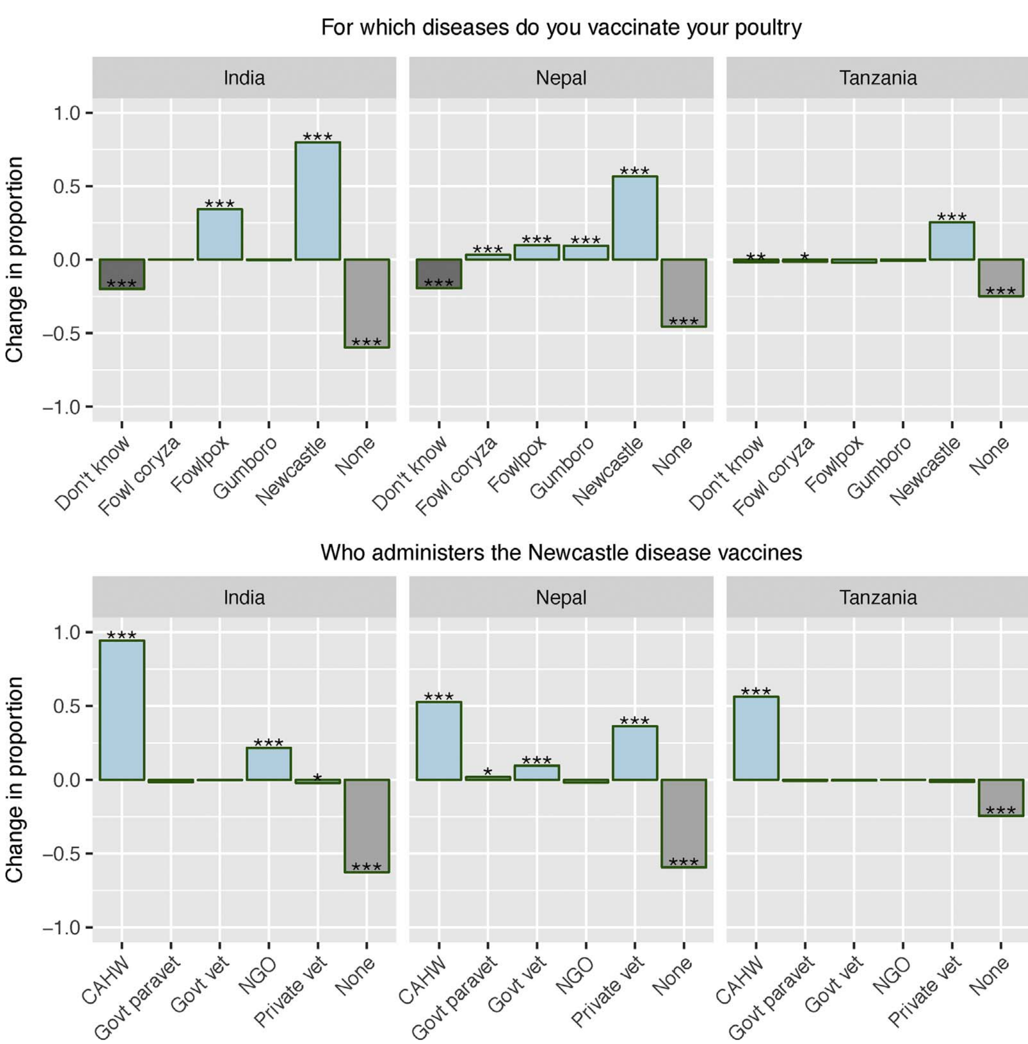

Fig. 3. The proportional change in responses to questions at endline compared to baseline. (Top) diseases that respondents vaccinated against and (bottom) the person or organisation that administers the vaccine. A positive change in proportion represents an increase at endline relative to baseline; a negative value a decrease. "*" is significance from a χ^2 test; * $p < 0.05$; ** $p < 0.01$; ***$p < 0.001$. CAHW = community animal health worker; NGO = Non-governmental organisation. The specific question is given as the plot title.

surveys, 97 in Tanzania and 70 in Nepal. The slopes of linear models with endline flock size as the outcome are 1.94, 1.47 and 1.91 for India, Nepal and Tanzania respectively, p-values were all < 0.001 and R^2 = 0.813, 0.578 and 0.755 respectively (Table S1).

