Journal of Geography, Environment and Earth Science International
5(3): 1-19, 2016; Article no.JGEESI.23528
ISSN: 2454-7352

SCIENCEDOMAIN *international*
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Assessing Water Vulnerabilities: Successes, Failures, and Missed Opportunities in a Karen Hill Tribe Village on the Thailand-Myanmar Border

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Authors' contributions

This work was carried out in collaboration between all authors. Authors KNI, NM, JB, TK, and PP collaboratively developed the project design. Authors KNI, NM, JB and PP conducted the fieldwork for the project. Authors TK and KNI reviewed the designs for the rainwater harvesting and sanitation systems. Author KNI was lead in developing the manuscript while authors TK, NM and JB provided critical review and edits for the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2016/23528
Editor(s):
(1) Dr. Chew Hung Chang, National Institute of Education, 1 Nanyang Walk, Singapore.
(2) Dr. Diganta Das, National Institute of Education, 1 Nanyang Walk, Singapore.
Reviewers:
(1) Diganta Das.
(2) Shiv Sidh.
Complete Peer review History: http://sciencedomain.org/review-history/13398

Conference Proceeding

Received 13th February 2015
Accepted 20th August 2015
Published 23rd February 2016

ABSTRACT

Aims: This paper uses a narrative, case study approach to illustrate water vulnerabilities associated with a remote, Karen Hill Tribe village in northwestern Thailand and discusses some of the measures taken to address these vulnerabilities.
Place and Duration of Study: Huai Pla Kong Village, Tak Province, Thailand; October, 2011-November, 2013.
Methodology: A needs and vulnerability survey was administered to the head-of-household or spouse of 11 families in the village. The survey tool was a combination of closed and open-ended questions that provided basic information on demographics, drinking water, sanitation, health, and agricultural practices. Drinking water sources including wells, rainwater harvesting systems, a local

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Note: This paper was presented in SEAGA (Southeast Asian Geographers Association) International Conference 2014, Siem Reap, Cambodia (at Royal University of Phnom Penh), 25 - 28 November 2014.

stream and a mountain spring were sampled in the rainy and dry seasons and analyzed for *E. coli* levels. Health care interventions were introduced, including a couple of day-long health clinics and the distribution of ceramic drinking water filters.

Results: Wells and the local stream generally were contaminated with *E. coli*, while the rainwater harvesting systems tended to have lower *E. coli* levels. The majority of families had a main source and secondary source for domestic water, which reduced vulnerability, although on average per capita water use was towards the low end of the global range. Families boiled their water about half the time before use, but only 2 of 11 families were able to link contaminated food or water to diarrhea. Most families had access to pour flush toilets or pit latrines, although 27% defecated in the open. Farmers noted that water availability for crop irrigation could be limited. Most farmers used pesticides on their crops and it was observed that pesticide handling practices were inadequate. The village practices traditional shifting or swidden agriculture and extensive deforestation was visible, which may negatively impact crop productivity and water quality, although farmers interviewed did not believe erosion was a concern. The introduction of a ceramic drinking water filter with one family improved the quality of their water and appeared to positively impact the health of the babies in the household. Ceramic filters subsequently were distributed to 7 additional families. Finally, a team of graduate students from the Asian Institute of Technology designed and costed a rainwater harvesting system and a wastewater collection and vertical flow wetland treatment system for the village.

Conclusion: The study successfully identified water vulnerabilities for the village, including limited availability for irrigation (and to a lesser extent, domestic use); bacterial contamination of well water sources; poorly managed use of pesticides; and clear-cutting of forest which produced high erosion potential. Some measures were developed to address these vulnerabilities, the most successful being the introduction of a ceramic drinking water filter to a study family. Shortcomings of the program included our lack of a more permanent presence in the village which reduced our capacity building opportunities that could address water vulnerabilities more fully. The headman of the village had limited interest in the initiatives, which meant progress was slow. A missed opportunity resulted from the recent political turmoil in Thailand which eliminated our access to the village and therefore no follow up on the 7 water filters or construction of a rainwater harvesting and sanitation system has been done to date.

Keywords: Waterscape; water vulnerability; Karen Hill Tribe; sanitation; ceramic water filter; agricultural practices.

