

Improving Trade in Large Ruminants and Products by Transboundary Animal Disease Control in Lao PDR

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Abstract - Within the Greater Mekong Subregion (GMS) the nation of Lao PDR has a small population of ~6.3 million people and a relatively large population of large ruminants (cattle and buffalo) at ~2.7 million head. With the growing demand for red meat in South-East Asia driven by a rising middle class and the associated changes in dietary intake, Lao smallholder farmers have the opportunity to satisfy this demand provided key constraints are addressed. Recent research has highlighted a series of best practice interventions directed at the smallholder level to improve animal health and production. Animal movement and trade have been identified as a major risk factor involved in transboundary animal disease (TAD) transmission including foot and mouth disease. Hence, understanding the supply chain is important for effective TAD control. The results of a survey of 32 large ruminant traders in northern Laos in 2011 were matched to a longitudinal production survey from 6 villages in northern Laos to develop a value chain analysis. The 32 traders provided details on 8,796 large ruminant trades, operating locations, large ruminant purchase prices, transport methods, major costs, livestock destinations and trader views on major constraints to development of the large ruminant market. The 2011 farm gate value of the national large ruminant herd was estimated as USD 835.8 million based on trader purchase price and village herd production data. As improvement of large ruminant production has been linked to reducing regional rural poverty and food insecurity in smallholder communities through opportunities for business development and rural employment, addressing both TADs and the underdeveloped market in the GMS is important. Whilst control of TADs will need to remain a medium term priority, further research is needed to ensure that market development remains aligned with disease control efforts.

Keywords; *cattle, buffalo, FMD, livelihoods, rural poverty, and food security*

I. INTRODUCTION

The Lao People's Democratic Republic (Lao PDR or Laos), together with Cambodia, Myanmar, Thailand, Vietnam and (the Yunnan Province of) China, make up the six nations of the Greater Mekong Subregion (GMS), a natural economic area bound by the Mekong River basin, consisting of 2.6 million km² and inhabited by ~326 million people [1]. Laos has a population of ~6.3 million people, of which 85% are involved with agricultural activities [2]. The total land area is 236,800 km², and constitutes three main farming systems predominated by mountainous (~80%), upland and lowland. Despite the majority of the population actively involved in agriculture, the contribution to gross domestic product (GDP) was 30.8% in 2011 [3]. Laos is one of the poorest countries in the world, ranked 138th on the United Nations Human

Development Index [4]. Although significant improvements have been made in the last two decades, rural poverty remains an important issue with an estimated 27.6% of people living below the national poverty line [5]. While rice production remains the primary contributor to the agricultural sector, livestock play an important role in smallholder farm systems, often serving multiple purposes including sale for beef, wealth storage, fertiliser, draught and for cultural festivities.

Laos has a substantial national large ruminant population with 1,520,300 cattle and 1,197,100 buffalo in 2011, yet the market remains underdeveloped. Smallholder farmers own greater than 94% of the nations large ruminants, typically owning less than 5 head [6,7]. Increased livestock production has been identified as a key means of alleviating poverty in developing countries [8,9,10] as livestock products benefit the poor by alleviating the protein and micronutrient deficiencies prevalent [8]. Furthermore, livestock typically contribute to environmental sustainability in mixed farm systems that strike a proper balance between crop and livestock intensification, through the provision of manure for fertiliser and draught power to sustain intensive crop production [8].

Smallholders' participation in markets is crucially important for improved food security and poverty reduction [11]. Smallholder agriculture is characterized by small production volumes of variable quality that reflect limited access to inputs and finance, low levels of investment and limited access to, and knowledge of, improved agricultural technologies and practices [11]. Limited smallholder participation in markets is not necessarily a result of inadequate commercial orientation per se, but the result of constrained choice in a risky environment [11]. Smallholders need to be linked vertically with processors and marketers of perishable products to combine the environmental and poverty alleviation benefits of smallholder production with the economies of scale and human health benefits achieved through larger scale processing [8]. Producers, traders, and processors may find it difficult to access productive assets such as credit and refrigeration facilities and information about microbial infection prevention [8]. Inadequate infrastructure, high costs of storage and transportation and non-competitive markets also limit the production of a marketable surplus [11]. Attempts to improve smallholder productivity will have limited success if smallholder linkages to markets are not strengthened simultaneously [11].

The large ruminant market is amidst transformation in the GMS, driven by a sustained consumer demand for protein known as the 'livestock revolution' [8, 12]. Animal movement, and associated movement pathways, is highly dynamic with major changes evident in recent years, particularly with the emergence of high consumer demand in both Vietnam and China [13]. Per capita meat consumption increased from 16 to 43 kg in China and from 11 to 18 kg in South-East Asia between 1983 and 1997, and is projected to grow at 3.1% and 3.0% respectively to reach 73 kg in China and 30 kg in South-East Asia by 2020 [8]. Specifically in the developing world poultry consumption is predicted to increase at 3.9% p.a., followed by beef at 2.9% p.a. and pork at 2.4% p.a. [12]. Increased urbanisation and a rising middle class due to an increase in average capita income are driving the increased per capita meat consumption [14].

