Impacts on Rural Livelihoods in Cambodia Following Adoption of Best Practice Health and Husbandry Interventions by Smallholder Cattle Farmers


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Introduction

The Kingdom of Cambodia is a predominantly agrarian society of 14.3 million people, with an estimated 70% reliant on agriculture for employment (ADB, 2011; MAFF, 2012). Poverty is a concern for Cambodia with almost 4.8 million poor people, 90% of whom reside in rural areas (IFAD, 2013). Undernourishment in Cambodia is 17.1%, and alarmingly, 40% of all children aged less than 5 years old are stunted (FAO, 2013; UNICEF, 2013). Although there is a general decline in undernourishment and stunting of children (The World Bank, 2013), it is clear that...
significant effort is required to further improve rural livelihoods. In 2011, Cambodia experienced national economic growth of 6.9%, with agriculture contributing 28.4% of the national gross domestic product (MAFF, 2012). Livestock is the third largest agricultural subsector at 15%, behind crop production (54%) and fisheries (25%), with a national cattle herd of 3.4 million in 2011, declining approximately 2.6% from the 2010 census (MAFF, 2012). Economic and population growth leading to greater urbanization is increasing the pressure on food security. However, this provides an opportunity for smallholder farmers to move from ‘cattle keepers to producers’ to meet this growing demand. ‘One Health’ strategies for smallholder farmers to increase agricultural diversity and improve efficiency leading to greater productivity and profitability are considered likely to address both food security and rural poverty (Windsor, 2011).

Cambodia cattle are primarily Bos indicus, predominantly being either of the Haryana breed, the local ‘Yellow’ breed or a combination of the two (Meas et al., 2000; Sath et al., 2008). Smallholder farmers typically own less than five head each and collectively own the majority of the national cattle herd (Young et al., 2013a). Although rice is the main production activity and with fish forms the basis of the Cambodian diet, cattle are important as they serve a multitude of purposes which include providing draught power for tillage and transport, manure for fertilizer and biogas, an asset store, and are increasingly a source of family protein and income from trade (Mak, 2001; Harding et al., 2007; Tong et al., 2007; Maxwell et al., 2012; Young et al., 2013a,b). Cattle production systems are usually low input output systems, which leave cattle highly susceptible to endemic diseases and regularly suffering from malnutrition and low reproductive rates (Pen et al., 2009; Tanure et al., 2011; Nampanya et al., 2012). Low agricultural output results from a combination of limited knowledge of nutrition and poor husbandry procedures, deficient veterinary services and endemic disease control, plus lack of access to resources including markets, market information systems and finance (Nampanya et al., 2012).

In recent years, the demand for red meat has increased significantly in the Mekong region, and the traditional husbandry methods and uses of cattle are changing with a shift towards cattle production as a primary source of income for some smallholder families (Windsor, 2011). For this to be achieved, smallholder beef producers must overcome the constraints limiting their productivity, particularly their inadequate feeding practices and disease risk management for diseases such as foot-and-mouth disease (FMD) and haemorrhagic septicaemia (HS) (Windsor, 2008; Nampanya et al., 2012; Stahel et al., 2013).

Inadequate feeding practices resulting in poor nutrition are claimed to be the most significant constraint to improving smallholder productivity (Devendra and Sevilla, 2002; Pen et al., 2009). During pre- and post-harvesting of rice, cattle may be allowed to graze native grasses on rice paddy and levy banks but are usually tethered close to the household and fed rice straw or roadside native grasses on a ‘cut and carry’ basis (Maxwell et al., 2012). This practice limits productivity as rice straw is of low nutritional value and digestibility, leading to poor body condition, reduced reproductive performance and increased disease susceptibility (Sath et al., 2008). In addition, the ‘cut and carry’ system is extremely labour intensive, taking several hours of labour daily (Pen et al., 2009; Maxwell et al., 2012) and limiting the time available for other farm and household activities, off-farm employment and schooling of children (Millar and Phoutakhoun, 2008; Maxwell et al., 2012).

Susceptibility to disease and parasites is also a major constraint limiting the productivity of smallholder cattle producers in rural Cambodia (Suon et al., 2013). FMD is a highly contagious infectious disease commonly recognized as the most significant transboundary livestock disease in the world (Windsor et al., 2011). FMD outbreaks occur annually and have adverse impacts on smallholder production through reduced draught power and discounted values of sold affected cattle (Bellet et al., 2012; Nampanya et al., 2012; Young et al., 2013b). Control of FMD in the region is a major challenge due to the widespread endemic nature of FMD and low notification rates by livestock owners (Vergne et al., 2012). While FMD represents the biggest threat to cattle trade on a regional scale, HS is the disease most feared by smallholder cattle producers due to high fatality rates once clinical signs such as high fever and severe respiratory distress appear (Benkirane and De Alwis, 2002). Cattle and buffalo are the most susceptible species to HS, with vaccination the primary control method (Benkirane and De Alwis, 2002; Saveourn et al., 2013). The main parasitic diseases in Cambodian cattle are fascioliasis, trypanosomiasis, toxocariasis, cysticercosis, strongyloidiasis, schistosomiasis, thelaziasis, oesophagostomiasis and diseases caused by ticks and flies (Inoue et al., 2001; Tum et al., 2004; Sothouen et al., 2006; Suon et al., 2006; Dorny et al., 2011; Young et al., 2013c).