1. INTRODUCTION

Vulnerability assessment of both human and natural systems has received considerable attention and has become much refined over the past 15 years [1-9], with an important driver for some aspects of this research being the increasing concern about the potential impacts of climate change [8,10-15]. Cutter et al. [16] distinguish between vulnerability and resiliency, with vulnerability being "...the pre-event, inherent characteristics or qualities of social systems that create the potential for harm", while resiliency refers to the capacity of the system to respond to a disturbance and resist the impact or recover from the damage of the disturbance [17-19]. Cutter et al. [16] suggest that resiliency for human systems also includes "…post-event, adaptive processes that facilitate the ability of the social system to re-organize, change, and learn in response to a threat.", thereby making resiliency inherently different from vulnerability. Following Cutter's distinction, our study contains elements of both vulnerability and resiliency, but the main focus here is vulnerability. Eiken and Luers [20] conclude that traditionally there have been three general approaches to conducting vulnerability research: i) risk-hazard; ii) political economy/political ecology; and iii) ecological resilience, although they also note more recently there has been some effort towards trying to integrate elements of these approaches. Our paper provides a case study of the vulnerabilities related to the waterscape that we identified for a Karen Hill Tribe village in Tak Province, northwest Thailand. As Cutter et al. [16] note, place-based studies are a common approach in vulnerability assessment and this village represents the intersection of some interesting and challenging social, political, economic, and environmental characteristics. We also see this work as documenting what can be considered "geographies of academic underrepresentation" with respect to certain ethnicities, regions, populations, and their everyday waterscape. The objective of this paper, then, is to provide an overview of the vulnerabilities that we identified as we worked in the village. We hope to illustrate some of the successes we had in identifying and addressing water-related vulnerabilities, but also to discuss some of the challenges and lost-opportunities, as part of a lessons learned. Surprising to us given our past research careers, the bulk of this paper relies on a political ecology framework in addressing questions of causation and social difference such as: Why are particular populations vulnerable? How are they vulnerable? Who precisely is vulnerable? [20]. We also take some quasi-quantitative and design approaches in dealing with these questions. In this sense, perhaps we have moved a small step towards an integrative assessment approach to waterscape discourse, assessment, and management.

2. BACKGROUND TO THE STUDY

Huai Pla Kong village, the site for this study, is located in Tak Province, Thailand, about 430 km northwest of Bangkok and 60 km from Mae Sot, the nearest city (Fig. 1). The last 8 km to reach the village are over a single lane dirt trail, making the village quite remote. Furthermore, the village is only 300 m from the Moei River that separates Thailand and Myanmar. The village has an estimated population of 568, primarily Karen Hill Tribe people, with most of the older population originally coming from Myanmar. The village is not a formal refugee camp but because of the proximity to Myanmar, security is strictly maintained by the Thai military and access is limited.

Fig. 1. Location of Huai Pla Kong Village (after Karen Human Rights Group, 2005, http://www.khrg.org/sites/default/files/khrg05f5.pdf)

The political ecology of this area is complex. Certainly, the history of the conflict between the Karen people and the central government of Myanmar has been well documented [21,22], although as noted by Thawnghmung [22], "not all Karen share similar grievances and political aspirations." The diversity of aspirations and ideas on Karen identity similarly is explored by Kuroiwa and Verkuyten [23]. The Karen National Union (KNU) has been in conflict with the central Myanmar government since shortly after the country's independence from Britain in 1948, but it was not until the mid-1980's when the Myanmar army offences were extended into the rainy season, that Thailand started to see an increased influx of Karen people fleeing their homes [24]. Since then, there have been varying waves of refugees, precipitated by differing military campaigns and internal protests [24]. The Thai government currently hosts the refugees, primarily Karen, in nine temporary shelters (camps) along the border with Myanmar (http://www.unhcr.org/pages/49e489646.html). Understandably, it is difficult to get an exact count on the number of refugees in these camps, with the United Nations High Commissioner for Refugees (UNHCR) estimating 124,400 by the end of 2014, while other estimates are higher, at more than 140,000 (http://www.karen.org.au/karen_refugees.htm). As an added complexity, the Royal Government of Thailand does not officially recognize the Karen people as refugees, but as temporarily displaced people. It has only been since 2005 that Thailand began allowing third countries to receive people from the camps who were legally registered as refugees by the UNHCR [24]. Since that time, more than 55,000 Karen people have been resettled, primarily in the U.S., Canada, Australia, but also in Finland, Great Britain, Ireland, the Netherlands, New Zealand, Norway and Sweden (https://www.unhcr.or.th/about/thailand). In addition, the UNHCR recognizes 506,000 "stateless" people (many who are Karen) living in Thailand. These are people who may have been born in Thailand but do not have Thai (or Myanmar) citizenship. Many of the people living in Huai Pla Kong village are stateless.

The UNHCR has limited direct involvement with the temporary shelters, but there are numerous NGOs that operate in these areas to provide housing materials, food, necessities, and education. Although this may be debated as a positive or negative, we believe one of the first vulnerabilities for villages like Huai Pla Kong is that they are not a temporary shelter and therefore do not receive the focus or the resources that the shelters receive, yet movement and migration is controlled. Unlike the lowland rural northern Thailand communities documented by Rigg and Salamanca [25], that are increasing their mobility and pursuing off-farm, non-agricultural livelihood opportunities as a means of coping with vulnerability, these options are much less available to the large majority of people living in villages like Huai Pla Kong.