Transboundary animal diseases (TADs) are those that pose a significant economic, trade and/or food security risk for a considerable number of countries. TADs can rapidly spread across borders and reach epidemic proportions, requiring control and management cooperation between neighbouring countries [15]. Foot-and-mouth disease (FMD) and haemorrhagic septicaemia (HS) are two of the most significant TADs impacting large ruminant trade in the GMS [16], and are both endemic and major constraints to efficient and sustainable large ruminant production in Laos [17,18]. In 2010-11 a major FMD epizootic occurred with regional epizootic peaks in December 2010 until February 2011 with sporadic outbreaks in the following months [19]. This epizootic highlighted a major failure in international biosecurity in the GMS. Furthermore, the major FMD outbreaks that occurred in 2010 in both Japan and South Korea were of viruses that were shown to have originated in South East Asia [20]. Both Japan and South Korea had been FMD free without vaccination for eight and ten years respectively. Examination of government reports from Laos indicated almost 25,000 large ruminant FMD reported cases in 2010; 14,000 of which were reported from northern Laos (Table 1). The true impact of the 2010-11 epizootic remains largely unknown due to widespread disease underreporting [17,21] and paucity of socioeconomic studies.

The movement of live animals is considered the most important method of transmission of FMD virus [9,22,23,24,25], particularly as airborne spread has almost no influence on transmission in the tropics [26]. Cleland et al. [27] reported the greatest impact on reducing FMD spread among villages' involved strategies that reduce the likelihood of introductions through livestock purchases, and villagers taking greater care when grazing livestock with animals from neighbouring villages, particularly when sharing common water supplies.

Protection of livestock systems adjacent to trading routes through vaccination has also been advocated as an appropriate control tool [25]. A lack of biosecurity, poor enforcement by government of legislation on movement restrictions in infected areas during outbreaks and a lack of established on-road checkpoints may also contribute to the dissemination of FMD [28]. Furthermore, people movement is a significant risk in the spread of disease [22].

A previous collaborative investigation undertaken by the FAO, ADB and OIE reported Laos as a net importer of large ruminants as domestic production was not able to meet demand, particularly in high value markets of major urban centres [13]. This report identified major large ruminant transit routes across Laos from Thailand to Vietnam and China as well as described a number of supply chains operating within Laos. Key findings using a snowball sampling technique included unofficial movement dominating cross-border livestock trade within the GMS through porous borders with minimal regulation [13] limiting the ability to keep accurate official trade records. In addition, multiple cross border pathways remain that are not officially recognised by country authorities and, where official pathways exist, fees and taxes are often high and represent strong disincentives for traders [13]. Another challenge is the decentralised regulation of animal production and veterinary matters with significant policy and enforcement variations between provinces, which are subject to change [13].

TABLE 1. Large ruminant population and reported FMD cases and deaths in the seven northern provinces of Lao PDR in 2011

Province	Districts where FMD reported	Cattle			Buffalo		
		Total population	Reported cases	Reported deaths	Total population	Reported cases	Reported deaths
Phongsaly	Mai and Khua	40,745	-	-	37,301	-	-
Luangnamtha	-	19,545	-	-	19,749	-	-
Oudomxay	-	44,490	-	-	39,426	-	-
Bokeo	-	27,030	-	-	51,249	-	-
Luang Prabang	Xienggun, Pakou, Nambak, and Phoukoun	66,360	3,717	317	73,712	3,885	194
Huaphanh	Add and Xamtai	55,052	2,701	190	62,919	3,699	374

Xayabury	Xaya, Paklai, Xaysathan, and Xienghon	49,420	-	-	91,735	-	-
Total		302,642	6,418	507	376,091	7,584	568

Source: Population data OIE, and [17]

While the previously described constraints (including TADs) have been identified, research and development of smallholder market integration is limited compared to improving production. This is due to low smallholder participation in poorly understood markets and, as a result, the basis for effective policy and strategy choice is relatively weak [11,13]. Research describing the large ruminant supply and value chains is required to identify opportunities for development interventions. The value chain encompasses more than production processes; it implies a flow of information and incentives between stakeholders, which can be used to understand how the risk of disease spread may be managed [29]. Integrating biosecurity with improved animal health, productivity and market opportunities has been identified as a key priority for future biosecurity research and development in the GMS [30]. This paper aims to describe the large ruminant value chain with specific focus on the impacts and limitations of TADs in northern Laos. It is hoped that greater insight into the value chain will lead to improved understanding and enhance TAD control including FMD [13,25,31], as well as assist in market development to ensure all stakeholders achieve optimal outcomes, as well as contribute to the greater public good.