One Health has been defined as the collaborative efforts of multiple disciplines working locally, nationally and globally, to attain optimal health for people, animals and our environment (AVMA, 2008). To improve understanding of methods to increase the productivity and profitability of large ruminant production as a means of alleviating rural poverty in Cambodia, the University of Sydney, Australia, in collaboration with the Cambodian Department of Animal Health and Production (DAHP) has conducted a multidisciplinary research project ‘best practice health and husbandry of cattle, Cambodia’ (BPHH). This five-year project commenced in 2007 and concluded in late 2012.
and investigated how participatory education of farmers could improve knowledge and skills of cattle health and production. Smallholder farmers learned to effectively grow forages and improve cattle feeding, maintain and increase cattle weight gains, and manage disease threats through vaccination and biosecurity. Farmer knowledge was assessed at the commencement of the interventions in 2008 and again in 2010 and showed significant improvements in overall farmer knowledge scores on health and husbandry (Nampanya et al., 2012). These preliminary results indicated that ‘on-the-job’ training and participation in fieldwork were successful in enabling forage crop establishment and vaccination to prevent infectious diseases, but disease prevention through biosecurity and parasite control needed a greater amount of formal training delivered over an extended period to allow for reinforcement (Nampanya et al., 2012). More recently, the impacts of the BPHH interventions on cattle production have been reported (Young et al., 2013a).

The objective of this study is to determine the impacts on smallholder livelihoods of the BPHH project through a final questionnaire of farmer knowledge, attitude and practices (KAP). The resultant socio-economic impacts were conducted in 2012. It was hypothesized that the improved knowledge of husbandry and disease methods, such as forage growing and feeding plus vaccination and biosecurity, would lead to increased annual income in smallholder households. In addition to the surveys, a series of case studies were conducted to provide further insight into the socio-economic situation of individual smallholder cattle producers. Finally, extension methods and materials were assessed to assist future extension needs and activities. It is anticipated that the findings from this systems approach to research and extension would provide a strategy for development projects and smallholder communities that could be adopted more widely and improve the livelihoods of many smallholder cattle producers in rural Cambodia and beyond.

Materials and Methods

Best practice health and husbandry of cattle, Cambodia project design

Six project sites (villages) from three provinces (two in each province) were purposively selected to participate in the BPHH project. The two villages in each province were matched with one designated a ‘high intervention’ (HI) and one a ‘low intervention’ (LI) to serve as a baseline. Village selection criteria included: cattle population of at least 250 head, year-round road access, willingness of village authorities, farmers and local government agency personnel to participate in the project, and a distance of at least 10 km between project villages in the same province. The six villages selected and their designated intervention type included Nor Mo (HI) and Dem Pdet (LI) from Takeo province, Preak Por (HI) and Koh Kor (LI) from Kandal province, Senson Tbong (HI) and Veal (LI) from Kampong Cham province. Four DAHP extension office staff members were employed as project staff and received training in applied epidemiology including data collection and entry, analysis and reporting. Initially, 645 households collectively owning 1,519 cattle were enrolled from the six villages (Young et al., 2013a).

Interventions based on knowledge and technology improvements were delivered to farmers in the HI villages and involved workshops, on-farm training plus technology improvement support, including forage plot development with seeds and seedlings, forage ensiling, anthelmintic treatments and diagnostic testing for infectious disease and parasites. Although only HI sites received the knowledge interventions, both HI and LI villages received regular vaccinations for HS and FMD, which provided a participatory incentive for the LI farmers. The knowledge-based interventions introduced to the HI villages by the project staff have been previously described by Nampanya et al. (2012) and can be summarized into three components:

1. Participatory ‘applied field research’ involving the farmers presenting cattle for data sampling and preventive treatments eight times during the project.
2. ‘On-the-job’ training consisting of project staff working with small groups of farmers to improve cattle health and production through ‘best practice’ interventions.
3. ‘Formal training’ programmes were delivered to farmers, village and commune leaders, village animal health workers (VAHWs), district and provincial veterinary officers, as well as project staff using a ‘train the trainer’ extension strategy. A series of 20 workshops was delivered to over 630 smallholder farmers and over 420 VAHWs between 2008 and 2011. Workshops were delivered over 1-4 days, and a list of topics covered is provided (Appendix A). Further technical training was provided to district and provincial veterinary officers and project staff in the areas of biosecurity, disease investigation, control and reporting.

Project staff worked with HI smallholder farmers to develop forage plots, using five species of forages: *Panicum maximum* (cv. Simuang), *Brachiaria spp.* hybrid (cv. Mulato II), *Brachiaria brizantha* (cv. Marandu), *Paspalum atratum* (Terenos) and legume *Stylosanthes guianensis* (cv. Stylo 184). These species were targeted for cultivation development, as they are known to be generally well adapted to Cambodia’s climate and have superior nutritional quality to native grasses for cattle (Young et al., 2013a).
Questionnaire design

The questionnaire consisted of four predominant sections aimed at encompassing knowledge, attitudes, practice (KAP) and socio-economic aspects of BPHH project impacts on smallholder cattle production. Knowledge questions focused on four subtopics of cattle health and husbandry that comprised of (i) infectious diseases and biosecurity, (ii) internal parasites, (iii) nutrition, and (iv) reproduction. Marketing knowledge and practices were assessed through asking farmers whether they knew the current market price of their cattle, sought multiple quotes prior to sale and whether they knew the cattle’s destination. Practices relating to several key knowledge topic areas were investigated, including biosecurity activities such as vaccination, separation of diseased from healthy cattle, removal of manure from cattle housing and building fattening pens. Socio-economic questions focused on the current farming and household situation, including farm size, number of household members, current management practices such as forage growing and investigated changes in annual income and time savings for men, women and children.

The questionnaire was designed in January 2012 and consisted of 67 questions in total, including multiple choice questions where farmers had the option of ranking or choosing multiple options in some cases. The KAP questionnaire was structurally based on the survey used in 2008 and 2010 (Nampanya et al., 2012) and was modified to reduce the number of knowledge questions and increased the number of attitude, practice and socio-economic impact questions. Following six questions relating to general information including farm area, locality, livestock holdings and household members, a total of 26 knowledge, 12 attitudes and 23 practices questions made up the survey, with socio-economic questions interspersed within the attitudes and practices questions; for example, farmers were asked to estimate their changes in annual household income and time saved per day as a result of forage growing. Questions were kept straightforward to minimize verbosity and potential reporting errors and maintain ease of translation from English into Khmer.