The Karen refugee and stateless person situation certainly provides a layer of complexity to the interactions with the Thai host communities [26-28], but there are other social interactions that also need to be considered. Wittayapak [29], for example, explores the relationship between lowland Thais and those occupying highland areas: "Hill people are perceived to be nomads, animists, uncivilsed, stateless, and shifting cultivators.", which would suggest the potential for an imbalance of power relations that can make Hill Tribes more vulnerable. In fact, Crooker [30] states the argument even more strongly "In recent decades, Thai elites have ecologically marginalized Hill Tribe farmers in Northern Thailand. A region-wide population boom has fueled a 'land grab' by the elites and forced Hill Tribe farmers to live on less land with few off-farm options." Tipraqsa and Schreinemachers [31] have countered with their survey of 240 mostly Karen households in Chiang Mai province that showed them to be well-integrated into markets and this could be an important direction for policy-makers. There also is ongoing debate about the relative impact of swidden farming on the environment [e.g. 32-34], but some have noted that swidden, practiced along traditional lines, will have less of an environmental impact than replacement, mono-culture cropping and dry weather farming [34-36].

Against this complex social and environmental background, our team initially was invited to the village by the Thai military to evaluate options for increasing access to potable water, with specific thoughts of increasing the number of wells. This background serves to begin answering the questions Who precisely is vulnerable? How are they vulnerable? Why are particular populations vulnerable?

3. METHODOLOGY

This study is somewhat unusual in that it evolved organically. The authors formed the core of the study team and as we became more familiar with the village, the actors, and the issues, we collectively and continually re-assessed priorities for action, based on new understandings and resources (both human and financial) available. For example, at various points in the study, we recruited and paid a small honorarium to two Karen/Burmese/Thai/English speaking local college students to help conduct the needs (vulnerability) survey. An established Burmese doctor voluntarily conducted one of the health clinics, while a team of three Thai military doctors voluntarily operated the second health clinic. A class of graduate engineering students from the Asian Institute of Technology (AIT), Pathumthani, Thailand, conducted fieldwork and developed design scenarios for improved drinking water and sanitation systems. Because of the organic nature of the study that was powered essentially through volunteerism, this Methodology section is structured chronologically to reflect the evolution of efforts.

3.1 *E. coli* Analysis of Source Waters

In assessing the suitability of digging more wells to supply potable water, a first priority was to investigate the quality of the existing wells. Water samples were collected from wells (Fig. 2) and also a large concrete water storage tank (Fig. 3) that services the community and local Buddhist monastery upon a first reconnaissance visit to the village, 8 October 2011. This sample period represents the rainy season and because of challenges driving the 8 km dirt trail to the village during this period, sampling was repeated only once more for the rainy season, October, 2012. Sampling was done in the wells during the dry season in March, 2012; December, 2012; June, 2013; and November, 2013.

Fig. 2. Sampling wells in the village. Note the concrete apron base is exposed. Well rings were fully cemented, but no wells had covers

Fig. 3. Concrete water storage tank for the community and Buddhist monastery

During the first reconnaissance visit it became clear that the village used other source waters, in addition to the wells, including water from a mountain top spring that was piped to the large concrete storage tank, rainwater harvesting, and a small stream running through the village. These sources also were variously sampled on the dry season dates between March, 2012 and November, 2013.

Sample analysis for *E. coli* was done using the Coliscan Easygel system from Micrology Labs (http://www.micrologylabs.com/Home), Goshen, IN. Briefly, the community bucket at each well or rainwater harvesting system was rinsed three times with the source water before final collection of a sample to be analyzed. A new, sealed, sterile plastic pipette was used to withdraw 1 mL of sample from the bucket and the sample was dispensed into the Coliscan Easygel growth medium contained within individual plastic vials. The spring water and river water were collected directly using a sterile plastic pipette. Each growth medium vial was gently swirled to distribute the inoculum and then placed on ice in the field. The medium/inoculum mix was plated either at a staging area in the field, or in the hotel at Mae Sot, depending on the travel conditions at the time. The poured samples were incubated at room temperature for 48 hours and all purple colonies were then counted as *E. coli*. In a comparison between Coliscan tests and standard membrane filtration (done at a New York State Health Department certified lab), Irvine et al. [37] reported a correlation of 0.98 (n=21) over a range of 0 to 120,000 cfu/100 mL. This system has been used successfully in other locations in Southeast Asia [38,39,41,42].

3.2 Ceramic Filter Intervention

During a site visit in August, 2012, the team was introduced to a young mother with twin girls, approximately 6 months of age. Both girls were suffering from severe diarrhea and fever. The mother was struggling with a remittance of 500 baht (~15 USD, 2015) per month from her husband who was working elsewhere. The team took the twins to the hospital in Mae Ramat (23 km from Huai Pla Kong and slightly less than half way between Huai Pla Kong and Mae Sot) and purchased medicine, food (including eggs and milk), and a mosquito net. Back at Huai Pla Kong the team also provided demonstrations on basic washing and bathing the babies to improve sanitary conditions. The demonstrations attracted a considerable crowd. As a follow-up, in October, 2012, the team provided the mother with a ceramic drinking water filter produced by Resource Development International – Cambodia (RDIC, http://www.rdic.org/), a group with whom we have worked for a number of years previously in Cambodia, and whose filters have been shown to be effective [43]. Follow-up visits were conducted to assess the effectiveness of the filter, including analysis of the filtered water using the Coliscan Easygel system, per the methodology described in the previous section (Fig. 4).