In all study areas, relatively few eggs were consumed or sold. However, at endline, a greater number were set, hatched and reared to maturity, particularly in India, where at baseline a median of 9 eggs hatched and survived to maturity per year, and this increased to 18 at endline (Fig. 5, Table 5).

In India, respondents rarely reported purchasing birds (12.4% of

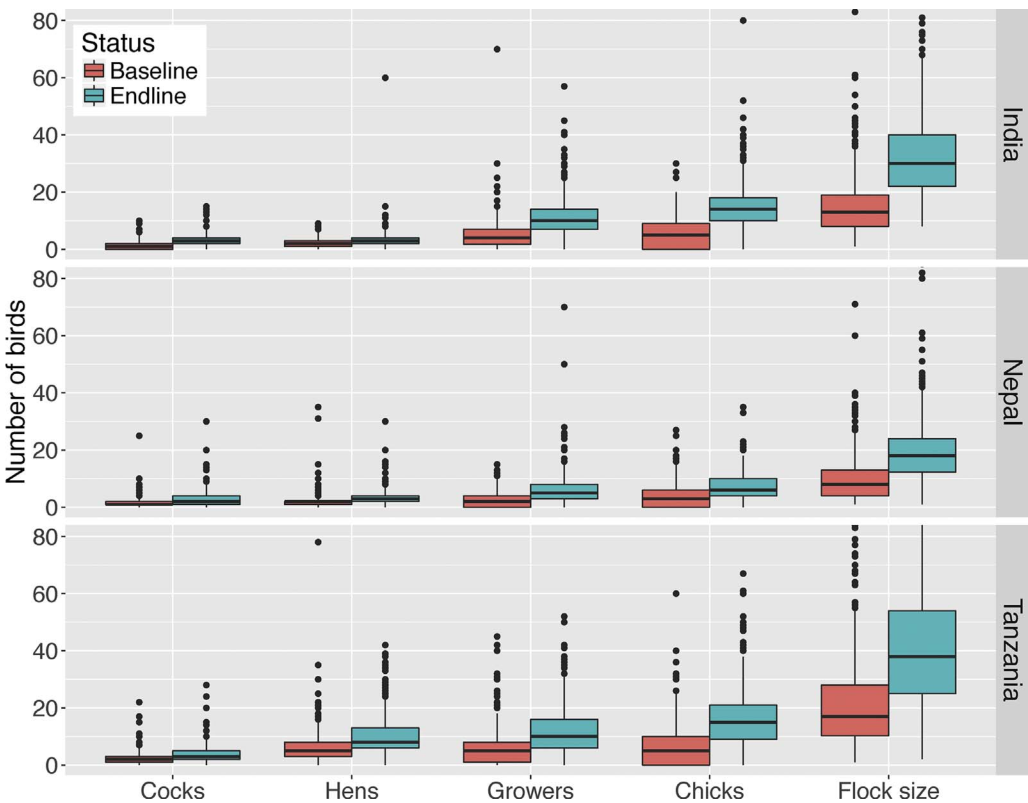

Fig. 4. Box and whisker plots of the numbers of birds of different age categories at endline and baseline. The boxes represent the 25th, 50th and 75th percentiles and whiskers are 1.5 times the interquartile range.

Table 4
Changes in flock composition between baseline and endline. The *p*-value is the *p*-value from a Wilcoxon signed rank test.