II. MATERIALS AND METHODS

The 'Best practice health and husbandry of cattle and buffalo in Lao PDR' (BPHH) project (AH/2006/159), funded by the Australian Centre for International Agricultural Research (ACIAR), was conducted between 2008-12 in three northern Lao provinces. The project was implemented by the University of Sydney in collaboration with the Department of Livestock and Fisheries (DLF), Luang Prabang, and sought to identify, implement and evaluate a series of health and husbandry best practice interventions at the smallholder farmer and village level using a multidisciplinary systems approach. The key BPHH hypothesis was through increasing farmer knowledge of large ruminant health and husbandry and marketing techniques improved health and productivity could be achieved, which could in turn lead to improved livelihoods. Much of the results and impacts of the research has been published [2,17,32].

To investigate the large ruminant market chain, a survey of 32 traders operating in northern Laos was performed between the 23 January and 24 February 2011. Traders were purposively selected through DLF staff networks, as no sampling frame was available. Traders were asked to provide details on large ruminant trading during the previous 12 months. The structured survey included closed questions on trader's address, years trading, primary operating location and

total number of large ruminants purchased during the previous 12 months broken down by:

- Species (cattle or buffalo)
- Sex (male or female)
- Age groups (0-2, >2-8, >8 years)
- Body condition score (skinny, medium or fat)

The purchase price, season purchased (wet or dry) and market sale price for both meat and offal was recorded. Traders were asked to identify transport methods used and what proportion of large ruminants was sourced directly from farmers and from other traders. Traders were questioned on costs relating to transport, slaughter, animal movement levies, meat inspection and market stall rental. Finally, traders were asked a series of open-ended questions to describe their views on current issues (including biosecurity) relating to the large ruminant market and what possible solutions they might suggest. The issues and solutions provided were grouped into four categories of 1) general market, 2) regulation, 3) disease, biosecurity and food safety, and 4) infrastructure, credit and capacity. The results of the trader survey were entered into and analysed in Microsoft Excel™ 2010 to provide a descriptive analysis of the supply chain. Traders provided purchase and sale data in Lao Kip, which was converted to USD at a rate of 8030 Kip = 1 USD (XE Currency 19 December 2011). In addition, an operating profit margin (OPM) analysis of a trader purchasing and selling one female adult buffalo in a fat condition was conducted, with a sensitivity analysis on the live weight relative to purchase price. The OPM analysis was calculated based on: $OPM = \frac{[Sale\ value - (Costs\ of\ goods\ sold - selling,\ general\ and\ administrative\ costs)]}{Sale\ value}$.

The results of the Trader survey were used to undertake a value chain analysis. This analysis included identification of:

- The products and by-products of interest
- Who is involved in the chain
- Physical location of activities and of the people in the chain
- Seasonality of supply and demand
- Appropriate analysis of profitability for different people at different points, including transaction costs between people and points
- Who sets regulations or conditions (pressures) for participation in the chain, who applies the rules and ensures compliance
- Who and what factors are driving developments or changes in a value chain
- Assessment of the equity across the chain and its efficiency to convert inputs into products demanded by consumers

As part of the BPHH project a longitudinal survey of cattle and buffalo production was undertaken between 2008-12 and results of baseline cattle production are currently in preparation [33]. This dataset was further reviewed to provide an overview of smallholder large ruminant herd structure, which was then matched to the trader survey price results. This systematic analysis allowed for both a northern and a national farm gate valuation of the Laos large ruminant herd.

III. RESULTS

A. Descriptive details of trader survey

The 32 traders had a mean of 12.8 years experience trading large ruminants, with a range of 1-31 years. Of the traders, 14 (44%) were females. The majority of traders (30 of the 32) recorded large ruminant purchases, with the remaining 2 solely operators of slaughterhouses charging a slaughter service fee. 14 traders operated their trader business as a sole operator, with the remaining 16 operating within a group of 2-8 people. On average, traders (n = 30) purchased large ruminants directly from farmers 51% of the time or from other traders (49% of the time). The majority (80%) of traders contacted farmers using a mobile phone (n = 24), 53% by direct contact (n = 16), and 10% through the use of a spotter (n = 3). 87% (n = 26) traders reported that farmers also contact them directly when they wish to sell. All 30 traders reported selling large ruminants for domestic slaughter, 30% (n = 9) for export, 17% (n = 5) for reuse and 7% (n = 2) reported selling to a commercial meat company. 9 traders (28%) reported slaughtering of cattle and selling at local markets.

B. Operating locations

The traders home addresses included three provinces; Luang Prabang (LPB) (6 traders), Huaphan (HP) (17) and Xiangkhouang (XK) (9) provinces. The traders identified 16 districts from 4 provinces as their primary operating (large ruminant sourcing) locations (Fig. 1). A total of 23 traders stated they also sourced on average 40.0% of large ruminants outside their regular district (range 5-95%), with 6 stating they only sourced livestock from their own district. Traders were less site specific of secondary operating location.