Fig. 4. Sampling the water from the ceramic filter for *E. coli* analysis

3.3 Needs (and Vulnerability) Survey

Based on our observations from a number of visits to the village, and following a team meeting in September, 2012, it was decided to better gauge the needs of the village through a field survey. The survey was drafted and subsequently administered on 7 December 2012. While the team could speak English, Thai and Burmese, two additional translators (college students) who were capable of speaking Karen, Burmese, Thai, and English were provided a small honorarium to help with the survey. The survey tool was a combination of closed and open-ended questions that provided basic information on demographics, drinking water, sanitation, health, and agricultural practices. Because there is a Thai government primary school in the village, we asked the deputy headman to provide a list of families with school-aged children (primary and secondary), with the intention of identifying issues that might be addressed through the school curriculum. The list was given to a village girl who acted as a guide to family homes. The survey was administered to the head-of-household or spouse of 11 families. Before the start of each interview, we read a language-appropriate statement about the objectives of the survey, that the information would help us to form a plan to provide more effective education and support community-based action, and that the information would only be viewed by the study team, was confidential, and could not be used to identify any individual. All who were surveyed voluntarily agreed to be interviewed.

3.4 Design of an Integrated Sanitation and Rainwater Harvesting System

Each year, Drs. Thammarat Koottatep and Kim Irvine collaboratively offer a graduate class in wastewater and collection system design at AIT. One of the course requirements is to conduct a field-based design project and in July, 2013 the class traveled to the village to identify the engineering design options for village sanitation and drinking water, to collect source-water samples for *E. coli* analysis, and to review the operation of the ceramic drinking water filter.

3.5 Health Clinics

Early in the project (September, 2012), the team arranged for a Burmese doctor to spend a day in the village to consult on health issues. After a team meeting on 17 August 2013, and based on the results of the Needs Survey, it was confirmed that three Thai military doctors would volunteer to do a free one day health clinic at the village on 23 November 2013, including distribution of non-prescription, basic medicines. Malaria is of concern in the village and a malaria education and response team has been established, consisting of members of the village and trained by a local doctor.

4. RESULTS

4.1 *E. coli* Analysis of Source Waters

The results of the *E. coli* analysis for source waters are presented in Tables 1 and 2. WHO drinking water standards for *E. coli* are 0 cfu/100 mL. Of the well samples collected in the dry season, only 4 met the WHO guideline, although the geometric mean was not extraordinarily high at 32 cfu/100 mL. The quality of harvested rainwater generally was quite good, but there is some concern about the quality of source-water from the stream in the village. It is a small sample size and care must be exercised in interpreting results, but it seems that *E. coli* levels in wells and the mountain spring water may be lower in the rainy season as compared to the dry season. This may be the result of dilution associated with the greater abundance of water in the rainy season.

Table 1. Dry season *E. coli* results*, 5 dates, October 2011 – November 2013

Wells (n=15)		Rainwater harvest (n=2)	Mountain spring Source (n=1)	Large tank at temple (n=1)	Small stream (Upstream of village)(n=1)	Small stream (In village (n=2)
Geometric mean	Range	Range				Range
32	0-7,880	0-100	300	300	2,200	2,800-8,320

All results expressed in cfu/100 mL

Table 2. Rainy season *E. coli* results*, October 2011 and 2012

Wells (n=5)		Rainwater Harvest (n=3)	Mountain Spring Source (n=1)	Large Tank at Temple (n=2)
Geometric Mean	Range	Range		Range
0.28	0-80	0-120	0	0-50

All results expressed in cfu/100 mL

4.2 Needs (and Vulnerability) Survey

4.2.1 Socio-economic characteristics

Socio-economic information elicited from the survey respondents is summarized in Table 3. The average number of people per household in the survey was 6 and extended families were common. While the sample size of 11 families is small, given the size of the households, we expect our results represent 12% of the village population. Of the 11 families interviewed, 5 identified themselves as "farmers", although one of the families did not own the land they farmed and therefore did not respond to some of the agricultural questions. More than half of the families (6) spoke only Karen. Although all families spoke Karen, the other 5 families also spoke Thai and 2 families could speak Burmese in addition to Karen and Thai. It could be argued that those families who spoke only Karen have a lower level of resiliency since their ability to interact with mainstream Thai society is impacted by a language barrier. Many of the children in the surveyed families were not of school age yet and in our general observations we were struck by how many young children lived in the village. In fact, many of the mothers appeared quite young themselves. One 7-year old girl and one 10-year old girl (two different families) were the only school aged children identified that did not attend school. Most of the children from the surveyed families attended the local village school, although at least one family sent their children to the Mae La Refugee Camp. Children going to school beyond primary level generally board in a larger town in the province.