Country	Variable	Mean baseline	Mean endline	Median baseline	Median endline	p-value
India	Cocks	1.38	3.29	1	3	< 0.001
India	Hens	2.35	3.54	2	3	< 0.001
India	Growers	5.39	11.25	4	10	< 0.001
India	Chicks	5.94	15.50	5	14	< 0.001
India	**Flock size**	**15.07**	**33.59**	**13**	**30**	**< 0.001**
Nepal	Cocks	1.81	6.78	1	2	< 0.001
Nepal	Hens	2.08	3.58	2	3	< 0.001
Nepal	Growers	2.68	5.84	2	5	< 0.001
Nepal	Chicks	3.65	6.90	3	6	< 0.001
Nepal	**Flock size**	**10.22**	**23.10**	**8**	**18**	**< 0.001**
Tanzania	Cocks	2.39	3.63	2	3	< 0.001
Tanzania	Hens	6.50	10.29	5	8	< 0.001
Tanzania	Growers	6.26	12.27	5	10	< 0.001
Tanzania	Chicks	6.57	16.31	5	15	< 0.001
Tanzania	**Flock size**	**21.72**	**42.52**	**17**	**38**	**< 0.001**

households at baseline). A greater proportion purchased chickens in Tanzania and this declined between baseline and endline (39.9% compared to 29.9%), this was statistically significant ($\chi^2_1 = 10.4$, p = 0.001). In Nepal there was a slight increase in the numbers of flocks that purchased chickens for replacement from 48.4% to 54.8%, albeit not significant ($\chi^2_1 = 3.05$, p = 0.08).

In Tanzania and Nepal there was an increase in the frequency with which poultry meat was consumed. In India, there was little difference in frequency among households that were eating chicken more than once per week at baseline. However, at endline in India, a greater proportion of households were eating poultry meat at least once per week – 83.6% compared to 65% at baseline (Fig. S2). This was matched by an increase in the numbers of chickens sold in all countries (Fig. S3).

3.5. Programme impacts – on poultry husbandry

There was a significant increase in the numbers of households that obtained poultry related information, the majority of this information was from community animal health workers, vaccinators or NGOs in India (Fig. S4).

In all study areas, there was an increase in the number of households providing supplemental feed, medicines and owning a poultry house (Table 6). All differences were statistically significant (Chi squared $p < 0.001$).

3.6. Programme impacts on respondent identified Newcastle disease outbreaks

In all study areas, the respondent's perceptions were of a decrease in the number of ND outbreaks (Fig. 6). This is particularly pronounced in India where respondents reported 2.17 outbreaks per year at baseline and 0.011 at endline, compared to 0.8 and 0.58 in Nepal and 1.08 and 0.46 in Tanzania (Fig. 6).

In India, there was a very large and significant decrease in the number of flocks that reported deaths due to infectious diseases, but this was not the case in Nepal where there was an increase in the numbers reporting losses due to ND (Fig. S5).

4. Discussion

This paper has described the development of programmes to improve husbandry practices and ensure the sustainable delivery of ND vaccines to rural villages that otherwise do not have reliable coverage of vaccines. At the baseline, the principal reasons given for not vaccinating related to the availability and delivery of vaccines and awareness and knowledge of vaccines. Reasons relating to costs and effectiveness of vaccines were rarely cited. This programme has overcome these issues by raising awareness of diseases and the vaccines that are available and by making ND vaccines available in these areas, with sale