A total of 120 farmers were selected from the six project villages (20 per village) to participate in the questionnaire, equating to 60 farmers from each HI and LI group. Project staff contacted the six respective village chiefs and requested chiefs to randomly select project participants for survey inclusion. Questionnaires were conducted in March 2012 by project staff in each village using a combination of face-to-face and group interviews (of maximum five farmers). Consistency was maintained by having at least two project staff members present at each interview session. All interviews were conducted in Khmer, and all responses recorded for each farmer in Khmer onto a predesigned survey and answer sheet. The results were translated into English and collated in a Microsoft Excel 2010 database.

Data analysis

Smallholder farmer knowledge 2012

Of the 26 questions testing farmer knowledge, questions were further divided into the four subgroups of infectious disease and biosecurity (ten questions), internal parasites (five), nutrition (six) and reproduction (five). To quantify farmer knowledge, ‘correct’ answers were converted to ‘1’ and ‘incorrect’ or ‘I don’t know’ answers converted to ‘0’ to allow assessment of any variation between intervention groups. Four generalized linear mixed models (GLMMs) were developed for each of the four subtopics (infectious disease and biosecurity, internal parasites, nutrition and reproduction) and used to determine predicted mean HI and LI farmer knowledge scores. Each GLMM model included the intervention level (HI or LI) as the fixed term, and province and village as the random terms. Each model underwent a log transformation for analysis and back transformation to calculate the predicted mean scores. Three marketing questions were asked in 2012 including knowledge of current market price, destination of sale cattle and do you seek multiple quotes prior to sale. As above, a GLMM was performed to assess any variation between HI and LI groups using the intervention level as the fixed term, and province and village as the random terms. The data were log-transformed for the GLMM analysis and then back-transformed to calculate the predicted mean scores. All quantitative analysis was performed using GenStat 14th ed. (VSN International) with results considered statistically significant based on a significance level of $P \leq 0.05$.

Comparison of farmer knowledge in 2008, 2010 and 2012

Of the 26 knowledge questions, 19 were retained from the original 2008 and 2010 surveys and used to evaluate changes in farmer knowledge over time. The 19 questions compared between the 3 years were divided into three subgroups for analysis that consisted of 11 animal health questions (infectious disease, internal parasites and biosecurity), three nutrition and five reproduction questions. Three GLMMs were developed with the fixed terms intervention level (HI or LI), year (2008, 2010 or 2012), interaction term (intervention year) and random terms consisting of province and village. Due to intervention level and year the key variables of interest, both terms and interaction were forced into the model. Two of the retained marketing questions including knowledge of market price and obtaining multiple quotes prior to sale were analysed for variation between intervention groups again using a GLMM with fixed terms.
intervention level, year and the interaction term (intervention year). The random terms were the province and village.

Smallholder farmer attitudes and practices 2012
Attitudes and practices answers consisting of ‘yes’ were converted to ‘1’ and ‘no’ or ‘I don’t know’ converted to ‘0’ for analysis and comparison between intervention groups. Farmers in LI and HI villages were asked to indicate important sources of information (people) and rank extension materials and methods on a scale of 1–5 with 1 the least important and 5 the most important. Where questions involved farmers ranking a choice, these were grouped and the means are provided.

Socio-economic impacts 2012
Socio-economic data responses were grouped according to the intervention level and descriptive statistics employed to determine the differences between HI and LI farmers. Quantitative analysis to test significance between intervention groups was performed using a two-way chi-squared or Fisher’s exact test for binary variables and a two-sample t-test for ‘time saved’ numerical variable. A logistic regression analysis was performed to test possible explanatory variables on the ‘increased income’ reported by farmers. The increased income farmer response was changed to a binary variable, with ‘yes’ converted to ‘1’ and both ‘no’ and ‘I don’t know’ converted to ‘0’. Explanatory variables tested included the intervention level (HI or LI), total farm area (ha), total cattle owned, rice cultivation area (ha), forage area (ha) and the number of people in each household. Explanatory variables were assessed using univariable regression analysis using a cut-off of 0.3 for multivariable model inclusion. Forward selection was used to build the final model, with testing performed for interaction and confounding.

Case studies of early adopters
In June 2012, five HI early adopter smallholder farmers (four from Takeo and one from Kampong Cham) were purposely selected and individually engaged by DAHP and University of Sydney staff and students in discussions consisting of open-ended questions with the aim of providing greater insight into the households’ socio-economic situation. The farmers had demonstrated successful adoption of new technology such as forage growing and were keen to engage with project staff to continually improve their farming systems. Questions included changes in their livestock holdings, annual income, % income from the farm and other BPHH project impacts on livelihoods. Case study farmer records were summarized using descriptive statistics.

Results
Farmer knowledge 2012
In 2012, infectious disease and biosecurity knowledge was significantly different with HI farmers scoring 97.5% compared with LI farmers at 47.2% (P < 0.001) (Fig. 1). In relation to internal parasites, LI farmers demonstrated almost no knowledge with 0.3% of questions answered correctly, with HI farmer knowledge significantly higher at 99.7% (P < 0.001). This trend was continued for cattle nutrition with HI farmers scoring 94.3% correct compared with 36.9% for LI farmers (P = 0.008) and cattle reproduction with HI farmers scoring 97.7% correct compared with 48.7% for LI farmers (P < 0.001) (Fig. 1). A significant effect of intervention level was found in 2012 with 90% of HI farmers electing that they did know the market price of their cattle compared with 51.7% LI farmers (P < 0.001). Farmers were asked whether they knew the destination of their cattle after sale with no significant difference between LI and HI farmers with proportions of 20.4% and 26.9%, respectively (P = 0.840). Of the HI farmers, 93.3% reported that they sought multiple quotes prior to sale compared with 63.3% of LI farmers (P < 0.001).