Table 3. Socio-economic characteristics of the surveyed families

Family I.D.	Main occupation of household member interviewed	Number of people in household	Languages spoken in household	Do school-aged children in the household regularly attend school?	If children attend school, what school?
1	Unemployed, but used to work in Bangkok	3	Karen (only)	Children not of school age	
2	Husband works construction in Bangkok	9	Karen (only)	3 children left at home who go	Village school
3	Husband is a laborer	5	Karen (only)	1 boy (age 8) does; 1 girl (age 10) does not	Village school
4	Laborer	4	Karen, some Thai, some Burmese	Children not of school age	
5	Laborer	4	Karen, some Thai	Children not of school age	
6	Laborer	7	Karen, Thai	None in school	
7	Farmer	6	Karen, Thai, Burmese	3 of 4 children are; fourth is not of school age	Village school and Mae La refugee camp
8	Farmer	8	Karen (only)	All 4 attend	Village school
9	Farmer	9	Karen (only)	Children not of school age	
10	Farmer	6	Karen (only)	Boys (age 10 and 14) attend; girl (age 7) does not, nor does baby	Village school
11	Farmer	5	Karen, Thai	Children not of school age	

4.2.2 Household water use

The majority of families surveyed had a main source and a secondary source for household water:

Main source	Secondary source
Well (5 families)	Piped (3 families)
River (4 families)	Well (3 families)
Piped (1 family)	River (1 family)
Rainwater (1 family)	None (4 families)

It could be noted that the piped water often was not available the entire year, as the mountain spring feeding the large concrete tank generally dries up between April and late June.

All but 1 family boiled their water before use, with an average frequency of 3.3 on the Likert Scale question, which meant they boiled about half the time (1=almost never; 3=around half the time; 5=always, or almost always). The mean volume of water used per household each day was 43 L and all families said they always had enough water. According to the U.N., humans need a minimum of 2 L per day to survive (http://www.unwater.org/downloads/Water_facts_and_trends.pdf). The average daily per capita consumption in the surveyed households (mean number of household members/mean volume of water used) is 7.2 L (for all uses combined). This use rate certainly is at the low end of data available globally. The correlation between the volume of water used per household and number of people per household is 0.49, which is significantly different from 0 at α=0.2 in a two-tailed test. Most (10 of 11) families stored their water, usually in a plastic container, and all but 2 families covered their storage vessel.

4.2.3 Agricultural practices

Crops grown included rice, corn, long bean, and yellow bean. The fields generally are located some distance from the village – typically 2.5-3 km away. Because one farmer does not own his own land he did not respond to the farming questions. Of the 4 households that responded, 3 must irrigate frequently and all pump the water from a local stream. When asked if they had enough water for farming, the answers ranged from never to always. The reason for the variability in answers should be investigated further and while there generally seems to be enough water available to meet domestic needs, water available for agriculture may be a different story and one worth pursuing further.

Three of the 4 responding families use pesticides in their farming practice, with 1 of the 3 reporting feeling sick after applying the pesticides. On a separate visit date (with the AIT students), laborers were observed mixing pesticides (with no personal protective equipment) in the same stream area as children were swimming and there was a strong odor of pesticide in the field areas outside of the village (Figs. 5-6). The laborers left a number of used pesticide containers on the bank of the stream and Paraquat was one of the herbicides identified as being used. Paraquat commonly is used as a herbicide throughout the world and the U.S. Centers for Disease Control (http://emergency.cdc.gov/agent/paraquat/basics/facts.asp) note that because of potential health impacts, application in the U.S. is restricted to licensed applicators. Health impacts can include heart, kidney, and liver failure, and when ingested or inhaled, lung scarring, although it does not appear paraquat is carcinogenic (http://emergency.cdc.gov/agent/paraquat/basics/facts.asp; https://www.federalregister.gov/articles/2014/10/29/2014-25592/paraquat-dichloride-pesticide-tolerance). There still is some uncertainty, but a link has been reported between Paraquat and Parkinson's Disease [44] and it also appears the herbicide can negatively impact fish [45]. The pathways for health impacts from pesticides include inhalation, diffusion through the skin or direct ingestion during application, through consumption of vegetables treated with the pesticides, or through consumption of surface or groundwater contaminated during the mixing process or from field runoff. We had plans to analyze water sources and vegetables for the presence of pesticides, but this was one of the opportunities lost, as discussed below. Therefore, while we directly observed mishandling of pesticides which can lead to health impacts, we were unable to confirm water contamination through testing and our observations can only indicate the possibility of water contamination.

While 2 of 4 farmers reported observing "mud" in the stream and correctly believed it "came from the soil" the other 2 farmers were not sure where the "mud" in the stream came from. Furthermore, 3 of 4 farmers did not believe high levels of mud in the stream were an indication of potential problems for their crops, while the fourth farmer was not sure. Field observation showed that swidden agriculture still is practiced in the area and levels of deforestation may be of concern (Figs. 7-8). Certainly, the slope steepness with respect to soil loss may result in declining agricultural productivity and off-farm impacts. Collectively, the results suggest we should investigate ways to improve farmer understanding of water and soil conservation and sustainable agriculture practices.

4.2.4 Sanitation

Most of the households interviewed had access either to a pour-flush toilet (64%) or a pit latrine (9%), although 27% defecated in the open/in a stream. It is not clear if this is the same stream used as a source-water for drinking. The mean distance from pit latrine to well, as identified for the specific households, was 315 m (n=7), with a range of 100-500 m. The WHO minimum suggested distance between pit latrine and drinking water source is 30 m, so the surveyed families seem to meet this guideline. However, the steep slopes of the village, combined with the number of pigs tied under homes, and the presence of *E. coli* in well samples, suggest there may be more rapid percolation and downslope movement than desired and this issue should be examined through a more thorough survey of all latrine and well locations in the village.