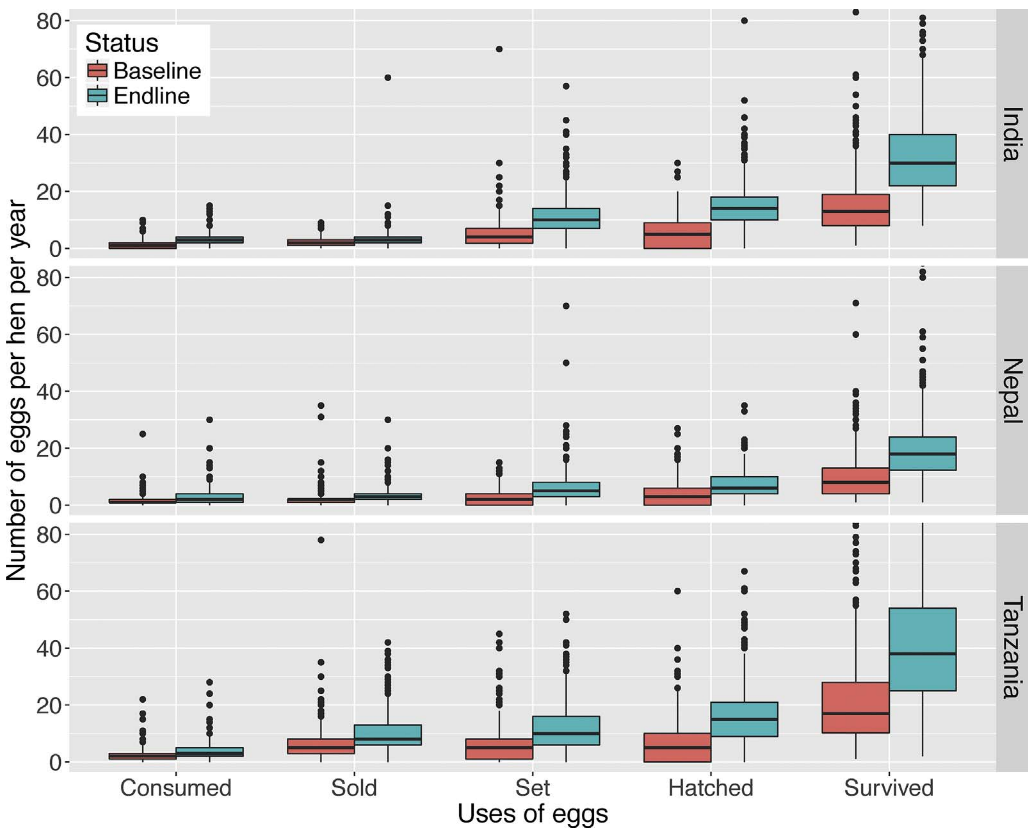

Fig. 5. Box and whisker plot of the uses of eggs. The number of eggs refers to the number of eggs per hen per year. "Survived" = the number of hatched chicks that are reared to maturity. The boxes represent the 25th, 50th and 75th percentiles and whiskers are 1.5 times the interquartile range.

Table 5
The uses of eggs produced per hen per year by country and by baseline and endline. The *p*-value is the *p*-value from a Student's *t*-test.

Country	Variable	Mean baseline	Mean endline	Median baseline	Median endline	p-value
India	Consumed	4.26	5.96	4	6	< 0.001
India	Sold	0.34	0.01	0	0	0.022
India	Set	25.89	32.75	24	30	< 0.001
India	Hatched	19.34	26.28	18	24	< 0.001
India	Survived	10.01	19.38	9	18	< 0.001
Nepal	Consumed	16.12	15.60	16	15	0.486
Nepal	Sold	8.47	10.90	0	8	0.026
Nepal	Set	35.11	45.78	36	48	< 0.001
Nepal	Hatched	26.15	35.36	24	36	< 0.001
Nepal	Survived	15.90	25.07	16	24	< 0.001
Tanzania	Consumed	7.43	8.11	6	8	0.157
Tanzania	Sold	2.22	3.40	0	0	0.003
Tanzania	Set	27.43	32.57	27	30	< 0.001
Tanzania	Hatched	23.42	30.10	24	30	< 0.001
Tanzania	Survived	12.25	18.68	12	18	< 0.001

Table 6
The number of flocks reporting particular husbandry practices at baseline and endline.