Farmer knowledge changes in 2008, 2010 and 2012
At commencement of the project in 2008, there was no significant difference in animal health knowledge between LI and HI farmers with 26.4% and 26.3% of questions answered correctly respectively. However by 2010, HI farmer knowledge scores increased significantly to 89.7% compared with LI farmers at 47.2% (P < 0.001) (Fig. 1). A significant difference was found for internal parasites knowledge with HI farmers scoring 99.7% correct compared with 0.3% for LI farmers (P < 0.001) (Fig. 1). The increased income farmer response was changed to a binary variable, with ‘yes’ converted to ‘1’ and both ‘no’ and ‘I don’t know’ converted to ‘0’. Explanatory variables tested included the intervention level (HI or LI), total farm area (ha), total cattle owned, rice cultivation area (ha), forage area (ha) and the number of people in each household. Explanatory variables were assessed using univariable regression analysis using a cut-off of 0.3 for multivariable model inclusion. Forward selection was used to build the final model, with testing performed for interaction and confounding.

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time on farmer knowledge with HI significantly higher than LI farmers \((P < 0.001)\) (Fig. 2).

At the beginning of the project, there was no significant difference between LI and HI farmer knowledge on cattle nutrition with 62.3% and 42.2% correct answers, respectively \((P = 0.233)\). However, in 2010, the nutritional knowledge of HI farmers had increased to 94% and was significantly higher than LI farmer scores at 58.9% \((P < 0.001)\). HI farmer knowledge of nutrition further increased to 99.6% in 2012 with a decrease in LI farmer knowledge to 30%.

Farmers from the LI cohort had significantly higher reproductive knowledge scores in the 2008 survey with 30.9% correct compared with 21.5% correct in the HI cohort \(<0.001\). However, this was reversed in the 2010 and 2012 surveys with LI farmers scoring significantly lower scores than HI farmers, with 40.3% compared with 59.0% in 2010 \(<0.001\) and 48.7% compared with 97.7% in 2012, respectively \((P < 0.001)\). LI farmer knowledge on cattle reproduction showed a small but significant increase over time, while HI village scores showed significant increases from 2008 to 2012 with scores improving by over 75% in the 4 years (Fig. 2).

In 2008 and 2010, there was no significant difference between HI and LI farmers on knowledge of the market price of their cattle \((P = 0.121, P = 0.068\), respectively). There was no significant change over time in LI farmers. In 2008, there was no significant difference in the proportion of HI and LI farmers who sought more than one quote from traders at 84.2% compared with 75% \((P = 0.561)\) and in 2010 again with 90.2% in LI and 92.3% in HI farmers \((P = 0.825)\). HI villages showed no significant change over time, while in the LI villages there was a significant drop in farmers seeking multiple quotes of 30% from 2010 to 2012 \((P = 0.046)\).

Farmer attitudes and practices

Farmer attitudes and practices relating to disease control are presented (Table 1).

Information sources and extension

Farmers were asked to indicate their primary sources of information relating to animal health and husbandry in 2012 and results are presented (Table 2).

The highest rated extension method for both LI and HI cohorts was the use of demonstration, scoring 3.5 and 3.9 of 5, respectively. Both LI and HI farmers ranked banners and visits and meetings as their 2nd and 3rd preferred extension method. There were no significant differences between LI and HI cohorts for all extension materials and methods except for demonstrations and visits and meetings \((P < 0.001)\) (Fig. 3).

Socio-economic impacts

Descriptive statistics showing the mean number of household members, cattle owned per household and mean land use are presented (Table 3) for each village and intervention group.

For all 120 farmers, nearly 74% of land area is dedicated to rice cultivation, with 22% used for gardens and less than 2% used for forages.

Forage growing practices

Of the 120 farmers interviewed, 35 reported currently growing forages in the project villages, including 20 farmers in the HI village of Nor Mo in Takeo province and 15 farmers in the HI village of Senson Tbong in Kampong Cham province (Table 4). The type of forage species grown differed amongst these 35 farmers with Simaung being the most widely grown (34 farmers) followed by Mulato II (30), Paspalum (27), Murando (19) and Stylo 184 (6) (Table 4).

Time savings

In the HI villages, 39 of 60 farmers (20 in Nor Mo and 19 in Senson Tbong) agreed that growing forages saved time that would be otherwise spent feeding cattle. From their responses, it was recorded that on average, men saved

Fig. 2. The GLMM predicted scores of HI and LI farmers of the 19 retained knowledge questions in the topics of animal health, reproduction and nutrition in 2008, 2010 and 2012.
2.88 h per day ($n = 39$, range 0–6 h), women saved on average 2.18 h per day ($n = 39$, range 0–6 h) and children saved on average 2.13 h per day ($n = 39$, range 0–7 h) (Table 4). Farmers were asked what they did with this saved time with 33 men stating that they directed these time savings towards other employment, 11 to farming activities and 8 spent this time on household activities; note, farmers could choose more than one option (Table 4). Of the 19 farmers who stated that the women in their household gained time savings as a result of forage growing, all 19 said that the women allocated their time savings to household activities, nine to other employment and six to farming activities. The 15 farmers who stated that their children saved time from growing forages said that the children devoted it solely to school work (Table 4).