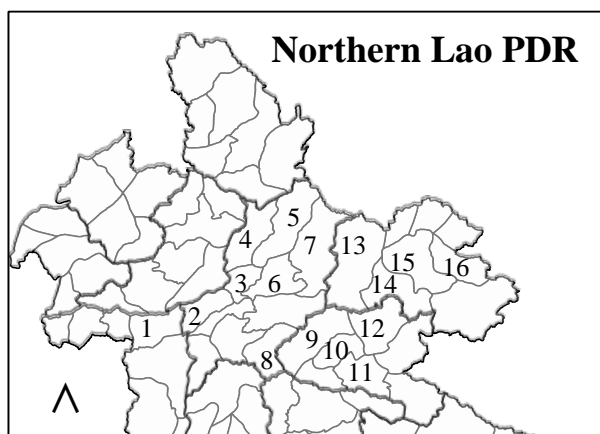


FIGURE 1. Interviewed traders identified 16 districts) from 4 provinces where they primarily sourced large ruminants. NB:

Operating districts and provinces of surveyed traders: 1 – Hongsa (Sainyabuli); 2 - Chomphet (LPB); 3 – Pak Ou (LBP); 4 – Nam Bak (LPB); 6 – Ngoy (LPB); 7 – Viengkham (LPB); 8 – Phoukhoune (LPB); 9 – Phou Kout (XK); 10 – Pek (XK); 11 – Khoune (XK); 12 – Kham (XK); 13 – Viengthong (HP); 14 – Houameuang (HP); 15 – Xam Neua (HP); 16 – Viengxay (HP)

C. Trades, prices, transport and fees

The 30 traders reported data for 8,796 trades in total, with a mean of 293.2 large ruminants trades during the previous 12 months (range 16-1440). This included the purchase of 5,637 buffalo, with 2,657 (range 3-620, n = 29 traders) during the wet season and 2,980 (range 1-664, n = 29 traders) during the dry season. A total of 3,159 cattle were purchased with 1,481 (range 2-264, n = 28 traders) during the wet season and 1,678 (range 4-344, n = 28 traders) during the dry season. Traders from LPB reported shortages of large ruminants occur both in the wet season (4 traders) and the dry (2). Traders from XK reported shortages predominantly in the dry season (7) and also wet (2) including one trader who said there were 'always' shortages. All 15 traders from HP who supplied an answer to this question stated that there is a large ruminant shortage in the wet season. Two traders noted increased demand during domestic festivals and Vietnamese New Year in January/February.

The traders provided mean purchase price data on 22 of the 36 possible categories of large ruminants (Table 2). The remaining 14 categories values' were estimated based on the body condition score range of other groups. The 30 traders reported that they assessed purchase prices through the estimated 'meat weight' (15 traders) or by general appearance (14) which included an assessment of the body condition score. One trader stated they used both the meat weight and general appearance in their negotiation. The mean meat weight purchase value was stated to be USD 4.95 (n = 16 traders).

The traders identified 4 methods of transporting large ruminants. These were by truck (traders = 28), walking (n = 10), Tuk-Tuk (n = 1) and by boat (n = 1) or a combination (8 traders used both walk and truck transport methods). The mean transport cost reported was USD 8.53 per head, however the distance travelled was not specified. Slaughter fees were reported by 14 traders, who paid a mean of USD 9.59 per head. There was some variation between regions, with traders from XK paying on average USD 3.74 per head and traders from HP paying USD 12.84 per head. Meat inspection fees were reported by 20 traders at a mean of USD 1.26 per head, with variation between regions at USD 0.75 for XK (n = 13) and for HP USD 1.53 per head (n = 7). 10 traders reported movement fees with a mean of USD 5.76 per head (range USD 1.25-12.45). The daily market stall rents was USD 1.20 on average of all traders (n = 10). This also varied per region, with XK traders (n = 5) reporting a mean of USD 0.52 per day and HP traders (n = 5) USD 1.87 per day.

The sale price of processed meat and offal products at market is presented (Table 3). A supply chain diagram was constructed detailing the movement of large ruminants and products between key people (Fig. 4). The responses to traders

asked open questions regarding market issues and suggested solutions were grouped and presented (Table 4).

D. Trader perspectives on biosecurity

Of the 30 traders, 26 preferred to purchase large ruminants that had been vaccinated for FMD and HS, with 3 stating they did not have a preference for vaccinated animals. The reasons stated for vaccination preference included investment protection (13 traders), reluctance to spread disease (3) and food safety (1). 29 of the 30 traders stated they would not purchase animals from a region with a disease outbreak, with 15 stating it would infringe district rules to do so.