Fig. 5. Mixing pesticides using the village stream water

Fig. 6. Swimming after laborers mixing the pesticide had departed

Fig. 7. Swidden agriculture in Huai Pla Kong

Fig. 8. Bare fields and steep slopes

The mean response on the Likert Scale question regarding frequency of washing hands after defecation was 3.8, which means the surveyed households regularly wash their hands, although 5 families specifically noted that they do not have soap to wash with. The households that defecated in the open tended to wash their hands less frequently. We also need to determine generally where and how people wash their hands (e.g. whether they dip their hands into the water storage containers).

4.2.5 Health Issues

The frequency of visits to a doctor varied, but only 3 of the 11 households interviewed visited a doctor regularly and these households generally did so for the health of their babies. Most households did not see a doctor unless they were sick and a few households claimed that they had never seen a healthcare worker in the village. The healthcare workers and a doctor clearly were there the day we visited for the survey, but this raises a question regarding the level of effectiveness of the healthcare workers. Perhaps an outreach program can be implemented to improve this situation. If they are sick, most households noted that they go to Mae Rahmat Hospital, although 3 households also went to the Mae La Refugee Camp as an alternative to Mae Rahmat. One household noted that transportation to Mae Rahmat was cost-prohibitive, at 500 Baht (~15 USD, 2015), unless they were really sick.

A surprisingly high proportion (45%) of households said they never got diarrhea and of this group, 3 households primarily obtained their water from the stream and 2 obtained it primarily from a well. This result does not provide a clear link between source and incidence of diarrhea, suggesting a more detailed analysis/data are needed. Misreporting of diarrheal incidence also may be a confounding factor, as discussed below. Only 2 of 11 households were able to link contaminated food or water to diarrhea, so developing a basic health and sanitation education program to be delivered at the school would be useful.

All but 2 households cook their fish, although it was noted that one husband ate fish raw. Since the village does not appear to simply ferment the fish, and provided the fish are cooked thoroughly, there appears to be limited risk for liver fluke infection. As part of the basic health and sanitation education program, a message could be included about the importance of thoroughly cooking fish to avoid liver fluke (parasite) infection that is common in northern and northeastern Thailand [46-49].

The majority (73%) of households do not drink milk, despite the number of small children, with most citing the cost of milk as being the prohibitive factor. All but one household indicated that they would be willing to try goat milk and a number of families were interested in raising goats for food and profit.

All households used mosquito nets and generally were able to make the connection between mosquitos and malaria. We did not determine the average age of the nets or whether they were treated nets of some sort. Despite the apparent widespread use of mosquito nets, nearly half (45%) of the households had experienced malaria during the past year.

4.3 Design of an Integrated Sanitation and Rainwater Harvesting System

After visually examining satellite images and conducting a reconnaissance visit to the village, the first solution to water demand challenges proposed by the young graduate engineers from AIT was to design a solar powered pump system to draw water from the Moei River, only 300 m away. While this is a sustainable and efficient engineering approach that seems most reasonable, unfortunately the students soon learned that politics can be more important than engineering, and they had to abandon this idea due to security concerns of having a water intake on the border with Myanmar.

As the students observed the village further, conducted water testing, and talked with villagers when possible, they soon made a connection between potable water and sanitation. This underscores the importance of "familiarisation" with a study area, as discussed by Ghosh [50]. The students understood that simply digging more wells may not be the solution to

Fig. 9. Existing rainwater harvesting system for the village school

provide greater access to potable water due to the ongoing potential for contamination. As such, they developed a number of design scenarios, but favored two that would see construction of rainwater harvesting stations (an example of which was already is existence in the village, Fig. 9) together with a wastewater collection system connected to a constructed wetland for treatment. One of the favored designs took a centralized vertical flow constructed wetland approach, while the other was decentralized, with a number of smaller vertical flow wetlands to be constructed in a distributed way throughout the village (Fig. 10).