### Income changes

In 2012, a total of 52 of 60 HI farmers stated that their annual income had increased as a result of the project, including all 20 farmers in Nor Mo, 18 of 20 in Senson Tbong and 14 of 20 in Preak Por. The remaining eight farmers in the HI villages did not agree nor disagree with the statement, responding they were unsure (Table 4). This also applied to the majority of farmers interviewed in the LI villages where 14 of 20 farmers in Dem Pdet, 18 of 20 in Veal and 17 of 20 in Koh Kor stated they were unsure whether their annual income had increased due to the project. The remaining ten farmers in the LI villages said their annual income had not increased while one farmer in the LI village of Koh Kor reported an income increase. In a follow-up question of the 53 farmers who stated their annual income had increased, farmers were asked to state whether their income had less than doubled, doubled or more than

### Table 1. Proportion of smallholder farmers from each intervention group who responded in the affirmative to biosecurity and disease control

<table>
<thead>
<tr>
<th>Proportion of farmers who:</th>
<th>Low Intervention (%)</th>
<th>Standard error</th>
<th>High Intervention (%)</th>
<th>Standard error</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identified signs of FMD since vaccination</td>
<td>38.00</td>
<td>±6.7</td>
<td>5.00</td>
<td>±2.9</td>
<td>0.002*</td>
</tr>
<tr>
<td>Continue to vaccinate for FMD at own cost</td>
<td>85.00</td>
<td>±5.7</td>
<td>98.00</td>
<td>±1.6</td>
<td>0.021*</td>
</tr>
<tr>
<td>Vaccinated all cattle &gt;6 months for FMD</td>
<td>5.00</td>
<td>±0</td>
<td>100.00</td>
<td>±0.3</td>
<td>0.004*</td>
</tr>
<tr>
<td>Identified signs of HS since vaccination</td>
<td>31.00</td>
<td>±8.8</td>
<td>6.00</td>
<td>±3.5</td>
<td>0.001*</td>
</tr>
<tr>
<td>Continue to vaccinate for HS at own cost</td>
<td>88.00</td>
<td>±5.7</td>
<td>100.00</td>
<td>±0</td>
<td>0.989*</td>
</tr>
<tr>
<td>Vaccinated all cattle &gt;6 months for HS</td>
<td>1.20</td>
<td>±2.5</td>
<td>100.00</td>
<td>±0</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Separate sick cattle from the main herd</td>
<td>77.00</td>
<td>±3.9</td>
<td>100.00</td>
<td>±0</td>
<td>0.773*</td>
</tr>
<tr>
<td>Remove manure from cattle housing</td>
<td>100.00</td>
<td>±0</td>
<td>100.00</td>
<td>±0</td>
<td>na</td>
</tr>
<tr>
<td>Treat newborn calves for <em>Toxocara vitulorum</em></td>
<td>0.10</td>
<td>±0.2</td>
<td>11.00</td>
<td>±15.8</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Build fattening pens for stock</td>
<td>82.00</td>
<td>±5.0</td>
<td>98.00</td>
<td>±1.7</td>
<td>0.017*</td>
</tr>
</tbody>
</table>

na, not applicable.  
*a*two-way chi-squared test.  
*b*Fisher’s exact test.

### Table 2. Primary sources of information on project technologies as identified by farmers in low and high intervention villages (%)

<table>
<thead>
<tr>
<th>Intervention group</th>
<th>Project staff</th>
<th>VAHW*</th>
<th>District veterinarian</th>
<th>Farmer</th>
<th>Village chief</th>
</tr>
</thead>
<tbody>
<tr>
<td>High intervention</td>
<td>100</td>
<td>28.3</td>
<td>36.7</td>
<td>8.3</td>
<td>10</td>
</tr>
<tr>
<td>Low intervention</td>
<td>16.7</td>
<td>46.7</td>
<td>23.3</td>
<td>0</td>
<td>70</td>
</tr>
<tr>
<td>$P$-value*</td>
<td>&lt;0.001</td>
<td>0.053</td>
<td>0.208</td>
<td>0.022</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*VAHW, village animal health worker.  
*P*-values based on two-way chi-squared test.
Table 3. Mean values of smallholder household (HH) and land use parameters of each village, province and intervention group

