Abstract: The VAC model of integrated small scale agriculture has been important to economic and ecological sustainability in Vietnam for many centuries. Recently, emerging waterborne diseases including avian influenza have jeopardized the VAC model. In order to promote mitigation of the risk of waterborne disease in the VAC system, there needs to be recognition of the significant predictors of such behaviour, particularly with respect to water sources including well and rain water. We report on research results generated from 300 farms in each of North and South Vietnam that indicate the small scale farmers who are more likely to engage in mitigation of waterborne disease are those who raise pigs, perceive themselves to be more at risk of HPAI infection from well water, report they are good livestock managers, value the advice of health care workers, and where a female household member is the decision maker for family health. These results bear importance to water and health policy formulators in rural Vietnam. (JEL I130, I180, O130, Q180, Q570)

Keywords: water public health, biodiversity conservation, poverty alleviation, emerging infectious disease, agricultural policy.

JEL classifications:
I130: Health and economic development
I180: Public health
O130: Economic Development: Agriculture; Environment
Q180: Agricultural policy; Food policy
Q570: Ecological economics: biodiversity conservation

Perceptions and mitigation of risk of waterborne disease in Vietnam among small scale integrated livestock farmers.

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Introduction:

Agricultural production in Vietnam remains an integral part of the Southeast Asian country's economy accounting for 18.4% of GDP in 2013 (World Bank, 2015). However, more than 80% of Vietnamese farmers are small-scale producers (MARD, 2012), incorporating some form of livestock and directly or indirectly dependent on agriculture (Hall, *et al.*, 2006; Pica-Ciarmarra, *et al.*, 2011). A small-scale integrated farming model particularly popular in Vietnam is the VAC mode (*Vuon* = Garden, *Ao* = Pond, and *Chuong* = Livestock housing), incorporating crops such as rice, fish, and livestock including poultry (Bui, Madsen, and Dang, 2009).

For small scale farmers in Vietnam, the transmission of water related zoonotic diseases (WRZD) due to poor farm management and lack of access to health and veterinary services has been a major constraint to containing and reducing risk of zoonotic disease (Dalsgaard, 2001; Gleeson and Dung, 2010; Hall and Le, 2009; Kamakawa, Thu, and Yamada, 2006; Pham, 2010). Part of the problem has been lack of awareness and understanding of basic public health including risk factors for zoonotic disease such as contamination of water sources by livestock. This seems to be especially so for small scale integrated farmers (Cristalli and Capua, 2014; Dalsgaard, 2001; Dang and Dalsgaard, 2012; Desvaux *et al.*, 2011; Le, Hall, and Cork, 2014).

We propose that there is a strong association between Vietnamese small scale farmers' perception of risk of disease of waterborne origin and engagement in mitigating actions related to protection of water sources from contamination. This paper reports on participatory research with small scale farmers in two provinces of Vietnam in which we tested this hypothesis.

Methodology:

Using a randomly selected cross-sectional approach we identified two cohorts of 300 small scale farmers for our study in each of North and South Vietnam (Thai Binh and An Giang provinces respectively). Communes in these provinces were identified by our Vietnamese colleagues as highly representative of typical agricultural communities in

Vietnam. Small scale farmers were included in our sample frame based on low income levels, farming activities that included crops and fish, raising of some livestock including 50 or fewer poultry, access to at least one of the main water sources of rural farmers (*e.g.*, pond, river, well, and canal), and willingness to participate in the research. This general agricultural profile is typical for the VAC model in Vietnam. Both quantitative and qualitative methods were employed in the research using questionnaires, interviews, focus groups, and discussion and training sessions. Software tools included Excel, Stata 13, and NVivo 10. Ethics certification was secured by both the University of Calgary and the Hanoi School of Public Health for this research.

Questionnaires and interviews were implemented by trained Vietnamese university graduates with experience in these methods. Methods for qualitative analysis and interpretation including coding, thematic analysis, and interrelating themes using narrative passage followed those outlined by Creswell (2009) and Patton (2011). Quantitative data collected described agricultural, household, demographic, and economic variables. Binary and multinomial choice variables were also collected describing perceptions and preferences including likelihood of infection with H5N1 virus from water sources, value of health information from various informal sources including neighbors and media, self-evaluation of ability to raise livestock and crops, importance of hand washing, and impact of cost as a barrier to seeking health intervention assistance.