E. Large ruminant herd structure and valuation

Data was analysed from the longitudinal surveys to establish the herd structure by species (cattle and buffalo), sex (male and female) and age group (Fig. 2 and 3). Based on this

data and the herd structure, the value of large ruminants in northern Laos was calculated at USD 171.2 million for cattle and USD 251.0 million for buffalo. This equated to USD 422.2 million dollars. Using the herd structure data the national cattle herd was valued at USD 303.9 million, and the buffalo herd at USD 531.9 million, to give a combined total of USD 835.8 million.

TABLE 2. Mean price of large ruminants purchased in northern Lao PDR in 2011 based on trader surveys

Species	Sex	Age (years)	Body Condition Score	n Traders	n Large ruminants	Price based on n traders or estimated*	Mean price (USD)
Cattle	Male	0 to 2	Skinny	0	0	<i>Estimated</i>	50.00
Cattle	Male	0 to 2	Medium	5	47	5	68.49
Cattle	Male	0 to 2	Fat	0	0	<i>Estimated</i>	75.00
Cattle	Male	>2 to 8	Skinny	3	14	3	309.11
Cattle	Male	>2 to 8	Medium	23	873	23	256.17
Cattle	Male	>2 to 8	Fat	12	568	12	267.53
Cattle	Male	>8	Skinny	1	30	1	342.47
Cattle	Male	>8	Medium	1	5	1	168.12
Cattle	Male	>8	Fat	0	0	<i>Estimated</i>	250.00
Cattle	Female	0 to 2	Skinny	0	0	<i>Estimated</i>	50.00
Cattle	Female	0 to 2	Medium	8	108	8	62.55
Cattle	Female	0 to 2	Fat	0	0	<i>Estimated</i>	100.00
Cattle	Female	>2 to 8	Skinny	0	0	<i>Estimated</i>	170.00
Cattle	Female	>2 to 8	Medium	22	688	22	233.67
Cattle	Female	>2 to 8	Fat	4	290	4	189.50
Cattle	Female	>8	Skinny	1	2	1	249.07
Cattle	Female	>8	Medium	10	530	10	218.68
Cattle	Female	>8	Fat	1	4	1	224.16
Buffalo	Male	0 to 2	Skinny	0	0	<i>Estimated</i>	148.29
Buffalo	Male	0 to 2	Medium	4	48	4	156.31
Buffalo	Male	0 to 2	Fat	0	0	<i>Estimated</i>	200.08
Buffalo	Male	>2 to 8	Skinny	0	0	<i>Estimated</i>	376.04
Buffalo	Male	>2 to 8	Medium	27	1218	27	525.07
Buffalo	Male	>2 to 8	Fat	14	1258	14	733.17
Buffalo	Male	>8	Skinny	0	0	<i>Estimated</i>	446.52
Buffalo	Male	>8	Medium	4	190	4	470.67
Buffalo	Male	>8	Fat	0	0	<i>Estimated</i>	494.20
Buffalo	Female	0 to 2	Skinny	0	0	<i>Estimated</i>	98.81

Buffalo	Female	0 to 2	Medium	6	44	6	104.15
Buffalo	Female	0 to 2	Fat	0	0	<i>Estimated</i>	133.31
Buffalo	Female	>2 to 8	Skinny	0	0	<i>Estimated</i>	312.09
Buffalo	Female	>2 to 8	Medium	25	1143	25	434.86
Buffalo	Female	>2 to 8	Fat	12	1189	12	605.93
Buffalo	Female	>8	Skinny	1	10	1	311.33
Buffalo	Female	>8	Medium	12	500	12	328.17
Buffalo	Female	>8	Fat	2	37	2	436.54

NB: *Estimated values were based on variation between species, sex and age

E. Analysis of trader Operating Profit Margin (OPM)

The operating profit margin of a trader selling one female adult buffalo in a fat condition was based on a purchase price from the smallholder farmer at USD 622.67 and the sale of meat at USD 457.24 and offal, hide, feet and bones at USD 260.24 (total sales USD 717.48). Costs included a transport fee, slaughter fee, movement fee, stall rental, meat inspection and a labour fee for two day for total costs of USD 36.34. A significant number of assumptions were made in the calculation including the purchase live weight (329 kg), the dressing percentage (50%), muscle, bone and fat percentage (67.5%, 12.5%, 15.2% respectively) and the weight of offal, hide and bones were estimated. The OPM for the sale was 8.1% on the base model. The model was rerun using the scenario of the trader overestimating the weight by 20 kg and underestimating the weight by 20 kg. In these cases the OPM shrunk to 4.1% when the live weight at the point of sale was overestimated and increased to 11.9% when it was underestimated.

IV. DISCUSSION

This study uses information obtained from Traders to describe the large ruminant value chain in northern Laos in a level of detail not previously reported. The structure of the large ruminant industry including the dominance of smallholder producers and informal trading networks combined with a dynamic market responding to changing consumer demands presents a number of challenges to the industry's development. The successful advancement of large ruminant production in Laos will require the matrimony of both improving production and disease prevention and control. Within the group of traders substantial variation is seen in operational practices including livestock numbers traded, source locality, transport methods, markets supplied (domestic and export) and the use of processing (slaughter points) and sale (market stalls). With this variation, efforts to direct disease prevention and control interventions at the trader level will provide challenges in terms of meeting the needs of a dynamic group.