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of HH members</th>
<th>Cattle owned</th>
<th>Farm area (ha)</th>
<th>Rice area (ha)</th>
<th>Garden area (ha)</th>
<th>Forage area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Village and Province</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nor Mo</td>
<td>5.4 (±1.8)</td>
<td>3.2 (±1.3)</td>
<td>1.007 (±0.529)</td>
<td>0.863 (±0.383)</td>
<td>0.049 (±0.133)</td>
<td>0.048 (±0.061)</td>
</tr>
<tr>
<td>Dem Pdet</td>
<td>4.7 (±1.4)</td>
<td>2.9 (±1.6)</td>
<td>0.789 (±0.454)</td>
<td>0.585 (±0.445)</td>
<td>0.106 (±0.127)</td>
<td>0.000 (±0.000)</td>
</tr>
<tr>
<td>Takeo</td>
<td>5.0 (±1.7)</td>
<td>3.0 (±1.5)</td>
<td>0.898 (±0.498)</td>
<td>0.724 (±0.433)</td>
<td>0.077 (±0.131)</td>
<td>0.024 (±0.049)</td>
</tr>
<tr>
<td>Senson Tbong</td>
<td>5.1 (±1.6)</td>
<td>4.5 (±3.8)</td>
<td>1.117 (±0.935)</td>
<td>1.058 (±0.889)</td>
<td>0.010 (±0.031)</td>
<td>0.044 (±0.066)</td>
</tr>
<tr>
<td>Veal</td>
<td>5.1 (±1.4)</td>
<td>4.2 (±1.9)</td>
<td>0.976 (±0.625)</td>
<td>0.913 (±0.641)</td>
<td>0.064 (±0.093)</td>
<td>0.000 (±0.000)</td>
</tr>
<tr>
<td>Kampong Charm</td>
<td>5.1 (±1.5)</td>
<td>4.4 (±2.9)</td>
<td>1.046 (±0.788)</td>
<td>0.985 (±0.769)</td>
<td>0.037 (±0.074)</td>
<td>0.022 (±0.051)</td>
</tr>
<tr>
<td>Preak Por</td>
<td>4.5 (±0.9)</td>
<td>3.8 (±1.4)</td>
<td>0.772 (±0.774)</td>
<td>0.248 (±0.199)</td>
<td>0.535 (±0.771)</td>
<td>0.000 (±0.000)</td>
</tr>
<tr>
<td>Koh Kor</td>
<td>4.0 (±0.9)</td>
<td>4.0 (±2.4)</td>
<td>0.721 (±0.695)</td>
<td>0.315 (±0.473)</td>
<td>0.428 (±0.350)</td>
<td>0.000 (±0.000)</td>
</tr>
<tr>
<td>Kandal</td>
<td>4.2 (±1.0)</td>
<td>3.9 (±1.9)</td>
<td>0.746 (±0.727)</td>
<td>0.281 (±0.359)</td>
<td>0.481 (±0.594)</td>
<td>0.000 (±0.000)</td>
</tr>
<tr>
<td>Intervention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>5.0 (±1.5)</td>
<td>3.8 (±2.4)</td>
<td>0.965 (±0.765)</td>
<td>0.723 (±0.660)</td>
<td>0.198 (±0.505)</td>
<td>0.031 (±0.055)</td>
</tr>
<tr>
<td>Low</td>
<td>4.6 (±1.3)</td>
<td>3.7 (±2.0)</td>
<td>0.828 (±0.600)</td>
<td>0.604 (±0.574)</td>
<td>0.199 (±0.273)</td>
<td>0.000 (±0.000)</td>
</tr>
<tr>
<td>Mean of all</td>
<td>4.8 (±1.4)</td>
<td>3.7 (±2.2)</td>
<td>0.897 (±0.688)</td>
<td>0.663 (±0.619)</td>
<td>0.198 (±0.404)</td>
<td>0.015 (±0.042)</td>
</tr>
</tbody>
</table>

doubled. Responses indicated that farmers income had less than doubled in 21 cases (40%), doubled in 23 cases (43%) and more than doubled in nine cases (17%).

In the development of the logistic regression model assessing explanatory variables on the increased income (with a binary outcome of yes – income increased, or no – income did not increase/unsure), only intervention level and total farm area were significant in the univariable analysis at the cut-off of less than 0.3. The number of household members, number of cattle owned, land area used for rice cultivation and land area used for forage growing were not significant. There was no interaction between intervention level and total farm area. However, as the total farm area was likely associated with both the intervention and the income without intervening or as a consequence of each, it was tested for confounding and was found to change the parameter estimate substantially by 24%. Therefore, total farm area was also removed from the model. In the final model containing the intervention level as the only explanatory variable, the odds ratio of income increasing in high intervention smallholder farms was 383 (P < 0.001) higher than farms in the low intervention group.

Socio-economic case studies of early adopters

The mean age of the five farmers was 50.6 (range 36–70) years old. Prior to the project commencing in 2008, farmers owned on average 3.8 cattle, 0.2 pigs and 10.0 chickens. At the time of the 2012 survey, this had increased to 6.2 cattle, 1.8 pigs and 60.0 chickens, with four of the five farmers stating that adopting project interventions had enabled them to expand their farm and three of five farmers could now have a secondary job (two teachers, one VAHW). Prior to the project, the mean annual income was reported at US$ 1360 of which US$ 480 (35%) came from the farm. At the time of the interview, the mean income was US$ 3340 of which US$ 2020 (60%) was farm sourced. Three of the five had sold forage feed or seeds to other farmers, collectively assisting 140 farmers establish their own forage plots.

One farmer stated that he had been better able to support his family financially and could now pay for study expenses of family members. Another stated that he had been able to purchase a new car, a new motorbike and a rice milling machine, with a third farmer stating the project had allowed him to upgrade his standard of living and allowed his children to attend school more frequently. In the most exceptional case, the project had facilitated one farmer’s participation in the National Farmer Competition who after being placed 1st received a new motorbike, a new hand tractor and a sum of money that allowed him to import a Brahman bull that he used for breeding, charging his neighbours for servicing their cows and consequently further increasing his income.

Discussion

This study provides evidence that farmer participants from the HI group in the BPHH project continued to improve their knowledge following the previously reported study (Nampanya et al., 2012). The knowledge scores for the topics of disease and biosecurity, internal parasites, nutrition and reproduction were improved markedly with HI farmer mean scores exceeding 94%, indicating a strong basic knowledge. Furthermore, not only did the HI farmers perform better than LI farmers, but an improvement over time between 2008 and 2012 was observed. While LI village farmer knowledge also increased over the duration of the BPHH project in some topic areas, it remained low overall.
In some cases, the difference between HI and LI farmers was striking, that is, LI farmers had almost no knowledge of internal parasite management. These results support previous conclusions that the most effective intervention methods to improve farmer cattle health and husbandry knowledge are ‘on-the-job’ and ‘formal training’ (Nampanya et al., 2012).

The sample population of 120 farmers was selected based on available time and project resources and constituted 18.6% of the original 645 enrolled households in the project. Farmers were selected to participate in the questionnaire by the respective village chiefs, who were asked to select participants at random. It is likely that no formal randomized sampling technique was used; therefore, selection bias may have occurred if they purposely selected higher or lower performing farmers. However, randomizing farmer selection is very difficult in rural Cambodia as many farmers are unavailable on any given day due to commitments such as secondary employment off-farm. Nonetheless, greater attention and efforts to include formal randomization techniques, such as the use of a table of random numbers to select survey participants, are recommended in future research to minimize selection bias. Farmer recall bias may also have been of relevance but is difficult to manage in a longitudinal study of this nature.