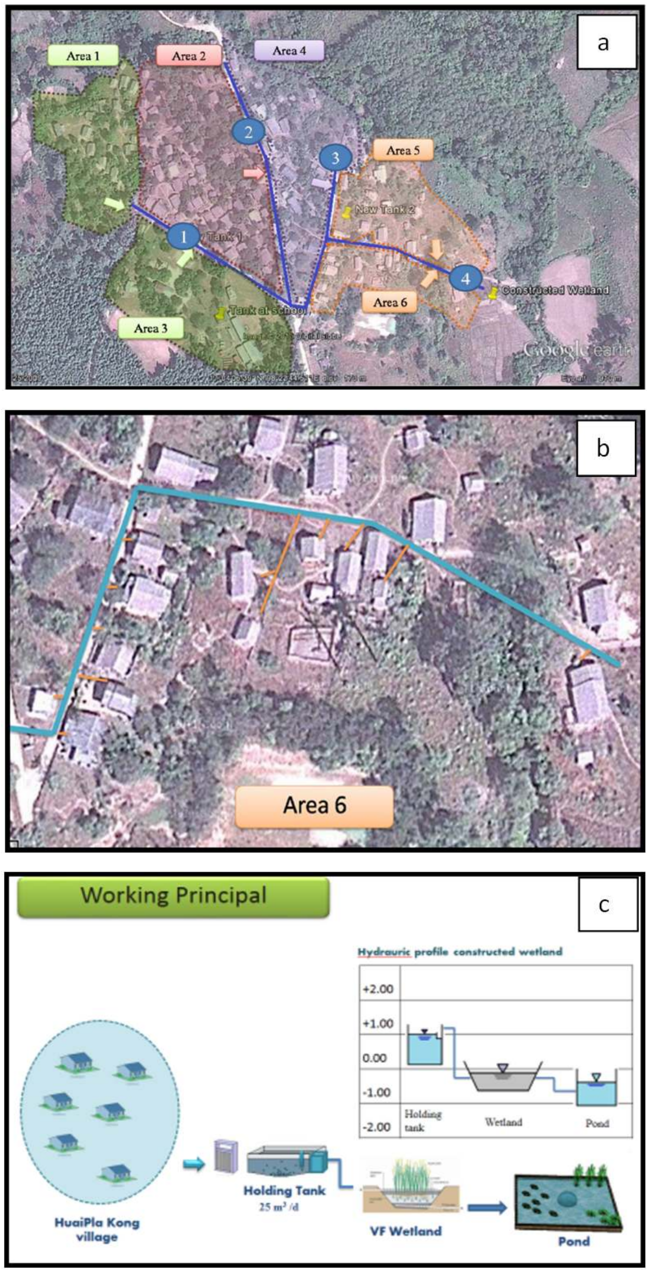

Fig. 10. Example design of the centralized collection system and vertical flow (VF) constructed wetland treatment for wastewater; (a) shows the plan view of the village with different collector areas and the main collection system; (b) provides an enlarged view of the individual house connections to the main collector system; and (c) is a schematic of the system design

4.4 Health Clinic

A total of 64 people attended the free health clinic on 23 November 2013. The ages of the patients ranged between 4 months and 78 years, with 31 of the patients being 9 and under. The most common complaints were cough, fever, skin rash, and some staph infections, although 3 people (ages 28-44) complained of dizziness, 2 children had apparent ringworm, 1 child was sent to hospital for suspected malaria, and two women saw the doctors because they were pregnant.

5. DISCUSSION

This study successfully identified geographies of water vulnerabilities for Huai Pla Kong village. Water demand for domestic use in the village was at the low end of U.N. standards but none of the surveyed families reported a shortage. Furthermore, most of the families had developed a strategy to increase resiliency as they generally had a primary and secondary source of domestic water. Water availability for irrigation, on the other hand, was identified as a constraint to agriculture and therefore represents a vulnerability. Source-water quality for domestic purposes was variable. Some wells exhibited elevated *E. coli* levels (in the dry season only 4 of 15 samples had levels of 0 cfu/100 mL) and the stream passing through the village also had high *E. coli* levels. Rainwater harvesting and the mountain spring seemed better options from a water quality perspective, although if the well water is to be used it should be filtered or boiled.

A number of vulnerability issues are linked to water; health and waterborne disease being the most obvious. There is a need to improve basic sanitation and hygiene education, as only 2 of 11 households were able to link contaminated food or water to diarrhea. Interestingly, however, only slightly more than half the families reported regular incidence of diarrhea. This unexpectedly low incidence may be an artifact of self-reporting and should be interpreted with caution [51-53]. For example, Sen [52] notes: “To take an extreme case, a person brought up in a community with a great many diseases and few medical facilities may be inclined to take certain symptoms as “normal” when they are clinically preventable.” It also is possible that there is confusion about the definition of diarrhea. The cost of travel to see a doctor was seen by some villagers surveyed as being prohibitive and most certainly preventative medicine is not viewed by many as practical. The free clinic offered in November, 2013 was attended by 11.3% of the village population, but some who had claimed doctors never came to the village did not attend the clinic. We believe that free health clinics run on a more regular basis would begin to attract more people and improve the overall health of the village.

Farming vulnerability issues also can be linked to water and health. Forest clearcutting, with the potential for excessive soil erosion, and poorly managed use of pesticides, were observed and photo documented. Farmers generally were not able to make the link between soil loss and loss of crop productivity, although such relationships have been established [54]. The observed poor pesticide handling and mixing practices, combined with reported dizziness in the needs and vulnerability survey (and in the health clinic), suggest an agricultural outreach program is warranted.

In an open-ended final question “if there was one thing that could make your life better in the village, what would it be?” the leading responses were: training (leading to employment), health/medical care, clean water, and an interest in raising goats. Some of these responses are related to the vulnerabilities identified in the foregoing paragraphs. Interest in goats was related both to a health concern and it was seen as an opportunity for income. Goat-raising programs have been successfully implemented in other areas of Southeast Asia and Africa and rearing methodologies are documented [55]. Similarly, there was an interest in training that might lead to non-agricultural employment. This ideal is consistent with the trend in vulnerability coping strategies reported for areas in rural northern Thailand by Rigg and Salamanca [25], although it seems likely that the Huai Pla Kong village population would have more restricted mobility.