The matching of the herd structure data from the BPHH project results [33] with the trader price results allowed an estimation of the farm gate valuation for cattle and buffalo in both northern and greater Laos, with a national herd value at USD 835.8 million.

TABLE 3. Sale price of large ruminant products at market

Product	n Traders	Price per kg (USD)
Meat	27	3.75
Bones	27	1.89
Heart	26	3.34
Intestine	27	2.56
Kidney	27	3.24
Liver	27	3.38
Lungs	26	2.16
Skin (cattle)	26	1.00
Skin (buffalo)	23	1.16
Stomach	12	3.01
Blood	2	1.00
Fat	1	0.12
Feet (each)	3	1.49
Intestinal fluid	8	1.42

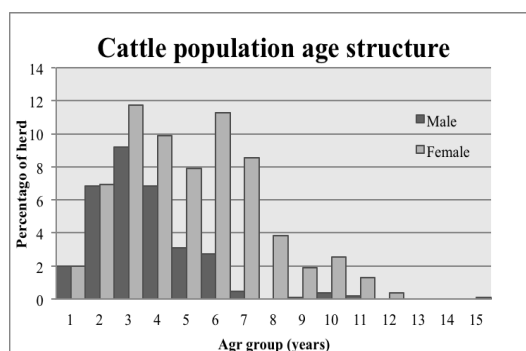


FIGURE 2. Cattle population age structure

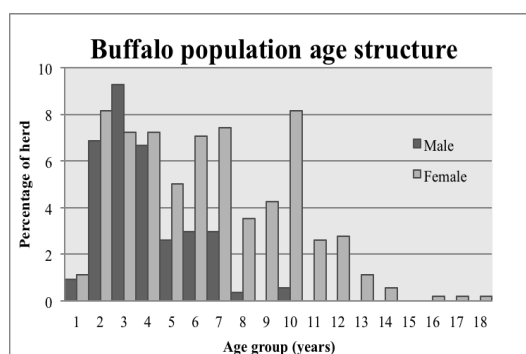


FIGURE 3. Buffalo population age structure

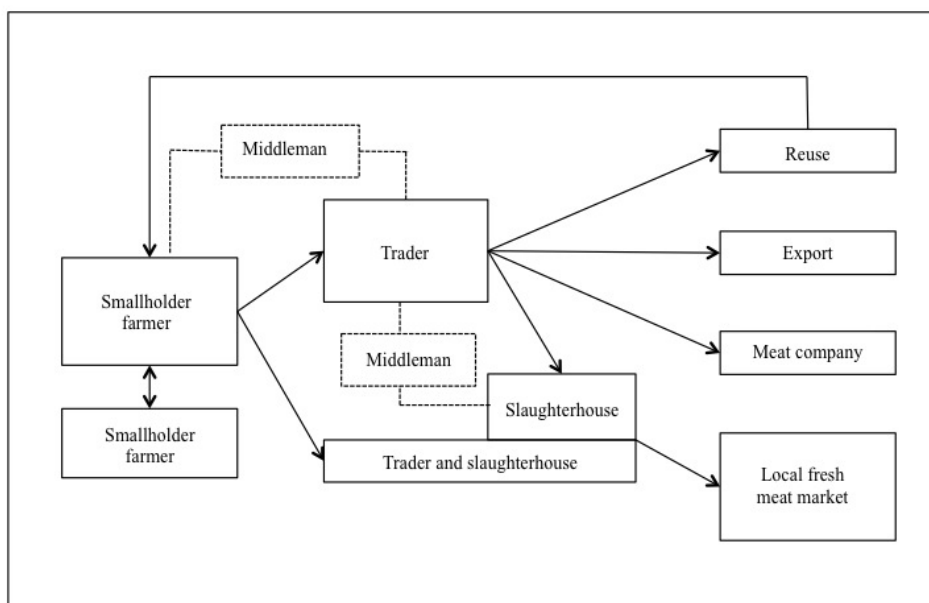


FIGURE 4. A diagram of the supply chain of large ruminants

TABLE 4. Summary of trader identified issues suggested solutions (NB: the number of traders who raised the issues and solutions in brackets)