The 120 households collectively represented 573 people and 448 cattle, equating to an average household of 4.8 members and 3.7 cattle. The average land area per farm was 0.90 ha, with 0.66 ha used for rice cultivation and 0.20 ha used for growing garden vegetables and fruit. Approximately 96% of land area is used for rice and gardens leaving limited available land area for forage.

### Table 4. Socio-economic variables of smallholder households in each province and intervention group

<table>
<thead>
<tr>
<th>Socio-economic variable of smallholder</th>
<th>Number of farmers in provinces</th>
<th>Number of farmers in intervention groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kampong Cham</td>
<td>Takeo</td>
</tr>
<tr>
<td>N’</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Forage grower</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Species grown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mulato II</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>Murando</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Stylo 184</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Terenos</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Simuang</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>Annual income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Did not increase</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Unsure</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>Change in annual income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than doubled</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Doubled</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>More than doubled</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Time savings of farmers who grew forages</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>Average time saved per day (hours) – men</td>
<td>2.70 (n = 19)</td>
<td>2.91 (n = 20)</td>
</tr>
<tr>
<td>Average time saved per day (hours) – women</td>
<td>1.45 (n = 19)</td>
<td>2.80 (n = 20)</td>
</tr>
<tr>
<td>Average time saved per day (hours) – children</td>
<td>0.90 (n = 19)</td>
<td>3.25 (n = 20)</td>
</tr>
<tr>
<td>Application of time saved – men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other employment</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Farming activities</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Household activities</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Application of time saved – women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other employment</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Farming activities</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Household activities</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Application of time saved – children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School</td>
<td>3</td>
<td>12</td>
</tr>
</tbody>
</table>

*two-way chi-squared test.
bFisher’s exact test.
ctwo-sample t-test.
development, suggesting that the development of forage plots will be restricted to the limited uncultivated land or require a change of land use from either rice or gardens to forage. The current practice of growing forage plots for cattle feeding was reported by 35 of the 60 HI farmers; however, 39 farmers reported that forage growing saved time, indicating that more farmers had grown forages prior to the questionnaire. Surprisingly, the 20 HI farmers from Preak Por in Kandal did not report growing forages despite being exposed and trained in the practice, confirming reports from project staff that growing garden cash crops to supply nearby Phnom Penh markets was a higher priority for these smallholder households. It was also reported that many of these households were affected by major flooding that occurred in 2011, resulting in the loss of forage plots and an increased workload to manage crops. In Preak Por, smallholders also had smaller farm areas than the HI sites of Nor Mo and Senson Tbong, indicating that land size may be a constraint to growing forages for cattle feeding. The lack of forage uptake in Kandal indicates that despite the initial project selection criteria including a willingness to participate, a number of competing factors may prohibit this, which warrants further investigation should a programme such as the BPHH be scaled out.

The grass forages Sinaung and Mulato II were the most commonly grown followed by Paspalum and Marandu. Only 17% of farmers who grew forages reported growing the legume Stylo 184. The addition of this legume to rice straw based cattle diets has recently been shown to double rice straw and total nitrogen intake, and increases total dry matter intake by 32% (Pen et al. 2013). It could also be used through ‘inter-rowing’ between the other grass forages and boost growth. Engaging in forage growing activities saved time that would otherwise be spent seeking feed for cattle, as recently reported (Maxwell et al., 2012), and shown to benefit multiple household members. Men from households who grew forages in the HI villages of Nor Mo and Senson Tbong saved nearly three hours per day. Most of these men directed the time saved to other employment that increased their annual income or were able to spend this time doing other farm activities such as planting and growing vegetables and attending to their pigs and chickens. A similar study in Lao PDR also found the introduction of forages for livestock resulted in time savings of 2–3 h per day (Millar and Phoutakhoum, 2008). Women and children also benefitted directly from forage growing, with women directing their time saved towards household activities, other employment and even farming activities and thus contributing to the overall productivity of the household. Children benefitted directly by being able to spend more time doing schoolwork. This extra time created by forage growing, in lieu of no longer having to spend up to six hours per day by men or women and seven hours per day per child, became an important driver for interventions as the results were observed by farmers in a relatively short time period. Time saved by growing forages was an important socio-economic outcome, both because it was observed early in the project and because it allowed greater farmer engagement, particularly in the light of improvements in cattle weights taking longer to occur (Young et al., 2013a). It also allowed farmers to engage in alternative activities of their own choice, being expansion of their farm enterprise, other employment, household activities or a combination of these activities.

In the analysis of attitudes and practices relating to disease and biosecurity, both LI and HI farmers indicated they would continue to use FMD and HS vaccination at their own cost, yet a marked difference was seen in recent vaccination levels between groups. HI farmers indicated all their cattle over 6 months of age were vaccinated, yet less than 5% of LI farmers could say the same. This mismatch between farmer intention and action indicates that the very poor vaccination rates within LI villages is likely due to the failure to improve knowledge and attitudes on disease and biosecurity in a manner that could elicit sustainable change. The findings suggest that vaccination for FMD and HS in isolation and without addressing smallholder farmer knowledge is very likely to be unsustainable and have minimal long-term impacts on the livelihood of smallholder farmers. Both a high proportion of LI and HI farmers indicated they separated their sick animals and removed manure from cattle housing, although this latter practice is likely due to use of manure for biogas fuel or fertilizer rather than a disease mitigation strategy. Similarly, a high proportion of farmers indicated they would build fattening pens for cattle, with a higher proportion of HI farmers stating this. Field observations indicate this practice has not been widely adopted yet, although several farmers have commenced constructing pens. Few farmers from either group stated they treated calves <4 weeks old with pyrantel to prevent detrimental effects in young calves due to the roundworm Toxocara vitulorum despite HI farmers having relatively good internal parasite knowledge. This represented another mismatch between knowledge and practices. The availability of preventive products including vaccines and anthelmintics, cost, ability to restrain and treat cattle may all be factors limiting the uptake of preventive practices, and we suggest that these issues be addressed in future livestock development and research programmes.