To engage farmers in participatory research while gathering data on water quality, farmers were trained in the use of basic colour change presence/absence tests for their drinking water. This training took place the same day as invigilation of the questionnaire. Farmers were asked to use the indicator test to test for the presence of coliforms in their drinking water and record the result. A water sample was also taken from the drinking water source to be tested for pH, turbidity, and level of *E. coli* in a national microbiology laboratory in Hanoi using both plating and broth culture techniques.

Results were prepared using summary statistics and probit regression methods utilizing the software indicated above.

Results:

Summary statistics of the demographic, economic, and some qualitative variables are shown in Table 1. The most popular crop was rice (441 farmers) followed by vegetables (293 farmers) and fruit (241 farmers). All farmers reported they produced some kind of livestock and many produced fish (292 farmers). Livestock produced included chickens (476 farms), ducks (309 farms), pigs (304 farms), and cattle (198 farms). For their primary source of drinking water, 170 farmers reported they used well water while 119 reported they used rain water. Others used piped, river, pond, or bought water. We also asked some general awareness questions relating to public health: 541 farmers said they had heard of highly pathogenic avian influenza (HPAI), 443 had heard of *E. coli* when prompted, but only 37 said they would report sick birds to authorities if they were concerned the birds might be infected with HPAI.

The results of the probit regression for Vietnamese small scale farmer engagement in mitigation of waterborne disease at source by water biosecurity methods are shown in Table 2. Engagement in mitigation strategies was measured as a binary choice variable based on cumulative positive responses to options including covering the water storage unit, preventing livestock and wild bird access to wells, maintaining wells in good working condition, and preventing sewage runoff into wells. Household respondents had to indicate they used at least three of these offered measures to score a 1 (*i.e.*, 1 = engages in mitigation strategies); otherwise, they scored zero. The best-fit probit model contained 10 significant of 26 independent variables, including raising of pigs, years of schooling, and perception of skillful ability to manage livestock (all positively associated), and cost as a barrier to mitigation (negatively associated).

The results of the probit regression for Vietnamese small scale farmer engagement in mitigation of waterborne disease by treatment and disinfection of water are shown in Table 3. Engagement in mitigation strategies was measured as a binary choice variable as described above, with the difference that options included storing water in confined tanks, investing in household water treatment technology (*e.g.*, small scale filtration equipment), using disinfectants, and repairing water storage. The best-fit probit model contained 12 significant of 25 independent variables, including raising of pigs, having a female in charge of family health decision making (both positively associated), and cost as a barrier to mitigation (negatively associated).

The following variables were significant (positively associated) for both models: having a female in charge of family health decision making, raising of pigs, having either rain water or a drilled well as primary water sources, perceived susceptibility to HPAI from well water, and the advice of a health care worker. Cost as a barrier to mitigation was significantly negatively associated for both models. Years of schooling was only significant for the biosecurity model specified in Table 2, but was commonly a significant predictor for several other specifications of both models. Concordance was more than 85% for both models; pseudo-R^2 values and other test statistics can be seen at the bottom of both tables.

Discussion:

The presence of livestock on small scale mixed agriculture farms in Vietnam is known to be a source of potential infection from zoonotic disease and a concern for emerging infectious diseases (EIDs) in Southeast Asia. The VAC model has been successfully used for centuries in Vietnam as an ecologically balanced approach to profitable integrated agriculture and a useful method for recycling of biological waste. However, the emergence of HPAI in Southeast Asia challenged not only the VAC model but also the raising of poultry in Vietnam where chickens and ducks are not only a valuable source of protein and cash, but also important elements of the rice and fish cultivation systems for many farmers, small to large scale.

A common key factor of EIDs is water, illustrated clearly in Southeast Asia in recent emergences of HPAI, dengue, Nipah virus disease, and schistosomiasis. The role of livestock and water has been contentious but there is no question that raising of livestock in open management systems has contributed to the complicated picture of EIDs (Daszak, Cunningham, and Hyatt, 2000; Morens, Folkers, and Fauci, 2004). However, recognition of this risk factor and integrated management with water systems can have significant impact on reducing those risks (Liveriani, *et al.*, 2013; Duc *et al.*, 2014).