1. Market issues and solutions	
Large ruminant supply unable to meet demand (24), Limited large ruminants of high quality (3), Land use pressure decreasing large ruminant population (1), Lack of fair value assessment tools at sale points (1), High competition driving up prices (particularly Vietnamese traders) (6), High fluctuation in large ruminant prices (5), Low margin (2), Large ruminants from other district impact sales (1)	Government to assist farmers in producing healthy and quality animals (16), Government to promote large ruminant production (6), Government to develop/increase forage grazing areas (22), Improve method of fair value assessment (2), Set quota for export to ensure adequate local supply (10), Government to restrict illegal trading export (1), Market needs development support (3)
2. Regulation issues and solutions	
Animal movement documentation overly complicated (1), Variation of movement regulations/fees between districts (6), High tax, levies and animal movement fees (12)	Need standardised animal movement regulations/fees (2), Improve regulation of live animals (create standard rules and fees) (4), Review tax, animal movement levies (10), Improve live animal assessment by government (1)
3. Disease, biosecurity and food safety issues and solutions	
Disease restricts market access and sales (3), Diseased or dead animals presented to slaughterhouse (1), Underdeveloped market poses food safety risk (1), No standard slaughter point leading to food safety risk (1)	Improve disease prevention and control (11), Need cleaner meat markets (2), Need a standard slaughter point to maintain good process and food safety (4)
4. Infrastructure, credit and capacity issues and solutions	
No livestock holding facilities (1), Slaughterhouse capacity limitations (1), Labour shortage at sale (end) (1), Poor roads restricts access to large ruminant sources (particularly in wet season) (9)	Develop holding yard facilities (1), Development and support for slaughterhouses (3), Government to provide credit for slaughterhouse development (3), Supply farmers with credit for large ruminant production (2), Improve road infrastructure for greater access (6)

This valuation should be interpreted with caution, as a number of assumptions were made as well as price data which was only available for 22 of the 36 stock classes, requiring 'estimated' values for the remaining 14 stock classes. As some stock classes also only had a limited number of large ruminant sale records and the trader survey had limited stratification of animal age; both of which would be expected to influence the result. Nonetheless this estimated value highlights the considerable importance of large ruminants to rural households and signifies the need to limit TAD threats from reducing this smallholder asset. Further detailed investigations would improve the accuracy of this valuation.

Traders identified two main methods of determining the purchase price for large ruminants. The most common was a visual 'meat weight' assessment based on the estimated processed meat weight of live animals (excluding offal, hide and feet), which is used to negotiate with the smallholder seller. Traders will then offer an average of USD 4.95 per kg for the estimated meat weight; interestingly almost a 25% premium above the mean meat market price reported at USD 3.75; possibly due to help compensate the smallholder farmer for the non-meat products. The second most common method of price assessment utilised the general appearance of the animal including its body condition score (BCS) to negotiate a purchase price. In a recent study in Cambodia, traders admitted they had difficulty determining actual body weight of cattle using BCS [34]. Traders visually estimated the weights of cattle before being weighed on an electronic scale with trader's estimations 3-24% above or below the actual weight [34]. Hence, the smallholder farmer (seller) or trader (buyer) would likely lose money if the price negotiated were based on either an under- or over-estimation respectively. In the OPM analysis this was the case with the traders margin varying from 4.1% to 11.9% depending on if their assessment of weight was ± 20 kg from the actual live weight. While this analysis used a number of assumptions, it confirmed that margins are relatively low for traders the variation shown in the sensitivity analysis provides further support for a fair value assessment tool at the point of sale.

As part of the BPHH longitudinal survey, approximately 7,800 girth and weight measurements were collected from cattle and buffalo in northern Laos [35]. This data was used to develop a cubic spline model to predict both cattle and buffalo live weights using a girth measure (cm), resulting in the development of a girth weight tape for both cattle and buffalo [35]. This weight tape was initially designed for smallholder farmers to promote improved production and health of their animals through objective weight monitoring as well as assist in the valuation of their cattle. This tool has significant potential to also be used by traders as a fair value assessment tool.

The transport of animals represents a risk of disease transmission, particularly in the pre-clinical phase of FMD where animals may be shedding virus prior to showing clinical signs. In this study, 4 different methods of transport were identified, with each likely to represent a different TAD transmission risk profile requiring different biosecurity interventions. For example, the chance of direct contact

between trade animals and non-trade animals is expected to be higher when walked compared to transport by boat. Sale of large ruminants for reuse represents a major risk of transmission particularly if these animals are mixed with those destined for slaughter, which may have a different health status. The majority (87%) of purchasing traders prefer FMD and HS vaccinated livestock, indicating that they are keen to protect their investment and avoid outbreaks and infringement of regulations. Farmers have been known to sell sick animals in the hope to salvage potential lost income, and one trader operating a slaughterhouse stated that diseased and even a dead animal had been presented for processing. While the use of large ruminants for draught is becoming less common in Laos due to the uptake of hand tractors, work and transport animals represent a major risk of disease transmission and should be a priority for vaccination [16].