Farmers were questioned on their marketing knowledge and practices through three main questions relating to knowledge of market price of cattle, the number of quotes they receive prior to sale and whether they knew the destination of sold cattle. Only towards the end of the project
did HI farmers have a greater knowledge of market price than LI farmers. This may reflect the existing informal trader networks where traders are regularly contacting farmers seeking to purchase cattle (O’Connell et al., 2013). Both groups generally sought multiple quotes, with the exception of LI farmers in 2012 where a reduction was seen. The reasons for this are unknown and require further investigation. Few farmers from either group knew the destination of their cattle after sale, indicating that knowledge of the destination markets is a potential strategy that may assist farmers to target sale cattle and improve profitability, especially during festivals when demand will be higher (Henry and Bush, 2013).

In the HI villages, the most important source of cattle health and husbandry information was BPHH project staff, with the village chief the most important source in the LI villages. This indicates that in the absence of an external source of expertise, the Village Chief is most influential and should be engaged in future attempts to improve smallholder cattle productivity at the village level. Although there was no significant difference between the HI or LI cohort in this study in their use of the VAHW or district veterinarian as a source of expertise, both were seen as important sources of additional information. Demonstration was the highest ranking extension material in both groups, followed by village meetings and the use of banners, commonly used by Cambodia DAHP staff to promote vaccination days. The use of posters, leaflets and radio/television was not ranked highly. Incorporating a high proportion of demonstrations, banners and village meetings would be beneficial in future intervention programmes as farmers find these extension practices most effective.

Importantly, this study provides a link of increasing large ruminant productivity and disease control measures to increased annual household income. Of the 87% of HI farmers reporting an increase in annual income from their involvement in the BPHH project, 53% reported that their income had either doubled (38%) or more than doubled (15%). This provides further support that improving large ruminant productivity can offer a pathway to reduced rural poverty and food insecurity in the Mekong (Windsor, 2011). Surprisingly, when investigating factors associated with farmers increasing their income, forage area grown was not a significant factor in the logistic regression analysis. The financial costs and benefits of the use of interventions have been investigated for FMD and HS vaccination, showing a strong incentive for their use (Young et al., 2013b; M. Kawasaki, personal communication). Further profitability studies are recommended, particularly focusing on cost–benefit analysis of interventions.

Five case studies have been included to demonstrate the socio-economic impact of the project interventions on early adopters and ‘champion farmer’ households. These farmers displayed enthusiasm for the ready adoption of project interventions, seeking regular advice and working closely with project staff. They provided important leadership, community engagement, an information resource and examples of what could be achieved by adoption of interventions. The willingness of such farmers to participate in so-called ‘cross visits’ enabled the development of a broader learning community. They also provided examples of the success of interventions in achieving impacts on households, including both increased secondary employment and farm expansion opportunities, that in some cases involved increasing holdings of poultry and swine in addition to cattle.

During the BPHH project, one outbreak of FMD in the LI village of Veal in 2010 was belatedly reported to project staff as previously reported (Nampanya et al., 2012; Young et al., 2013a). However, despite no other formal reports of outbreaks occurring, in the current survey, 38% and 31% of LI farmers and 5% and 6% of HI farmers stated they had identified FMD and HS clinical signs in their herd, respectively, since the commencement of the BPHH project. Without formal disease reports, interpreting this finding is difficult, as the results may indicate a failure of disease reporting, both a lack of or improved farmer knowledge and ability to differentiate disease, misinterpretation of the survey question or a combination of these factors. Under-reporting of endemic TADs is recognized as a major issue in Cambodia (Bellet et al., 2012; Nampanya et al., 2012; Young et al., 2013a).

**Conclusion**

This study provides evidence that positive impacts on the livelihoods of smallholder cattle farmers were achieved through a knowledge-based multidisciplinary intervention programme that led to improved cattle productivity, increased time saved for household members, farm expansion, secondary employment, more time for schooling of children and enhanced incomes. Smallholder farmers in the HI groups significantly increased their knowledge of disease and biosecurity, internal parasites, nutrition, reproduction and marketing, positively influencing their attitudes and practices. We conclude that for interventions to lead to sustainable improvements in rural livelihoods, addressing farmer knowledge is vital. Interventions such as HS and FMD vaccination should be accompanied by increasing knowledge of biosecurity and improved productivity if the objective is to achieve sustainable improvements in rural livelihoods. This systems approach is recommended to policymakers, international aid donors, researchers and extension workers aiming to address TAD control, food insecurity and reduction in rural poverty in smallholder livestock systems.
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Conflicts of Interest

The authors declare there is no conflict of interest.

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Appendix A

I. Prophylaxis for controlling major animal diseases
   • Good husbandry practices
   • Nutrition
   • Vaccination
   • Biosecurity

II. Infectious diseases in cattle and buffaloes
   • Haemorrhagic septicaemia (HS)
   • Foot-and-mouth disease (FMD)
   • Blackleg

III. Parasitic disease in cattle and buffaloes
   • Fasciolosis
   • Toxocariasis
   • Paramphistomiasis
   • External parasites: Ticks, Flies
IV. Forage cultivation and management
- Importance of the forage and nutrition
- Selection site for cultivation
- Land preparation
- Seed preparation
- Planting techniques
- Forage management
- Soil management
- Weed control

V. Husbandry, breeding and reproduction management
- Husbandry
- Feed management
- Breeding selection and management
- Reproduction
- Irrigation
- Cutting and feeding management