	% Baseline/% Endline		
	India	Nepal	Tanzania
Providing supplemental feed	7.6/37.7	59.5/78.2	82.9/91.1
Providing medicines	37.8/98.2	79.5/94.7	75.4/94.2
Own a poultry house	14.8/42.2	63.6/79.9	11.5/17.6

directly to the households overcoming issues related to the number of doses in a vial.

The programmes resulted in a two-fold increase in flock sizes, characterised by an increase in the ratio of chicks to hens indicating greater chick survival rates. The change in flock sizes is matched by an increase in the numbers of eggs that are produced and set. There was a corresponding increase in the frequency with which respondents reported consuming poultry meat, with between 70 and 86% of households consuming poultry meat at least once a week at endline. There was also a substantial increase in the sale of chickens in all study areas (Fig. S3), income which could be reinvested in the chicken flock (Mtileni et al., 2013) or used for other purposes. In all areas there was very little consumption or sale of eggs. As well as changes in flock size and off-take, there were changes in general husbandry practices, such changes have been identified as important steps in development (Copland and Alders, 2005; Mtileni et al., 2013).

The baseline surveys showed different levels of knowledge of disease and availability of vaccines between the three surveyed areas. In Tanzania, ND was named as the disease responsible for a large proportion of mortality due to disease in the chicken flocks, and accordingly, there was relatively high usage of ND vaccines, with 68% of flocks vaccinating. The high uptake in Tanzania may have been driven by the larger flock sizes making the purchase of vaccines more economical. By contrast, in Nepal, there was a lack of knowledge of the diseases that were killing poultry, and accordingly a lack of vaccination and awareness of the vaccines were cited as the principal reason for not vaccinating.

There were declines in the numbers of respondents reporting ND as a cause of death matched by a drop in the numbers of reported outbreaks, with very few respondents reporting outbreaks in India where uptake was near 100%. Whilst there was a reported reduction in perceived ND outbreaks in Tanzania and Nepal, this reduction was not as marked as in India. However, respondents' diagnosis of ND must be treated with caution as there is no pathology or epidemiological data to support this. The respondents may incorrectly diagnose diseases, and this may be particularly pronounced in this study where sensitisation activities were carried out following the baseline survey. The sensitisation included farmer education about the different diseases and may

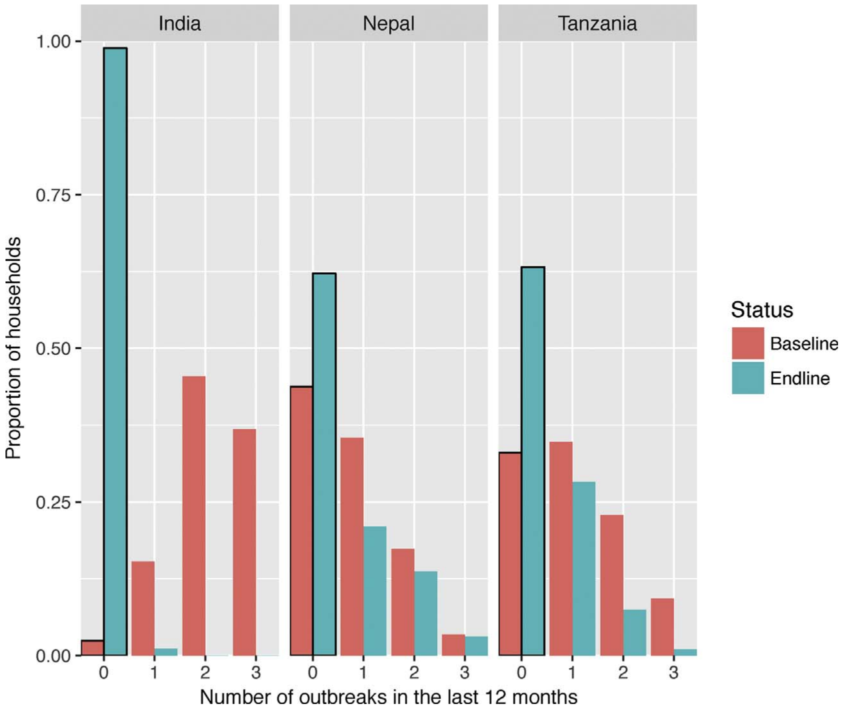

Fig. 6. The proportion of households that were reporting ND outbreaks in each study area at baseline and at endline.