The most common concern for traders was the limited supply of large ruminants to meet market demand. This in itself is a biosecurity risk as price pressure may entice traders to flaunt movement or reporting regulations in the event of an outbreak. Encouragingly over 1/3rd of traders voluntarily welcomed improving disease prevention and control as disease restricts market access and sales. Road access may also influence the traders' ability to source animals during the wet season. Therefore regions with superior road infrastructure may have a market advantage over suppliers in regions with less developed access. On a regional scale, there are a number of significant (road and rail) infrastructure projects underway within the GMS, as well the development of a cross-border transport agreement that seeks to integrate the trade practices of the GMS countries [36]. The aims of this agreement include having a single-stop customs inspection point, establishing minimum standards for the design and reliability of infrastructure, providing cross-border visas for people engaged in transporting goods, and instituting transit traffic regimes [36].

The Law on Livestock Production and Veterinary Matters [37] outlines 99 articles defining the principles, rules and regulations related to the organisation, management and inspection of production and veterinary activities in order to boost, promote and develop the nation's potential in animal production and related livestock resources. Legal animal uses by households include 1) labour and 2) consumption, processing and distribution in order to generate income. Business activity uses of animals include trade, slaughter, meat distribution and processing in accordance with the laws and regulations. Businesses operating in the field of livestock production are required to be approved, registered and licensed by the Agriculture and Forestry Sector. Veterinary activities include all functions related to veterinary management and service including:

- Prevention and control of epidemic diseases of animals;
- Control of animal movements, animal commodities, and the temporary confinement and quarantine of animals;
- Supervision of slaughter and the inspection of meat and animal products.

Compulsory notification of diseases is required for epidemic diseases are identified (OIE List A Diseases) including both FMD and HS. Domestic movements of animals and animal commodities from one place to another shall comply with the specific regulations of the Livestock and Veterinary Management Authority. International movements of animals and animal commodities, import, export and transit via the territory of the Laos shall be inspected by a veterinarian at border checkpoints, and the inspection must be conducted in accordance with the specific regulations of the Livestock and Veterinary Management Authority. Supervision of slaughter and the inspection of meat and animal products include:

- Slaughterhouses and slaughter points;
- Slaughter and dressing;
- Meat and animal products inspection;
- Zoosanitary certification of animal products;
- Storage, processing, trade and transportation of animal products.

The Law also outlines both rewards and penalties.

Increasing smallholder production of higher quality large ruminants in the current market environment is likely to benefit all stakeholders. Previous research has shown live weight, carcass weight, dressing percentage, fat thickness and muscle:bone ratio are all known to increase linearly as BCS increased [38], therefore interventions including improving nutrition through forage plot development and disease control including vaccination at the farm and village level as were developed by the BPHH [39] should be continued and scaled out to wider regions. Smallholders are very heterogeneous, facing different types of constraints and opportunities, and will react differently to new market opportunities (Arias et al 2013) therefore an education-based systems approach is needed to meet specific farmer and regional needs.

Public policy including supportive legal and policy frameworks, improved infrastructure, and collaboration with the private sector are generally needed to foster smallholder market integration [11]. Policy interventions need to be prioritised and sequenced according to evidence-based diagnosis of the constraints faced by different categories of smallholders, particularly as evidence-based policy-making minimizes the risks of policy failure [11].

It has been previously believed that smallholder farmers have limited access to formal market information and traders, who are more likely to have better knowledge of consumer demands, could potentially take advantage of premium markets without passing on benefits to producers [29]. This current analysis suggests that in fact the opposite may be true, with smallholder farmers having a good idea of their large ruminant value due to a 1) high demand and the associated regular contact with traders, and 2) highly established informal networks that may include media such as radio providing regular market updates, and increased communication through the use of cellular phones.

Despite its limitations, this value chain analysis and report helps provide important information not previously reported from Laos. Suggestions for further research include;

- Define market ideals in terms of animal species, age, weight etc.
- Define peak demand and identify regions or groups capable of supply
- Develop industry standard BCS system using multiple stakeholder engagement and input (suggest a 1-5 point scale)
- Develop standardised movement requirements and fees
- Social network analysis to further identify risk pathways
- Further studies to examine profitability of producers, traders, distributors and marketers involved in part or total supply chain
- Improved animal identification and traceability

V. CONCLUSION

This study uses quantitative and qualitative data collected from traders to provide details of the large ruminant value chain in northern Laos. Understanding the value chain provides insight to the production system dynamics, product flows and the disease transmission impact of different stakeholder incentives structures and behaviours. Markets and value chains are not static therefore the reporting of baseline trends and activities provides important information. In addition, participatory value chain analysis including stakeholder consultation can act as a focus for communicating knowledge leading to more transparent decision-making in animal disease management. While governments have a key responsibility in promoting greater market participation, producers and the private sector have important roles to play in protecting the industry from key risks and constraints. While the number of traders surveyed in this study was relatively low at 32, the information reported is useful in guiding market and disease control interventions, particularly in the context of establishing baselines to which the benefits of delivering improved knowledge and understanding can be measured. Additional larger studies are in planning to investigate sustainable interventions for the development of a biosecure market-driven large ruminant beef production system in Lao PDR.

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