The VAC model in Vietnam has been a valuable tool for promoting sustainable integrated livestock and fish management while assuring a reliable source of household income, contributing to poverty alleviation for small scale farmers with limited alternate livelihood options. The VAC model follows classic recommendations of farm management that secure income and environmental stewardship including diversification of operations, recycling of animal waste in a non-toxic manner, and respect for the environment as a resource for future generations. Within this model, management of water is of course critical, and the emergence of water as a risk source of EIDs is an important concern that jeopardizes the future of the VAC model.

It is interesting to note that those farmers in our study who were more likely to mitigate against waterborne disease had the following attributes that were significantly different predictors of their mitigating behaviour than for their peers: raised pigs, expressed concern that they are more susceptible than average to HPAI from well water, a female family member is the decision maker for health decisions, recognize cost of health care as a barrier to health interventions, and follow the advice of health care workers. There are several interesting insights these significant findings.

Pig manure is used to feed fish; it is simply pushed into the pond where it causes no harm to the fish and in fact they thrive on the additional nutrients it provides them. However, pig farmers are aware the manure is messy, bears a strong odour, and is not something they want tracked into the house. This perspective probably makes them more conscience of preventing contamination of water sources with pig manure and other contaminants. If individuals state they value the advice of health care workers and recognize health interventions are costly (*i.e.*, value health care as a resource) then we can reasonably conclude they likely value this knowledge and resource enough to take the effort to follow through on extended actions including mitigating actions against waterborne disease.

The significance of well and rain water sources compared with other sources of water as a predictor of mitigation against waterborne disease is also highly intriguing. We suggest there are several reasons for this. Those farmers who take the time and effort to catch rain water and manage a bored well are more likely to be concerned with the quality and cleanliness of that water. Those farmers who use river or piped water are more inclined to view it as a resource that requires little maintenance (*i.e.*, it always seems to be there when they need it), and thus perhaps pay less attention to the quality of the water at source. It should be noted that most of the farmers in our study area do claim that they filter their water (results not shown here), so we are not claiming they are not concerned about water quality, only that piped and river water users seem less concerned with protecting the water at source.

Conclusions:

Our research identifies several attributes and characteristics of farmers and integrated small scale farms in Vietnam that can be used in a policy framework to sustain the economic and environmental benefits of the VAC model while reducing the risk of EIDs from water contaminated with livestock waste. Water and farm management policy options to support agricultural economic activity in rural areas while promoting sustainable eco-friendly methods targeting low income small scale farmers would benefit from addressing mitigation strategies against waterborne disease. Such policy options should consider the livestock species raised, source of water (rain and well users are more likely to benefit), and awareness of susceptibility to waterborne disease. Improving the latter and increasing access to health care advice as well as promoting well and rain water as sources of water are also elements of what we see as a likely successful water and farm management policy in Vietnam.

The VAC model should continue to be promoted in Vietnam due to the ecological and poverty alleviation benefits. However, there is a need to address the increased risk of waterborne disease inherent with application of the VAC model. We have identified several factors and characteristics of small scale farmers in Vietnam that we see as valuable to water and farm policy development while promoting the VAC model.

Table 1. Basic summary statistics for small scale farmers in Vietnam (n=598).

Variable	N	Mean	s.d.	Min	Max
Age	597	45.94	11.31	17	85
Number of household members	598	4.40	1.34	2	10
Number of hhld mmbrs < 18 yo	598	1.18	0.96	0	5
Years of schooling	598	6.89	3.23	0	18
Years farming	598	9.64	8.27	0	50
Mean cfu *E. coli* in drinking water	581	739.74	10,077.24	0	213,156
Hours per day in contact with water for agricultural production	567	3.48	5.21	0	20
Training interest – farm mgmt.[1]	563	3.08	1.10	1	5
Training interest – water mgmt.	574	3.14	1.11	1	5
Number chickens on farm[2]	571	26.03	30.84	1	500
Number ducks on farm	484	138.27	207.29	1	3000
Number pigs on farm	401	22.84	24.52	1	200
Number cattle on farm	598	4.75	9.71	1	226

1. For training interest, farmers were asked to rate their interest in management training ranging from 1 (no interest) to 5 (extremely interested).
2. Mean numbers of animals reported are for those who have any of each species.

Table 2. Probit regression results for Vietnamese small scale farmer engagement in mitigation of waterborne disease at source by biosecurity of source.