make farmers over-sensitive to certain diseases at the endline survey. The levels of sensitisation and degree of farmer uptake of sensitisation activities may have varied between study areas.

The improvements in flock sizes, sales, consumption and husbandry found in this study may be a product of both the vaccination and the sensitisation campaigns but can not be attributed to any single intervention. In Tanzania, the relative increase in uptake of vaccines was small, yet there was a substantial increase in flock sizes, so this increase may have been a result of the sensitisation campaigns as demonstrated by changes to the number owing poultry houses, and the number providing supplementary feed and medicines (Table 6). It could also be attributable to the quality of vaccines that were being purchased previously, the frequency with which vaccines were administered or the small increase in numbers that were vaccinating. If vaccines are being sold in the village directly to the farmer, then the likelihood of vaccinating every 3–4 months as recommended is greater. If vaccines are less easily acquired, for instance if they require a visit to a veterinary store then they may be administered less frequently, or in response to an outbreak once it is too late to achieve any benefit from vaccination.

One of the weaknesses of this type of survey is that it relies on the recall of the respondent rather than direct observation, as such it may be prone to inaccuracies in the responses. Questions such as “How frequently do you eat chicken meat?” and “How many birds have you sold?” can be prone to errors due to the recall of the respondent or their recent behaviours. However, there is little scope for systematic bias in these responses, unless there had been a recent cultural festival or some other event that could result in an increase in numbers of birds sold. In contrast, questions relating to the frequency of ND outbreaks and diseases that were killing birds are prone to systematic bias due to the implementation of the sensitisation which was discussed earlier. There will also be some variations in flock sizes due to the times of year that the surveys were conducted, in India and Nepal the surveys were in different months of the year. In Nepal both surveys were conducted during the dry season, whilst in India both surveys were in the wet season, albeit the baseline at the start of the wet season and the endline at the end of the wet season. As flocks are known to be larger during the wet season (Ahlers et al., 2009; Guèye, 1998) this may explain some of the difference, but in some areas, the feed base is reported to be smaller during wet season (Desta and Wakeyo, 2013). Cultural festivals may further impact flock sizes as poultry are consumed, sacrificed or gifted (Conan et al., 2012; Guèye, 1998; Miguel et al., 2013).

The wider context of these studies is that the commercial distribution networks trialled in these projects were part of a larger GALVmed strategy to make ND vaccines and other essential animal health products widely available to the many millions of smallholders in Africa and Asia who depend on livestock for their livelihoods. In many areas vaccinators started to add dewormers to the products that they sell, and in a few areas fowlpox vaccines are being added to the portfolio of products. The practical points of learning gained through these projects are now being embedded in significantly larger commercial distribution initiatives with several private vaccine manufacturing companies. The focus of this paper, however, is on the impact of community sensitisation and vaccination rather than the mechanism of commercial distribution.

In summary, this paper has outlined a strategy for community sensitisation and delivery of vaccines to rural households that is sustainable and has a demonstrable positive impact on rural development. This strategy has been deployed with success in three distinctly different poultry farming areas. Further work is required to analyse the longer term impacts of vaccinating in these settings – including investigation of the long term impacts of vaccination on poultry husbandry and rural development. Such changes include investigation of whether flocks become larger and more professional, and whether households shift to farming different species once household economics permit it. Additionally, modelling of the economics of this mechanism of vaccine delivery will give information on long term sustainability.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.prevetmed.2017.08.022.

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