We believe that our efforts resulted in some successes. Certainly, the ceramic filter intervention is a case in point and worth discussing further. In a follow up visit, 2 months after the ceramic filter had been provided to the mother of the twin girls, it was found that the *E. coli* level in the filtered water was 60 cfu/100 mL. It was determined that the filter had not been cleaned in those two months, so we took this as an educational opportunity and provided detailed demonstration and instructions for cleaning. After the filter was cleaned, the *E. coli* level registered

0 cfu/100 mL and a similar result was recorded again 6 months later. The mother commented that neighbors were now coming to borrow her water, that the twins were healthier, and that she would never again use raw well water. Our team subsequently distributed 7 ceramic filters at the 23 November 2013 health clinic to 7 families identified through the needs and vulnerability survey. With no prior preparation (she was asked impromptu at the clinic), the mother of the twin girls successfully demonstrated proper cleaning and maintenance procedures for the filters.

The AIT graduate students produced a number of design options for drinking water and sustainable sanitation that could effectively address some of the water vulnerabilities in the village. Their estimated cost to construct 5 rainwater harvesting tanks distributed throughout the village that would store 5,112,000L of water was 310,000 Thai Baht ($9,394 USD, 2015). The cost of the collection and constructed wetland treatment system was between 860,000 and 1.1 million Thai Baht ($26,060-33,333 USD, 2015).

In some areas, our program failed. Initially, it was not intended that the program would go beyond a feasibility study for additional wells. However, as the team saw need and new opportunities, plans evolved in an organic way, which created flexibility but also depended primarily on the good will of the team. There was no sustained presence in the village and for training and education purposes that was a clear negative. Ghosh [50] also noted the importance of "…continuous attachment of the research team with the community…". It took several visits and meetings with both the Thai military personnel and the villagers before trust was gained and we were able to freely and confidently interact within the village, but we were pleased that this eventually occurred. While the deputy headman was helpful, the headman showed limited interest in our initiatives, which meant progress was slower than it might have been. We were unable to make strong contacts with the Thai school, so education initiatives did not develop. Clearly, a number of the identified vulnerabilities could be addressed through education programs.

Perhaps the biggest disappoint was the opportunity lost. The National Institute of Education (NIE), Singapore, requires its majors to conduct an overseas final year project. A plan was in place for NIE students to carry out a number of studies in Huai Pla Kong in mid-December, 2013. These studies included follow up assessment of the first ceramic water filter and the 7 new filters distributed in November, 2013; field testing of a prototype UV treatment chamber for drinking water; infiltration and sediment erosion measurements; soil nutrient and textural analysis; combined satellite image and ground truthing assessment of changes in swidden patterns over the past decade; and additional testing of source-waters, including *E. coli* and nutrients. Unfortunately, due to the political turmoil in Bangkok, NIE canceled the field course 3 days before the scheduled departure. Because of heightened security following the installation of the military government in May, 2014, our team has not be able to get access to the village. The follow up to the use and performance of the ceramic filters is particularly important, as there have been mixed reports about successful household water treatment interventions without intensive trials [56-58] and Fiebelkorn et al. [59] note there is a paucity of work fully documenting point-of-use water interventions. We also were not able to follow up on plans to sample source water and vegetables for pesticide residue.

6. CONCLUSION

This paper took an integrated approach to assessing water vulnerability in the Huai Pla Kong village. The approach included elements of political ecology, field observation and photo documentation, surveys, and some quantitative information to characterize the village's waterscape. This information was used to guide elements of engineering design for sustainable water and sanitation systems. Importantly, the paper provides insights on approaches, successes and failures in working with remote village communities in Thailand.

We believe that our approach successfully addresses Walker's [60] question, "where is the ecology in political ecology?", although it might be argued that thematically we present more of a "politicized environment" study. We have examined the political ecology questions of "Who is vulnerable?" and illustrate Hill Tribe villages such as Huai Pla Kong, with a predominantly stateless population, do not receive support or resources from the international NGO community and are less mobile than those in lowland rural Thai communities. In looking at "How are they vulnerable?" we have shown that water quantity and water quality are connected issues impacted by the physical environment, agricultural and social practices of the village area. Finally, a complex set of political, cultural, and economic factors are involved in considering “Why are they vulnerable?” Hill Tribes historically have been marginalized societies in Southeast Asia and this has been exacerbated by the unrest in Myanmar and their statelessness in Thailand. Huai Pla Kong is a remote community whose population has restrictions on movement and limited access to health care, education, and economic opportunities.

ACKNOWLEDGEMENTS

Thanks to Jaruwat Watanatanachart, Mov Chimeng, Rawintra Eamrat, and Rieke Winter, graduate students at AIT for their study and design work.

DISCLAIMER

SEAGA (Southeast Asian Geographers Association) International Conference 2014, Siem Reap, Cambodia (at Royal University of Phnom Penh), 25 - 28 November 2014.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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