Variable	Beta	s.d.	z-score	P>|z|
Years schooling	0.0892**	0.0384	2.32	0.020
Years farming	0.0188	0.0165	1.14	0.254
Household members >18	-0.0037	0.1230	-0.03	0.976
Respondent				
Male health role	-0.1877	0.3336	-0.56	0.574
Female health role	0.9059**	0.3705	2.45	0.014
On-farm income	-0.3427	0.3494	-0.98	0.327
Chickens	-0.0016	0.0044	-0.35	0.723
Pigs	0.0161**	0.0076	2.12	0.034
Cattle	0.0028	0.0080	0.35	0.729
Log *E. coli* levels drnk water	-0.0608	0.0560	-1.09	0.277
Dummy water source				
Rain	2.0403***	0.4991	4.09	0.000
Well	1.9960***	0.5143	3.88	0.000
Pipe	0.2796	0.5024	0.56	0.578
River with flocculation	0.2929	0.5158	0.57	0.570
Perceptions				
Susc to HPAI (agr water)	-0.1276	0.2446	-0.52	0.602
Susc to HPAI (well water)	0.7442**	0.3767	1.98	0.048
Severity HPAI	-0.7742	0.4885	-1.58	0.113
Cost is a barrier	-0.4789*	0.2498	-1.92	0.055
Knowledge barrier	0.1844	0.2632	0.70	0.483
Peers barrier	-1.0684**	0.4636	-2.30	0.021
Benefits encourage	0.5251	0.3620	1.45	0.147
Ability livestock	0.2463	0.2389	1.03	0.303
Triggers to action				
Health worker advice	0.8031***	0.2774	2.90	0.004
Lost income	0.0082	0.3096	0.03	0.979
Peers	0.8845***	0.3314	2.67	0.008
Worry	0.4100	0.2706	1.52	0.130
Constant	-2.9400	0.7657	-3.84	0.000

Number of observations = 304; LR $chi^2(26)$ = 225.04; Prob > chi^2 = 0.0000; Log likelihood = -95.0037; Pseudo R^2 = 0.5422; * P<0.10; ** P<0.05; *** P<0.001
Concordance = 86.51%

Table 3. Probit regression results for Vietnamese small scale farmer engagement in mitigation of waterborne disease at source by treatment of water.

Variable	Beta	s.d.	z-score	P>|z|
Years schooling	0.0632	0.0399	1.59	0.113
Years farming	0.0195	0.0169	1.16	0.247
Household members >18	0.0115	0.1300	0.09	0.929
Respondent				
Male health role	0.1008	0.3474	0.29	0.772
Female health role	1.4816***	0.4397	3.37	0.001
On-farm income	-0.9672***	0.3344	-2.89	0.004
Chickens	-0.0008	0.0047	-0.16	0.871
Pigs	0.0172*	0.0106	1.63	0.103
Log *E. coli* levels drnk	0.0181	0.0608	0.3	0.765
Dummy water source				
Rain	1.5554***	0.5100	3.05	0.002
Pipe	0.2886	0.5032	0.57	0.566
Well	2.1583***	0.5893	3.66	0.000
River with flocculation	0.1225	0.4841	0.25	0.800
Perceptions				
Susc to HPAI (from agr	-0.3159	0.2602	-1.21	0.225
Susc to HPAI (from well	0.7093*	0.3845	1.84	0.065
Severity HPAI	0.6662	0.4682	1.42	0.155
Cost is a barrier	-0.6230**	0.2636	-2.36	0.018
Knowledge barrier	0.6054**	0.2798	2.16	0.031
Peers barrier	0.0639	0.5397	0.12	0.906
Benefits encourage	1.3906***	0.4408	3.15	0.002
Ability livestock	0.4928*	0.2757	1.79	0.074
Triggers to action				
Health worker advice	0.8077***	0.2787	2.9	0.004
Lost income	0.6833**	0.3430	1.99	0.046
Peers	0.5982	0.3913	1.53	0.126
Worry	-0.1829	0.2958	-0.62	0.536
Constant	-4.3756	0.9117	-4.8	0.000

Number of observations = 304; LR $chi^2(25)$ = 233.44; Prob > chi^2 = 0.0000; Log likelihood = -84.3955; Pseudo R^2 = 0.5804; * P<0.10; ** P<0.05; *** P<0.001
Concordance = 86.51%

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